

*Modularity, life cycle and new entry
without fundamental patents: lessons from
the American household refrigerator
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of 1929*

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Modularity, life cycle and new entry without fundamental patents: lessons from the American household refrigerator industry before and after the great crash of 1929

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Despite the absence of live fundamental patents, early movers in a new industry can face a daunting task to create a mass market. Using historical methods and rich archival materials we explore the role of modularity in shaping an industry's market structure. We show how shifting dynamics undermined established industry "kingpins," who invested heavily in product design, giant factories, and considerable marketing expenditures. However, those investments paved the way for new entrants, using lower-cost strategies. Falling costs associated with standardization, modularity, and third-party component manufacturers enabled late entrants to undercut the prices of the successful early movers, leading to a substantial "shake-in" of small firms and the dethroning of industry kingpins. The case of the household refrigerator shows the implications of a low intellectual property regime that captured value before the rise of a dominant design, but increasingly lost value capture on maturity.

JEL Classification: O14, O31, O32, O33, O34.

1. Introduction

Understanding the dynamics of how industries evolve over a product's life cycle, in different contexts, is a question that has long interested scholars. Utilizing historical contexts, a rich literature has focused on the evolution of industries such as automobiles, computers and telecommunications. Within the automobile industry for example, [Carroll and Teo \(1996\)](#) illustrate the duality of innovation in driving technology but also undermining firms who do not innovate effectively or are unable to adapt to new technologies. [Klepper \(2002\)](#) also using the automobile industry, suggests that the assemblers integrated to improve their market power in what became an oligopolistic industry, while [Helfat \(2015\)](#) highlights that the evolution of vertical firm structures depends on contextual factors that differ in their impact across industries and produce different patterns of vertical firm structure. Other sectors that have been intensively explored include the computer and telecommunications sectors (e.g. [Iansiti and Clark, 1994](#); [Lipartito, 1994](#); [Malerba et al., 2008](#); [Tan, 2011](#)).

In this study, we explore how, in the absence of active fundamental patents, the ready availability of modular and interchangeable components can open markets to late entrants, even after product maturity. Our theoretical approach derives from the Product Life Cycle (PLC) framework and related perspectives, drawing on and integrating theoretical work on bottlenecks and kingpins, creating oligopoly structures ([Jacobides et al., 2006](#); [Jacobides and Tae, 2015](#)), and

on Baldwin's work on modularity (Baldwin, 2015, 2023). We explore how leading firms found that their greatest competitive challenges occurred not only in their formative period, but also on and after maturity, explaining the breakdown undermining oligopoly structures and facilitating substantial *shake-ins* of entrant firms.

We explore these issues in the context of the most important high-cost labor-saving, durable of the interwar era in the United States: the household refrigerator. We show how leading consumer durables companies found that their greatest competitive challenges occurred not only in their formative period, but also on and after maturity. To do so, we adopt historical methods, consistent with established approaches in business and strategy research (Argyres *et al.*, 2020: 344). Our study employs historical methodologies to critically analyze both primary and secondary sources, focusing on firm strategizing and decision-making in response to evolving technological, competitive, and market conditions.

This “history-informed strategy research” approach (Argyres *et al.*, 2020: 345) enables theory building and testing in a context-specific manner, while also drawing on relevant theoretical models. A commitment to “historical cognizance” (Kipping and Usdiken, 2014; Argyres *et al.*, 2020) is particularly valuable for unpacking the complex interactions between firms and other stakeholders by integrating diverse sources and forms of evidence. Our methodological approach also involves triangulating across industry case studies with shared core features—in this instance household consumer durables—to identify both patterns and variations, in line with recent work in the field (e.g. Scott and Spadavecchia, 2023).

New entry was facilitated by the industry's limited scale economies—especially compared to, for example, automobiles—and the very minor role of patent protection. Fundamental patents, filed several decades earlier for industrial refrigeration, had expired. Meanwhile, the main *bottleneck* in the value chain that the kingpins had to resolve was consumer acceptance of the refrigerator. In addition to strong consumer resistance—owing to early refrigerators leaking poisonous and corrosive refrigerants, refrigerators were also very expensive. In 1928, the average refrigerator cost \$275 (equivalent to \$4890 in 2023 prices, or \$27,500 when deflated by incomes).¹ The bottleneck of consumer acceptance and inertia was solved by Frigidaire and other early entrants by recruiting armies of salesmen, using personal selling techniques to “sell” the advantages of mechanical refrigeration over the icebox, before moving to the particular merits of their brand. This approach not only boosted their own sales but also inadvertently helped competitors by increasing overall market acceptance.

Rather than being increasingly dominated by early movers, the 1930s witnessed a substantial “shake-in” of new market entrants who significantly outnumbered market exits, even during the Depression. These newcomers capitalized on the emergence of a dominant refrigeration design and growing consumer acceptance of refrigeration, which had been largely driven by intensive marketing and instructional efforts of the early movers. Unlike their predecessors, these *followers* typically operated with much less integrated value chains, relying heavily on third-party components and leaving distribution to standard distribution channels. This allowed them to undercut the incumbents on price, making refrigeration available to lower-income groups and intensifying price competition in the sector.

This study examines industry dynamics in the US refrigerator sector during two key periods: the 1920s, when only high-income groups could afford refrigerators, and the 1930s, when refrigerators became more generally affordable. We start by analyzing PLCs and the conditions under which early entrants might be vulnerable to price competition following market maturity. We then conduct an in-depth examination of the pre-maturity development of the refrigerator market. During the market growth stage, a small group of firms operated as a collusive oligopoly that prohibited price competition and created a mass market through intense personal selling techniques. However, as the market matured, the sector became increasingly vulnerable to new competitors. The shift was driven by relatively low returns to scale, growing consumer acceptance, the emergence of a large third-party components sector, weak intellectual property rights (beyond branding), and leaner distribution channels. For customers, the outcome was overwhelmingly positive: the industry rapidly converged on a dominant design and prices fell substantially.

¹ ‘Purchasing Power of British Pounds from 1270 to Present’, *MeasuringWorth*, 2024. <https://www.measuringworth.com/calculators/ppoweruk/>

Meanwhile, although early market leaders lost market share to new entrants, many remained profitable by serving higher market tiers and other strategies, such as producing refrigerator mechanisms for retail home brands.

2. The evolution of the household refrigerator industry

Our theoretical approach derives from the PLC framework and related perspectives. The PLC model proposes that the evolution of a product class or industry moves through several distinct stages, from initial development to decline (Geroski and Mazzucato, 2001). While there is some disagreement on the number of stages, there is consensus that when a market becomes *mature*, with customer acceptance and the emergence of a *dominant design*, firm numbers begin to fall, owing to a *shake-out* of weaker competitors. However, there is no consensus as to whether early entrants, so-called *fast followers* (Markides and Geroski, 2005: 120–128) or even late entrants will gain most market share following maturity.

The nature and timing of the shake-out process have been the major focus of research (Klepper and Graddy, 1990; Klepper, 1996; Klepper and Simons, 2005). This process is influenced by several factors, including economies of scale, barriers to entry, and the possibility of lowering costs and prices by simplifying the product and/or its value chain. Following the emergence of a dominant design—an industry standard that sets performance standards and renders all models following this design readily identifiable as meeting them (Markides and Geroski, 2005: 52–53)—incumbents are more vulnerable to market entry. New entrants can capitalize on this by simplifying the product and lowering costs or prices downstream from the factory.

Sutton (1992: 4–12, 312–314) has argued that as markets expand, for any given configuration of entry barriers, incumbent firms become more profitable, attracting new entrants to surmount such barriers and therefore reducing industry concentration. However, he also maintained that this pattern would not hold in industries with high advertising and/or research and development (R&D) expenditures, as these represent sunk costs that create a competitive advantage for incumbents. This view is supported by more recent research (see Kim and Lee, 2011: 1306). However, their work neglects the nature of consumer durables in the 1920s, where marketing expenditure during the pre-consumer-acceptance phase was not about competing between brands but concentrated on convincing customers of the benefits of refrigeration over traditional ice-boxes—emphasizing health, convenience, and cost savings. At this stage, household refrigerators were supply-driven products and the main bottleneck was lack of consumer demand, to be overcome by intensive personal selling and instruction.

Patents had relatively little influence on market entry, competition, or rent extraction because the basic technologies had been pioneered several decades before the emergence of a reliable domestic refrigerator. Another defining characteristic of the industry was its modularity. One of the main advantages of modular systems is that interconnecting components can be produced without detailed knowledge of how they will be incorporated into systems. This flexibility allows designers and users to mix and match components as needed (Baldwin, 2023: 12). Thus, refrigerators were designed using a common “architecture”—the abstract description of their technical system design, that defines the refrigerator’s components, the interfaces between them, and specifies ways of testing their performance (Baldwin, 2015: 3). Additionally, even a top-of-the-range refrigerator had relatively few major components when compared to more complex products, such as motorcycles. This simplicity is illustrated by the blueprint for the Frigidaire Super Line, introduced in 1934 (see Figure 1).

3. The development of the US refrigerator industry to 1929

Although the fundamental patents for mechanical refrigeration had been filed decades before the 1920s, the pioneer household refrigerator manufacturers faced formidable technological challenges. They needed to develop a machine that was quiet, compact, and free of coolant leakages—which were generally poisonous or corrosive. Most importantly, they had to ensure reliability, as industrial refrigerators at the time required constant maintenance to address frequent breakdowns.

