Volume Title: Mergers and Productivity

Volume Author/Editor: Steven N. Kaplan

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-42431-6

Volume URL: http://www.nber.org/books/kapl00-1

Conference Date: January 16-18, 1997

Publication Date: January 2000

Chapter Title: The Eclipse of the U.S. Tire Industry

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Chapter URL: http://www.nber.org/chapters/c8649

Chapter pages in book: (p. 51 - 92)

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The Eclipse of the U.S. Tire Industry

Raghuram Rajan, Paolo Volpin, and Luigi Zingales

It is difficult to think of an industry that was affected more by the wave of mergers and acquisitions (M&A) in the 1980s than the U.S. tire industry. Seventy-five percent of the companies in the industry (accounting for 90 percent of the value) experienced a takeover bid or were forced to restructure during the period 1982–89 (Mitchell and Mulherin 1996). As a result of this activity, control changed hands in over half the companies in this industry. Even more remarkable, in the majority of cases, control was transferred to foreign owners. By the end of the decade, traditional American firms like Firestone, Uniroyal, Goodrich, Armstrong, and General Tire belonged to foreign companies. As a consequence, large U.S.-owned tire manufacturers, who in 1971 represented 59 percent of the world production and included four out of the top five producers, in 1991 represented only 17 percent of world production with only one of the top five producers (see table 2.1 below). These changes are even more dramatic

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Rajan and Zingales acknowledge financial support from NSF grant no. SBR-9423645, and Volpin from an NSF graduate fellowship. The authors are grateful for the insights provided by tire industry executives, especially Mr. Maki, Mr. Mihelick, and Mr. Tee. The authors benefited from the comments of Mike Jensen, Robert Porter, and participants at the conference and at a seminar at the University of Chicago. The authors also thank the Bureau of the Census and the NBER for making available the Longitudinal Research Database (LRD). In particular, they acknowledge the help of Joyce Cooper, Wayne Gray, and Arnold Resznek. The opinions expressed in the paper do not necessarily represent the views of the Bureau of the Census or the NBER. The LRD matched sample has been screened to ensure that no confidential data have been revealed. Whenever a single company's name is mentioned, there is no intention to suggest that such a company is in the LRD sample.

when compared with the stability of the relative market shares of U.S. tire manufacturers for the previous fifty years.

The U.S. tire industry therefore presents an intriguing example of the changes wrought by the M&A wave that swept through the United States in the 1980s, and of its effect on the position of U.S. manufacturers in a global market. Anyone interested in the effects of M&A on the productivity and the long-term competitiveness of the U.S. economy cannot ignore what has happened in this industry. The purpose of this paper, then, is to undertake an in-depth industry analysis of the events that led to the demise of U.S. ownership in the tire industry, and of the effects of mergers on industry restructuring and productivity. To do so we call upon a variety of different sources, ranging from plant-level data to industry analyses (including contemporary reports in trade publications), interviews with executives, and accounting data. The goal is to attempt to explain why the merger wave occurred, why it was led by foreign producers, and what its effects have been.

We are able to test (and reject) two main interpretations of these events. The first (neoclassical) hypothesis is that foreign manufacturers were more efficient in producing tires, and that this advantage (be it superior know-how or better management) could not be transferred to U.S. manufacturers without acquiring their plants. According to this view, the takeovers in the 1980s in the tire industry were simply a reflection of the fundamental tendency for assets to move to the most efficient producers. Contrary to this view, we find that plants are not acquired by the most efficient producers (at least as far as plant-level productivity is concerned) and we do not find any evidence of an increase in plant-level productivity after an acquisition.

A second explanation of the phenomena is advanced by Jensen (1993). He suggests that the evolution of the U.S. tire industry during the 1980s is a textbook example of the effects of what he calls "the third industrial revolution." According to Jensen, rapid technological change generates overcapacity in certain industries, requiring some firms to downsize or exit. But "managers fail to recognize that they themselves must downsize; instead they leave the exit to others while they continue to invest. When all managers behave this way, exit is significantly delayed at substantial cost of real resources to society. The tire industry is an example. Widespread consumer acceptance of radial tires meant that worldwide tire capacity had to shrink by two-thirds (because radials last three to five times longer than bias ply tires). Nonetheless, the response by the managers of individual companies was often equivalent to: 'This business is going through some rough times. We have to make major investments so that we will have a chair when the music stops'" (Jensen 1993, 847). Since internal control systems do not force managers to shrink, only the intervention of outside raiders can force these companies to downsize or exit.

That the acquirers were foreign rather than domestic is not relevant for this interpretation, all that matters is that they were outsiders to the industry.

We do not find much support for this interpretation either. While, as suggested by Jensen (1993), there were some delays in closing bias ply capacity (also see Sull 1996), the industry had made most of the necessary closures by the early 1980s—before the takeovers started! More specifically, we find no evidence that acquisitions hastened the closure of plants in general and more inefficient plants in particular. We also find that capital expenditures increase after an acquisition, which is inconsistent with the overinvestment hypothesis.

We then try to explore the reasons for the demise of the U.S. ownership in the tire industry by looking at the historical evolution of the tire industry in the United States and the rest of the world, with particular emphasis on the relationship between the car and the tire industries. The car industry plays an important role for two reasons. First, original equipment sales represent about one-quarter of all sales. Moreover, they have an important effect on the replacement sales given the tendency of consumers to buy the same type of tires. Second, major changes in type of tires used, like the introduction of radials, require some modifications in the design of cars. This raises an important coordination problem.

The most striking aspect of the U.S. tire industry is its delay in the introduction of radials. Michelin first commercially produced radials in France in 1948, and by 1970, 98 percent of tires sold in France were radials. The rest of Europe and Japan followed a similar path. Yet, in 1970 radials represented only 2 percent of the tires sold in the United States. The technology was well known to U.S. manufacturers, who were using it in their European subsidiaries. An attempt by Goodrich to launch radial production in the United States in 1965 failed because of the strong opposition of U.S. car manufacturers, who did not like the fact that radial tires required a new suspension system in the cars. Only in the beginning of the 1970s did the car producers announce that they wanted to switch to radials. Therefore, U.S. tire manufacturers delayed the transition to radials until the 1970s, a period characterized by the oil crisis and a severe recession in the car industry.

The switch to the radial technology required major capital investments because it was not economically feasible to convert the existing bias-ply capacity to producing radials; Firestone's attempt to do so ended in fiasco. As a result, tire producers faced the prospect of making major capital investment in a low margin sector at the same time as the growth prospects for the entire sector looked grim. The major diversified tire companies (Goodrich in particular) made the conscious decision to reduce their capital and development expenditure in the tire business, sell their foreign operations, and look for a buyer for domestic operations. Others, like Uniroyal, were less clear-cut about their prospects. However, barring Goodyear, all the tire manufacturers reduced their focus on tires. It is entirely possible that this was indeed the optimal strategy, since foreign producers had already sunk their investment in radials, while U.S. producers had to sink at a time when the long-term growth prospect of the car industry (and thus indirectly of the tire industry) had worsened.

One possible solution at this stage was a consolidation of the U.S. tire industry. There were two reasons, however, why that could not occur without the cooperation of outsiders. First, it was unclear whether such a move would be accepted by the Federal Trade Commission. Second, and most important, automobile manufacturers strongly opposed any consolidation among their suppliers. They liked having a number of independent tire suppliers to ensure competition. As a result, a merger between two tire suppliers would inevitably result in a redistribution of some of their share of the original equipment business to other tire manufacturers. The importance to tire manufacturers of having original equipment sales to the automobile manufacturers therefore precluded a large domestic tire manufacturer from merging with another large domestic manufacturer (unless, of course, one of the manufacturers had no original equipment sales as was the case with Goodrich, which merged with Uniroyal).

In the meantime, the economics of the industry were changing in other ways. Most important, automobile sales and manufacture were becoming increasingly international and there was a growing need for tire manufacturers to follow their customers across countries. If Honda cars are equipped with Bridgestone tires, then Honda's exports in the United States automatically generate demand for Bridgestone tires in the U.S. replacement market. It is only natural for Bridgestone, thus, to take advantage of this demand by starting to sell in the United States. Given the high transportation costs, this will generate also the need for producing in the United States.

The globalization of the car industry also produced the need for a higher level of research and development (R&D), which could be borne only if spread over a higher volume of sales. For example, Goodyear's R&D and advertising expenses as a fraction of sales rose 27 percent between 1970–75 and 1980–90. As a result, only large multinational companies could survive.

If only multinationals could survive and there was not much room to build new capacity in any of the major industrialized countries, then only two possibilities were left: either the foreign producers acquired U.S. firms or U.S. firms acquired foreign producers. The latter alternative, however, was not feasible since most of the foreign companies could not be acquired. Michelin, for example, which is the major French tire producer, is fully controlled by a limited partnership, whose unlimited partner is Francois Michelin. He, rather than a majority of Michelin shareholders, determines the future of Michelin. Similarly, the major German producer, Continental, is controlled by a complicated web of shareholdings that prevented Pirelli from taking it over in 1990. The Japanese firms are even harder to acquire. By contrast, acquisitions, even acquisitions by foreign firms, were extremely easy in the United States during the 1980s. Although it is hard to establish how much of a role this asymmetry played, it is an important (and often ignored) factor that should be taken into consideration.

We therefore conclude that the roots of the dramatic change in the world and U.S. tire markets between 1970 and 1990 lie largely in the failure of U.S. tire manufacturers to adopt the radial technology when the rest of the world did so. Of course, hindsight is always 20/20. But even manufacturers such as Goodrich who realized the potential of the technology back in 1965 could not force its widespread acceptance. The structure of the domestic market, and specifically the relationship between the automobile manufacturers and the tire producers, was probably instrumental in retarding adoption of the technology. In other words, even though they acted rationally and in their own self-interest, the structure of the domestic market led U.S. tire manufacturers—like characters in a Greek tragedy—inexorably toward their doom. By contrast, the domestic market structure in countries like France probably spurred innovation. Thus the paper highlights a possible link between domestic market structure, innovation, and the ability to compete internationally.

The rest of the paper is organized as follows. In section 2.1, we discuss the structure of the tire industry; in section 2.2, we discuss the reasons for the delay in the introduction of radials into the United States. Section 2.3 tests the "neoclassical" and "overinvestment" hypotheses, while section 2.4 examines the hypotheses that the U.S. manufacturers willingly quit a business they were too weak to compete in. Section 2.5 concludes with policy conjectures.

2.1 The Structure of the Tire Industry

2.1.1 History

The tire industry had its beginnings in tires made for bicycles.[1] At first, bicycles used solid rubber tires, but the invention of the pneumatic tire by John Dunlop in 1888 soon made it the dominant product. The industry took off on the back of an explosion in the demand for bicycles in the 1890s. By the time the craze for bicycles waned in the beginning of the twentieth century, automobiles started driving the demand for tires, and they account for the majority of tires manufactured today.

1. This section draws heavily from French (1991) and Tedlow (1991).

The early focus in product innovation was on making the tire fit the wheel without slipping, while at the same time making it easily removable. But the demand for product innovation did not cease once this was achieved. Automobiles became heavier and faster, which triggered major innovations in tire manufacture including the introduction of patterned treads. French (1991) argues that these innovations enabled smaller firms such as Goodyear and Firestone to compete with the large bicycle tire manufacturers.

