R&D Activities and Innovativeness of Foreign-Owned Firms in Ohio

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I. Introduction

A great deal of attention has been directed to the role of multinational corporations (MNCs) in international R&D (research and development) activities and transfer of technology.[1] MNCs produce, own, and control most of the world's advanced technologies because they are responsible for a significant part of global R&D. According to Blomstrom [1992, 105], based on his review of the literature, "there is strong evidence that multinational firms have contributed to a geographical diffusion of technology and that active host countries can obtain access to modern technology via foreign direct investment." In fact, the desire to acquire modern technology may have become the most important reason why most countries try to attract direct foreign investment (DFI).[2] Dunning [1993, 287], from his review of the literature, concludes "that, in the past, both inward and outward DFI has often (though not always) been a significant contributory factor to the level and structure of a country's technological capacity." According to OECD [1994, 69], based on an analysis of the technological links between parent companies and foreign affiliates in the OECD countries, "the bulk of technology used by affiliates comes from the parent companies."

Do foreign-owned firms transfer non-U.S. technologies to their U.S. subsidiaries, as we would expect on the basis of the theory of DFI, or do they rely primarily on U.S. technologies in establishing a beachhead in the United States? Do they contribute significantly to U.S. technological capabilities through their R&D and technology transfer activities or do their foreign parents confine R&D activities and best technologies to their home countries?

The effects of foreign-owned firms in the United States on U.S. technological capability have been controversial. Two earlier studies [Sametz and Backman, 1974; Ajami and Ricks, 1981] concluded that although the size of the U.S. market and the attractiveness of a new market or desire to preserve the existing U.S. market had been the most frequently cited reasons for inward DFI (IDFI) in the United States, the primary motive was the desire to benefit from a higher level of U.S. technology and innovation. This view still has proponents, especially as regards Japanese investments in U.S. R&D-intensive, high-technology sectors [OTA, 1993; OTA, 1994]. It seems to have been reinforced by the fact that IDFI has consisted mainly of acquisition of existing U.S. firms (brownfield investments) rather than establishment of new firms (greenfield investments) [Aguilar, 1996].

Many other studies [e.g., McCulloch, 1991; Lipsey, 1993; Arrison et al., 1992; Florida and Kenney, 1994; OECD, 1994; Graham and Krugman, 1995; Reid and Schriesheim, 1996], however, have argued that the increasing role of MNCs in the U.S. economy has been primarily due to shifts in international technology and comparative advantage, in accordance with the theories of DFI and international trade, resulting in significant technological benefits to the U.S. economy.

Since technology is partly a public good, DFI can also yield indirect productivity gains for the host country firms through external economies or spillovers. Blomstrom [1992, 95-100] divides these into (i) *intra*industry spillovers (i.e., the effect of foreign firms on the efficiency of their host country competitors) and (ii) *inter*industry spillovers (i.e., the effect of foreign firms on their local suppliers and customers).

*Intra*industry spillovers can consist of greater competition, training of local labor and management, and faster transfer of both product and process technology. As for *inter*industry spillovers, foreign firms can stimulate local suppliers of intermediate goods to improve quality and reduce cost ("backward spillovers"), and can also enhance the productivity of local firms purchasing their products ("forward spillovers"). Blomstrom [1992, 104] concludes, from his review of the empirical literature on spillovers, that "such effects exist, and that they may be substantial both within and between industries, but there is no strong evidence on their exact nature." Furthermore, Blomstrom and Kokko [1993] and Blomstrom et al. [1995] find that spillovers vary significantly among host countries, increasing with their local capability and competition.

In this paper, we analyze the R&D activities and technology-related payments and receipts, innovativeness, and competitiveness of foreign-owned firms in Ohio, on the basis of our two case studies and survey data, which we collected from 180 companies. Using nonparametric tests, CHAID (Chi-squared Automatic Interaction Detector) and logistic regression analyses, we explain these companies' R&D expenditures; R&D expenditures to sales ratios; R&D employment; R&D employment to employment ratios; technology payments to and receipts from U.S. companies, major parent company, and other foreign companies; major orientation of their innovations; major contributions to the modernization of Ohio's economy and sources of competitiveness.[3]

II. Role of Foreign-Owned Companies in U.S., R&D and Inward Technology Transfer

Most modern explanations of DFI focus on the role of ownership-specific advantages, especially proprietary technological advantages exploited through internalization [Dunning, 1993]. Therefore, we would expect U.S. IDFI to be motivated by the superior R&D and technological assets of foreign companies. The recent growth of U.S.-based R&D activities by foreign-owned companies has been the subject of several studies. According to the National Science Board [1996, chapter 4], from 1980 through 1993, the annual real growth of R&D expenditures by U.S. affiliates of foreign firms averaged 12%, more than thrice the real rate of growth in domestic R&D spending by U.S. companies. Dalton and Serapio [1995] estimated nominal R&D spending by the U.S. affiliates at more than $14.6 billion in 1993, up from $6.5 billion in 1987. They also found that the factors behind foreign R&D in the United States were strikingly similar to those for U.S. R&D abroad, much of the R&D consisting of applied research. These factors ranged from helping the parent company to satisfy host country buyer needs, keeping abreast of technological advances to enabling the companies exploit their proprietary special competencies in the host countries. At the end of 1994, there were more than 645 foreign-owned R&D centers in the United States, 224 of which were owned by Japanese parent companies. The second-largest number (109) belonged to U.K. companies.

In their investigation of Japanese R&D in the United States, Florida and Kenney [1994, 345] found two underlying interrelated geographic concentration patterns:

> On the one hand, Japanese R&D investment reflects an underlying strategy of "global localization" and the development of integrated innovation-production complexes. In these cases, R&D is located in close proximity to existing factory sites. On the other hand, Japanese R&D investment aims aims to harness the new sources of knowledge and ideas embedded in regionally based centers of innovation. In these cases, R&D facilities locate in regional innovation complexes such as Silicon Valley in electronics or the Detroit area in automotive technology. Such investments function to gain access to pockets of knowledge, skill, and social capability inherent in such areas.

The foreign-owned R&D centers employed more than 105,000 R&D workers at the end of 1993, having risen from 104,000 employees (about 15% of the R&D employment of all U.S. businesses) in 1992. The 1992 benchmark survey of IDFI by the U.S. Department of Commerce noted that U.S. affiliates of foreign companies, with a share of only 6% in all U.S. business GDP, accounted for 17% of the privately funded R&D performed by all U.S. businesses but for less than 1% of government-funded R&D [Zeile, 1994, 164].

According to Reid and Schriesheim [1996, 42-47], R&D spending by U.S. affiliates of foreign-owned companies as a percentage of all privately funded R&D rose from 9.3% to 15.5% from the beginning of 1982 to the end of 1993, with Japanese-owned firms registering the fastest increase. This significant rise in R&D was accompanied by the rapid growth in IDFI during the same period. Close to two-thirds of all foreign-funded R&D in the United States is concentrated in a few high-technology sectors where foreign-owned firms have established strong export positions.

> Foreigners become involved in American privately funded R&D for two basic reasons: to serve customers in this country better and to gain better access to American scientific and technological expertise. Most major foreign-owned R&D facilities are located near major U.S. centers of R&D activity, and most affiliate R&D performed in the United States appears designed to meet the immediate technical needs of U.S. based production facilities. Comparative surveys of U.S.- and foreign-owned multinational companies suggest that the motives for engaging in R&D in foreign markets and the type of R&D activity vary by industry but are not significantly influenced by the nationality of the company [Reid and Schriesheim, 1996, 4].

Reid and Schriesheim [1996, 81] also find that, on the whole, foreign-owned firms in the United States tend to receive significantly more codified technology from their parent companies than they send to them or to other firms abroad. As for the contributions of these firms to U.S. technological capabilities, Reid and Schriesheim [1996, 66-67] note the significant interindustry variation revealed by several empirical studies. In particular, they draw attention to the studies that have found significant transfers of organizational and managerial innovations by U.S. affiliates of Japanese companies in the automotive and steel sectors. Also, "case studies show that foreign-owned companies, and Japanese companies in particular, have imported significant amounts of advanced production technology and methodologies into the United States in several industries" [Reid and Schriesheim, 1996, 81].