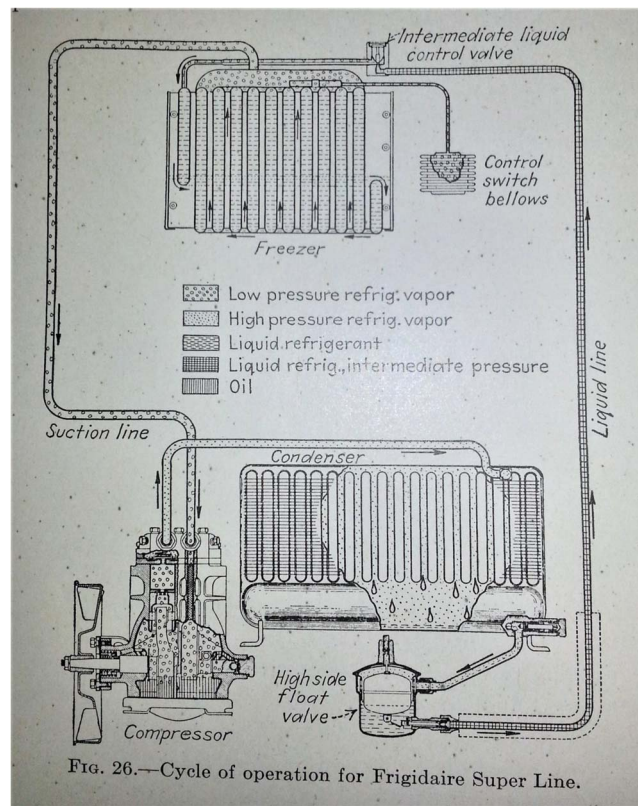


Figure 1. A diagram of the refrigeration mechanism for the Frigidaire Super Line (introduced in 1934). Reproduced owing to the generous permission of Michael Pletcher.

Two of the early market leaders, Frigidaire and Kelvinator, were associated with auto manufacturers: General Motors (GM) and Nash, respectively. GM President William C. Durant personally invested in the Guardian Refrigerator Co., which subsequently adopted the name Frigidaire and became a division of GM. As Durant explained, “What are refrigerators but boxes with motors” (Gantz, 2015: 99). However, if Durant anticipated that refrigerators would benefit from Fordist economies of scale associated with the automobile industry, he was mistaken. As GM’s next president, Alfred P. Sloan, noted in the early 1930s, Frigidaire “had nothing to do with the automobile industry” (Tedlow, 1990: 434). Other industry entrants included major electrical equipment manufacturers, particularly General Electric (GE) and Westinghouse.

3.1 The structure of the early domestic refrigerator sector

The U.S. industry’s trade association, the National Electrical Manufacturers Association, only started collecting data on refrigerator market share in 1929, as shown in Table 1.² However, GE estimated that in 1924, four manufacturers—Frigidaire, Kelvinator, Copeland, and Servel (who had then not yet switched to gas refrigerators)—controlled 90% of the US household market.³ Meanwhile, the refrigerator was still a long way from acquiring a dominant design. Refrigerators were very expensive, noisy, unreliable, and prone to potentially fatal refrigerant leakages. Moreover, they required a connection to a water source, and in some cases, even an external motor (Anderson, 1953: 196).

² Kettering, Frigidaire, 79.10.1.41B, T. R. Shellworth, ‘Report on Frigidaire’s Development’, Section III, 8.

³ Museum of Innovation and Science, Schenectady (hereafter MISci), General Electric papers, data folder No. 1120; A. R. Stevenson, Jr. (1925), ‘Domestic Refrigeration’ (Appendix 45, p. 408). General Electric Company: Schenectady, NY. <https://www.ashrae.org/File%20Library/About/Mission%20and%20Vision/ASHRAE%20and%20Industry%20History/Report-on-Domestic-Refrigerating-Machines1923---1925.pdf>

Table 1. Annual sales of refrigerators, washing machines, and vacuums, 1922–1941; numbers, sales values, and average unit prices

Year	Refrigerators			Washing machines			Vacuums		
	Number	Sales \$ (000)	Unit Price	Number	Sales \$ (000)	Unit Price	Number	Sales \$ (000)	Unit Price
1922	11,000	4000	364	4,15,000	65,000	157	8,00,000	40,000	50
1923	15,000	5300	353	5,65,000	70,000	124	10,25,000	56,000	55
1924	30,000	13,500	450	6,12,100	87,000	142	9,43,600	63,634	67
1925	75,000	26,250	350	7,26,000	1,03,500	143	9,70,000	60,000	62
1926	2,50,000	75,000	300	8,28,000	1,25,000	151	10,50,000	65,000	62
1927	3,65,000	82,125	225	7,90,000	1,18,500	150	10,28,000	49,344	48
1928	4,68,000	1,28,700	275	8,09,900	1,08,000	133	12,20,000	60,973	50
1929	6,30,000	1,81,175	288	9,56,000	1,07,900	113	12,53,200	62,660	50
1930	7,75,000	1,97,625	255	8,02,000	83,809	105	9,60,300	52,819	55
1931	9,65,000	2,36,425	245	8,12,000	69,020	85	6,86,700	34,332	50
1932	7,70,000	1,46,860	191	5,69,800	33,620	59	4,47,100	17,882	40
1933	10,65,100	1,77,000	166	9,66,700	59,935	62	5,47,500	27,377	50
1934	12,84,000	2,20,848	172	11,21,100	72,874	65	9,68,400	43,556	45
1935	15,68,800	2,60,421	166	12,28,800	79,932	65	12,00,900	54,710	46
1936	19,91,000	3,26,524	164	17,29,100	1,19,160	69	15,10,900	67,457	45
1937	23,10,000	3,95,010	171	16,42,000	1,22,869	75	17,06,300	77,784	46
1938	12,54,000	2,15,688	172	11,37,600	84,136	74	12,95,700	62,557	48
1939	19,00,000	3,21,100	169	14,33,300	1,00,519	70	14,36,200	68,815	48
1940	26,00,000	3,95,200	152	15,52,700	1,13,156	73	17,43,400	81,195	47
1941	35,00,000	5,42,500	155	20,14,400	1,59,330	79	21,17,900	99,259	47

Source: “50 years of statistics and history”, *Merchandise Week*, 104, 9 (February 28, 1972): 21–54 and 110–160.

GE entered the domestic refrigerator market in 1926 with a model that offered several key advantages: quiet operation, exceptional reliability, substantially lower power consumption, and “plug-in portability” with no need for belts or drainage. Drawing on the Audiffren Dumbbell, invented in France around 1894, GE’s “Monitor Top” refrigerator (see Figure 2) featured a hermetically sealed refrigerating mechanism mounted on top of the cabinet, with the motor and compressor operating within the refrigerant atmosphere.⁴ These product advantages enabled GE to gain a 34.1% market share by 1930.⁵ In 1927, Servel launched its gas-powered refrigerator, licensed from Electrolux, that offered silent running and was popular in areas of the United States that lacked mains electricity (Cowan, 1985: 212). Both GE and Servel aggressively pushed their “quiet” sales pitches, helping to render the public “noise conscious”.⁶ However, as mains electricity diffused rapidly across the United States, gas refrigerators became niche products for localities without electrical supplies (Cowan, 1985: 212).

The early entrants invested heavily in plant and machinery. In 1926–1927, Frigidaire built a \$20 million plant at Moraine City, Ohio—reportedly the largest single-storey building of its kind in the world—to augment its existing “Plant 1”.⁷ Similarly, Kelvinator began developing a new plant in Detroit, which was completed in May 1927 with 690,000 sq. ft. of floorspace, in addition to its nine-acre plant in Grand Rapids. GE also opened a new factory in Cleveland, Ohio, with \$18 million allocated for plant and equipment, supported by a \$1 million advertising budget (Nagengast, 1997: S49).

T. K. Quinn, the GE executive in charge of the Monitor Top project, correctly estimated that annual sales of just 50,000 units would reduce costs sufficiently to compete with Frigidaire and Kelvinator—a relatively low “minimum efficient scale” compared to automobiles (Quinn, 1953:

⁴ Kettering, Frigidaire, 79.10.2.17, ‘Notes on General Electric Competition’, folder, memo by Mr Newell, 1 June 1929.

⁵ MISci, GE papers, 1997.2212, Ralph Roeder, ‘GE Electric Refrigerators Silver Anniversary’, (internal historical note) 30 October 1952; Gerald Swope papers, Box 1, Folder 115–3, I., GE President’s reports, 5 Feb. 1932 and 30 Dec. 1932.

⁶ Paul Laurence Dunbar Library, Wright State University Special Collections and Archives, unpublished history of Frigidaire (1964), 1A/5, household refrigerators chapter: 12.

⁷ Wright State, Frigidaire history, 1A/5, household refrigerators chapter: 11.