Even though the basic form of the automobile tire was set by 1910, there have since been tremendous advances in the product. The introduction of balloon tires in the 1920s and, as we will detail shortly, radials in the 1970s were fundamental changes. Tires became flatter and wider, and tire life improved rapidly, especially in the 1920s and 1970s. Changes in manufacturing technology accompanied the changes in product technology. The industry had moved to mass production using tire-building machines by the 1920s. French (1991, xv) suggests that "technical changes increasingly disadvantaged smaller producers and consolidated the position of larger firms, leading to a decline in the number of firms after 1920." Interestingly, innovation seems to have enabled small manufacturers to establish themselves when the industry was in its infancy, but as the industry matured, it seemed to become a barrier to entry. This relationship between innovation and number of firms has been formalized and applied to the tire industry by Jovanovic and MacDonald (1994).[2]

This is reflected in the market shares of the various manufacturers. Four of the five biggest producers of tires in 1970 (Goodyear, Firestone, U.S. Rubber [later Uniroyal], and Goodrich) were also among the five biggest in 1910. This is not to say that there was no entry or exit early on. For instance, sixty firms entered the industry in 1919–20 alone. But the turnover was largely confined to the small firms and new entrants. The large firms and their market shares remained surprisingly stable. Moreover, entry eventually dropped off with virtually no entry between 1929 and 1970.

The major tire manufacturers in 1970—the starting point for much of our analysis—had somewhat different origins. BFGoodrich and U.S. Rubber (Uniroyal) were primarily rubber goods manufacturers before they began producing tires. The tire business was a form of diversification for them. By contrast, Goodyear and Firestone started out in the tire business. The differences in their origins seemed to reflect the extent to which they diversified outside the tire industry. Goodrich and Uniroyal had approximately 60 percent of their sales in the tire industry in 1970, while the figure was over 80 percent for both Firestone and Goodyear. The exception to this pattern is General Tire which started in 1915 by supplying repair ma-

2. Interestingly, they end their analysis in 1973 on the basis that the introduction of radials did not increase the optimal scale of production of tires.

terial but soon began tire production in 1916. It had only 40 percent of its sales in tires by 1970. As we will see, the extent to which the firm was diversified appeared to influence top management's commitment to stay in the business.

2.1.2 Structure of the Industry circa 1970

Table 2.1 shows the share of the world market for tires held by the major producers. Michelin was the only non-U.S. manufacturer in the top five in 1971. The top four producers controlled 60 percent of the world market. According to Dick (1980), the tire industry has been heavily concentrated in this way since the thirties: in the U.S. market in 1935, the four largest producers accounted for 80 percent of the total sales; in 1958 their share was 74 percent, and at the end of the 1960s, 72 percent.

Economies of scale in production do not seem to explain such a level of concentration. Plants in 1976 had capacity varying from 300 tires per day to 30,000 tires per day, with a mean capacity of 14,500 tires. *Modern Tire Dealer* reports there were fifty-five plants of significant size in 1976. That the minimum economic scale is not very large seems to be obliquely confirmed by John Ong, Chairman of the Board of BFGoodrich, "Today, under normal competitive conditions, it's not economically feasible to operate a tire plant with capacity lower than 9,000 to 12,000 tires a day. Mixing, calendering, and other equipment investments mandate a mini-

Table 2.1 **World Market Share of the Largest Tire Producers**

Company	Home Country	1971	1979	1986	1993
Goodyear	U.S.	24	23	19	17
Michelin	France	11	16	18	19
Firestone	U.S.	17	14	7	
Dunlop	U.K.	4	4		
Pirelli	Italy	6	6	6	5
Bridgestone	Japan	3	7	9	18
Uniroyal	U.S.	8	5	6	
Goodrich	U.S.	6	4		
General Tire	U.S.	4	4		
Continental	Germany	2	3	8	7
Sumitomo	Japan			6	6
Yokohama	Japan			4	5
Toyo	Japan			2	3
Concentration indexes					
C4		60	60	54	61
Herfindahl		12	11	10	11

Sources: West (1984) and *Financial Times*, 1988 and 1995.

Note: This table presents each manufacturer's tire sales as a percentage of world sales. C4 is the sum of market shares of the four largest producers. The Herfindahl index is the sum of the squared market shares of each producer.

mum size." This estimate would allow for about one hundred plants in the United States.

2.1.3 Channels of Distribution

The tire industry essentially serves two markets: the original equipment (OE) market and the replacement market. OE manufacturers are the automobile producers who, historically, have had tremendous bargaining power. In the words of William O'Neil Sr., founder of General Tire, "Detroit wants tires that are round, black, and cheap—and it don't care whether they are round and black" (Tedlow 1991, 15). The automobile manufacturers have been content to play tire manufacturers against each other without actually building their own tire factories (though Ford briefly did so in 1938). But despite its low profitability, the OE market has historically been important because it provides large orders (and hence the scale) as well as the prospect of future replacement sales (car owners typically replace tires with the same original equipment brand).

A possible explanation for the concentration of tire sales is that sales to the OE market are critical. The primary requirement of an OE supplier according to *Rubber World* (January 1966) is that the supplier must be a technological innovator. As a tire veteran put it "You just can't stand still with those boys [the automobile manufacturers]. . . . Your tires have to carry heavier loads, last longer and go faster. The smaller firms cannot afford the kind of R&D operation this entails." Another requirement is that the tire manufacturer must be able to deliver the product. In other words, it must have "a distribution set-up capable of giving Detroit what it wants, where it's wanted—and on time. . . . It must have acceptance as [a] national supplier . . . it must be able to warehouse Detroit's requirements well ahead of the call, stockpiling them, in order to avoid the risk of strikes." Finally, a sales network that is capable of servicing the OE tires is an added advantage in obtaining OE orders. Thus the economies of scale in research and distribution appear to be an important element of this industry.

Table 2.2 shows the share of the domestic OE market held by U.S. manufacturers. Smaller manufacturers had a presence only in the replacement market, but even there, the majors controlled a significant fraction of the overall sales.[3] The automobile manufacturers did not buy from one tire supplier. Instead, they spread their orders among the tire manufacturers, though they had their favorites. For instance, Goodyear and Chrysler, Uniroyal and General Motors, and Firestone and Ford were thought to enjoy

3. Most major manufacturers also produced for private labels. As a result, it is not easy to obtain an exact figure for the share of the replacement market controlled by each manufacturer. If we restrict our attention to the share of the market controlled by the majors under their original names, Goodyear controlled 13 percent of the replacement market in 1974 and Firestone 10 percent.

Table 2.2 **Tire Manufacturer Shares of Original Equipment Market in the United States**

Company	1968	1975	1980	1985	1990
Goodyear	31.0	35.0	28.0	32.0	36.5
Firestone	24.0	24.0	21.5	21.5	17.0
Uniroyal	25.0	20.0	24.4	22.0	17.0
Goodrich	15.0	8.0	10.3	0.0	
General Tire	5.0	11.5	10.8	13.0	12.0
Michelin		1.5	5.0	11.0	15.7
Continental				0.4	
Pirelli				0.1	
Dunlop					1.5
Bridgestone					0.3

Source: Modern Tire Dealer (1991).

Note: This table presents each tire manufacturer's share of sales to the OE market. All the figures are percentages of total sales of tires to automobile manufacturers in the United States.

special relationships. Since no foreign tire manufacturer produced locally, this explains why virtually the entire OE market was held by the five major U.S. manufacturers in 1970.

The OE sales of 37.5 million tires in 1970 accounted for 22 percent of the market. The rest is accounted for by replacement sales that were a further 130 million tires and accounted for 77 percent of the market, while exports represented less than 1 percent. Buyers in the replacement market range from mail order and retail chains like Sears and Montgomery Ward, which became significant buyers in the 1920s, to oil companies that entered tire retailing in the 1930s, tire company stores, and independent merchants. In 1970, replacement sales were composed of sales to the service stations of large oil companies (15 percent), large department stores (15.5 percent), tire company stores (11 percent), and independent tire dealers (56 percent). Profits in the replacement market have historically been higher than in the OE market. Rosenbloom and Benioff (1990) report that in 1966 the profit margins were between 3 percent and 5 percent in the OE market and between 5 percent and 8 percent in the replacement market.

In the replacement market, not all tires are sold under the producer's own name. Part of the output sold to large oil companies and to department and chain stores were distributed under private names specific to the outlet. This market was especially important for smaller companies such as Armstrong and Mohawk, since they did not need to advertise in order to sell. The tire producers distributed the rest under their own names (the national brands), or under less well-known names called "associate brands." As a result, even though the tires were produced by only a small number of companies, they were sold under more than 170 brand names.

The market was effectively segmented; national brands that were highly advertised across the United States and were used as original equipment could command a higher price, while the other brands were sold in a very price-competitive market.

2.1.4 Technology

In the 1960s, there were fundamentally two different types of tire construction: bias ply and radial ply. Technically, the two tires differ in the way the body cords are layered in the body of the tire. In bias ply tires, the cords are at an angle to the direction of rotation, while in radials they are perpendicular. In practice, the two tires differ substantially in performance. On well-maintained roads, bias tires ensure a smoother ride, but they are inferior to radials on bumpy roads and they do not hold the road as well when it is wet. The radial tire offers more safety with better braking and cornering power. Radial tires also give better gas mileage. The major difference, though, is in life expectancy: a bias ply tire lasts about twelve thousand miles while the radial lasts forty thousand miles.

For reasons we shall discuss shortly, the tire manufacturers by and large continued to produce bias ply tires, though Goodrich made a failed attempt to introduce radials in 1965. From 1967 onward, however, they quickly switched to an intermediate product, the belted bias ply tire. This tire had much of the ride characteristics of the bias ply tire but lasted about twenty-four thousand miles. The belted bias tire had one advantage over radials: it was much cheaper to convert existing production lines to produce belted bias tires. In 1970, approximately 85 percent of tires manufactured were belted bias ply tires.

2.1.5 Investment and Financial State

The majors invested substantial amounts in the 1960s as they expanded production and switched production to belted bias ply (while conversion was cheaper than converting to radials, it was not costless). Goodyear opened four new plants over this decade while Firestone opened three. Both Goodyear and Firestone were largely in tire production, so Compustat firm-level data can be used as an approximate measure of their investment in tires (domestic and foreign). Both firms invested 6 percent of sales, on average, in the first half of the 1960s, and 8 percent on average in the second half.

Despite the substantial investment (the majors did not invest such large amounts relative to sales again), the majors entered the 1970s in reasonably good financial condition. Interest coverage (earnings before interest, taxes, depreciation, and amortization (EBITDA)/interest expense) ranged from a low of 3 for Goodrich to a high of 7 for Firestone. Netting out cash from both debt and assets, the debt-to-assets ratio ranged from a high of 0.38 for Goodrich to a low of 0.23 for Firestone. Interestingly, Goodyear, which was the only major to survive, entered the 1970s right in the middle of the pack in terms of leverage.