These recent observations on the technological benefits of U.S. IDFI are consistent with many earlier ones. For example, according to Cantor [1989], DFI has played a major role in the U.S. steel industry since 1983, ranging from the construction of specific product mills to joint ownership of entire steel plants. One important reason for this IDFI was the import restrictions of the "voluntary export restraints" (VERs), which went into effect in late 1984 for five years. As we discuss in our first case study below, the USS Steel Division of USX Corporation entered into a joint venture with Japan's Kobe Steel Company to take over and modernize the operations of USX's Lorain, Ohio, works, which had been manufacturing steel pipe and tube products. Cantor [1989, 108] concludes that "the influx of foreign equity capital ... has contributed to the modernization of the domestic industry by facilitating technology transfer and by making investments economically feasible, given the relatively high cost of capital in the United States."

The GAO [1988, 11], focusing on the rapidly rising Japanese DFI in the U.S. automotive and autoparts sectors in the 1980s, noted:

> Reacting to the competitive pressures, U.S. auto manufacturers began to change the way they were doing business. Some formed joint ventures with Japanese automakers, which provided first-hand experience in Japanese production and management techniques. Many of the features which made Japanese models a success are now being tried and implemented by U.S. automakers.

Giese [1989], from her study of DFI in the U.S. automotive and autoparts industries in the 1980s, concluded that, as in the case of steel, VERs had played a crucial role in motivating mostly Japanese DFI and that, subsequently, several U.S. companies in these industries had improved their competitiveness through technology transfers from, or synergistic joint ventures with, foreign-owned firms. We discuss Honda below as our second case study to illustrate the critical direct and indirect role it has played in the resurgence of the U.S. auto industry.

In short, since the early 1980s, IDFI has played an increasingly significant role in the development of U.S. technological capabilities through R&D activities of, and technology transfers by, foreign-owned firms. Within this general empirical framework, we now focus on the R&D activities, innovativeness, and competitiveness of foreign-owned firms in Ohio, beginning with our two case studies. These case studies illustrate the critical technological contributions made by Japanese multinational corporations, reflecting Japan's rise as a global technological power [Mowery and Teece, 1992], to the resurgence of U.S. steel and automotive industries as well as the economic development of Ohio.

1. Case Study: USX and Kobe Steel Joint Venture

USS/Kobe Steel Company, a joint venture between USX, the parent firm of U.S. Steel International, Inc., the largest U.S. steel maker, and Kobe Steel, Ltd., Japan's fifth-largest steel producer but leading steel bar products manufacturer, marked Kobe Steel's first mainline steel venture in the United States. Owned 50% by USX and 50% by Kobe Steel, it took over the assets, management, and business of the former Lorain Works, with 2,850 employees, located in Lorain, near Cleveland, Ohio. It was formed in July 1989 to produce steel bars and pipes. Inputs to automotive applications, bars are used in making mainly engine parts and drive shafts, for which high-quality materials are essential. Tubular products, on the other hand, are used primarily in the oil and gas industry. USS/Kobe Steel was to be managed by a committee consisting of six directors, three from USX and three from Kobe Steel, but chaired by one of the Japanese directors, the president of Kobe Steel USA Inc., headquartered in New York City.

USX had approached Kobe Steel in February 1989 with the idea of the joint venture partnership to improve the Lorain Works, its only bar-making operation, and to maintain its eroding leadership in the domestic bar market. Without the joint venture, the future would have been bleak for the Lorain Works and the Lorain community. Over the next five to ten years, the Lorain Works would have seen its volume slowly slip away to competition from mostly nonunion minimills if its aging facilities had not been modernized. USX had focused its steel production and investment on sheet products and committed no resources to the upgrading of the Lorain mill, its only bar and pipe products facility. Before the joint venture with Kobe Steel, the Lorain mill had been supplying bar products to the Big Three auto producers, namely, GM, Ford, and Chrysler, but not to any of the Japanese auto transplants, whose strict quality standards could not be met. Before the joint venture, the work force of the Lorain mill, which was a dark, dirty, and dreary work place, suffered from low morale and was apprehensive about its future, the future of its families, and the future of its community.

Appreciation of the U.S. dollar and protectionist trade policies had begun to affect Kobe Steel exports to the United States adversely in the first half of the 1980s. Kobe's exports of steel bars to the United States had been expected to increase rapidly with the growth of Japanese auto transplants. Construction of a new steel plant in the United States would have been too costly. Instead, Kobe began to explore an alliance with a U.S. producer. As a result, Kobe entered into a 50-50 joint venture with USS. The marketing advantage of USS was another reason why Kobe formed the joint venture. Kobe's major contribution to the joint venture was to be in technology and quality control. Kobe was motivated by the growth of Japanese auto transplants and their increasing demand for high-quality steel. Furthermore, at that time Kobe Steel had no tubular-products manufacturing in Japan. Its participation in USS/Kobe Steel would enable it to acquire such capacity to supply both the U.S. and world markets.

At the time the USS/Kobe Steel Company was formed, Kobe Steel, Ltd. already had 21 subsidiaries, ventures, and other investments in the United States, including four in Ohio. In 1988 Kobe Steel was the first Japanese steel company to establish a U.S.-based headquarters; it was known as Kobe Steel USA Inc. and was to provide overall direction for Kobe Steel's subsidiaries and oversee the activities of two U.S. research facilities, one at North Carolina's Research Triangle Park and another in California's Silicon Valley.

One of the critical elements in the formation of the joint venture was a technology transfer agreement between USS/Kobe Steel and Kobe Steel to be implemented under the leadership of USS/Kobe Steel's vice president for technology, a Japanese executive with metallurgical engineering training, who later became the president of Kobe Steel USA Inc. Under this agreement Kobe Steel would receive for four years licensing royalties and technical fees for its technological contributions to the joint venture. Technology was transferred through four channels. First, 17 Kobe Steel engineers and scientists were employed full-time at the Lorain plant for the technology transfer from Japan. Second, occasionally specialists from Kobe Steel came to Lorain for limited periods to help solve technical problems encountered in the modernization process. Third, as the need arose, engineers and technical managers from USS/Kobe Steel spent time at Kobe Steel's facilities in Japan to receive special training required by the modernization. Finally, USS/Kobe Steel personnel could consult freely by telephone and fax with their counterparts in Kobe, Japan, on problem solving in engineering and production.

In June 1990, USS/Kobe Steel announced its intention to initiate a massive overhaul of the Lorain mill, crucial for the company's ability to compete. The company noted that its ability to compete in bar products was critically dependent on its meeting the higher quality standards of U.S. domestic auto firms as well as those of Japanese auto transplants. In the pipe market, where much of the company's competition came from imported steel, its customers were also insisting on higher-quality tubular products. This required the modernization of its seamless pipe mills.

Key elements of the renovation and modernization package were tax abatements from the city and smooth labor relations. In May 1991, USS/Kobe Steel began to spend $200 million to upgrade its Lorain mill. The improvements included installation of new equipment such as a second bloom caster, a machine that forms molten steel into long sections ready to be made into pipes or bars, rebuilding one of the plant's blast furnaces, and upgrading the plant's finishing mills. This represented the first phase of a six-project, five-year $410 million (later raised to $500 million) modernization program despite a severe slump in the bar market, which had cut the plant's production rate to 50% of capacity, well below the industry average. The bar market had been plagued by excess capacity and shrinking demand in the 1980s as autos were reduced in size and design changes, such as the switch to front-wheel drive, were introduced. The construction and off-highway equipment market had also shrunk, and many bar plants were shut down as operations were consolidated into fewer facilities.