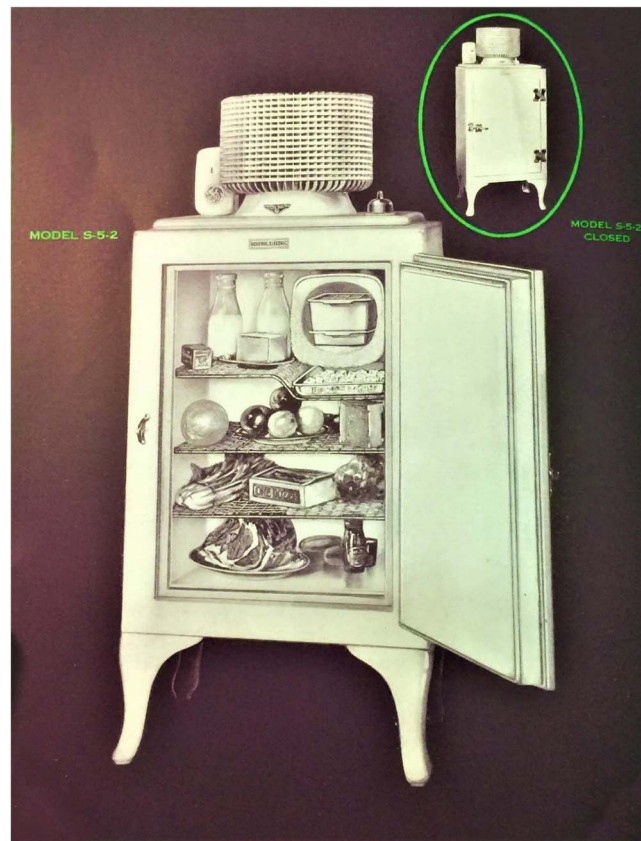


Figure 2. The “monitor top”—the world’s first quiet portable plug-in household refrigerator. Source: June 1927 GE advertisement, reproduced by generous permission of Misci.

88). Nevertheless, the major firms believed that their nationwide distribution and sales operations would give them a strong competitive advantage.

3.2 Selling methods in the 1920s

The introduction of domestic refrigeration was a classic *supply-push* innovation, emerging in the absence of a clear demand driver (Markides and Geroski, 2005: 25–30). As Dean (1950: 49) observed, “there is an intimate interaction between the pricing of a new product and the costs and the problems of floating it down the distribution channels to the final consumer.” Like all complex new consumer durables, refrigerators were classic *experience goods* (Nelson, 1970), meaning that customers need direct or indirect “experience” of the product before committing to a purchase. They were also *credence goods* (Darby and Karni, 1973), as customers typically had very little knowledge of their potential obsolescence, reliability, maintenance, or the availability of replacement parts—one rationale for manufacturers favoring modular and interchangeable components.

Given refrigerators’ high unit costs, technical complexity, and potential customer fears regarding reliability, noise, and leakages, consumer acceptance required persistent personal selling, extensive advertising, and door-to-door canvassing to provide the necessary “second-hand experience”. Similar to washing machines, vacuum cleaners, motor vehicles, and (initially) radios, they also required a considerable “service” element, before, during, and after the sale—what we term “S-goods”. Salesmen used *push selling* techniques, first educating the customer regarding the merits of mechanical refrigeration relative to the icebox, before highlighting their specific brand’s strengths. This approach relied upon home demonstrations (door-to-door selling), supported by heavy advertising and sales aids. Leading refrigerator, washing machine, vacuum cleaner, and



Figure 3. Selling Frigidaires, one household at a time, with a catalog and other sales aids. Source: Reproduced thanks to the generous permission of GM archives, 79.10.11.46, *Frigidaire era magazine*, May 1, 1931, front cover.

radio firms, all invested in extensive sales forces, initially to sell the advantages of their new product to a hesitant public (Scott and Walker, 2016; Scott, 2017, 2019, 2020).

Frigidaire's marketing methods were influenced by John H. Patterson's sales methods at National Cash Register (NCR) from the 1880s. Patterson pioneered techniques such as monthly sales quotas for salesmen (based on their territories' sales potential), motivation via inspirational company bulletins and conventions, together with a mix of financial and *purposeful* (symbolic) incentives—such as exclusive “clubs” for top-performing salesmen. He also emphasized statistics-based monitoring of each salesman, sales training, and scripted sales presentations. Most importantly, perhaps, he employed a charismatic leadership style that framed the firm's mission as a driving force in its workforce (Friedman, 2005: 117–147).⁸ An unpublished Frigidaire company history attributed “the whole chain of speciality selling techniques” taught at Frigidaire during its early years to the example set by NCR.⁹

Frigidaire and its main competitors used the franchise system. Under this system, franchised distributors and retail dealerships were granted exclusive territories and ongoing assistance with marketing, running a direct sales force, and other business practices. To maintain control and ensure compliance with corporate policies, manufacturers employed field managers who monitored the franchisees and met sales quotas (Scott, 2022). Unlike most other household durables, refrigerators were too bulky and expensive for home demonstrations or free trials. Salesmen, therefore, conducted demonstrations using sales aids provided by the company, including a demonstration album of pictures to accompany their sales pitch (see Figure 3). Another favored technique was to drive customers to the firm's showroom, where they could see the models in person.¹⁰

Salesmen were indoctrinated into the firm's *system*, encompassing both selling techniques and the firm's *corporate ideology*—a set of driving ideas regarding its “mission”, ideals, and standards that salesmen were expected to buy into (Zunz, 1990: 181–182). However, in practice, their primary day-to-day interaction with their firm's system mainly involved conforming to its standardized demonstration and scripted sales pitch. This helped to ensure a consistent minimum

⁸ Wright State, Frigidaire history, A2/2, salesmanship chapter: 39.

⁹ Wright State, Frigidaire history, A2/2, salesmanship chapter: 1–2.

¹⁰ Kettering, Frigidaire, 79.10.1.106, “The Standard Plan of Selling Frigidaire”, 1934, 20–21.

Table 2. Estimated average factory and retail prices for electrical refrigerators, 1928–1937

Year	Average prices (\$)		Mark-up (%)
	Factory	Retail	Over factory
1928	166	334	101
1929	134	292	118
1930	132	275	108
1931	129	258	100
1932	101	195	93
1933	83	170	105
1934	84	172	105
1935	78	166	113
1936	81	164	102
1937	85	173	104

Source: US Temporary National Economic Committee, 1940: 144.

level of competence in the sales pitch, particularly important given the difficulty of directly supervising a large salesforce (Biggart, 1989: 148).¹¹

There was also an industry advantage in using similar high-cost distribution and sales systems. Each refrigerator firm was selling the concept of mechanical refrigeration and thereby accelerating consumer acceptance. While the industry's kingpins had relatively weak leverage over competitors, they nevertheless persuaded most substantial firms to avoid price competition and focus on non-price competition. They appear to have assumed that scale economies and nationwide distribution systems would give them an enduring competitive advantage over later entrants. But these high-cost sales and marketing systems had the downside of excluding many lower-income households. This left a substantial gap in the market, akin to the personal computer market of the 1970s, that initially catered only for wealthier consumers before more affordable alternatives emerged (Duguid, 2010).

A typical sales pitch would take several hours, significantly increasing overall selling costs. This contrasted sharply to the automobile industry, where customers typically visited the dealership, which maintained inventory on-site. Cars were sold at just under 25% below the list price, after factoring in trade-in allowances (US House of Representatives, 1938: 118, 207).¹² In the late 1920s, factory gate prices of refrigerators were typically just under half their retail price. Even as prices declined in the 1930s, that ratio remained roughly constant (see Table 2). High distribution costs provided substantial scope for undercutting prices by streamlining downstream value chains, especially in the 1930s.

3.3 Control of competition and the “price understanding”

Industry leaders viewed themselves as operating a concentrated oligopoly and deliberately avoided price competition. For example, Quinn was instructed that he should never undercut its major competitors (Quinn, 1953: 93–94). When Frigidaire initiated a local price war with GE in Pittsburgh in 1929 and GE retaliated, a top-level meeting was rapidly convened, which included GM's president, Alfred Sloan, and GE's president, Gerald Swope, leading to informal price cooperation between GE, Frigidaire, Kelvinator, and—eventually—other major manufacturers (Quinn, 1953: 98–99).

Given the imperative to build public acceptance, there was a clear rationale for price collusion. The refrigerator industry employed tens of thousands of salesmen, who spent most of their time selling the general idea of home refrigeration and its superiority to the icebox by instructing them on their proper use. In effect, these sales efforts promoted the industry as a whole, not just for their firm. This created potential free-riding, by reducing salesmen's instructional activities or leaving this entirely to competitors. Inter-firm collusion constituted a powerful tool to remove price competition and incentivize non-price competition, facilitated by the industry's domination by large corporations.

¹¹ Kettering, Frigidaire, 79.10.1.106, ‘The Standard Plan of Selling Frigidaire’, 1934, 7.

¹² Based on GM's Buick Division and Chrysler Corporation dealer documentation for autumn 1936.

3.4 Bottlenecks and kingpins

Industry kingpins typically leverage their superior capabilities—such as leading positions in R&D—to create and capture value by addressing bottlenecks. Bottlenecks are critical technical and structural problems that, when resolved, enable firms to capture a larger share of the value chain's rents (Jacobides *et al.*, 2006; Baldwin, 2015; Jacobides and Tae, 2015). As sectors evolve, kingpins can dictate the *industry architecture* or “rules of the game”—for example, over technological standards—thereby reinforcing their dominance (Jacobides *et al.*, 2006; Pisano and Teece, 2007: 283–284).