2.1.6 Industrial Relations

The last important aspect of the tire industry to be considered is industrial relations. Workers in the tire industry were organized by the United Rubber Workers (URW) during the 1930s and early 1940s. Historically, wages in tire plants have moved in tandem with increases in the Big Three auto contracts. This principle has underlined URW bargaining since the forties. Competition from imports, however, placed greater pressure on tire companies to reduce costs over the 1970s and 1980s. In response, management attempted less expensive settlements. Also, they shifted production by opening new plants in the southern part of the United States, where unions were less strong. As a result, of the nine plants constructed since 1970, only one has been organized, while all twenty-one plants built during the 1960s were organized.

2.2 Radial Technology and Its Delayed Entry in the U.S. Market

In 1970, U.S. manufacturers were the largest in the world with extensive international operations. Looming ahead, however, was the specter of wrenching change for the tire manufacturers. Even though they had just converted to the intermediate technology of belted bias ply tires, the single most important issue faced by the tire industry in the beginning of the 1970s was the impending arrival of radial tires. Contrary to popular belief, neither were radials a new technology nor did the oil crisis in late 1973 precipitate their introduction. This raises the question why the U.S. manufacturers sunk so much in the intermediate belted bias technology rather than moving directly to radials, and why they then took so long to introduce radials. We argue that both the U.S. automobile and tire industries were in a low technology equilibrium that was disrupted only by the entry of foreign manufacturers.

2.2.1 Brief History of the Radial Tire

The radial tire was invented in 1913 by Gray and Sloper of the Palmer Tyre Company (United Kingdom). In 1948, Michelin first introduced the tire into commercial production (the Incredible X) and patented a radial with a steel belt. In 1951, Pirelli patented its own radial tire, with rayon belts (named Cinturato), and in the late fifties, Continental, Dunlop, and the European subsidiaries of Goodyear, Firestone, and Uniroyal started the production of radial tires. In 1970, when over 98 percent of tires manufactured in the United States were bias ply or belted bias ply, 97 percent of tires in France and 80 percent of tires in Italy were radials. Thus, radial technology was not commercially new, nor was it unknown to U.S. manufacturers. It simply was not used in the United States.

2.2.2 Production Technology

In 1970, radial production required 20 to 35 percent more labor than bias tires. Furthermore, it required substantial investment and changes in the method of production. "One of the certainties about radial-ply manufacture is that, new production equipment will be a necessity . . . new tire building machines, fabric and wire bias-cutters, new or modified curing, special stacking and handling systems, and (perhaps) new feeding equipment. This is due to the radial's unique construction" (*Rubber World*, November 1965). Moreover, radials necessitated closer tolerances, stricter quality control, and frequent inspections, and the percentage of scrap and defective radial tires was twice as high as with conventional tires. Another reason for their increased cost was that the raw materials needed to produce a radial tire cost 35 percent more than for a bias tire.

2.2.3 The Attitude of the Automobile Manufacturers

Automobile manufacturers in the United States had grown complacent over the 1960s. Tedlow (1991, 24) points out that the 1967 Cadillac Eldorado was "priced at $6,277" and, weighing in at three thousand pounds, "plowed through tight corners in ungainly fashion and got only ten miles to the gallon." The Mercedes Benz 250 of that year weighed half a ton less, cost two thousand dollars less, was more than a foot and a half shorter, and ran twice as long on a gallon of gas. American cars were built to be land cruisers, floating on large highways and fueled by cheap gas. The smooth, mushy ride that manufacturers thought consumers required could only be provided by the bias ply tires. The emphasis in automobile design was not so much on the handling or product quality but on looks. "There was only one kind of car headquarters wanted to hear about: A Car Just Like Last Years" (Easterbrook 1992, 317). The problem, however, was that customer preferences had changed considerably: they now wanted better handling, quality, and—after the oil crisis—mileage. This was reflected in the rising tide of automobile imports as Detroit failed to meet the needs of its customers.[4]

2.2.4 The Diffusion of the Radial Tire in the United States

Seeing the changing preferences of consumers, Ford in 1970 and General Motors in 1972 announced plans to introduce models with steel belted

4. It is also possible that the driving experience with car imports led customers to acquire a taste for radials.

radials. "Suddenly [the tire manufacturer's] expectations were confounded by dramatic external changes, and the switch to radials had to be undertaken swiftly. . . ." (French 1991, 101). What were the changed expectations? In 1972, *Rubber Age* projected the growth of the radial market in the United States based on the diffusion of the tire in the German and U.K. markets. It estimated that the radial ply would grow from 3 percent of the OEM market in 1972 to 65 percent in 1976. It was somewhat more conservative in its estimate of penetration in the replacement market, given the popularity of belted bias ply tires. *Rubber Age* felt radials would have 30 percent of the replacement market by 1976. Sull (1996) also argues that two tire manufacturers in 1973 made similar projections for 1976.

These estimates are important because they preceded the oil crisis (recall that the trebling of oil prices was unimaginable until it actually occurred in late 1973). It is amazing that the actual penetration of radials in the OE market in 1976 was 64 percent, while in the replacement market it was 29 percent (table 2.3). This suggests that at least some industry sources could see the writing on the wall, and the forces precipitating the change to radials were in place even prior to the oil crisis. This view is confirmed by our conversations with industry sources.

What is puzzling about the switch to radials is not that it occurred so fast. In fact, the switch from bias ply to belted bias ply toward the end of the 1960s occurred even faster. The puzzle is why radials were not introduced while belted bias ply tires were—the latter almost as soon as they could be produced commercially. As we will argue, this delay in adopting an innovation that the rest of the world had already implemented put U.S. industry at a disadvantage. We will also attempt to explain why the introduction took place when it did. These are critical to understanding the takeovers in the 1980s.

2.2.5 Causes for the Delayed Introduction of the Radial Tire

Three special characteristics of radials explain why U.S. manufacturers settled into a low technology equilibrium. First, car suspensions have to be built differently to accommodate radials. This involves substantial redesign and investment. Thus, unlike the change from bias to belted bias, the change to radials required the support of the automobile manufacturers. As we have already pointed out, the car manufacturers were reluctant to abandon the cushy ride offered by the bias ply tires even though consumer preferences may have been changing. Thus the reluctance to innovate upstream hampered innovation downstream. To complicate matters, radials were a radically different technology, unlike the belted bias ply tires. While U.S. manufacturers had some experience in manufacturing radials in their European subsidiaries, they were certainly not the leaders (see *Rubber World,* April 1976). Adapting radials to U.S. cars and U.S. production

Table 2.3 Relative Importance of Original Equipment and Replacement Tire Markets

	Original Equipment Market		Replacement Market		
Year	Total Shipments	% Radials	Total Shipments	% Radials	Car Production
1965	51,413	0.0	94,893	0.0	9,329
1966	47,362	0.0	101,812	0.0	8,599
1967	40,827	0.0	108,499	0.0	7,405
1968	49,873	0.0	121,088	0.0	9,843
1969	46,172	0.4	129,112	1.5	8,219
1970	37,535	0.3	129,608	2.1	6,545
1971	48,609	0.1	135,009	3.6	8,578
1972	51,292	4.6	141,295	6.2	8,821
1973	55,960	17.6	142,002	12.1	9,661
1974	43,307	43.1	123,460	22.4	7,290
1975	39,281	63.9	122,469	27.0	6,706
1976	49,905	64.3	122,690	29.1	8,492
1977	55,689	66.3	129,270	32.7	9,211
1978	54,963	67.2	135,151	37.5	9,173
1979	48,188	76.6	121,922	42.4	8,423
1980	34,932	80.0	106,912	50.0	6,373
1981	35,979	83.3	125,263	60.9	6,251
1982	33,981	83.6	130,539	65.9	5,074
1983	43,845	83.5	133,964	70.1	6,782
1984	50,993	83.8	144,580	75.7	7,774
1985	54,839	83.5	141,455	81.6	8,185
1986	54,392	84.2	144,267	86.7	7,829
1987	52,913	85.0	151,892	90.2	7,098
1988	54,131	85.5	155,294	93.7	7,136
1989	51,170	87.3	151,156	95.3	6,825
1990	47,199	87.6	152,251	96.7	6,076
1991	41,859	88.4	155,400	97.9	5,439
1992	46,307	89.1	165,794	98.9	5,667
1993	52,335	88.7	165,146	99.2	5,982
1994	58,448	90.0	169,983	99.4	6,601

Note: Passenger tire shipments in the OE market and the replacement market are in thousands of units and are taken from the Rubber Manufacturers Association (1994). The number of cars produced (also in thousands of units) is from *Ward's Automotive Year Book, Shipments.*

methods still required considerable innovation. Thus U.S. automobile manufacturers did not have an assured supply of high quality radials if, in fact, they decided to switch.

Second, unlike with belted bias tires, radials could not be manufactured on the same machinery as bias ply tires. Enormous investment in new machinery was required to change to radial manufacture. But the third factor comes in here. In the OE market, much of the rents from the improved technology would be extracted by the automobile manufacturers. And the technology had the potential to shrink the replacement market even more than belted bias ply tires. Thus rents from the new technology would accrue largely to the automobile manufacturers, and indirectly to consumers, while the investments costs would be wholly borne by the tire manufacturer.[5] To summarize, there were two barriers to switching to the radial technology: a coordination problem and a rent sharing problem. The coordination problem was that car manufacturers were afraid to change their designs absent a serious commitment to radials by tire manufacturers. Tire manufacturers, on the other hand, were unwilling to make the massive investments in moving to radials without the assurance of rents from a large market.[6] Yet, in all likelihood, it appeared that their most profitable market (the replacement market) would shrink as a result of the longer life of the new product. This appears to be a textbook example of the hold-up problem as modeled by Grossman and Hart (1986).

What was different in the other countries? Consider France, which was the first to switch to radials. When Michelin introduced the radial tire, it controlled Citroen, having acquired it in the 1930s when Citroen was unable to repay the debts owed to the tire company. Thus the coordination and rent sharing problem in upstream and downstream innovation was solved by the simple expedient of vertical integration. Moreover, the tire market in France was dominated by Michelin (it had 63 percent of domestic market share in 1975 with the second producer having only 12 percent; see West 1984, 44). So not only could it keep some of the rents from innovation while dealing with other car manufacturers, it could also capture rents in the replacement market from the improved product. As in Grossman and Hart (1986), the hold-up problem is resolved by integration.

Even though tire manufacturers in Italy, Germany, and the United Kingdom did not own automobile manufacturers, they adopted quickly. This was because once Michelin had shown the success of the radial, it could offer it in neighboring countries where it had a foothold.[7] This forced tire manufacturers in the other countries to offer radials.

5. Implicit in this argument is that the OE market and the replacement market are only loosely connected so that the automobile manufacturer does not extract all the rents from replacement sales also. If consumers always replaced tires on their car with the same brand, then presumably the automobile manufacturer could extract not only the profits on the OE tire but also the profits on the replacement.

6. West (1984) focuses on this last issue: "the way in which the US transnationals delayed launching the radial tire in their home market is a classic example of the use of market power by large firms to slow down the pace of innovation in an industry." We, however, believe that automobile manufacturers also played an important part in the delay.