In short, without Lorain mill's modernization, to increase productivity, lower costs, and improve quality, the plant would have been doomed to extinction soon. This modernization required Kobe Steel's state-of-the-art technology. The improvements would be accompanied by extensive training of hourly and salaried employees. The modernization program required USS/Kobe Steel to bring its future labor costs under control and to institute less restrictive work rules. This, in turn, necessitated the cooperation of the national United Steel Workers (USW) union for allowing the USS/Kobe and the local USW union to negotiate a new labor agreement independent of the master agreement between the USW and USS, which had covered the local plant through

February 1991. This new agreement had to recognize the fact that unlike USS, which was mainly a flat-rolled steel producer, the Lorain mill produced primarily bar-shaped steel with lower profit margins and faced stiff competition from many nonunion, low-cost producers such as North Star Steel and MacSteel, known as minimills. The national USW leadership initially resisted but later accepted the separate agreement.

In order to improve USS/Kobe Steel's labor-management relations, the state of Ohio awarded, in September 1990, a $50,000 Ohio Steel Futures Program grant toward a joint project between USS/Kobe Steel, the United Steel Workers of America, and Cleveland State University's Industrial Relations Center. This grant contributed to a $140,392 project to develop and implement a model cooperative labor-management education program at Cleveland State University (CSU).

In October 1991, USS/Kobe Steel began to modify its steel-bar mill operation in Lorain to accommodate demand for smaller-diameter, lighter bars, interpreted widely as a foray into the market for steel-rod or wire-rod, used to produce steel wire and fasteners. Moreover, it moved up its rolling-mill modernization on its capital-spending priority list, all part of its five-year modernization program announced earlier.

In conclusion, USS/Kobe Steel, thanks to technology transfers from its Japanese parent, cleaner and safer working conditions for its employees, and improved labor-management relations, has modernized its facilities and increased production of value-added products in line with capital investment and modernization programs implemented since 1990. In 1994 it brought a new pulverized-coal injection facility on line for its No. 3 blast furnace, and in 1995 it completed the installation of a continuous bloom caster. It also remodeled its ten-inch bar mill with the world's fastest rolling speed, and a reheating furnace.

These innovations have enabled the company to supply a wider range of bar products, especially smaller-diameter-quality bars for auto parts. Due to improvements in productivity and operational efficiency, USS/Kobe Steel, currently with 2,730 employees and a crude steel production capacity of 2.4 million tons, has been profitable since its establishment. It has become a major direct and indirect supplier of the transplant operations of Honda, Nissan, and Toyota, as well as the Big Three auto producers.

The first successful USS/Kobe Steel joint venture was soon followed by another one. This second 50-50 joint venture between Kobe Steel, Ltd., and USX Corporation, Pro-Tec Coating Company (originally named AZTEC), with a $200 million greenfield facility in Leipsic, near Toledo, Ohio, was formed in March 1990 and went into production in January 1993 with 90 nonunion employees. This joint venture, initiated by USX and encouraged by the success of USS/Kobe Steel, became profitable in its second year of operation. Pro-Tec produces world-class-quality coated steel sheet products mainly for U.S.- and Japanese-owned automotive plants in the United States. Its hot-dip galvanizing line is designed to supply high quality coated and corrosion-resistant sheet steel. Its master coils are supplied by USS's Gary Works in Indiana, Mon Valley Works near Pittsburgh, and Fairfield Works near Birmingham, Alabama. The demand for galvanized steel had been growing as auto makers used more zinc-coated parts in their cars and extended their rust protection warranties.

Pro-Tec set a new steel industry world record for annual production by a hot-dip galvanizing line, making close to 651,000 prime tons of coated steel sheet in 1995, exceeding its annual 600,000-ton capacity. It was also certified in January 1996 as meeting the stringent ISO 9002 quality assurance standards. For Kobe Steel, this achievement marked its first production unit in the United States to have met the stringent ISO standards.

In summary, both of these successful steel industry joint ventures, one brownfield and the other greenfield, illustrate the critical technological contributions made by Kobe Steel through direct investment to the resurgence of the U.S. steel industry and the economic development of Ohio.

2. Case Study: Honda.

On 10 September 1979, the first U.S.-made Honda motorcycle rolled off an assembly line, with 64 workers in Marysville, Ohio, following an initial investment of $35 million. A decade later, in December 1989, Honda of America Manufacturing Inc. (HAM), part of Honda North America, Inc., a wholly owned subsidiary of Honda Japan, began production at its *second* automobile assembly plant in west-central Ohio. It had 6,400 workers at its two plants (automobile and motorcycle) in Marysville, an additional 1,200 at its engine plant in Anna, and 150 at its new East Liberty automobile plant. Honda Accord, whose production had started in 1982, was the best-selling car in the United States. In Ohio, Honda began to produce motorcycle engines in 1985, the Honda Civic in 1986, and the Acura CL in 1996.

Honda is a major Japanese multinational corporation with 119 facilities in 46 countries. Its total U.S. investment reached $3.2 billion in mid-1996 after producing 552,995 cars and 128,107 motorcycles in Ohio in 1995. Since 1987, most Hondas sold in the United States have been manufactured in North America reaching 77% of total sales in 1995. For the second year in a row, Honda, with 14,000 employees in manufacturing (with 11,500 Ohio production workers who produce half of all the cars made in the state), R&D, engineering, and marketing, was the top automobile exporter, selling more than 87,835 cars to 52 countries, 49,509 of them to Japan. By the end of 1996, Honda will produce every Accord sold in the United States in Marysville, Ohio. When the redesigned 1998 Accords debut in late 1997, every one sold in 130 countries, including in Japan, will be built in Ohio.

In 1995, Honda Accord, with sales of 341,384 units, was the second best-selling car in the United States after Ford Taurus, which sold 366,266 units; Honda Civic, with sales of 289,435 units, was the fourth best-selling car after Toyota Camry, which sold 328,595 units. Honda's share of the passenger car market in 1995 was 10%, about the same as the shares of Chrysler and Toyota.

In 1995, Honda purchased $4.6 billion in parts and materials from 353 North American suppliers in 35 states, reaching a domestic content of at least 90% according to the EPA formula. It had more than 140 Ohio-based automotive and power equipment OEM (original equipment manufacture) suppliers. The top supplier states after Ohio were Michigan, Indiana, Illinois, Kentucky, North Carolina, Wisconsin, Georgia, and Texas.

In September 1987, HAM had announced a five-part strategy for its future operations in the United States:

- Export 70,000 cars per year to Japan and other countries
- Increase domestic content to 75% by 1991
- Increase U.S. R&D activities
- Expand production engineering in the United States
- Construct a second auto plant and further expand engine manufacturing in Ohio

In terms of the third part of its strategy, HAM had stipulated further:

- Expand R&D employment in the United States to 500 from 180 employees
- Designate as primary R&D goals the design and engineering of cars and testing evaluations in the United States to develop new models for the U.S. market, and increased U.S. sourcing
- Purchase the Transportation Research Center of Ohio for $31 million to support further the R&D effort and provide a site for a second auto plant

As part of an infrastructure package worked out with the state government, Honda purchased for $31 million the Ohio Transportation Research Center adjacent to its East Liberty facilities, 40 miles northwest of Columbus, Ohio. The state also made various highway improvements in the area, provided rail lines in cooperation with Conrail, financed site and infrastructure improvements, and funded the training of new Honda employees.

In July 1994, HAM announced its new five-part Automobile Strategy for the Americas:

- Increase annual automobile manufacturing capacity in the United States and Canada from 610,000 to 720,000 units and begin auto manufacturing in Mexico
- Expand annual capacity of the Ohio engine plant from 500,000 to 750,000 engines in 1998
- Expand U.S. R&D capabilities
- Strengthen the auto sales networks in the Americas
- Expand annual exports of Canadian-produced cars to more than 150,000 units by 1999, including component sales

After completing nearly all of its July 1994 strategy in 1996, HAM announced in May 1996 its Americas Strategy ’96 to expand and accelerate Honda’s self-reliant strategy for the Americas through the end of the decade:

- Increase annual production at the Ohio engine plant from 750,000 to 900,000, including production of an all-new V6 engine in 1996 and the first-ever gasoline Ultra Low Emission Vehicle (ULEV) engine in 1997
- Create an automatic transmission center for the Americas in Ohio and increase annual production from 380,000 to 650,000 units
- Further localize production and sourcing of automatic transmission and engine components by domestic suppliers, increasing supplier investment by more than $310 million and creating more than 1,200 new jobs
- Expand annual auto production in North America from 720,000 to 840,000 units, including production of a new van in 1998
- Expand U.S. R&D employment to 800 persons in 1996, four years ahead of the initial expansion target.