A firm's ability to capture the financial benefits of solving a bottleneck depends on securing property rights over it (Baldwin, 2015: 12–13). However, this becomes challenging if the bottleneck cannot be protected. As Pisano and Teece (2007: 280–281) note, to provide value to end users, innovations require complementary products, technologies, and services along the value chain. If these are controlled by other parties, these parties may accrue a large proportion of the innovation's rents. In the refrigerator sector, maintaining control over innovation was problematic: the fundamental patents had expired, components were generally in competitive supply, and there were no strong barriers to imitation (except during the industry's early years, when developing national distribution and sales systems involved considerable investment).

Frigidaire and GE emerged as industry kingpins, playing leading roles in shaping the refrigerator's dominant design. However, the principal bottleneck that they resolved was not technological but information: educating consumers about mechanical refrigeration, demonstrating its advantages over iceboxes, and persuading them to buy their specific brands. Their salesforces thus helped both them and their rivals—similar to how the invention of containerization revolutionized shipping. Once the standard design rules had been settled, no firm could monopolize the concept, making it impossible to block the system-wide innovation (Baldwin, 2015: 25). Frigidaire and GE created considerable value from the refrigeration industry, but found it impractical to capture that value, which was instead dispersed across the industry.

During the 1920s, this was not a great problem since all significant firms employed broadly similar high-cost sales techniques. Firms thus shared in consumer education and hard-selling in proportion to their size, with the largest reaping the greatest value. The potential threat of free-riding—by reducing or ignoring personal sales and selling on price instead—was mitigated by an industry-wide informal agreement to avoid price competition, thereby reinforcing non-price competition. However, the situation became problematic during and after the Depression, which saw a large shake-in of new firms that sold on price, in a market that had now achieved consumer acceptance.

3.5 Scale economies

Another challenge for leading firms was the absence of any clear productivity advantages from their large factories. In 1929, Frigidaire, GE, and Kelvinator led the sector, collectively holding an 81.4% market-share in the United States (as shown in Table 3), with Serval the only other significant firm. However, analysis of the original returns to the 1929 *Census of Manufacturers*—following a similar analysis (Scott and Ziebarth, 2015) for radios—reveals that these industry giants did not show substantial productivity advantages. Individual figures for the largest 15 (including Frigidaire's two Dayton plants, which were treated in the census as a single plant), together accounted for 99.1% of output, as shown in Table 4, with the bottom row aggregating all 34 plants in the census.

The relative importance of the largest plants, particularly those operated by Frigidaire, is exaggerated owing to their higher proportion of commercial refrigerator production. While rankings of value and value added for the seven largest plants are the same, this was not the case for smaller plants. There is no clear relationship between size and labor productivity in the top 15 plants. Indeed, for the full sample of 34 firms, the pairwise correlation coefficient between output and output per dollar of wages is only -0.023 , and that between value added and value added per dollar of wages is 0.041 —both insignificant even at the 15% level. This may partly reflect composition effects, although the product information does not indicate substantial distortion owing to product composition (other than for commercial refrigeration), with much less product heterogeneity than, for example, the radio sector (Scott and Ziebarth, 2015: 1101–1,102).

Table 3. Percentage market shares of household refrigerators, by volume, 1929–1941

Year	Frigidaire	GE ^a	Kelvinator ^b	Servel	Westinghouse	Norge	Crosley	Sears	Montgomery Ward	Philco	Others	Total	Total (no.)
1929	38.6	30.4	12.4	6.0	0.0	0.8	0.0	0.0	0.0	0.0	11.8	100.0	8,00,221
1930	24.5	34.1	7.8	6.8	0.0	1.6	0.0	0.0	0.0	0.0	25.2	100.0	8,48,508
1931	23.1	27.9	7.1	8.2	5.9	6.5	0.0	1.4	0.0	0.0	19.9	100.0	9,86,680
1932	20.4	13.7	12.0	6.5	6.7	8.0	n.a.	2.3	0.0	0.0	30.3	100.0	8,53,784
1933	20.9	14.0	14.0	6.2	7.6	7.7	n.a.	1.9	0.0	0.0	27.8	100.0	10,72,302
1934	17.5	14.6	15.7	7.6	7.6	10.3	n.a.	4.2	0.0	0.0	22.4	100.0	13,88,450
1935	17.4	14.5	11.6	9.5	8.3	10.1	7.1	8.0	0.0	0.0	13.5	100.0	17,32,347
1936	20.1	12.9	11.7	9.8	7.9	10.6	5.4	9.8	1.0	0.0	11.0	100.0	22,11,751
1937	19.6	16.6	9.6	10.0	9.7	7.7	3.3	11.5	2.2	0.0	9.7	100.0	25,67,836
1938	18.2	16.7	6.7	11.9	6.5	6.5	3.4	14.1	5.1	0.0	10.9	100.0	14,23,437
1939	16.1	18.6	6.6	10.4	9.2	5.1	3.7	13.8	4.5	1.7	10.3	100.0	21,03,823
1940	22.1	19.1	10.0	8.1	9.4	4.0	3.0	11.7	3.5	3.2	6.0	100.0	28,17,690
1941	18.9	20.6	12.8	7.4	8.2	4.9	4.2	8.1	3.5	4.8	6.6	100.0	38,15,551
Avg. 1929–1933	25.5	24.0	10.7	6.7	4.0	4.9	0.0	1.1	0.0	0.0	23.0	100.0	9,12,299
Avg. 1934–1937	18.6	14.6	12.2	9.2	8.4	9.7	5.3	8.4	0.8	0.0	14.2	100.0	19,75,096
Avg. 1938–1941	18.8	18.7	9.0	9.5	8.3	5.1	3.6	11.9	4.2	2.4	8.5	100.0	25,40,125

Source: Philco—"Radio, Refrigerators and Radar", *Fortune Magazine*, 39, 5 (November, 1944), 115–243 (p. 119); other companies – Teddlow, 1990; 313–314 and 321 (based on Frigidaire archival data). ^aIncludes Horpoint. ^bincludes Leonard. "Total" for 1933 is 10,000 less than the sum of the previous columns.

Table 4. Comparison of 1929 labor productivity in the 15 largest US refrigerator plants, and all refrigerator plants as a whole

Firm/Plant	Location	Output (\$)	Ranking by:		Output per:		Value added per	
			Value	Value added	Wage-earner month	\$ of wages	Wage-earner month	\$ of wages
Frigidaire Corporation—Plants 1&2	Dayton, OH	8,28,19,021	1	1	892	6.89	538.08	4.16
GE—Schenectady Works	Schenectady, NY	3,00,72,653	2	2	765	4.95	361.51	2.34
Kelvinator Corporation	Detroit MI	1,75,48,922	3	3	1,291	8.92	679.15	4.69
Servel Inc.	Evansville, IN	1,30,80,339	4	4	521	5.36	280.19	2.88
GE—Fort Wayne Works	Fort Wayne, IN	51,97,630	5	5	380	3.35	226.76	2.00
Copeland Products Inc.	Mount Clemens, MI	28,20,741	6	6	2,018	13.09	1,046.98	6.79
GE—Erie Works	Erie, PA	22,22,658	7	7	386	3.34	126.47	1.09
Norge Corporation	Detroit MI	12,16,457	8	11	2,014	11.52	517.75	2.96
Zerozone Corporation	Chicago, IL	11,79,102	9	10	804	8.19	303.60	3.09
Universal Cooler Corporation	Detroit MI	9,63,583	10	9	1,369	8.91	774.29	5.04
Welsbach Co.	Gloucester, NJ	9,07,913	11	8	405	3.74	292.89	2.70
Trupar Manufacturing Co.	Dayton, OH	6,30,000	12	14	4,038	68.06	1,407.18	23.72
The Wayne Home Equipment Co.	Fort Wayne, IN	5,50,700	13	13	971	18.20	388.97	7.29
Absopure Refrigeration Co.	Detroit MI	4,35,458	14	12	606	4.43	378.07	2.76
Electro-Kold Corporation	Spokane, WA	3,48,290	15	15	403	3.63	182.31	1.64
All (34) plants	n.a.	16,15,00,626	n.a.	n.a.	797	6.17	439.72	3.40

Source: US National Archives, Washington D.C., 1929 US Census returns for mechanical refrigerators and parts.

Data for the washing machine sector similarly show no clear evidence of substantial scale advantages. Table 5 presents the 1929 *Census of Manufacturing* returns for the 15 largest washing machine plants, alongside figures for the whole sector (excluding firms that only made ironers). Washing machine plants were more numerous and had weaker concentration than the refrigerator sector. The top three washing machine plants accounted for 49.2% of total output, and the top 15 plants produced 85.5%, whereas refrigerators had much higher concentration, with corresponding figures of 80.8 and 99.1%. Once again, the data indicate weak scale economies. For example, Maytag, the largest washing machine manufacturer, had lower output and value added per dollar of wages than the industry average. This aligns with findings from Scott and Ziebarth's (2015) study of the US radio sector, which also found no significant evidence of scale economies in the Census of Manufacturers returns from 1929–1935.

The absence of Fordist scale advantages further deterred price competition in the household durables sector. Unlike Ford, which drastically lowered automobile prices to both create a mass market and deter competitive entry, leading appliance manufacturers in the 1920s such as Frigidaire, Hoover, and RCA followed a different strategy. They priced their products at the high end of the market, similar to earlier market leaders in complex machinery sectors, such as Singer and McCormick Harvesting Co. – but instead invested heavily in sales and marketing to create mass markets for their novel products (Hounshell, 1984: 5–10; Bresnahan and Raff, 1991).