7. West (1984) reports that Michelin had 30 percent of the Italian market in 1973, 23 percent of the U.K. market in 1972, and 21 percent of the German market in 1975. It should also be noted that Pirelli independently made substantial innovations in radial manufacture. Furthermore, unlike Michelin, it appropriated the rents not by manufacturing elsewhere but by licensing the technology out.

What changed in the United States in the early 1970s to propel adoption? Ford and GM expressed the intent to start manufacturing cars with radials. An important factor in this decision was Michelin's decision in 1970 to reenter the U.S. market (which it had abandoned in 1930) and produce radials from a plant in Nova Scotia. Not coincidentally, it obtained a contract to produce radials for the 1970 Ford Continental at the same time (see Tedlow 1991). In mid-1973 Michelin also announced plans to build two tire plants in the United States (*Wall Street Journal,* 28 August 1973).

Another factor was the growing volume of automobile imports from Europe and Japan that convinced manufacturers of changing consumer preferences, even before the oil crisis. Once the automobile manufacturers signed on to the new tire technology, and there was a credible high-quality producer (Michelin) to supply it, the low technology equilibrium was broken. Now the competitive nature of the industry forced all the manufacturers to either adopt the technology or exit. The oil crisis in 1973 did not initiate the move to radials. It simply reinforced and perhaps accelerated it.

2.2.6 The Structure of the Tire Industry and Innovation

A number of issues have been highlighted about the industry that will help us in our later discussion of the causes of the takeovers. First, rents in this business exist only in markets where firms interact with individuals; the intermediate goods market is very competitive. Second, the tire industry is mature enough that it is hard for manufacturers to get a sustainable advantage through innovation. Finally, there is a coordination problem especially when both the upstream tire manufacturers and downstream automobile manufacturers have to innovate.

These features of the market explain why the returns to innovation accrue, if at all, to the largest tire manufacturers who have a substantial presence in the replacement market, while the costs of innovation are borne by all. Goodrich failed in its early attempt to introduce radials in the United States in 1965 because it could not convince the automobile manufacturers to switch. Goodyear, on the other hand, was not the first out with the belted bias ply tire. But once it saw customer acceptance of the belted bias, it accelerated development and retained its share of both the OE market and the replacement market. Of course, once Goodyear switched to producing belted bias, the automobile manufacturers demanded it of the other manufacturers.

Similarly, when radials were introduced, Goodyear was not in the vanguard of innovators. It misjudged the acceptability of the tire and lost a few points in OE market share between 1972 and 1974. But once it was convinced the radial was there to stay, it switched its substantial resources to developing and producing them. Its large (and somewhat inertia bound) position in the replacement market gave it an advantage in recovering market share in the OE market. The nod of approval from Goodyear then made radials the de facto industry standard. The other manufacturers had to scramble to adapt.

With this understanding of the industry and the dramatic impact of the introduction of radials, we will return to the question of why the major U.S. producers were acquired by foreign firms. Before doing so, however, we next review the major events in the merger and acquisition wave.

2.2.7 The Corporate Control Events

The tire industry has a long M&A history. In 1968, shortly after the failed attempt to introduce radials, Goodrich was the target of one of the first hostile takeover attempts in U.S. history. Goodrich, however, succeeded in fending off that attempt and there is no record of any major corporate control transaction until 1985.

As table 2.4 indicates, in 1985 Uniroyal had to undertake a defensive leverage buyout in response to a hostile bid by Carl Icahn. At the same time, Sumitomo (a Japanese company) emerged as a white knight to rescue Dunlop (a British company) from a hostile bid. In the next five years, every major U.S. tire producer had to face a hostile bid and all but one, Goodyear, ended up being acquired by foreign manufacturers. Table 2.4 also shows the relationship between acquisitions and plant closure. Clearly, most plant closures took place between 1978 and 1981, well before the beginning of the intense takeover activity.

2.3 An Empirical Analysis of the Possible Causes of the Acquisitions by Foreign Firms

We now test the "neoclassical" and "overinvestment" hypotheses set forth earlier in the introduction.

2.3.1 Higher Productivity of Foreign Producers?

The first hypothesis is that the acquisition of existing plants by foreign producers was the best way to transfer plants into the hands of more efficient producers. To address this question, we analyze plant-level productivity following an acquisition. In particular, we test two direct implications of the hypothesis that foreign manufacturers acquired U.S. plants because they were more efficient. First, we should observe higher productivity in plants owned by foreign manufacturers. Second, we should observe an increase in the productivity following an acquisition, especially an acquisition by foreigners.

Table 2.4 **Chronology of Events in the U.S. Tire Industry**

Year	Corporate Control Events	New Plants	Closed Plants
1966		Firestone (Bloomington, Ill.)	
		Goodyear (Danville, Va.)	
1967		General (Charlotte, N.C.)	
1968		Goodyear (Union City, Tenn.)	
		Mohawk (Salem, Va.)	
		Mohawk (Salem, Va.)	
1969	Hostile takeover attempt against Goodrich by Northwest Ind.	Dunlop (Huntsville, Ala.)	
		Firestone (Oklahoma City, Okla.)	
		Goodyear (Fayetteville, N.C.)	
		Uniroyal (Ardmore, Okla.)	
1970			
1971			
1972		Firestone (Lavergne, Tenn.)	
1973	Armstrong buys Nashville (Tenn.) plant from Gates	Firestone (Wilson, N.C.)	
1974		General (Mt. Vernon, Ill.)	
1975		Michelin (Greenville, S.C.)	
1976			Goodrich (Akron, Ohio)
1977			Goodyear (Akron, Ohio)
1978		Goodyear (Lawton, Okla.)	Mansfield (Mansfield, Ohio)
			Mohawk (Akron, Ohio)
			Uniroyal (Los Angeles, Cal.)
1979		Michelin (Dothan, Ala.)	Iri (Louisville, Ky.)
			Mohawk (West Helena, Ark.)
1980			Firestone (Barbeton, Ohio)
			Firestone (Dayton, Ohio)
			Firestone (Los Angeles, Cal.)
			Firestone (Salinas, Cal.)
			Goodyear (Los Angeles, Cal.)

			Uniroyal (Chicopee Falls, Mass.) Uniroyal (Detroit, Mich.)
1981		Michelin (Lexington, S.C.)	Armstrong (West Haven, Conn.) Firestone (Akron, Ohio)
1982	Firestone and Bridgestone agreement for Lavergne (Tenn.) plant ($52 million)		
1983	Cooper buys Tupelo (Miss.) plant from Mansfield		Firestone (Memphis, Tenn.)
1984			Goodyear (Conshocken, Pa.) Goodyear (Jackson, Mich.)
1985	Hostile takeover (BTR) attempt against Dunlop, bailed out by Sumitomo Hostile takeover attempt (C. Icahn) against Uniroyal		
1986	Uniroyal and Goodrich merge in Uni-Goodrich Hostile takeover attempt (Goldsmith) against Goodyear		Goodrich (Miami, Okla.) Goodrich (Oaks, Pa.) Firestone (Albany, Ga.) General (Waco, Tex.)
1987	Continental buys General ($650 million) Goodrich adopts antitakeover plan		Goodyear (Cumberland, Md.)
1988	Pirelli's bid for Firestone Bridgestone buys Firestone ($2.6 billion) Pirelli buys Armstrong ($197 million)		
1989	Yokohama buys Mohawk ($150 million)		
1990	Cooper buys Firestone's Albany (Ga.) plant Michelin buys Uni-Goodrich		
1991			
1992		Cooper (Albany, Ga.)	
1993			

Sources: Modern Tire Dealer and *Wall Street Journal Index.*

Data

The plant-level data we use come from the Longitudinal Research Database (LRD) maintained at the Center for Economic Studies (CES) at the Bureau of the Census. The LRD file is a time series of economic variables collected from manufacturing establishments in the Census of Manufactures (CM) and Annual Survey of Manufactures (ASM) programs.

The census universe covers approximately 350,000 establishments. The CM reports data on all these establishments every five years (in years ending in "2" and "7"), while the ASM covers a subset of the universe in each of the four years between censuses. The ASM, though, contains a complete time series for establishments with 250 or more employees.

The LRD file contains identifying information at the establishment level, basic information on the factors of production (inputs such as levels of capital, labor, energy, and materials) and the products produced (outputs), and other basic economic information used to define the operations of a manufacturing plant. In addition to these items, since 1972, establishments in the ASM sample panel have been asked to supply detailed information on assets, rental payments, supplemental labor costs, consumption of specific types of fuels, and other selected items. Unlike the census, the ASM does not request data on individual materials consumed and products shipped, although product class information is collected. These data, thus, are available only in census years.

Because we are interested in U.S. tire plants, we extracted from the LRD all the data on manufacturing establishments with SIC code 3011 (tire and inner tubes). We identified 3,061 plant-year observations from 493 plants and 402 firms. The first year for which we have comprehensive data is 1967. The next year of data is 1972, after which we have data for all the years until 1993.

To maximize the homogeneity of the group we analyze, we restrict our analysis to passenger tire plants (primary product code 1), ignoring truck tires and other special tires. This reduces our sample to 71 plants and 741 plant-years. Twenty-one observations and four plants lack some or all of the data required by our specification. This leaves us with 67 plants corresponding to 720 plant-years.

Table 2.5 contains the summary statistics for this data set. Note that the census data are confidential and this prevents us reporting data when it would reveal the identity of a single company in the sample. All the reported analysis based on LRD data will, by necessity, be aggregated.

To check how exhaustive the ASM is, to obtain data on plant ownership from an independent source, and to produce a series of dummy variables (foreign, acquisition, and nonunionization), we collected a data set on passenger tire plants from the trade magazine *Modern Tire Dealer.* Starting in 1976, the January issue of the journal lists all U.S. tire plants, their

Table 2.5 **Summary Statistics**

	A. Continuous Variables		
	Means	Stand. Dev.	N. Obs.
Value added	11.08	0.99	720
Capital	4.92	0.95	720
Labor	7.90	0.68	720
Capital expenditures	0.05	0.17	720
Employment	7.20	0.68	720
	B. Discrete Variables		
	Frequency	Percent	N. Obs.
Closure	13	1.82	712
Foreign	107	14.86	720
Acquisition	110	15.28	720
Nonunion	96	13.33	720

Note: Value added is the logarithm of a plant's value added measured in thousands of U.S. dollars. Capital is the logarithm of the net amount of property, plant, and equipment. Labor is the logarithm of production-worker-equivalent man-hours, as defined in Lichtenberg (1992). The foreign ownership indicator is one if the plant is owned by a foreign company in that particular year. The acquisition indicator is one in all plant-years following a change in control taking place in the period 1970–93. The nonunion indicator is one for those plants that were not unionized. All the data are from the LRD, except for foreign ownership and unionization indicators, which are constructed from data in *Modern Tire Dealer.*

production capacity, their location, the company they belong to, and (starting in 1984) whether the plant is unionized or not. We identified a sample of 66 plants. Overall our impression is that the LRD data set is representative of passenger tire plants operating in the United States.[8]

Methodology

We want to compare productivity across different plants and over time. It is standard in this literature (see Lichtenberg 1992) to use the notion of total factor productivity, defined as output per unit of total input:

$$\pi = \frac{VA}{F(L, K)}, \qquad (1)$$

where VA is output net of purchased intermediate goods and $F(L, K)$ is a production function, with L denoting labor input and K capital input.