In the R&D area, originally established in California in 1975 to conduct market research, Honda R&D North America, Inc. (HRA), has steadily expanded the size and scope of its operations. In September 1996 it had 750 employees. Formally incorporated in 1984, the primary mission of HRA today is to design, develop, and engineer products for customers in the Americas and to support local parts sourcing. Like Honda R&D Co., Ltd., in Japan, HRA is a separate company with the flexibility to pursue its design and development goals.

HRA has been involved in the design and development of many Honda products, including the Accord Coupe, Accord Wagon, and Civic Coupe. All three models are manufactured exclusively in North America in both right-hand- and left-hand-drive versions, and exported to several countries. The Acura CL Coupe is the latest automobile conceived, designed, engineered, and produced exclusively in North America.

The continued expansion of HRA operations is expected to result in more locally developed products. With the latest expansion of the company's Ohio Center in December 1995, the capital investment in R&D facilities in the United States exceeded $250 million. The Ohio Center, which began operations in 1985, is responsible for product development, prototype fabrication testing, support of North American suppliers and technical support to manufacturing operations. The Los Angeles R&D Center is responsible for product planning, styling design, and market research.

In October 1996, Ohio State University in Columbus, Ohio, announced the creation of two endowed chairs in engineering that will bear the name of Honda. The two new Honda Chairs in Transportation, endowed with $1.5 million each, are intended to advance research in transportation, including ergonomics and materials development. These chairs are being funded by the Transportation Research Endowment Program (TREP), which has in turn been largely funded by the surplus income generated at the Transportation Research Center (TRC) Inc. in East Liberty, adjacent to Honda's Ohio R&D Center. TRC Inc., now a part of HRA, had been sold in 1988 to Honda by the state of Ohio for $31 million, of which $6 million was earmarked for the creation of TREP. Although owned by HAM, TRC Inc. is independently managed and conducts research and testing not only for Honda but also for many other clients, including the U.S. government and all U.S. and several foreign auto manufacturers. With 400 employees, TRC Inc. serves 170 clients at its outdoor crash safety testing site and rough road course, and generates $20 million annually in revenues.

On the basis of this brief history of Honda's U.S. operations, Honda's technology transfer can be analyzed in terms of three effects [Craig et al., 1994, 26-44]: 1. demonstration effect, 2. communication and location effect, and 3. competitive strategy and policy effect.

1. *Demonstration effect.* Honda was the first foreign auto company to use foreign auto technologies in the United States successfully. It showed that Japanese production and management techniques can work in the United States. Although these techniques were well known in the United States, many people had believed that they could not be applied there. Honda's success was all the more remarkable following the earlier dismal failure of Volkswagen to produce passenger cars in Pennsylvania. Since Honda began producing passenger cars successfully in the United States in 1982,

the share of transplants, primarily Japanese direct investments, in U.S. passenger car production has increased from 1.7% to 30.0% in 1995; their share in U.S. retail sales rose from 1.1% to 19.6% during the same period.

There were three important elements in the Japanese techniques introduced by Honda into the U.S. auto industry, still the largest U.S. manufacturing sector: (i) commitment to "Kaizen," or "continuous improvement," (ii) cooperative relationships between workers, managers, and suppliers, and (iii) heavy emphasis on measurement and statistical analysis of all business operations, from serious faults to misplaced labels, to identify precisely what required improvement.

2. *Communication and location effect.* Honda's U.S. location of auto production triggered technology transfers to U.S. domestic auto producers and suppliers. It is widely agreed that technology transfer is most effective through direct foreign investment (DFI). There are two alternative channels of technology transfer through DFI: (i) Labor turnover, which has been very low in Honda's case and thus not very significant and (ii) direct interaction among firms, which in Honda's case has been very significant in terms of (a) Honda and its suppliers, and (b) Honda and its competitors.

In understanding the interaction between Honda and its suppliers, it is useful to distinguish between Honda's Tier I (direct) and Tier II (indirect) suppliers. Honda has brought with it many Japanese Tier I suppliers into the United States, several of them in joint ventures with itself. Honda helps its Tier I suppliers, who in turn help the Tier II suppliers. Also, Tier I suppliers that supply other U.S. auto companies benefit those companies.

3. *Competitive strategy and policy effect.* Honda's U.S. location of auto production changed the competitive strategies of U.S. domestic producers and benefited U.S. consumers through cost reductions and quality improvements. It also affected the evolution of U.S. trade policies in general and bilateral trade relations with Japan in particular.

The three essential components of Honda's technology transfer to the U.S. auto industry can be identified in terms of 1. supplier relations, 2. design partnerships, and 3. organizational technologies.

1. *Supplier relations.* Honda's emphasis has been on long-term and mutually beneficial relationships with its suppliers [Fitzgerald, 1995]. Purchasing is considered a critical function by Honda's top management. HAM has about 800 people working with its about 350 suppliers. Of the 800 workers, 300 are in purchasing, 200 are in quality, and 300 are in manufacturing. Purchasing outsources 75% to 80% in parts of the total cost of the car, including those supplied by Honda affiliates. Honda's "continuous improvement," "hands-on" approach to its suppliers has been formalized through its BP (alternatively known as "best practice," "best price," "best process," or sometimes "big problem!") Program, which is run by purchasing.[4] Through BP Honda shows its suppliers how to reduce manufacturing to its basic components and minimize the seven wastes of manufacturing: 1. Idle time, 2. Movement, 3. Rejects, 4. Downtime, 5. Over-production, 6. Delivery, and 7. Inventory. Recently, Honda has developed its BQ ("best quality") Program as an offshoot of BP, after realizing that 30% of BP was quality related. In 1985, poor quality levels were near 7,000 ppm (parts per million). In 1995, the level was down to between 100 and 200 ppm.

2. *Design partnership.* Honda has devolved increasing responsibility for parts design to its suppliers. It also works closely with suppliers on overall product design. They typically get involved two to three years before a new model is introduced. Some suppliers spend up to three months working with Honda's design engineers in Japan. Most suppliers send engineers to work with Honda's engineers at HAM facilities in Marysville, Ohio. Honda expects suppliers to become experts in the technology applied to their parts.

3. *Organizational technologies.* Honda has emphasized and diffused to the U.S. automotive industry such principles and concepts as "the Honda Way," "worker as the expert," "continuous improvement," "quality circle," and "just-in-time." Honda's clean and well-lit Ohio plants have become showcases for the domestic auto industry. At Honda all employees, who all wear white overalls, are addressed as "associates." At Honda all offices are organized as open space without walls; there are no executive dining rooms or special parking privileges for anyone. Perhaps an indication of Honda's successful labor-management relations is the fact that repeated attempts over the last 15 years to unionize Honda's work force have failed.

In short, Honda's direct investment in the U.S. auto industry has been critical to the resurgence of car making in both Ohio and the United States. Its has paved the way for other foreign car makers to start U.S. production and energized U.S. producers to modernize their operations in order to compete more effectively with both transplants and imports. Ultimately, U.S. consumers have gained the most in being able to buy lower-priced and better-quality cars.

III. Data and Methodology

We now turn to our statistical research, a comprehensive investigation of inward direct foreign investment (IDFI) in Ohio, required primary and firm-specific data on all foreign-owned companies operating in the state [Wolf, 1993]. Such data were unavailable from either published or unpublished sources. We collected these data directly from the foreign-owned companies operating in Ohio. For this purpose, we used an eight-page questionnaire, a copy of which is available on request.[5]

Before we could mail our questionnaire, we had to try to determine the identities of all the foreign-owned companies operating in Ohio. In discovering the names and addresses of the companies, we received help from several sources, including the Ohio Department of Development (ODOD).