4. Product maturity and accelerated market entry in the 1930s

Despite the economic turmoil of the Depression, refrigerator diffusion continued to rise, increasing from 9.4% of electrified homes in 1929 to 24.7% by 1933.¹³ Compared to other groups, white-collar and high-skilled workers experienced relatively low unemployment and benefited from rising real incomes, as prices fell substantially while nominal earnings remained relatively static (O'Brien, 1989; Levine, 2009; Field, 2011: 36–39). Diffusion accelerated further during the recovery, reaching 56% of wired homes in 1939 and 72% by 1941.¹⁴ This was driven in part by substantial falls in the real price of refrigerators, led by the sector's new entrants.

By the 1930s, the domestic refrigerator had developed a *dominant design*, emerging from the race to solve the technical and ease-of-use problems that had delayed completion of the “cold chain”—keeping food chilled or frozen from farm to table. A common architecture emerged, based on steel cabinets and sealed units, with rotary compressors and brine tanks to chill the food compartment directly, with the refrigeration mechanism placed at the bottom of the refrigerator, to make it easier to access the food (Anderson, 1953: 197–198).

As Langlois and Robertson (1989: 364–365) noted, standardization allowed third-party component developers to benefit from mass production of standardized components, therefore reaching minimum efficient scale. This enabled them to compete on price, with the potential to undercut the costs of vertically integrated refrigerator manufacturers. This enabled refrigerator firms to outsource most components, further reducing minimum efficient scale. A particularly efficient components market could make backward integration unattractive even for industry leaders.

During the 1930s, the Frigidaire/GE-led oligopoly became weakened, as the sector became increasingly contestable. The Depression saw a wave of new entrants, who adopted a substantially different value proposition: based on outsourced components, product simplification, and, critically, simplifying the value chain downstream from the factory, to substantially undercut incumbents' prices. Meanwhile, a rapidly growing proportion of consumers became familiar with refrigerators, either directly or via friends and family, making the salesman's instructional role less important. R&D offered only very limited protection, given that the refrigerator's fundamental patents had expired and most later innovations (such as the refrigerant Freon, developed by

¹³ '50 years of statistics and history', *Merchandise Week*, 104, 9 (28 Feb. 1972), 21–54 & 110–160.

¹⁴ '50 years of statistics and history', *Merchandise Week*, 104, 9 (28 Feb. 1972), 21–54 & 110–160.

Table 5. Comparison of 1929 labor productivity in the 15 largest US washing machine plants, and all washing machine plants as a whole

Firm/Plant	Location	Ranking by:		Output per:		Value added per	
		Value	Value added	Wage-earner month	\$ of wages	Wage-earner month	\$ of wages
Maytag Co.	Newton, IA	1	1	1,034	6.19	575	3.44
Electric Household Utilities Co.	Gicero, IL	2	2	1,052	8.38	532	4.24
Syracuse Washing Machine Co.	Syracuse, NY	3	3	801	6.23	463	3.60
Apex Electric Manufacturing Co.	Cleveland, OH	4	4	542	5.22	248	2.39
Altorfer Bros. Co.	E. Peoria, IL	5	5	942	8.02	518	4.41
Nineteen Hundred Co.	Binghamton, NY	6	7	1,246	11.51	682	6.30
Automatic Washer Co.	Newton, IA	7	8	1,503	15.42	686	7.04
Lovell Mfg. Co.	Erie, PA	8	6	454	4.74	259	2.70
Meadows Manufacturing Co.	Bloomington, IL	9	10	676	6.78	318	3.19
Dexter Co.	Fairfield, IA	10	11	876	6.61	462	3.49
Voss Bros. Mfg. Co.	Davenport, IA	11	12	1,373	12.99	643	6.09
Hagg Brothers Co.	E. Peoria, IL	12	9	1,373	14.67	1,292	13.81
One Minute Manufacturing Co.	Newton, IA	13	13	943	7.30	481	3.72
Horton Manufacturing Co.	Fort Wayne, IN	14	14	865	7.98	407	3.76
Prima Mfg. Co.	City Fields, OH	15	15	1,053	8.19	431	3.35
All (61 plants)	n.a.	n.a.	n.a.	831	6.74	435	3.53

Source: US National Archives, Washington D.C.; 1929 US Census returns for washing machines. Totals for all plants are lower than in the published census because firms producing only ironers have been excluded.

Frigidaire) had close substitutes. This left market leaders vulnerable to new competitors, both directly and indirectly (i.e. via third-party component suppliers).

In 1929, the early market leaders Frigidaire, GE, and Kelvinator collectively had 81.4% share of the sector. By 1939, their collective share had been cut in half, to 41.3%. While Frigidaire and GE remained in the top three, Kelvinator dropped to seventh place. Frigidaire, the long-term market leader, saw its market share decline from 38.6% to 16.1% (see Table 2). Meanwhile, successful late entrants—including Norge, Crosley, Sears, Montgomery Ward, and Philco—collectively captured a significant proportion of market share, demonstrating the changing competitive dynamics in the industry.

4.1 The shift to less integrated business models

The onset of product maturity and the Great Depression made customers more price-conscious, boosting demand for cheaper refrigerators and further boosting firm entry. According to *Electrical Merchandising*, the number of electrical refrigerator manufacturers rose from 13 in 1921 to 32 in 1925 and 61 in 1929. The early 1930s saw a shake-out, as predicted in the PLC literature. However, there was a substantially larger *shake-in*, with the overall number of refrigerator firms rising rapidly, from 69 in 1930 to 77 in 1931 and 114 in 1932.¹⁵

These new competitors exploited the industry's modular technology to reduce costs in several ways: outsourcing components, simplifying refrigerator design, and, crucially, slashing marketing, sales, and distribution costs. Third-party markets for components were strong substitutes for scale. Moreover, competition within the component sector led to simplification of components—without threatening their modularity. Collectively, these policies enabled new entrants to substantially undercut the incumbents on price, even for equivalent size categories. These late entrants (Markides and Geroski, 2005; Adner, 2013) capitalized on consumer acceptance and a flourishing third-party components sector, exploiting the product architecture of high modularity and interchangeability. In sum, modularity became a key mechanism for competition for late entrants. The industry's architecture was beginning to move from a “vertical” one, in which firms directly undertook or controlled most of the value chain, to a “horizontal” model, with firms specialized in particular layers of the production/distribution process. This reflected the architecture of the specific components and stages involved in these layers, facilitated by the standardization and modularity of most such components.

Similar trends had already occurred in the radio industry (Scott and Walker, 2016). Some of the new refrigerator firms capitalized on low Depression component prices, including “cat-and-dog” firms that assembled surplus components. This phenomenon paralleled the 1980s microcomputer sector that saw the rise of “no-name” clone personal computers, built from third-party components (Langlois, 1992). These refrigerator manufacturers exploited increasing modularity of design and interchangeable standardized parts developed to a common technological standard. Meanwhile, assembly typically involved simple, non-mechanized methods (Scott and Ziebarth, 2015: 1098–1099). While their market share was negligible, some survived the Depression and were still active in 1940. This suggests that in a market where components were cheap and accessible, firms could survive even on very low outputs.¹⁶

4.2 The incumbents' value chains

Early household refrigerator firms had faced formidable challenges in creating a reliable, safe, silent, and portable plug-in refrigerator. This required free exchange of information, without the risks of knowledge appropriation and/or hoarding information. Such problem-solving included the design, production, and integration of individual components into a refrigeration system—tasks that were most efficiently undertaken by vertically integrated firms. Forward integration into marketing and sales was also necessary to align with capacity production (Nickerson and Zenger, 2004). Panel A of Figure 4 illustrates a simplified value chain for early movers that had entered the sector in the 1920s and were members of the “price understanding.” These firms did not just integrate design, component, and assembly operations, but also distribution and sales.

¹⁵ ‘Refrigeration Manufacturers Multiply’, *Electrical Merchandising* (October 1932), 36; Tedlow, 1990, 313–321.

¹⁶ ‘The Nudes Have It’, *Fortune Magazine*, May 1940, 73–111 (pp. 102 & 111).