If we assume that the production function is Cobb-Douglas so that $F(L, K) = L^{\alpha}K^{\beta}$ and we take logarithms, we obtain

$$\log VA = \alpha \log L + \beta \log K + \log \pi. \qquad (2)$$

8. For disclosure-related reasons we cannot give further detail about the nature of and exact differences between the two samples.

If we assume the technical parameters α and β are invariant across plants, we can test our hypotheses using the following specification:

$$\log VA_{it} = f(X_i) + \alpha \log L_{it} + \beta \log K_{it} + \delta \text{Year}_t + \varepsilon_{it}, \quad (3)$$

Where $f(X_i)$ are plant-specific characteristics (like ownership, unionization, etc.), Year_t is a calendar year dummy, and ε_{it} is an error, which we assume orthogonal to the input quantities.

Results

Panel A of table 2.6 reports the results obtained by estimating equation (3). Columns (1) to (3) estimate equation (3) with ordinary least squares (OLS) on the entire sample of plants. The plant-specific characteristics we test are an acquisition indicator (equal to one in the years subsequent to an acquisition), a foreign ownership indicator (equal to one if the plant belongs to a subsidiary of a foreign manufacturer), an indicator if the plant is not unionized,and the age of the plant measured as years since the plant was built.[9]

Column (1) tests whether foreign-owned plants are more or less productive in general. The estimates indicate that the total factor productivity of foreign-owned plants is 20 percent less than that of U.S.-owned plants. This effect is highly statistically significant. There is no evidence that non-unionized plants are more productive. Column (2) adds the acquisition indicator to the basic specification. Plants that have been acquired are 9 percent less productive after an acquisition, but this effect is not statistically significant even at the 10 percent level. The results are substantially unchanged if we insert a measure of a plant's age (col. [3]).

It is possible that the estimated adverse effects of foreign ownership are the result of some misspecification. We might miss some plant-specific characteristics that reduce productivity and happen to be correlated with the foreign ownership indicator. For example, since foreigners bought, rather than started, most of their U.S. plants, it is possible that the observed effect captures adverse selection rather than inefficiency: foreigners buy less-productive plants. For this reason we reestimate equation (3) (estimates not reported) restricting the sample to new plants. Productivity of foreign-owned plants is again significantly less than U.S.-owned plants.

Is it that foreign acquirers pick poor plants, or are they poor managers? We try to control better for plant-specific characteristics by reestimating equation (3) with plant fixed effects. Since our measure of capital is a noisy proxy for the real level of capital, it is not surprising that the coefficient on capital drops by 50 percent and becomes insignificant. However, the indicators are the variables of interest. Controlling for the plant-specific

9. Since we do not have data on construction years before 1960, for any plant built before 1960 we set the year of construction to 1959.

Table 2.6 **Effects of Ownership on Productivity**

	OLS			Fixed Effects		
	(1)	(2)	(3)	(4)	(5)	(6)
A. Whole Sample						
Capital	0.091	0.091	0.088	0.061	0.056	0.056
	(0.033)	(0.032)	(0.033)	(0.039)	(0.038)	(0.041)
Labor	1.022	1.015	1.018	1.102	1.111	1.111
	(0.038)	(0.038)	(0.038)	(0.051)	(0.051)	(0.055)
Foreign dummy	−0.196	−0.163	−0.145		0.184	0.184
	(0.056)	(0.071)	(0.076)		(0.094)	(0.101)
Acquisition dummy		−0.086	−0.085	−0.249	−0.354	−0.354
		(0.080)	(0.082)	(0.061)	(0.093)	(0.100)
Nonunion dummy	0.041	0.039	0.013			
	(0.047)	(0.048)	(0.051)			
Age			−0.002			0.061
			(0.001)			0.004
Adjusted R^2	0.846	0.846	0.852	0.908	0.908	0.920
N. obs.	720	720	720	720	720	720
B. Radial Sample						
Capital	0.115	0.139	0.159	−0.033	−0.051	−0.051
	(0.069)	(0.073)	(0.072)	(0.085)	(0.079)	(0.041)
Labor	0.952	0.961	0.941	0.838	0.853	0.853
	(0.077)	(0.076)	(0.074)	(0.097)	(0.097)	(0.097)
Foreign dummy	−0.487	−0.546	−0.543		0.226	0.226
	(0.056)	(0.079)	(0.079)		(0.147)	(0.147)
Acquisition dummy		0.124	0.095	−0.136	−0.307	−0.307
		(0.088)	(0.090)	(0.078)	(0.149)	(0.149)
Nonunion dummy	0.051	0.069	0.115			
	(0.049)	(0.049)	(0.055)			
Age			0.006			0.054
			(0.002)			0.007
Adjusted R^2	0.776	0.779	0.782	0.888	0.891	0.891
N. obs.	265	265	265	265	265	265
C. Whole Sample, Proxy for Capital						
Capital (energy)	0.280	0.284	0.281	0.207	0.209	0.209
	(0.054)	(0.052)	(0.052)	(0.079)	(0.078)	(0.078)
Labor	0.870	0.860	0.862	0.997	1.003	1.003
	(0.046)	(0.046)	(0.046)	(0.096)	(0.095)	(0.095)
Foreign dummy	−0.135	−0.094	−0.084		0.199	0.199
	(0.052)	(0.064)	(0.066)		(0.102)	(0.102)
Acquisition dummy		−0.102	−0.101	−0.227	−0.340	−0.340
		(0.078)	(0.077)	(0.063)	(0.099)	(0.099)
Nonunion dummy	0.052	0.049	0.033			
	(0.045)	(0.045)	(0.047)			

(*continued*)

Table 2.6 (continued)

C. Whole Sample, Proxy for Capital

	OLS			Fixed Effects		
	(1)	(2)	(3)	(4)	(5)	(6)
Age			−0.001			0.056
			(0.001)			0.004
Adjusted R^2	0.867	0.868	0.868	0.912	0.912	0.912
N. obs.	729	729	729	729	729	729

Note: The dependent variable is the logarithm of a plant's value added in a given year. Capital is the logarithm of the net amount of property, plant, and equipment. In panel C the logarithm of constant price energy consumption has been used as a proxy for capital. Labor is the logarithm of production-worker-equivalent man-hours, as defined in Lichtenberg (1992). The foreign ownership indicator is one if the plant is owned by a foreign company in that particular year. The acquisition indicator is one in all plant-years following a change in control taking place in the period 1970–93. The nonunion indicator is one for those plants that were not unionized. Age is the number of years since the plant was originally built. For plants built before 1960, we set the year of construction to 1959. All the data are from the LRD, except for foreign ownership, unionization indicators (which are constructed from data in *Modern Tire Dealer*), and age of the plant (which is from *Tire Business*). All the specifications contain calendar year indicators (coefficient estimates not reported). Heteroskedasticity robust standard errors are reported in parentheses.

characteristics, an acquisition reduces a plant's total factor productivity by a statistically significant 25 percent. This phenomenon is not just temporary. In an unreported regression we allowed for the impact of an acquisition to be different in the two years following an acquisition and in the long run. The effect is entirely concentrated in the long run. The effects are robust to the inclusion of a measure of the age of the plant. Older plants are less productive, 0.2 percent per year of age.

When we include plant-specific effects, the acquisition indicator is almost collinear with the foreign indicator (there are only few acquisitions that are not made by foreign firms). Nevertheless, we try including both variables in the regression. The effect of acquisition is still negative and bigger in absolute sign, while the incremental effect of foreign ownership (separate from that of acquisition) is positive and statistically significant. The combined effect of a foreign acquisition, though, remains negative: it reflects a 17 percent drop in total factor productivity. Interestingly, the coefficient of age becomes positive and highly statistically significant. This suggests that while newer plants are more productive, a plant itself becomes more productive with age. Hence the difference in coefficient between the OLS and the fixed effects estimates.

Although we could not reject the hypothesis that the production function for plants was the same independent of the quantity of radials produced, in panel B of table 2.6 we test the robustness of our result to restricting the estimates to plants producing at least 80 percent radials. The main thrust of the results is unchanged. If anything the results are more striking: foreign-owned plants are 50 percent (rather than 20 percent) less productive than U.S.-owned plants.

Since our measure of the capital stock is likely to be very noisy, in panel C of table 2.6 we report the basic regressions when the amount of energy consumed is used as a proxy for capital. The coefficient for capital and labor now appears more sensible, but all the other results remain substantially unchanged. In an unreported regression we also estimated the same specifications using the quantity of energy consumed as an instrumental variable. The results are substantially unchanged.

In sum, little support emerges for this narrow version of the neoclassical hypothesis, which focuses on plant-level productivity. Plants do not seem to be acquired by more efficient producers. Even more surprisingly, plants do not experience an increase in productivity following a change of ownership. This implies that if we want to explain the M&A activity of the late 1980s, we have to look elsewhere.

2.3.2 Failure of Internal Control Systems?

The second hypothesis we want to test is that acquisitions forced the closure of inefficient plants that were kept open long after they became unprofitable because of a failure of internal control systems. The argument is that internal systems do not force managers to downsize when needed (Jensen 1993), and market forces take a long time to act because internal resources take a long time to be fully dissipated.

This hypothesis has already been challenged by Sull (1996), who documents that 69 percent of the plant closures took place before 1981, the year of the first hostile takeover threat in the tire industry. He also shows that the adoption of antitakeover devices is not significantly related with the plant closure.

Here we extend Sull's analysis in three ways. First, we consider the effect of acquisitions themselves on the probability of plant closure. Second, we control for the total factor productivity of the plant. Third, we fully use the data on the time dimension by estimating the probability of closing a plant between time t and time $t + 1$, conditional on it not having been closed till time t. This captures the essence of Jensen's hypothesis that a failure of the internal control system delayed the closing of inefficient plants.