We mailed a grand total of 723 questionnaires in May 1991. Each questionnaire was accompanied by a cover letter from the ODOD, signed by its director requesting participation in the study. According to KPMG Peat Marwick [1990], there were 547 foreign-owned firms in Ohio, 166 of which (i) had their U.S. headquarters in Ohio and (ii) were at least 50% foreign owned. We began to receive responses in June 1991. Ninety-nine uncompleted questionnaires were returned to us because either (i) we had used an incorrect address or (ii) the company had gone out of business, moved to another state, or the forwarding address had expired and no other address was on file with the post office and the company could not be found anywhere else in Ohio. This brought the total down to 624. A follow-up letter was later sent to the non-respondents, again requesting that the completed questionnaire be returned.

We received a total of 228 either partially or completely filled out questionnaires by the end of 1991. We tried to telephone all the individual respondents directly in order to either complete unanswered questions or clarify information.

The following is a summary of the 228 responses:

180	Included in the study (as input into SPSS/Windows [Norusis, 1993])
23	Excluded due to less than 10% foreign ownership
5	Excluded due to no operations in Ohio
4	Excluded because the company/plant was closed
16	Returned to us as “not completed” because of company policy or various other reasons.

Of the 180 respondents included in the study, 154 firms, 86%, were engaged in manufacturing. According to KPMG Peat Marwick, of the 166 foreign-owned firms with U.S. headquarters in Ohio and with at least 50% foreign ownership, 119 firms, 72%, were engaged in manufacturing.

In short, we attempted to survey all the foreign-owned firms (i.e., firms with at least 10% foreign ownership) operating in Ohio, targeting our questionnaire at that population. Since a few firms from that *target* population refused to participate in the survey and since we may have also failed to contact a few others, we ended up with a *sampled* population although that was not our intention. Of course, almost always empirical researchers have to work with the sampled population and must assume that the sampled population is similar to the target population, at least with respect to the properties under investigation. We believe that our sample is highly representative of the population of the IDFI firms operating in Ohio, in terms of both their numbers and their economic importance. It includes all the well-known and large firms that account for the bulk of assets, sales, employment, and the like. Nevertheless, our results could be subject to unknown sample bias.

Table 1 Percent of Manufacturing Employees in U.S. Affiliates of Foreign Owned Companies

	1988	1989	1990	1991	1992	1993	1994
Illinois	9.5	10.9	11.8	12.6	12.8	12.6	12.3
Indiana	8.4	10.0	13.7	13.0	13.6	13.4	13.3
Michigan	7.0	7.2	7.6	7.8	8.3	8.8	8.6
Ohio	**7.9**	**10.1**	**11.2**	**11.9**	**12.3**	**12.3**	**12.2**
Wisconsin	7.2	7.6	8.3	8.5	8.2	7.6	7.5
U.S.	8.2	9.5	10.4	11.0	11.2	11.3	11.4

Source: Fahim-Nader, Mahnaz and William J. Zeile, “Foreign Direct Investment in the United States, *Survey of Current Business*, July 1996, pp. 102-130.

How important has been the role of foreign-owned companies in Ohio's economy? One way to measure this role is to look at employment. According to our estimate, based on 175 responses of mostly manufacturing firms, in 1990 foreign-owned companies had 70,083 employees in Ohio. The corresponding U.S. Department of Commerce estimates were 72.3 thousand employees in 1990 and 70.7 thousand employees in 1991 [Fahim-Nader and Zeile, 1996, 116]. Obviously, expressing this as a percentage of total manufacturing employment is more revealing. Based on Fahim-Nader and Zeile [1996, 116], from the beginning of 1988 to the end of 1994, the percentages for the Great Lakes region states and for the United States are shown in Table 1.

IV. Empirical Results

We used two different statistical techniques, CHAID (Chi-squared Automatic Interaction Detector) analysis[6] and logistic regression analysis [Norusis, 1994, 1-30], in analyzing R&D activities, technology-related payments and receipts, and innovativeness of foreign-owned firms in Ohio. We supplemented them with several nonparametric tests [Conover, 1980; Hollander and Wolfe, 1973; Siegel, 1956]. Our empirical results are grouped under R&D activities, innovativeness, and competitiveness of foreign-owned firms in Ohio.

1. R&D Activities of Foreign-Owned Firms in Ohio

This section contains our empirical results on R&D activities in terms of R&D employment, R&D expenditures, and technology payments to and receipts from U.S. and foreign companies.

R&D employment

Fifty-nine percent of the respondents had no R&D employees. The observed frequencies of the RANDDEMP (R&D employees) responses were significantly different from equal expected rankings according to the one-sample chi-square test. According to table 2 below, RANDDEMP has, as expected, positive and significant rank correlation with RANDDEXP (R&D expenditures). It has also positive and significant rank correlation with USTECPAY (technology payments to U.S. companies), FCTECPAY (technology payments to nonparent foreign companies), PCTECREC (technology receipts from foreign parent company), and FCTECREC (technology receipts from nonparent foreign companies); and negative and significant rank correlation with PTECHORI (country of origin of present technology), ITECHORI (country of origin of initial technology), INNOVATE (major orientation of company's innovations), and MAJCONTR (major contribution of company to Ohio's economy).

The best CHAID predictor of RANDDEMP, with a mean of 15, is TOTEMPL (total employment), merged into four groups in figure 1 below. In this figure, CHAID shows the final subgroups (segments) as a tree diagram whose branches (nodes) represent the groups. The tree generates additional nodes as each of these groups is split further into smaller groups. The initial or the parent (root) node of the tree represents the total sample of valid observations and is the parent of four child nodes

Table 2 Spearman Rank Correlation Coefficients

	PTECHORI	ITECHORI	RANDDEMP	RANDDEXP	USTECPAY	PCTECPAY	FCTECPAY	USTECREC	PCTECREC	FCTECREC	INNOVATE	MAJCONTR
ITECHORI	.8182**											
RANDDEMP	–.3133**	–.3761**										
RANDDEXP	–.4057**	–.3944**	.8603**									
USTECPAY	–.1753	–.2390*	.3601**	.4313**								
PCTECPAY	.1594	.1064	.1058	.1386	.1701							
FCTECPAY	.1240	.0592	.1942*	.1585	.3017**	– .1136						
USTECREC	–.0590	–.0414	.1553	.0933	.1952*	.0895	.0191					
PCTECREC	–.2683**	–.2558**	.4090**	.3186**	.0668	.0627	–.0624	.2565**				
FCTECREC	–.1005	–.0848	.1943*	.1800	.2341*	.0957	–.0567	.4078**	.3975**			
INNOVATE	.0738	.0737	–.3005**	–.3210**	–.1881	–.0421	–.1413	.0647	–.1002	–.0518		
MAJCONTR	.4648**	.5287**	–.2542**	–.1524	–.0674	.0574	.0100	–.0140	–.2331*	.0257	–.0155	
MAJBENEF	–.0910	–.0828	.1072	***	.1359	–.0554	–.0267	–.0402	–.0252	–.0265	–.0604	–.1020

*Significant at the .05 level. (2-tailed)
**Significant at the .01 level. (2-tailed)
*** is printed if a coefficient cannot be computed.