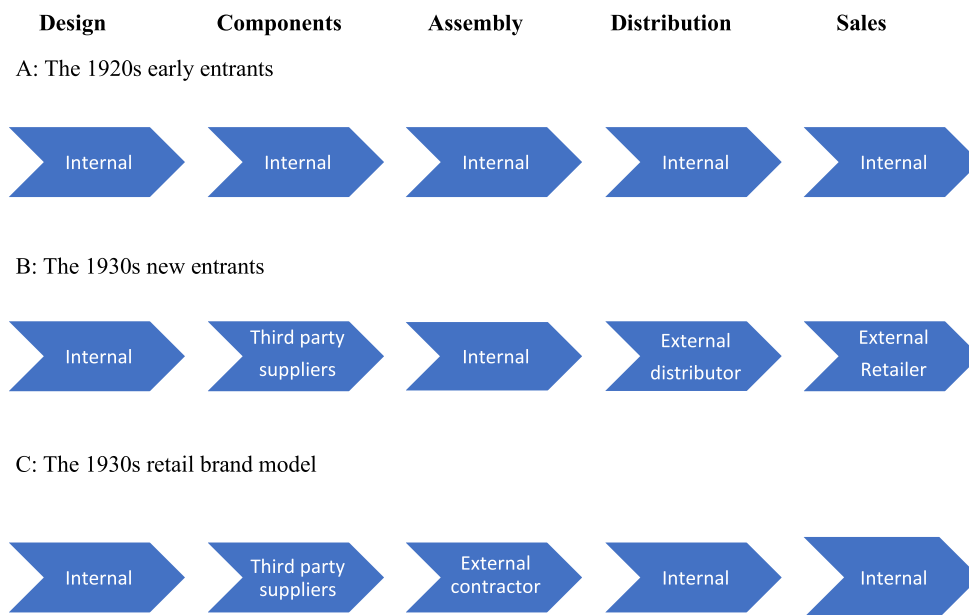


Figure 4. Simplified refrigerator value chains for the 1920s incumbents, the 1930s manufacturing new entrants, and the 1930s retail brands. *Source:* Based on this case study. *Note:* There is some degree of variation within each model (e.g. Montgomery Ward sourced its refrigerator mechanisms from Frigidaire).

These controlled armies of salesmen, whose jobs involved not only selling the products, but the whole concept of electric home refrigeration.

4.3 The new entrants' value chains

During the 1930s, a cluster of firms emerged, independent of the informal cartel that exploited the industry's open, modular design rules and typically adopted more fragmented and vertically disintegrated structures. These supplied or used third-party components, analogous to the computer industry's transition from a vertical to a more horizontal industry architecture between the 1960s and 1990s (Baldwin, 2023: 14). As shown in Panel B of Figure 4, these new entrants streamlined their value chains. Some, including well-known brands such as Norge and Crosley, gained significant market shares by reducing costs by outsourcing components. One such strategy involved simplifying the product and reducing its size, again paralleling the radio sector (Scott and Ziebarth, 2015). For example, radio entrepreneur Powell Crosley entered the refrigerator sector in 1932 with a strategy of developing the first refrigerator priced below \$100. This was achieved with a simplified design that dispensed with unnecessary features, in line with Crosley's vision of creating a refrigerator for the "Ford automobile class... not so quiet as more expensive makes, but one that would get you there".¹⁷

Some of the most successful business models involved undercutting the industry incumbents' prices by substantially reducing costs downstream from the factory. These new entrants, labeled "the new competition" by *Fortune*, relied heavily on third-party components and typically outsourced final assembly, becoming "manufacturers without factories."¹⁸ Their business models were based on undercutting prices—mainly by reducing sales and distribution costs in a "mature" market, characterized by machines that were essentially similar to one another and had high product reliability, transforming refrigerators from S-goods into commodities. Product maturity is associated with weakening brand preference, rising cross-elasticity of demand between brands, narrowing product differentiation, and market entry by own-brand retailers, all of which restrict

¹⁷ 'How Crosley broke £100', *Electrical Merchandising*, April 1941, 18.

¹⁸ 'The Nudes Have It', *Fortune Magazine*, May 1940, 73–111 (p. 102); Tedlow, 1990: 315–316; US Federal Trade Commission, 1944: 143; Gereffi and Memedovic, 2003.

the ability of market leaders to charge premium prices (Dean, 1950: 52–53; Tedlow, 1990: 315–316; US Federal Trade Commission, 1944: 143).

Evidence suggests that during the 1930s, smaller yet significant refrigerator firms had only small manufacturing cost penalties compared to the industry's giants. Although raw plant-level productivity data for this period are not available, the 1939 *Census of Manufacturers* provides grouped data for refrigerator and air conditioning plants. This data shows that productivity, proxied by value added per worker, peaks in the \$500,000–\$999,999 range of annual output (US Department of Commerce, 1942: 183–217). In 1939, a total of 53 plants operated within or above this output range, implying that all the firms named in Table 3 would have had outputs above minimum efficient scale in the late 1930s, as would some firms with lower market shares.

4.4 Price wars and leaner value chains

The influx of new entrants, who undercut incumbents' agreed prices, triggered a price war during 1931–1932. This was followed by a period of price stability, with major brands setting surprisingly similar prices for each size range (even for guarantees). This pattern corroborates Quinn's claims of price collusion (U.S. Temporary National Economic Committee, 1940: 131–134). However, while such collusion might raise net margins, the suppression of price competition reduced the competitive advantage of the highest productivity firms. Price-fixing, in turn, boosted incentives for non-price competition, which may have played a significant role in the market leaders' retention of their expensive, but effective, selling systems, despite rapid growth of “over the counter” sales methods, typically used by more recent entrants who remained outside the price-fixing agreement.

By the late 1930s, the locus of cost minimization and, for lower-income market segments, competitive advantage, had switched from manufacturing to downstream value chains, a strategy not generally discussed in the PLC literature.¹⁹ The most important driver in the new competition was mail-order firms, especially Sears and Montgomery Ward, who accounted for 18% of total refrigerator sales by volume in 1940 (Haring, 1962: 33). Although Sears had an unsuccessful venture into own-brand refrigerators in the 1920s, it was far more successful in the 1930s, owing both to the product's technical maturity and Sears' new policy of opening physical stores. Sears designed its Coldspot refrigerator “almost from the ground up”, partly to economize on costs, in a belief that the market could be substantially widened at its base (Emmet and Jeuck, 1950: 391).

To manufacture Coldspot, Sears contracted Sunbeam Domestic Appliance Co. of Evansville, Indiana, which had a washing machine plant but no contract, to manufacture the mechanism, while Seeger, an established Sears supplier, produced the cabinets. That Sears did not contract with an established refrigerator manufacturer is further evidence that product-specific knowledge had become relatively unimportant in what was by now a mature industry (Tedlow, 1990: 317). There was a similar trend in radios, with the development of buyer-driven value chains (Kaplinsky and Morris, 2002: 33), orchestrated by firms such as Sears, Montgomery Ward, and several tire companies (Maclaurin and Harman, 1949: 148–149; Scott and Ziebarth, 2015). The value chain for these retail brands is shown in Panel C of Figure 4. These value chains were particularly flexible; for instance, several firms contracted with the incumbents to obtain refrigerating mechanisms or even whole refrigerators—the most significant being Montgomery Ward's sourcing of its refrigeration mechanisms from Frigidaire (see Table 3).

Major retailers gained a significant advantage by integrating value chains downstream from the factory, eliminating elements in the distribution system and associated markups or commissions. Markides and Geroski (2005: 4–8) define radical, or disruptive, innovation as meeting two conditions: it introduces major new value propositions that disrupt established consumer habits and behaviors, and undermines the competences and complementary assets on which incumbents have built their success. *Lean distribution* constituted such a strategic innovation, because it was a novel system for household durables that threatened the incumbents' business models rather than their technologies, yet nevertheless introduced new value propositions that changed the habits and behaviors of its target, generally lower-income, market segments. By the mid-1930s, multiple value chains co-existed in the refrigerator industry, with the incumbents focused on selling on

¹⁹ For exceptions see Scott and Walker, 2016; Scott, 2022.

branding and features, and the *new manufacturer* and *new retail* firms competing primarily on price.

Lean distribution underpinned the dramatic rise of Sears in refrigerator market share, from 1.4% in 1931 to a peak of 14.1% in 1938, making it the US's third most important refrigerator company by volume. Sears dispensed with the 10% of list price for manufacturers' advertising and sales promotion by contracting with a manufacturer to take all their production. Distributor margins, which ranged from 7% to 12% of list price, were also removed by shipping products directly from the factory to Sears' 521 stores and mail-order customers. Further savings came from paying store salesmen commission of only 5%, rather than the customary 10%, because directly owned dealerships could not be lured away by other manufacturers, with Sears relying on higher volume sales to maintain their salesmen's incomes. Collectively, this strategy cut refrigerator list prices by around 30%.²⁰

In 1934, Sears launched a six-foot refrigerator model at a price normally associated with a four-foot one, while commissioning leading industrial designer Raymond Loewy to develop a restyled Coldspot, promoted with a generous advertising budget.²¹ Costs were reduced throughout the value chain by adopting a narrower product range (three models in 1934, compared to 14 for Frigidaire and 16 for GE), a strategy later copied by Philco (Emmet and Jeuck, 1950: 391; Tedlow, 1990: 319). Servicing costs were also reduced; for example, Coldspots had freezing units that could be mailed to, and fitted by, the purchaser if the original failed (Emmet and Jeuck, 1950: 391–392), foreshadowing the servicing strategies of smaller microcomputer firms in the 1980s.

Sears, Crosley, and Montgomery Ward (that sourced its refrigerator mechanisms from Frigidaire but reaped economies from downstream distribution), together with new manufacturer entrants such as Apex and Stewart-Warner, collectively put growing pressure on the industry leaders.²² Nor were these newer entrants confined to the bottom of the market. By 1939, Sears' market share by volume had grown to 13.8%, around 80% of which were six-foot machines, rather than the cheaper four-foot models.²³

By the late 1930s, most refrigerators were sold in department and other stores, rather than the customer's home or the manufacturer's showroom. However, sales were still based on personal selling, using in-store salesmen. Major brands were still colluding on prices, but had introduced "stripped" six-foot models that lacked some features and were priced more cheaply than their standard models (\$140 versus \$175) (U.S. Temporary National Economic Committee, 1940: 142). These were intended mainly to draw customers into the shop, where the salesman would "upsell" them more luxurious models with much higher profit margins.