Results

The results obtained estimating a proportional hazard ratio model of the probability of closing a plant are shown in table 2.7. Column (1) reports the estimates obtained when the only determinants of plant closure are the logarithm of total factor productivity, as defined in equation (2), and calendar year dummies. Not surprisingly, more efficient plants are less

Table 2.7 **Determinants of Plant Closures**

	(1)	(2)	(3)	(4)
Total factor productivity	−1.73	−1.82	−1.85	−1.86
	(0.61)	(0.63)	(0.63)	(0.63)
Acquisition dummy		−0.78	−0.80	−0.94
		(1.26)	(1.36)	(1.56)
Acquisition × total factor productivity			0.61	0.35
			(1.92)	(1.69)
Foreign dummy				0.43
				(2.19)
Pseudo R^2	0.11	0.11	0.12	0.12
N. obs.	549	549	549	549

Note: We estimate a proportional hazard ratio model, where the dependent variable is the probability of closure between year t and year $t+1$ conditional on surviving up to time t. The explanatory variables are the total factor productivity as estimated with specification (3) in the text, a foreign ownership indicator, and an acquisition indicator. The foreign ownership indicator is one if the plant is owned by a foreign company in that particular year. The acquisition indicator is one in all plant-years following a change in control taking place in the period 1970–93. The nonunion indicator is one for those plants that were not unionized. All the data are from the LRD, except for foreign ownership and unionization indicators, which are constructed from data in *Modern Tire Dealer.* All the specifications contain calendar year indicators (coefficient estimates not reported). The standard errors are reported in parentheses.

likely to be closed, and this effect is statistically significant at the 5 percent level. More interesting for our purposes is column (2). It shows that acquisition of a company has no impact on the probability of closing a plant (after the efficiency of the plant is accounted for). If anything, the impact is negative (albeit not statistically significant). A more direct test of whether acquisitions improved the ability of managers to close inefficient plants is to examine the differential effect of productivity on plant closure when a firm is acquired. As column (3) shows, less productive plants were no more likely to be closed by acquirers. Similar results obtain when a plant is owned (or acquired) by a foreign firm. So there is no evidence that different corporate governance systems or external threats had any impact on the decision to close a plant.[10] Nor is there evidence that acquisitions changed the speed of plant closing.

A different approach to the same question is to analyze the behavior of capital expenditures following an acquisition. If acquisitions were aimed at disciplining managers who were overinvesting in their plants, we should observe a reduction in investment following an acquisition. In fact, as table 2.8 shows, the opposite is true. The level of capital expenditure (over sales) of a plant goes up by four percentage points after an acquisition

10. The raw data confirm this. No plant was closed by a foreign manufacturer and, as pointed out earlier, most of the closures took place prior to acquisition.

Table 2.8 **Effects of Acquisitions on Capital Expenditure and Employment**

	Capital Expenditures				Employment			
	OLS		Fixed Effects		OLS		Fixed Effects	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Acquisition dummy	0.02	0.01	0.04	0.00	−0.43	0.15	−0.02	−0.19
	(0.01)	(0.01)	(0.02)	(0.02)	(0.11)	(0.09)	(0.08)	(0.10)
Foreign dummy		0.01		0.04		−0.50		0.09
		(0.01)		(0.01)		(0.10)		(0.05)
Nonunion dummy					0.15	0.13		
					0.07	0.07		
Adjusted R^2	0.01	0.01	0.61	0.61	0.02	0.02	0.81	0.79
N. obs.	731	731	731	731	731	731	731	731

Note: The dependent variables are either the level of capital expenditure over sales or the logarithm of the number of plant employees in the year. The foreign ownership indicator is one if the plant is owned by a foreign company in that particular year. The acquisition indicator is one in all plant-years following a change in control taking place in the period 1970–93. The nonunion indicator is one for those plants that were not unionized. All the data are from the LRD, except for foreign ownership and unionization indicators, which are constructed from data in *Modern Tire Dealer*. All the specifications contain calendar year indicators (coefficient estimates not reported). The heteroskedasticity robust standard errors are reported in parentheses.

and this effect is statistically significant at the 5 percent level. Interestingly, this effect is due entirely to foreign acquisitions.

The results are less clear for employment. If we control for plant-specific factors, acquisitions do not seem to have any effect on employment. However, decomposing acquisitions further, acquisitions increase employment, albeit not statistically significantly, while if the acquirer is foreign, employment falls.

Comments

In sum, we find no evidence supporting the idea that acquisitions were aimed at disciplining managers who were delaying the closure of inefficient plants or were overinvesting in existing plants. Assuming foreign acquirers made sensible investment decisions, we find quite the opposite; there was some underinvestment before the plants were acquired.[11]

This is not to say that internal control systems worked perfectly, only that much of the needed restructuring had taken place before the acquisitions. We will argue that the advent of radials and the inability of the conglomerate tire manufacturers (General, Goodrich, and Uniroyal) to improve their position even with such dramatic change simply confirmed for them the need to get out of the tire industry. Thus they were unlikely to overinvest in tires. Goodyear was fortunate in 1972 to get a CEO who was an outsider, understood the potential of radials, and quickly implemented the needed restructuring. Firestone best exemplifies a firm's failure to rationalize its operations (see Sull 1996), but even it got an outside CEO in 1979 who quickly closed down plants. Thus it was not the inability of internal systems to respond quickly to the radials that led to takeovers by the foreign firms.

Rather, we will argue that the conglomerate tire manufacturers did not have a secure enough position in profitable markets to justify the demand for continuous innovation. They were ready to sell out, though during the 1970s and early 1980s, there was no obvious domestic buyer. But during this time, car exports and cross-border car production by domestic car manufacturers increased. Large manufacturers with secure domestic markets—Michelin, Pirelli, Bridgestone, and Continental—were eager to move into the United States and realize the economies of scale in product development and marketing. Even if they wanted to, Goodrich and Uniroyal, who had neglected R&D and investment in the tire business and had withdrawn from international tire production in the 1970s, were poorly positioned to capture these economies. General Tire was too small and, furthermore, had little international experience to speak of. Firestone had

11. For instance, Bridgestone announced capital expenditures of $1.5 billion after it took over Firestone, and industry sources suggest that some of this was to compensate for past underinvestment by Firestone.

a severe liquidity problem in the late 1970s as a result of its problems in switching to radials. This forced it to withdraw from international operations, and it also became a willing candidate for acquisition. Only Goodyear maintained its international operations even as it switched to radials. It had the scale both domestically and internationally to justify the expenditures on R&D and advertising to keep it competitive with the large foreign manufacturers. As a result, only Goodyear survived the "internationalization" of the industry.

2.4 What Led to the Eclipse of the U.S. (Owned) Tire Industry?

We now elaborate on our explanation. Table 2.9 shows the fraction of total sales accounted for by tires for each of the five major manufacturers between 1970 and 1985. While Firestone and Goodyear tire sales were steady at approximately 80 percent of total sales, Goodrich tire sales dropped from 58 percent in 1970 to 44 percent in 1985 and Uniroyal sales dropped from 56 percent to 49 percent. This suggests that both Goodrich and Uniroyal were attempting to reduce their stake in the tire business. The exception among the diversified conglomerates is General Tire, which maintained a steady share at 39 percent, though as we shall see it decided to reduce its commitment to the tire business from the early 1980s onward.

Some of the tire manufacturers report data segment by segment. These data are available from Compustat from 1978 onward. While Goodyear and Firestone each invested an average of 5 percent of annual tire sales in their tire business in the period 1978–86, General Tire invested only 3.7 percent while Goodrich invested 3 percent. When we look at the ratio of investment in tires to total investment, the ratio fell from an average of 46 percent for General Tire in 1978–80 to 25 percent in 1984–86. Goodrich was already investing very little in the tire business, but this fell slightly further from 24 to 23 percent over this period.

Thus it appears that the diversified tire firms were investing more of their cash flows outside the tire business. They appeared eager to get out, a fact confirmed by published and industry sources.

Table 2.9 **Extent of Diversification away from the Tire Business by Major U.S. Producers**

	1970	1975	1980	1985
Goodyear	83	83	83	80
Firestone	83	83	79	89
Uniroyal	56	57	49	49
Goodrich	58	53	42	43
General Tire	39	36	44	41

Note: Percentage of total sales in tires (from company annual reports and from West 1984).

Consider Goodrich. It was the first to introduce radials in the United States (in 1965), and this turned out to be a miserable marketing failure as neither the automobile industry nor the other tire manufacturers responded. Tedlow (1991, 67) analyzes Goodrich's situation thus: "The failure to leapfrog the competition in radials was the beginning of the end of Goodrich's tire business. If they could not dramatically alter their position in the industry by pioneering a breakthrough of this magnitude, Goodrich management apparently realized they never would. . . . [P]laying second fiddle to Firestone and Goodyear was untenable on a long term basis . . . and it was [Firestone and Goodyear] . . . who would determine product policy in this industry. . . . In the mid-1970s, Goodrich realized that it had to get out of the tire business. . . . The strategy . . . was simplicity itself. The tire business was always to generate more cash than it used. . . . [The first step] was abandoning the Original Equipment market altogether [in the early 1970s]." By abandoning the OE market (table 2.2 shows that by 1985 Goodrich was out), it could focus on replacement sales which were highly profitable. Of course, the OE market was a way for a firm to invest in future replacement sales, so this move was again a form of cutting investment.

Uniroyal, by contrast, had historically been focused on OE sales, specifically sales to General Motors. It hoped to make a breakthrough in radials in the early 1970s with its Zeta 40M tire. But in order to make it profitable, and perhaps even to sell more in the OE market, Uniroyal had to establish a credible presence in the replacement market by expanding its retail stores (recall that automobile manufacturers like a supplier to have these stores because they can service tires sold as original equipment). But Uniroyal's internal cash flow was low because of the low profitability of the segments it served and it had an enormous debt burden, especially in the late 1970s (average interest coverage in the period 1976–80 was 2.4, the lowest in the industry). Moreover, it had an unfunded pension liability that, in 1979, amounted to 79 percent of its net worth. So Uniroyal faced a cash crunch just when it needed to expand its network of stores, and they dwindled from 535 in 1972 to none in 1981 (see Tedlow 1991, 59). Thus Uniroyal did not have the option of harvesting its OE sales, and limped along investing minimal amounts in maintaining its plants.

Finally, General Tire, which was run by the O'Neil family, was the only true conglomerate. Tedlow reports that "back in 1980, Jerry O'Neil was . . . determined about tires. He has no intention of getting out, he thinks Uniroyal probably will, and in the end, Goodrich. In the shrunken field, he sees General surviving and prospering." But by 1984, when our data show the fall in General Tire's investment in the tire business, "O'Neil was more willing to consider exiting the industry. The possibility of spinning the tire business off into a merger with another firm was on his mind" (Tedlow 1991, 84).

This suggests that the diversified majors initially perceived the advent of radials as a market opportunity where they could challenge the dominance of Goodyear and Firestone. Even though Firestone made a major misstep (see below) that General Tire and Michelin cashed in on, the industry was mature and innovation did not result in dramatic sustainable advantage. The market segment that was most ready to switch to the innovation (the automobile manufacturers) was unprofitable. There was substantial inertia in the profitable replacement segment, and by the time an innovator made some headway, the leaders would have their own products. At the same time, the smaller manufacturers had to constantly match the successful innovations or else lose market share. Therefore, even though we have argued that economies of scale in production were not significant for the major manufacturers, significant fixed investments had to be made in R&D, advertising, and the distribution network in order to keep up.