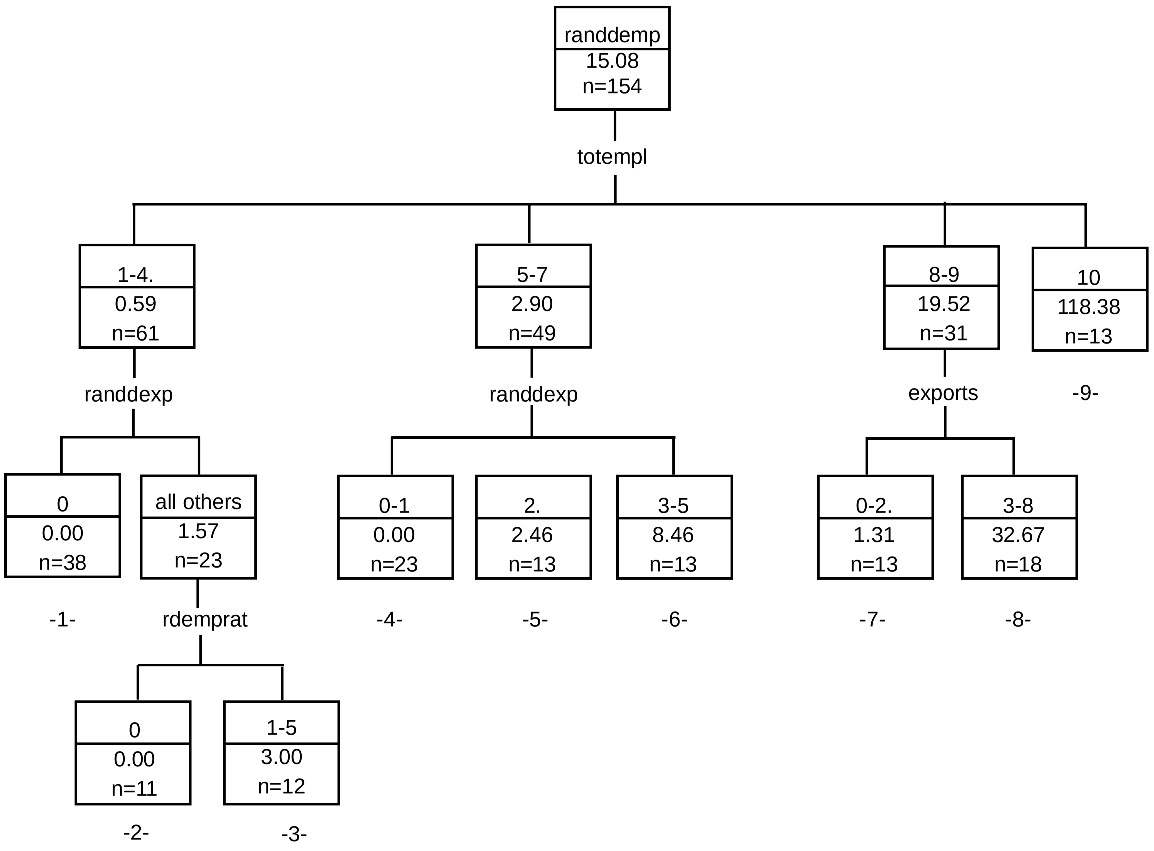
based on the statistically significant groupings of TOTEMPL (which we had categorized into ten groups). At the next level of the tree, three of these four child nodes have their own child nodes. The nine terminal nodes of the tree are identified by a dashed number. The nodes (segments) are mutually exclusive and exhaustive; each case is found in exactly one segment. The three or more rows of information in each node describe the subgroup. For example, in figure 1 the initial node, representing the entire sample of valid observations, lists in the first line RANDDEMP as the dependent variable. In the second line, we find 15.08 as the mean of RANDDEMP. The third line contains 154 as the number of valid observations (out of 180 total observations, including 16 missing observations). The first "child node" shows RANDDEMP as the best predictor of TOTEMPL, which we had divided prior to CHAID analysis into ten categories of more or less equal size based on the actual observations: 1. 1-6 employees, 2. 7-12 employees, 3. 14-25 employees, 4. 26-50 employees, 5. 51-90 employees, 6. 93-125 employees, 7. 139-230 employees, 8. 234-320 employees, 9. 322-590 employees, 10. 690-10,875 employees. CHAID groups these ten categories into four statistically significant subgroups: In the first subgroup, the first four categories are combined, with a mean RANDDEMP of 0.59 and subgroup size of 61. In the second subgroup, the fifth, sixth, and seventh categories are combined, with a mean RANDDEMP of 2.90 and subgroup size of 49. In the third subgroup, the eighth and ninth categories are combined, with a mean RANDDEMP of 19.52 and subgroup size of 31. The fourth subgroup contains just the tenth category itself, with mean RANDDEMP of 118.38 and subgroup size of 13. The fourth subgroup is also a terminal node of the tree.

RANDDEMP increases with TOTEMPL. For firms with no more than 50 employees, RANDDEXP (R&D expenditures), merged into two groups, is the best predictor of RANDDEMP; those that had no R&D expenditures had also no R&D employees. But as indicated by the next predictor RDEMPRAT (R&D employment ratio), merged into two groups, even some small firms that had some R&D expenditures had no R&D employees. For firms in group two, with 51 to 230 employees, again RANDDEXP, now merged into three groups, is the best predictor of RANDDEMP. RANDDEMP increases with RANDDEXP. For firms in group three, with 234 to 590 employees, however, EXPORTS, merged into two groups, is the best predictor. RANDDEMP increases sharply with EXPORTS.

The very large number of zero observations for the dependent variable RANDDEMP, as well as most other dependent variables below, rendered ordinary least squares (OLS) regression analysis unsuitable [Judge et al., 1988, 795-799]. Instead, we resorted to logistic regression analysis after transforming our continuous dependent variable RANDDEMP to a binary choice or dichotomous variable RANDDEMB with values 0=No R&D employees and 1=R&D employees.

We would expect larger and export-oriented foreign-owned firms with larger R&D expenditures to have a greater propensity to have R&D employees, as confirmed by our CHAID results. Accordingly, in the logistic regression specification, we hypothesized that the probability of a firm having R&D employees increases with TOTEMPL, EXPORTS, and RANDDEXP, controlled for nationality of the foreign parent company

Figure 1 CHAID Tree for R&D Employment



Note: . indicates missing observations in subgroups.

(FPNATION). RANDDEXP, positively signed as expected, is highly significant in table 3. EXPORTS, too, is highly significant but is negatively signed contrary to our expectations. TOTEMPL, too, is negatively signed, but is insignificant. Perhaps the most interesting result is the overall high significance of FPNATION, based on the Japanese (negatively signed) and Dutch (positively signed) dummies.

R&D expenditures

In accordance with our finding on R&D employment, 51% of the respondents had no R&D expenditures. The observed frequencies of the RANDDEXP responses were significantly different from equal expected rankings according to the one-sample chi-square test. According to table 2, RANDDEXP has, as expected, positive and significant rank correlation with RANDDEMP. It has also positive and significant rank correlation with USTECPAY and PCTECREC, and negative and significant rank correlation with PTECHORI, ITECHORI, and INNOVATE.

The best CHAID predictor of RANDDEXP, with a mean of $2.5 million, is RANDDEMP, merged into two groups.[7] RANDDEXP increases sharply with RANDDEMP. For firms with smaller RANDDEMP, RANDDEXP rises with predictor RDSRATIO (R&D sales ratio), merged into three groups. For firms with positive RANDDEXP but relatively low RDSRATIO, FORCOMP (foreign employee compensation) is the best predictor of RANDEXP. Firms with positive foreign compensation had lower RANDDEXP.

For the logistic regression analysis, we transformed our continuous dependent variable RANDDEXP, with many zero observations, to a dichotomous variable RANDDEXB with values 0=No R&D expenditures and 1=R&D expenditures. We would expect larger and export-oriented foreign-owned firms with larger R&D employment to have a greater propensity to have R&D expenditures, as confirmed by our CHAID results. Accordingly, in the logistic regression specification, we hypothesized that the probability of a firm having R&D expenditures increases with TOTEMPL, EXPORTS, and RANDDEMP, controlled for nationality of the foreign parent company (FPNATION). RANDDEMP, positively signed as expected, is highly significant in table 4. Both EXPORTS and TOTEMPL are negatively signed contrary to our expectations but are insignificant. Despite the overall insignificance of FPNATION, the Japanese dummy is negatively signed and is highly significant.