However, the price understanding was about to face a major new competitor: Philco—an aggressive, well-run firm that had already challenged RCA for market leadership in radios. Having noted that its radio distributors had also sold 186,000 refrigerators (mainly Kelvinators and Norges), Philco purchased the home appliance division of Fairbanks-Morse, including its patents, production inventories, and access to its distribution network (Haring, 1962: 38). Philco informed its distributors that if they wanted to continue selling Philco radios, they would also have to sell Philco refrigerators.²⁴ Supported by a big advertising campaign, Philco's sales grew to 184,000 (\$17 million) in 1941.²⁵ Meanwhile, Kelvinator's loss of Philco's distribution network contributed to its falling volume market share from 11.7% in 1936 to 6.6% in 1939, and appears to have forced it to finally break ranks with the price understanding.

In January 1940, Kelvinator rocked the sector by announcing substantially lower prices across its model range, including a stripped six-foot model for \$119.95 (compared to \$129–134 for similar models sold through conventional retailers, although still more expensive than the mail-order firms). Other major incumbents reacted with hasty introductions of their own cut-price six-foot models, which were little different in appearance to their more luxurious models, making upselling much harder. Further price cuts throughout the industry leaders culminated in Sears introducing a stripped model that retailed for just \$89.95 (Borden, 1944: 573).

²⁰ 'The Nudes Have It', *Fortune Magazine*, May 1940, 73–111 (p. 102).

²¹ 'The Nudes Have It', *Fortune Magazine*, May 1940, 73–111 (p. 104).

²² Kettering, Frigidaire, 79.10.1.52, Report, 'General Operating Trends', 18 Oct. 1935.

²³ 'The Nudes Have It', *Fortune Magazine*, May 1940, 73–111 (p. 106).

²⁴ 'The Nudes Have It', *Fortune Magazine*, May 1940, 73–111 (p. 106).

²⁵ 'Radio, Refrigerators and Radar', *Fortune Magazine*, Nov. 1944, 115–243 (p. 119).

Table 6. The value chain for 6-foot-tall US refrigerators in 1939/40 (\$)

	“Standard brand” ^c		Coldspot ^d		Kelvinator
	1939	1940	1939	1940	1940
Manufacturing costs:					
Production	55.00	55.00	53.00	53.00	53.00
Sales	7.00	6.00	0.00	0.00	5.00
Advertising & sales promotion	11.00	9.00	0.00	0.00	6.00
Administration	6.00	5.00	4.00	4.00	4.00
Excise tax	4.00	3.50	3.00	3.00	3.00
Total	83.00	78.50	60.00	60.00	71.00
Manufacturing profit	9.50	3.00	4.50	4.00	5.00
Distribution expenses	21.50	18.50	4.50	4.50	8.00
Dealer’s expenses:					
Commission to salesmen	17.95	15.50	6.50	6.00	13.95
Other expenses ^a	34.55	32.00	35.00	32.00	30.00
Total	52.50	47.50	41.50	38.00	43.95
Dealer’s profit	8.00	7.00	14.00	8.00	7.00
Four-year warranty ^b	5.00	5.00	5.00	5.00	5.00
List price	179.50	159.50	129.50	119.50	139.95

Source: “The Nudes Have It”, *Fortune Magazine*, May, 1940, 73–111 (p. 111). ^a Administration, rent, advertising, publicity, etc. ^b Most of this went to the manufacturers, to pay their share of the warranty on the mechanical unit. It was placed in a reserve fund and part of it might later revert back to profits. ^c These represent average figures for manufacturer brands. It was noted that the top producers, such as Frigidaire and GE, reaped economies of scale in promotion and distribution costs per unit, which lowered expenditure in these areas. ^d Dealers’ expenses include around \$7 for advertising.

Among the incumbents, Kelvinator made the greatest efforts to streamline its value chain. It reduced assembly costs by focusing on just two sizes (6 and 8 ft) and cut its number of franchised distributors to concentrate on its retail branches. Table 6 shows value chains in 1939/40 for a six-foot “standard brand” refrigerator, Sears’ Coldspot, and an equivalent Kelvinator, based on estimates reported in *Fortune*.²⁶ The standard brand was acknowledged to have higher costs than the market leaders, owing to lower scale economies. In 1939, the standard brand’s list price was \$179.50, while an equivalent Coldspot model was available for \$129.50. Production costs were roughly similar, but Coldspot avoided advertising and sales promotion costs and had lower distribution and commission expenses.

By 1940, the standard brand had reduced its price by \$20 through a squeeze on advertising and sales promotion costs, a much lower manufacturer’s profit, and a reduction in retailers’ commission and expenses. Coldspot retaliated with a further \$10 price cut, principally via cuts in retail expenses and profit margins. Kelvinator was in an intermediate position, with lower sales and distribution expenses than the standard brand (possibly reflecting scale economies in these functions) and lower retail commission and other expenses—capitalizing on its strong brand recognition. It could thus undercut the standard brand by \$20, but was still \$20 more expensive than the Coldspot.²⁷

By 1940, it was obvious that the era of the door-to-door refrigerator salesman was nearing its end. Information on refrigerator functionality and features was now widely disseminated, and even in department stores, the salesman could do little more than show the different features that separated his line’s basic refrigerators from its more luxurious models. The refrigerator salesman was rapidly becoming just an ordinary department-store salesman, facing relatively knowledgeable customers and hoping that a good pitch would close the sale.

²⁶ “The Nudes Have It”, *Fortune Magazine*, May 1940, 73–111.

²⁷ “The Nudes Have It”, *Fortune Magazine*, May 1940, 73–111.

5. Kingpin control of labor-saving durables under strong patent protection: the example of the semi-automatic washing machine

The incumbents' loss of industry control over the refrigerator value chain contrasts with that of another high-ticket consumer durable of this era—the washing machine. Unlike refrigerators, washing machines had much stronger patent protection, which allowed Maytag to dominate the interwar washer market via a ruthless strategy of extending its control of fundamental patents and using threatened, or actual, litigation if its stringent patent terms were not met.

From 1917, Maytag and its associates sought to take control of the industry via fundamental patents on the swinging wringer and drive gear mechanisms, using a portfolio of eight patents (plus one pending). The syndicate cemented its control by absorbing a rival patent pool, gaining the authority to grant licenses and to receive 60% of royalties. Following this amalgamation, the proportion of washing machines produced by licensed manufacturers grew from 25% in 1920 to 85% in 1922. Many firms only paid royalties following threats of litigation to themselves, or their distributors and larger retail customers.

The Maytag syndicate's claim to hold the industry's fundamental patents was generally regarded as problematic, because it did not own all of the patents on the key features of the reversible swinging wringer (Maxwell, 2003: 47; Hoover and Hoover, 1993: 118). However, the syndicate had considerable resources for litigation, enabling it to win by exhausting the finances of its adversaries. The syndicate also used patent control to enforce price-fixing agreements, until these were eventually negated by antitrust pressures (Maxwell, 2003: 47; Hoover and Hoover, 1993: 118).

By 1928, Maytag had gained a 33% share of the washer market—four times larger than that of its nearest competitor and six times that of its second-largest rival.²⁸ Maytag also blocked product innovation, using a license clause that prevented manufacturers from making washing machines that did not conform to a design shown in a circular accompanying the license (Harvard Law School, 1934). Litigation to enforce the circular proved successful (Scott and Spadavecchia, 2023) and it was not until 1939 that Maytag's industry control was finally negated in a Supreme Court case, by which time Maytag had succeeded in controlling washing machine design and prices for over 20 years. Maytag's tight control had blocked innovation and price competition but preserved its kingpin position and most of its market share, which fell from over 20% between 1926 and 1929 to 14% by 1933, recovering to 20% in 1935.²⁹

Maytag's suppression of price competition may account for the washing machine's relatively slow diffusion (from 24% of wired homes in 1925 to 66.8% in 1941, compared to the diffusion of the refrigerator from 1.0% to 72% between these dates).³⁰ Moreover, Maytag's product design had barely changed. After launching the very successful Model 80 washing machine series in 1922, Maytag thereafter produced models that were essentially very similar. A 1934 trade article noted, "the almost complete uniformity of present washer design," in terms of both mechanisms and features.³¹ Indeed, in 1935, when two young inventors developed the first fully-automatic washing machine, they had to seek backing from a firm outside the sector: Bendix Aviation Company.

6. Why didn't the incumbents abandon personal selling following market maturity?

Christensen *et al.* (2002) argue that dominant, integrated firms will lose substantial market share over time to more specialized and highly disintegrated entrants. The dominant household durables firms of the 1920s, such as Frigidaire and GE in refrigerators, Hoover and Eureka in vacuums,

²⁸ Jasper County Historical Museum, unpublished Maytag historical timeline history, n.d., c. 1950s, p. 312.

²⁹ Industry-level data: '50 years of statistics and history', *Merchandise Week*, 104, 9 (28 Feb. 1972), 21–54 & 110–160; Maytag data, *Moody's Investment Service (1929/1931)*, *Moody's Manual of Investments. American and Foreign. Industrial Securities* (p. 620/1752), New York; Jasper County Historical Museum, unpublished Maytag historical timeline history, n.d., c. 1950s.