Table 2.10 shows the average investment in R&D and advertising over the 1970s and 1980s. The figures for the diversified tire firms should be interpreted with caution since they are not by segment but are for the overall firm. Nevertheless, the pattern of investment by both Goodyear and Firestone suggests that the requirement for R&D and advertising increased dramatically over the two decades, from 3.1 percent in 1971–75 for Firestone to 4.2 percent in 1986–87, and from 4.1 percent in 1971–75 for Goodyear to 5.2 percent in 1986–87. By contrast, the level of invest-

Table 2.10 **Investment in R&D and Advertising by Major U.S. Tire Producers**

	1970–75	1975–80	1980–85	1985–90
Goodyear				
R&D	2.40	2.00	2.70	2.90
Advertising	1.80	1.80	1.90	2.30
Sum	4.10	3.80	4.60	5.20
Firestone				
R&D	1.50	1.40	2.00	2.30
Advertising	1.70	1.60	2.00	1.90
Sum	3.20	3.10	4.00	4.20
Uniroyal				
R&D	2.70	2.00	1.90	
Advertising	2.00	1.80	1.50	
Sum	4.70	3.80	3.40	
Goodrich				
R&D	2.20	1.70	1.90	2.20
Advertising	1.50	0.90	1.10	0.90
Sum	3.70	2.70	3.00	3.10
General Tire				
R&D	1.90	1.40	2.70	2.20
Advertising	1.00	1.00	1.20	1.60
Sum	2.80	2.40	3.90	3.80

Source: Compustat.

Note: Average R&D and advertising expenses as a percentage of total sales in different periods.

ment by the diversified majors was smaller, and perhaps would look smaller still if we had tire segment data. Furthermore, it declined steadily for Uniroyal and Goodrich. Again, General is the exception, but recall that in the early 1980s it was doing all that was necessary to stay in the industry. In fact, General's investment in R&D seems to mirror its changing commitment to the industry. It peaked at 3.1 percent of sales in 1983 and then fell steadily every year to 1.7 percent of sales in 1988 when the tire division was sold.

To summarize, then, the diversified majors did not have the scale to compete on R&D and advertising, or in sustaining the distribution network. Their decision to sell out, though made at different times, was understandable. We still have to ask why Firestone was taken over, why Goodyear survived, and why the acquirers were foreign.

2.4.1 Goodyear and Firestone

In hindsight, Firestone's problems can be traced to its large investment in the late 1960s in the intermediate technology of belted bias ply tires. In order to avoid scrapping its existing investment, Firestone manufactured radials through a process that required relatively minor modification of the machinery. The resulting product, the Firestone 500 Steel-Belted radial, was initially successful but had tread separation problems. Even though top management knew about the problem, it was only in 1978 (six years after production began) that production was stopped and the tire recalled at enormous cost. The popular press was very critical. Tedlow (1991, 60) cites *Time* magazine as reporting, "The company just kept churning out the 500 tires; they just kept failing; customers kept returning them. And company lawyers just kept defending lawsuits brought by accident victims—and their heirs." The damage to the company's reputation was enormous. Firestone's OE sales fell from 24 percent of the OE market to 21.5 percent between 1975 and 1980 (see table 2.2), while its replacement sales under its own brand name fell from 11.8 percent of the market in 1977 to 9 percent in 1981.

Table 2.10 shows that Firestone's annual investment in R&D in 1971–75 was only 1.5 percent of sales while, by comparison, Goodyear's was 2.4 percent of sales (and Goodyear's sales were considerably more). Therefore, even though Firestone matched Goodyear in capital expenditure and advertising, it lagged behind in expenditure on R&D, which may partly explain its quality problems.

Soon after the recall, John Nevin, who had been CEO of Zenith, became Firestone's CEO. The firm had now become, he declared, "a company of limited resources. The day has passed when Firestone can say: We are a tire company and we will participate actively in every element of the tire business, throughout America and throughout the world" (Tedlow 1991, 42). The strategy now was to eliminate the least profitable aspects of the tire business and diversify. As we will argue, the economics of the business had changed to make this strategy infeasible.

Goodyear, by contrast, made all the right decisions early on. Even though it was not the first out with radials, it neither attempted to skimp on the investment necessary to convert to radial production nor did it compromise on the quality of radials produced. A key factor in this was Charles Pelliod, CEO from 1972 to 1982, who came with substantial experience of radials from Goodyear's European subsidiary. According to industry sources, he saw the writing on the wall and forced Goodyear to make the difficult decisions to close down old plants and invest heavily in new ones. As can be seen, Goodyear's spending on R&D and advertising also went up at this time. But Pelliod also wanted to diversify out of tires. This did not happen until he was succeeded by Robert Mercer as CEO, after which Goodyear bought the Celeron Corporation (an energy company) in 1983 and started investing in the All-American Pipeline. Despite the sudden attempt at diversification (which proved disastrous), Goodyear did not reduce its investments in the tire business. In fact, both R&D and advertising increased, even as the firm was diversifying outside the tire business.[12]

2.4.2 The Eclipse of the U.S. (Owned) Tire Industry

Even while the U.S. manufacturers were struggling to adapt to radials and shut down excess capacity, another dramatic change was taking place around the world. The automobile industry was becoming more global and its methods of design and production were changing. There was increasing talk of producing the same car for different markets at different locations. The Japanese were the first to do this with cars like the Honda Accord, which was produced in both Japan and the United States. Similarly, as U.S. and European tastes converged, the U.S. automobile manufacturers started planning for production in both the United States and Europe. It made sense to have close cooperation between the tire supplier and the car manufacturer at both the design and manufacturing stages. Just-in-time manufacturing made it almost imperative that tires be produced close to the locale for automobile assembly. The greater the number of markets in which a tire manufacturer produced, the shorter the supply cycle and the more valuable the supplier would be to the car manufacturer. A related reason for a global presence is that car exports increased tremendously. A tire manufacturer who had a presence both at the point of production and in the country to which the car was exported would be able to take advantage of replacement sales. Furthermore, the car manufacturer

12. It is unlikely that pipelines need much R&D and advertising. So even though we only have data on firm-level R&D and advertising to sales, the firm-level ratio is likely to underestimate the ratio devoted to tires.

would be able to get some of the benefits of the advertising done by the tire manufacturer in the export market. In sum, the increasing cross-border production and trade of cars increased the need for multinational tire producers.

But barring Goodyear, the U.S. tire manufacturers had spent the 1970s concentrating their resources on domestic radial production and withdrawing from foreign markets. West (1984) reports that Firestone exited, among others, the United Kingdom, Switzerland, Australia, Sweden, and Chile. Uniroyal sold its entire European tire operations to Continental in 1979 and also quit Australia. Goodrich exited Australia, Holland, West Germany, and Brazil, and General Tire quit Spain and Venezuela (it did not have much of an international presence anyway). Interestingly, many of the plants were sold to the big foreign producers such as Continental, Bridgestone, and Pirelli. In fact, Continental became a multinational producer largely as a result of its purchase of Uniroyal's European operations.

Thus the conglomerate tire manufacturers, in pursuit of their objective of reducing their exposure to the tire business, sold their foreign plants. As the car manufacturers geared up to produce transnationally, the conglomerates had the choice of either returning anew to foreign markets or exiting the tire business entirely by selling their U.S. holdings. By contrast, the foreign multinational tire producers such as Bridgestone, Continental, Michelin, and Pirelli only needed a U.S. base to round out their portfolio. Given that new capacity was not needed by the late 1980s even in radials, and that the multinationals' position in their domestic markets was much stronger than the U.S. conglomerates' position in the United States, a transfer of ownership of the tire business from the U.S. conglomerates to the multinationals made eminent sense.

One could ask why Goodyear or Firestone did not buy out the tire operations of the conglomerate manufacturers earlier. Apart from a lack of funds on the part of these two firms, the foreign manufacturers probably valued the conglomerates more: in order for the foreign manufacturers like Bridgestone, Pirelli, or Continental to be credible partners for the automobile firms, they needed a U.S. production base. By contrast, neither Goodyear nor Firestone needed additional U.S. capacity. Rather, in all likelihood, they would probably lose some of the OE sales of the acquired firm as automobile manufacturers rebalanced their portfolio of suppliers to avoid too much dependence on one vendor. Thus the nature of the industry made it hard for mergers between U.S. firms to take place. Not coincidentally, the only merger that was consummated, albeit temporarily, was between Goodrich and Uniroyal. This was clearly helped by the fact that Goodrich had no OE sales.

Firestone was not interested in exiting the tire business. But it was extremely difficult to be a major niche player—after exiting from various lines and countries—in what had become a full service, global business. Tedlow (1991, 44) cites the vice president of international sales thus: "When we withdrew from radial truck tires in the United States, our overseas customers whose business with us is 25 percent for trucks, saw it as a lack of commitment to tires. . . ." Firestone simply did not have the resources to compete. If one had to point to a single factor leading directly to its demise, it would have to be its lack of attention to R&D and quality control that, in turn, led to the Firestone 500 disaster.

2.5 Conclusions

Our analysis of the forces that led to the demise of the U.S. tire industry points to two major factors. First, the U.S. tire companies were the last to switch to radials. They faced this choice when the prospects of the entire tire industry were most grim. While their competitors had already paid the sunk costs, U.S. firms had not and, as a result, were more resistant to invest. If any major player had to leave, the U.S. firms were the most likely candidate. As a result, in this period they did not invest sufficiently in their plants, which may partly explain the large capital expenditure made by foreign acquirers after the takeover as well the lower productivity of these plants.

Second, the internationalization of the market for cars triggered the need for tire producers to follow their customers. Since the flow of cars was toward the United States, it was natural that foreign tire firms wanted to penetrate the U.S. market and not the other way around. In the absence of major growth in the market, the way to acquire a presence in the United States was to integrate with existing producers.

Of course, a number of factors may explain why U.S. manufacturers were taken over by foreign manufacturers rather than the other way around. Of these, the most interesting possibility is that takeover legislation is much more friendly to targets in other countries, making it easier for ownership to change in one direction than the other. Understanding the influence that these barriers have in shaping international competition is an important topic for future research.

From a policy perspective, it is not clear that any changes are warranted. While there may have been insufficient incentives to innovate in the competitive U.S. domestic market, the internationalization and consolidation of the market ensured each of the large manufacturers has the scale as well as enough pockets of market power to reward innovation. Also, an international manufacturer can ignore the U.S. market only at the risk of losing credibility elsewhere. Therefore, despite the eclipse of the U.S.-owned tire industry, the U.S. consumer has no cause for complaint.

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Comment Robert H. Porter

Rajan, Volpin, and Zingales are to be congratulated for carefully assembling evidence from a broad variety of sources and for providing an interesting interpretation of this evidence. Their story is well told and provocative. My role as a discussant, however, is to question whether their story stands up to scrutiny and to describe some issues that might warrant further research.

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I cannot claim any expertise on the tire industry. I am not an avid, or even occasional, reader of *Rubber World.* Moreover, this industry has not been the subject of much previous research in industrial organization. For example, I could find no reference to the tire industry in the textbooks by Carlton and Perloff (1994) and by Scherer and Ross (1990). Hence my comments are those of an outsider.

Rajan, Volpin, and Zingales seek to discriminate among three explanations of why the U.S. tire industry experienced a series of hostile takeover bids in the 1980s, and why most of the acquired companies ended up under the control of foreign tire manufacturers. The authors call the first explanation "neoclassical." Essentially, according to this explanation the mergers were necessary to realize efficiency gains in production or distribution. Foreign firms were more experienced with radial production, which came relatively late to North America, and the takeovers may have been the only mechanism to achieve cost savings quickly.