After the analysis of the R&D employment and expenditures, attention turns to the R&D employment/total employment ratio and R&D expenditures/sales ratio in order to investigate the R&D intensities of the foreign-owned firms in Ohio.[8] We computed the R&D employment/employment ratio, as our first measure of R&D intensity, from the primary variables RANDDEMP and TOTEMPL (total employment). The best CHAID predictor of RDEMPRAT, with an overall mean of 7%,[9] is RANDDEMP, merged into two groups. However, as noted earlier, 59% of the respondents had no R&D employees. RDEMPRAT has a mean of 0.17 for firms that reported having R&D employees. For firms with R&D employees, RDSRATIO (R&D sales ratio), merged into three groups, is the best predictor.

Table 3 Logistic Regression for R&D Employment

Dependent Variable: RANDDEMB (R&D Employment, Binary)

Variables in the Equation

Variable	Estimated coefficient	S.E.	Wald Statistic	df	Sig	R	Exp(B)
EXPORTS	–1.1E-06	3.152E-07	11.7626	1	.0006	–.2554	1.0000
RANDDEXP	3.39E-05	1.108E-05	9.3714	1	.0022	.2219	1.0000
TOTEMPL	–.0005	.0012	.1529	1	.6958	.0000	.9995
FPNATION			20.1733	6	.0026	.2336	
FPNATION(1)	–2.4161	.6485	13.8789	1	0002	–.2817	.0893
FPNATION(2)	–1.4680	.9901	2.1983	1	.1382	–.0364	.2304
FPNATION(3)	–1.5863	1.1664	1.8497	1	.1738	.0000	.2047
FPNATION(4)	–2.5823	2.4804	1.0839	1	.2978	.0000	.0756
FPNATION(5)	–2.2156	2.5216	.7720	1	.3796	.0000	.1091
FPNATION(6)	11.9308	4.0130	8.8388	1	.0029	.2137	151866.80

	Value	Freq	Parameter Coding (1)	(2)	(3)	(4)	(5)	(6)
FPNATION								
Japanese	1	49	1.000	.000	.000	.000	.000	.000
German	2	11	.000	1.000	.000	.000	.000	.000
British	3	16	.000	.000	1.000	.000	.000	.000
French	4	4	.000	.000	.000	1.000	.000	.000
Swiss	5	6	.000	.000	.000	.000	1.000	.000
Dutch	6	3	.000	.000	.000	.000	.000	1.000
Other	7	19	–1.000	–1.000	–1.000	–1.000	–1.000	–1.000

		Predicted No. R&D Employees N	R&D Employees R	Percent Correct
Observed				
No R&D employees	N	63	2	96.92%
R&D employees	R	4	39	90.70%
			Overall	94.44%

–2 Log Likelihood 47.011

Goodness of Fit 208.970

	Chi-Square	df	Significance
Model Chi-Square	102.708	9	.0000
Improvement	102.708	9	.0000

Number of selected cases:	180
Number rejected because of missing data:	72
Number of cases included in the analysis:	108

Table 4 Logistic Regression for R&D Expenditures

Dependent Variable: RANDDEXB (R&D Expenditures, Binary)

Variables in the Equation

Variable	Estimated coefficient	S.E.	Wald Statistic	df	Sig	R	Exp(B)
EXPORTS	–2.0E-08	4.168E-08	.2414	1	.6232	.0000	1.0000
TOTEMPL	–.0015	.0022	.4376	1	.5083	.0000	.9985
FPNATION			8.2495	6	.2204	.0000	
FPNATION(1)	–1.0791	.4378	6.0743	1	.0137	–.1650	.3399
FPNATION(2)	–.3285	.8550	.1476	1	.7008	.0000	.7200
FPNATION(3)	–.7520	.9217	.6656	1	.4146	.0000	.4714
FPNATION(4)	–.6694	1.2747	.2757	1	.5995	.0000	.5120
FPNATION(5)	–4.1150	4.0325	1.0413	1	.3075	.0000	.0163
FPNATION(6)	7.7838	4.6405	2.8136	1	.0935	.0737	2401.4074
RANDDEMP	1.2829	.4417	8.4378	1	.0037	.2074	3.6071

	Value	Freq	Parameter Coding (1)	(2)	(3)	(4)	(5)	(6)
FPNATION								
Japanese	1	49	1.000	.000	.000	.000	.000	.000
German	2	11	.000	1.000	.000	.000	.000	.000
British	3	16	.000	.000	1.000	.000	.000	.000
French	4	4	.000	.000	.000	1.000	.000	.000
Swiss	5	6	.000	.000	.000	.000	1.000	.000
Dutch	6	3	.000	.000	.000	.000	.000	1.000
Other	7	19	–1.000	–1.000	–1.000	–1.000	–1.000	–1.000

Observed		Predicted No. R&D Exp. N	Predicted R&D Exp. R	Percent Correct
No R&D Exp.	N	52	1	98.11%
R&D Exp.	R	13	42	76.36%
			Overall	87.04%

–2 Log Likelihood	80.654
Goodness of Fit	191.734

	Chi-Square	df	Significance
Model Chi-Square	69.066	9	.0000
Improvement	69.066	9	.0000

Number of selected cases:	180
Number rejected because of missing data:	72
Number of cases included in the analysis:	108

We computed the R&D expenditures/sales ratio as our second measure of R&D intensity, with an overall mean of 2.62%,[10] from the primary variables RANDDEXP and SALESREV (total sales). RANDDEXP, merged into two groups, is the best CHAID predictor; firms that reported positive RANDDEXP have positive RDSRATIO. For firms with positive RANDDEXP, RDSRATIO rises with RDEMPRAT, merged into three groups.

Technology payments and receipts

Besides conducting in-house R&D for its own innovativeness, a company may buy/sell technology from/to other U.S. or foreign companies. In analyzing these payments and receipts, we distinguished among U.S. companies, a foreign parent company, and other foreign companies as our respondents' technology partners.

Seventy percent of the respondents made no technology payments to U.S. companies. The observed frequencies of the USTECPAY responses were significantly different from equal expected rankings according to the one-sample chi-square test. According to table 2, USTECPAY has positive and significant rank correlation with RANDDEMP, RANDDEXP, FCTECPAY, USTECREC (technology receipts from U.S. companies), and FCTECREC (technology receipts from other foreign companies), and negative and significant rank correlation with ITECHORI. In CHAID analysis, USTECPAY rises with RANDDEXP, merged into three groups. Almost two-thirds of the firms in the lowest RANDDEXP group, had no USTECHPAY and no TECHPAY (total technology payments) at all.

Seventy-four percent of the respondents made no technology payments to their major foreign parent companies. The observed frequencies of the PCTECPAY responses were significantly different from equal expected rankings according to the one-sample chi-square test. In CHAID analysis, PCTECPAY rises with TECHPAY, merged into three groups. Among firms in the group with the highest average PCTECPAY, those with lower FORPURCH (foreign purchases) had lower PCTECPAY.

Ninety-four percent of the respondents made no technology payments to other foreign companies. The observed frequencies of the FCTECPAY responses were significantly different from equal expected rankings according to the one-sample chi-square test. According to table 2, FCTECPAY has positive and significant rank correlation with RANDDEMP and USTECPAY.

In CHAID analysis, FCTECPAY rises with TECHPAY, merged into two groups. More than half of the respondents, merged into the first group, however, had no FCTECPAY and no TECHPAY at all. Among firms in the group with positive FCTECPAY, however, all those with positive PCTECPAY had zero FCTECPAY.

According to the Friedman Two-Way ANOVA and Kendall's W tests, which determine whether k samples have been drawn from the same population by comparing the distributions of k variables, USTECPAY had the highest and FCTECPAY had the lowest mean rank among USTECPAY, PCTECPAY, and FCTECPAY. This difference was statistically significant according to the Kendall's W test but not the Friedman Two-Way ANOVA test.

For an overall view of the technology payments, we added the primary variables USTECPAY, PCTECPAY, and FCTECPAY to focus on TECHPAY. Sixty percent of the respondents made no technology payments at all. In CHAID analysis, TECRPBAL (technology receipts-payments balance), merged into five groups, is the best predictor of TECHPAY. The larger the negative balance the larger was TECHPAY. Firms with zero TECRPBAL, about half of the respondents, had the smallest TECHPAY. Even firms with positive TECRPBAL had positive TECHPAY but on average less than those with negative TECRPBAL.