³⁰ Industry-level data: '50 years of statistics and history', *Merchandise Week*, 104, 9 (28 Feb. 1972), 21–54 & 110–160; Maytag data, *Moody's Investment Service (1929/1931)*, *Moody's Manual of Investments. American and Foreign. Industrial Securities* (p. 620/1752), New York; Jasper County Historical Museum, unpublished Maytag historical timeline history, n.d., c. 1950s.

³¹ 'Washers', *Electrical Merchandising* (January 1934), 29–31.

and Maytag in washing machines, were vertically integrated, either directly or via franchisees. According to Christensen *et al.* (2002), such firms initially attract customers by offering them products with high functionality, often over-serving customer needs. However, when a product reaches maturity, these vertically integrated firms lose market share and only retain dominance in the most demanding tiers (of functionality), while the rest of the market is most efficiently served by a horizontally stratified structure. Integrated firms retain stronger positions only in market tiers that demand higher functionality, which encompasses superior product features but also includes a firm's ability to "educate" customers regarding its brand's superiority over competitors. As a result, personal selling by display remained an effective strategy for firms pursuing higher market tiers, even after refrigerators reached product maturity.

This perspective offers a persuasive explanation regarding why major incumbents continued to focus on personal selling for refrigerators well into the late 1930s. In January 1938, Frigidaire still retained a national selling force of 24,000³² and had modified its personal sales methods to better serve high-tier customers, particularly department-store shoppers. In 1932, the company established a department-store division to extend its personal selling techniques to department, furniture, and other high-end stores. Beyond providing the Frigidaire brand name and promotional materials, the company actively trained retailers in personal selling methods.³³

This strategy leveraged Frigidaire's key marketing competencies. As Tripsas (1997) emphasizes, complementary assets are critical to maintaining a competitive market presence in the face of competence-destroying innovations. Moreover, this strategy posed far lower risk than price wars. Despite GM's reputation for statistics-driven management, the extensive Frigidaire archives have a surprising lack of profit data. However, the available figures show that Frigidaire's profit-to-net-sales ratio in 1929 (14.7%) was not surpassed until 1937. This suggests that major price cuts could severely erode profits or even lead to losses, especially given the strong likelihood of retaliation.³⁴

Other leading household durable firms of the 1920s, including Maytag, Hoover, and RCA, followed similar strategies. They maintained premium pricing, close to the top of the market, and used marketing strategies based on personal selling and display (although, like Frigidaire, they made progressively more sales in department and other high-end stores, rather than people's homes). Nevertheless, many of the leading incumbents, including RCA, Hoover, and Frigidaire (which made the mechanisms for Montgomery Ward's refrigerators), also managed to access lower market tiers without compromising their brands, either by supplying retail brands on contract or creating their own "no-name/any name" or private-label brands.³⁵

7. Conclusion

The pioneers of home mechanical refrigeration faced a daunting challenge to develop machines that were reliable, compact, silent, and especially safe (given that they had a potentially dangerous mix of poisonous or corrosive refrigerants, water, and electricity). While this had been a considerable engineering challenge, their eventual triumph was achieved using the same fundamental patents that had been developed for industrial refrigeration and were now spent. Without patent protection, successful early movers relied on giant plants to generate scale economies and armies of direct salesmen to "educate" customers regarding the value, simplicity, safety, and silent running of their machines.

Scale economies turned out to be largely elusive, but the early movers' strategy of extensive, high-pressure selling was successful in the 1920s. Indeed, the principal bottleneck that the incumbents had resolved was not technological but informational: educating consumers about mechanical refrigeration, demonstrating its advantages over iceboxes, and only then extolling the merits of their specific brand. Such education was a common good when all firms followed the same business models and marketing strategies. The first successful movers—Frigidaire and GE—became the industry's kingpins and reacted to new competitors in the 1920s by creating

³² Wright State, Frigidaire history, A2/2, salesmanship chapter: 21.

³³ Kettering, Frigidaire, 79.10.51, 'What department stores have accomplished to date with Frigidaire', report, 1934.

³⁴ Kettering, Frigidaire, 79.10.1.52, 'Operating Report, Frigidaire Division. Covering the Frigidaire Household Business', for GM Policy and Administration Committees, 31 Aug. 1937.

³⁵ Kettering, Frigidaire, 79.10.1.52, Report, 'General Operating Trends', 18 Oct. 1935.

an unofficial cartel to police them and deter price-cutting—that would undermine their business models.

However, diffusion typically only spread to upper-middle or high-class families, partly due to their use of intensive, and very expensive selling methods (door to door). Their machines were also typically deluxe products with high functionality, often over-serving lower-income customers' needs (Christensen *et al.*, 2002). Therefore, a large proportion of families were priced out of the market, creating a gap that enabled the rise of the new competition of the 1930s.

By the early 1930s, the 1920s industry model was being undermined by changing market and economic conditions. The refrigerator had reached its dominant design based on modular, interchangeable components, produced by a strong third-party components industry. Moreover, their direct-sales model was also gradually becoming less effective, as more families had first or second-hand knowledge of refrigeration from family and friends and were not keen on spending much more money on an expensive refrigerator, given the development of more basic, but reliable, refrigerators sold by later entrants.

The early 1930s saw a substantial “shake in” of new firms that cut costs by simplifying refrigerator design and using third-party components, while rejecting direct selling and simplifying supply chains downstream from the factory. The industry's kingpins proved powerless to block this new competition as they had weak intellectual property (apart from branding), while their scale economies were also weak, especially after the development of a third-party components industry producing modular, interchangeable parts.

This disruptive innovation by the new competition undermined the profitability of direct selling, while capturing growing market share from the incumbents. Markides and Geroski (2005: 4–8) define radical, or disruptive, innovation as meeting two conditions: it introduces major new value propositions that disrupt established consumer habits and behaviors, while undermining the competencies and complementary assets on which incumbents have built their success.

Lean distribution constituted such a strategic innovation, because it was a novel system for household durables that threatened the incumbents' business models rather than their technologies, yet nevertheless introduced new value propositions that changed the habits and behaviors of its target, generally lower-income market segments. By the mid-1930s, multiple value chains co-existed in the refrigerator industry, with the incumbents focused on selling on branding and features, and the *new manufacturer* and *new retail* firms competing primarily on price.

Frigidaire and GE progressively lost control of “the rules of the game,” becoming unable to dictate value to end users and technologies, plus services along the value chain, primarily in marketing and components (Pisano and Teece, 2007; 280–284; Jacobides *et al.*, 2006; Baldwin, 2015; 12–13). This led to price wars in the early 1930s and, especially, in the late 1930s, as many leading brands felt it necessary to retaliate in order to keep their large factories running at full capacity.

In the long term, the main winner from the home refrigerator's development without live fundamental patents was the consumer. Successful early movers such as Frigidaire, GE, and Kelvinator had played critical roles in addressing the considerable technological challenges of home mechanical refrigeration, together with the equally daunting task of selling the idea of mechanical home refrigeration to a hesitant public. Initial strategies of high prices to cover the costs of intensive, personal selling, rapidly created a mass—if far from universal—market, assisting the refrigerator's rapid adoption of a dominant design. Then, just as the high-income market was showing signs of moving toward saturation, a wave of new entrants emerged, focusing on cost reduction, mainly downstream from the factory.

These capitalized on growing consumer acceptance and expanded the market to middle- and working-class families, through simplifying value chains and undercutting prices—a strategy often under-emphasized in the standard PLC literature. Our analysis shows that the most significant competitive challenge for leading firms can often emerge not only in the early development phase of the PLC, but during and after the maturity phase, with shake-in's being much more important than shake-outs.

What would have happened if the fundamental patents had still been active? Patent holders had considerable power to exclude competitors, including refusing to license, imposing minimum pricing, and a relatively free hand over any conditions they wished to insert into licenses, even if these would otherwise be illegal under antitrust or other legislation

(Scott and Spadavecchia, 2023: 3). The industry's evolution would most probably have followed a different trajectory, with the most likely outcome being something resembling the Maytag syndicate. Licensees might be forced to use personal selling methods, while there would probably have been restrictions on minimum prices, design, innovation, and, possibly, territorial limits and maximum sales volumes. Collectively, this would have probably kept retail prices high while slowing technical development and diffusion.

The greatest negative impacts of active fundamental patents would have been felt following the onset of maturity, with potentially substantial impacts on consumer welfare. If restrictions on minimum prices had been made legally enforceable by being written into patent licenses, price competition would have been prevented or reduced. Thus, as in the washer sector, negative welfare costs could have been substantial, with the main losers being lower-income families, who would have struggled to buy refrigerators.

Conversely, with no fundamental patents constraining competition, lower-income families became served by new entrants, using strategies of reducing costs along the value chain. In 1925, only 1% of American wired homes had refrigerators. By 1941, this had rocketed to 72%, making the refrigerator the most successful high-ticket labor-saving durable of the interwar era.³⁶ Therefore, this case underscores the significant deadweight losses that can result from the monopoly power of fundamental patents, especially for lower-income groups.

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³⁶ '50 years of statistics and history', *Merchandise Week*, 104, 9 (28 Feb. 1972), 21–54 & 110–160.

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