The second explanation credits managerial factors associated with overinvestment. In particular, the existing management may have been intransigent or unwilling to make necessary changes. Changes may have been necessary because the increases in tire durability associated with the introduction of radials led to excess productive capacity.

The third explanation is an industrial organization story. According to this story, automobile production and marketing were becoming increasingly global, and as a consequence global production of tires became efficient. Foreign firms had greater relative expertise with radials. De novo entry by foreign companies in the United States would have led to excess capacity, and so takeovers were the least cost method of globalizing the U.S. industry. Why was there new entry rather than the necessary investments in R&D by the incumbent manufacturers once radials were introduced? Because the new entrants did not internalize the effect of new radial investments on the value of sunk investments in belted bias ply manufacturing, the old technology. It was not easy to convert existing belted bias ply plants to radial production. Why were the entrants foreign, not domestic? Because only they had sufficient expertise with radial technology. Why were there takeovers? Better that than going through a war of attrition to knock out inefficient or outmoded capacity (i.e., the inferior technology).

The authors prefer the third explanation. They rebut the second, managerial, explanation with two key facts. First, the transition of U.S. manufacturing capacity to radials was largely complete prior to the takeover wave. Second, radials were not that much more durable than belted bias ply tires, and replacement sales of tires actually increased in the relevant period, perhaps because of increasing awareness of and demand for safety, which might have induced more frequent tire replacement. Michael Jensen was one of the first proponents of the managerial explanation of takeovers in the tire industry, and considerations of comparative (and perhaps absolute) advantage dictate that I defer to him to defend this story.

In the case of the neoclassical explanation, the fact that radial conversion preceded the takeover wave does not preclude the possibility that there were unrealized efficiency gains that could be achieved only with a change in management. The centerpiece of their rebuttal of the neoclassical explanation is the total factor productivity computations summarized in table 2.6, which are based on a regression analysis of census of manufacturing plant-level data.

The regression analysis considers a panel of sixty-seven plants in the years 1967 and 1972–93, inclusive. There are 720 plant-years of data, so the average plant has a sample life of eleven years. The main regression equation employs ordinary least squares, and the logarithm of value added is regressed on the logarithm of labor (production worker equivalent man-hours), the logarithm of a capital stock measure (net property, plant, and equipment), and a variety of dummy variables, in many instances including plant fixed effects. The use of plant fixed effects is a major improvement on comparable studies, especially since the set of acquired plants does not seem to be similar to plants that were not acquired. I return to this point below.

The coefficients of most interest to Rajan, Volpin, and Zingales are associated with the dummies for plants that were owned by foreign manufacturers and those that were acquired after acquisition. The sum of these two coefficients is a measure of the average productivity change in plants that were acquired by foreign companies, in years after the acquisition. The sum of these coefficients is negative in all the regressions considered, although apparently not always significantly different from zero. I say "apparently" because standard errors are not reported for the sum of the two coefficients. Nevertheless, the coefficient sum indicates that there was not a productivity gain at the plant level associated with foreign takeovers, contrary to the neoclassical explanation.

I have some concerns with the reported regressions, however, and with the interpretation of the regression results. Because of these concerns, I believe that it may be premature to dismiss the neoclassical explanation.

First, the coefficient on the labor variable is greater than one in many of the reported regressions, and greater than 0.83 in all. These values are implausible, and probably inconsistent with the interpretation of the estimated equation as a production function. Measurement error of both the capital stock and labor input is a potential concern, as is potential endogeneity of the labor variable. Similar coefficients were found by Burnside, Eichenbaum, and Rebelo (1995, 67–110), for example, in their study of two- and three-digit manufacturing industry data. (One of their three-digit industries is tires.) Burnside et al. argue that their capital stock measure is suspect, and in particular that capital utilization is poorly proxied. Rajan, Volpin, and Zingales follow their lead in table 2.6C, which describes regressions that employ energy consumption as a proxy for capital utilization. The results are similar to the regression equations in table 2.6A that employ capital. However, Burnside et al. also correct for endogeneity of their labor and capital utilization regressors, and they then obtain more sensible production function parameters. Rajan, Volpin, and Zingales make no attempt to correct for simultaneity bias. The issue here is not that getting more reliable estimates of the capital and labor coefficients is of intrinsic interest, but rather that the foreign ownership and acquisition dummy variable coefficients may be biased because of biases elsewhere in the estimated equation.

Second, one wonders about potential sample selection bias associated with comparing plants that were closed during the sample period to those that remained open. In this sample, 20 percent of the plants were closed during the period considered. The positive coefficient on the age variable is symptomatic of a potential problem, if some older plants survive because they are relatively productive. Olley and Pakes (1996), who study productivity in telecommunications equipment plants using similar data from the Census Bureau, describe the potential biases and methods of correcting them in detail. If there is sample selection bias, then the equations reported in tables 2.6 and 2.7 should be estimated jointly. Note that the coefficient on the age variable is implausibly large in the fixed effects regressions. A coefficient of 0.05 implies that productivity grew 5 percent per year, for a productivity gain of more than 70 percent over the eleven-year sample life of an average plant. Again, the problem is that the coefficient seems inconsistent with a production function interpretation of the estimates.

Third, as the authors acknowledge, the capital stock is probably measured with error. I shall focus on one aspect. Many plants seem to have converted from belted bias ply to radial during the sample period. Surely some of the existing capital was rendered obsolete by the transition, yet no account is made of this. In short, it is not innocuous to use a standard capital stock construction with fixed and constant depreciation in a transitional environment. The regressions reported in table 2.6B employ a sample of plants with at least 80 percent radial production and therefore address concerns about whether one can pool observations from belted bias ply and radial plants. But splitting the sample will not necessarily solve the problem with capital measurement, for the capital stock of plants that were converted to radial may be measured with error in the years immediately following conversion.

Finally, there is a general issue of how to interpret plant-level productivity regressions in this instance. The firms under consideration are multiplant firms with global operations. It is possible that plant-level total factor productivity did not change, consistent with the reported regressions, and yet the takeovers led to firm-level efficiency gains due to the consolidation of nonproduction segments of the business, such as marketing, R&D, product design, advertising, or bargaining with the automobile manufacturers.

On the basis of the evidence presented in the paper, I would argue that the industrial organization explanation may be true, but also that the evidence is not sufficient to discredit the neoclassical, or efficiency-based, explanation.

The paper also raises a number of questions that may be worth pursuing in subsequent research. I shall describe a few.

First, the employment regressions reported in table 2.8 indicate that the plants that were acquired by foreign firms were much smaller than average, with about half the employment of the typical plant. (The coefficient on foreign ownership is −0.50 in the regression in column [6] explaining the logarithm of labor, and that on acquisition in column [5] is −0.43.) Again, one wonders whether it is appropriate to pool these smaller plants in the productivity regressions. But the coefficients also indicate that the acquired plants were atypically small. The fact that capital expenditures increased after acquisitions, as indicated by the capital expenditure fixed effects regressions in table 2.8, might be explained by underinvestment by domestic owners, as the authors claim. There may also have been an inefficient scale of operations in acquired plants prior to acquisition.

If the account in the paper is accurate, why was there a complete shift from belted bias ply to radial tires? Rajan, Volpin, and Zingales indicate that there are some advantages to belted bias ply in terms of their ride. Now that gas mileage is not as great a concern for consumers (as real gas prices have returned to pre-OPEC levels), why can't the two types of tires co-exist in the market to satisfy the various consumer preferences?

Another (small) puzzle is why, according to table 2.3, the replacement market went 100 percent radial before the original equipment (OE) market. In 1992, for example, 89 percent of original equipment sales were radials, yet radials accounted for 99 percent of replacement sales. Either the numbers are incorrect, or belted bias ply original equipment sales are for export, or belted bias ply replacement demand is being met by imports or retreads. Note that the car production numbers omit small trucks and minivans, which account for an increasing share of original equipment sales over the sample period.

A striking feature of table 2.1 is how stable global concentration measures have been over the period considered, especially given the pronounced cycles in the demand for tires (mirroring fluctuations in automobile sales), technological changes in the production of tires, and significant changes in the structure of the global automobile industry. Perhaps the global concentration of tire production is optimal, given the procurement requirements of the automobile industry. That is, it may be optimal for the car companies to have about nine effective competitors among tire suppliers. Nine is the approximate inverse of the Herfindahl index. This inverse is sometimes referred to as the number of effective competitors, for it is the number of symmetric firms consistent with the calculated Herfindahl index.

The data set used in the productivity and plant closure regressions of tables 2.6 and 2.7 does not seem to be as extensive as one might wish, especially in the case of the plant closure regressions. A total of thirteen plants closed in the sample studied in table 2.5, yet table 2.4 identifies twenty-four plant closures in the industry between 1976 and 1986. Virtually all of these closures preceded the takeovers, consistent with the story favored by the authors. But a full story of plant closure decisions might focus on the broader sample.

An important issue that is not considered in the paper is why mergers were necessary to realize efficiency, managerial, or strategic gains. Why were joint ventures or other contractual arrangements not employed?

It would also be interesting to learn more about what happened in this industry after the takeover wave. Are the mergers considered successful? For example, Milgrom and Roberts (1992, 510) cite the Bridgestone takeover of Firestone as an example of an extreme takeover premium. According to Milgrom and Roberts, the prebidding value of Firestone shares was on the order of $1 billion, and the final price paid by Bridgestone approximately $2.6 billion, amounting to a premium of 160 percent. Is this large takeover premium thought to be warranted? Michelin is described in a recent issue of the *Economist* ("Michelin Gets a Grip," 1 March 1997) as emerging from troubles associated with the debt it incurred in its acquisition of Goodrich. Is this merger a success? And how has Goodyear, the one U.S. company that survived without being acquired, fared in comparison to its rivals? The sample for the total factor productivity regressions does not cover many years after the takeovers, so that it is conceivable that a longer-run analysis may yield different conclusions. A return to the numbers a few years hence may provide a more definitive answer. It is also conceivable that the mergers occurred because of hubris or false expectations of synergies on the part of the acquiring firms' managers, consistent with the experience in several takeovers studied by other papers in this volume. The "eclipse" of the U.S. tire industry may have occurred because the acquired firms were offered a price far in excess of the value of the company, even under optimal management.

Finally, Rajan, Volpin, and Zingales argue in section 2.2.5 that the domestic tire industry faced a hold-up problem in converting to radials. They describe the necessity of coordinating conversion with the automobile manufacturers, as well as the automobile companies' ability to extract most rents from the original equipment market. The consequence, they claim, was inefficient delay in the introduction of radials. But the numbers of players involved is not large, and the tire and automobile companies were partners in longstanding relationships. One might expect that contractual remedies could have been found for any hold-up problem, and therefore that the delay in introducing radials may be due to other factors. As the authors argue elsewhere, the automobile industry was not a leader in the introduction of many other design innovations in the period around 1980.

None of the preceding skepticism should detract from the contributions of the paper. The authors have carefully combined data from a variety of sources, they employ appropriate techniques to analyze their data, and their economic analysis is novel and plausible. In short, this paper represents best practice methodology. But like most good research, it whets one's appetite for more, to corroborate results or to investigate alternative explanations.

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