These results thus far indicate that most of our respondents not only do not undertake much in-house R&D but also do not buy technology from other firms, including their foreign parent companies. So perhaps it is not surprising that most of them also do not have technology receipts.

Eighty-four percent of the respondents had no technology receipts from U.S. companies. The observed frequencies of the USTECREC responses were significantly different from equal expected rankings according to the one-sample chi-square test (i.e., R&D employees were not equally distributed among the different companies in the sample). According to table 2, USTECREC has positive and significant rank correlation with USTECPAY, PCTECREC, and FCTECREC.

In CHAID analysis, USTECREC increases with TECHREC (total technology receipts), merged into three groups. The sign test revealed that USTECREC had a statistically significant tendency toward being lower than USTECPAY. However, the Wilcoxon Matched-pairs signed-ranks test did not confirm this difference.

Ninety-four percent of the respondents had no technology receipts from their major foreign parent companies. The observed frequencies of the PCTECREC responses were significantly different from equal expected rankings according to the one-sample chi-square test. According to table 2, PCTECREC has positive and significant rank correlation with RANDDEMP, RANDDEXP, and FCTECREC, and negative and significant rank correlation with PTECHORI (country of origin of present technology), ITECHORI (country of origin of initial technology), and MAJCONTR (major contribution to Ohio’s economy).

In CHAID analysis, PCTECREC increases with TECHREC (total technology receipts), merged into two groups. Most of the respondents that had no PCTECREC, also had no TECHREC. But only one-third of the respondents that had positive TECHREC also had positive PCTECREC. Among the firms that had positive TECHREC, those with higher RDEMPRAT had larger PCTECREC.

Both the Wilcoxon Matched-pairs signed-ranks test and the sign test revealed that PCTECREC had a statistically significant tendency toward being lower than PCTECPAY. This suggests that, in accordance with the theory of DFI and with the empirical results on IDFI in the United States, technology transfers have occurred to a greater extent from foreign-based MNCs to their Ohio affiliates than the reverse.

Ninety-three percent of the respondents had no technology receipts from other foreign companies. The observed frequencies of the FCTECREC responses were significantly different from equal expected rankings according to the one-sample chi-square test. According to table 2, FCTECREC has positive and significant rank correlation with RANDDEMP, USTECPAY, USTECREC, and PCTECREC.

In CHAID analysis, FCTECREC increases with TECHREC, merged into two groups. Most of the respondents that had no FCTECREC also had no TECHREC. But only one-third of the respondents that had positive TECHREC also had positive FCTECREC. Neither the Wilcoxon Matched-pairs signed-ranks test nor the sign test revealed a statistically significant difference between FCTECPAY and FCTECREC.

According to the Friedman Two-Way ANOVA and Kendall's W tests, which determine whether k samples have been drawn from the same population by comparing the distributions of k variables, USTECREC had the highest and FCTECREC had the lowest mean rank among USTECREC, PCTECREC, and FCTECREC. This difference was statistically significant according to the Kendall's W test but not the Friedman Two-Way ANOVA test.

For an overall view of the technology receipts, we added the primary variables USTECREC, PCTECREC, and FCTECREC. Eighty-two percent of the respondents had no technology receipts at all. The best CHAID predictor for TECHREC, as it was for TECHPAY, is TECRPBAL, merged into three groups. Respondents with the relatively larger average negative TECRPBAL had greater TECHREC than those with relatively smaller average negative or zero TECRPBAL. Respondents with the largest average positive TECRPBAL, however, had the greatest average TECHREC.

We extended our investigation of the total technology payments and receipts by studying their difference in terms of the technology receipts-payments balance (TECRPBAL). Fifty-five percent of the respondents had a zero receipts-payments balance; only 11% had a positive balance. In CHAID analysis, respondents with zero TECHREC, 81% of those for which TECRPBAL could be computed, had on average a negative balance. Respondents with positive TECHREC, on the other hand, had a positive balance.

Our finding that most foreign-owned companies in Ohio had either zero or negative technology receipts-payments balance reflects the chronic negative balance at the national level as shown in table 5. According to the U.S. Department of Commerce, every year during the period from 1987 through 1993, the payments of royalty and license fees by U.S. affiliates of foreign companies were substantially larger than their receipts.

Table 5 Technology Receipts-Payments Balance of U.S. Affiliates ($ million)

	1987	1988	1989	1990	1991	1992	1993
Receipts	209	243	331	364	548	666	775
Payments	1,105	1,244	1,580	1,863	2,691	2,918	3,088
Balance	**–896**	**–1,001**	**–1,249**	**–1,499**	**–2,143**	**–2,253**	**–2,313**

Source: Fouch, Gregory G., "Foreign Direct Investment in the United States: Detail for Historical-Cost Position and Related Capital and Income Flows, 1993," *Survey of Current Business*, August 1994, pp. 98-126.

2. Innovativeness of Foreign-Owned Firms in Ohio

As is often done, we distinguished between product-oriented and process-oriented innovativeness in examining the innovativeness of foreign-owned firms in Ohio. The observed frequencies of the binary INNOVATE responses, 1=new products and 2=new processes, were significantly different from equal expected rankings according to both the one-sample chi-square test and the binomial test. According to table 2, INNOVATE has negative and significant rank correlation with RANDDEMP and RANDDEXP, indicating that product-oriented innovativeness required more R&D than process-oriented innovativeness.

In CHAID analysis, 63% of the 156 respondents indicated “new products” as opposed to “new processes” as their major innovatory orientation. The best predictor of INNOVATE is SERVICE (prompt and reliable service) as a source of competitiveness, merged into two groups. Respondents who regarded SERVICE as “very important” had a significantly lower “new product” orientation than others. Among firms with the higher “new product” orientation, those with the higher RDEMPRAT all had “new product” orientation. Among respondents who regarded SERVICE as “very important,” the best predictor of INNOVATE is SALESREV, merged into five groups. Although there is no monotonic relationship between the two, firms in the largest sales revenue group had the strongest “new product” orientation.

Closely related to the R&D activities and innovativeness of the foreign-owned firms would be their major contribution to Ohio’s economy (MAJCONTR), which we defined in three distinct ways. The observed frequencies of the MAJCONTR responses were significantly different from equal expected rankings according to the one-sample chi-square test. “The creation of a new enterprise in an existing industry” was the major contribution of 55% of the respondents. Another 12% reported that “starting a new industry” was their major contribution. The remaining responses were “foreign acquisition of an existing U.S.-owned enterprise to form present company” (i.e., brownfield investment). This implies that two-thirds of the responding companies in our survey were started as greenfield investments. This is corroborated by the fact that two-thirds of the respondents reported directly that their initial foreign-ownership percentage was greater than zero. According to table 2, MAJCONTR has positive and significant rank correlation with PTECHORI and ITECHORI, indicating that greenfield investments were primarily foreign-technology based, and has negative and significant rank correlation with RANDDEMP and PCTECREC, indicating that brownfield investments were relatively more R&D-oriented than greenfield investments.

In CHAID analysis, IFOWNPER (initial foreign ownership percentage), merged into two groups, is the best predictor of MAJCONTR. Among firms that were initially U.S. owned, 79% singled out “foreign acquisition of an existing U.S.-owned enterprise to form present company” as their major contribution. PTECHORI, merged into two groups, is the best predictor of MAJCONTR for the initially U.S.-owned firms. Those that had a foreign country as the origin of their present technology put a much higher emphasis on “creation of an altogether new enterprise to form present company” than those that had the United States as the origin.

Another issue relating to the R&D activities and innovativeness of foreign-owned companies is the major beneficiaries of their innovativeness (MAJBENEF). The observed frequencies of the MAJBENEF responses were significantly different from equal expected rankings according to the one-sample chi-square test. "Company's customers" were the major beneficiaries of all but one of the 167 respondents's innovativeness. Hence, CHAID analysis was pointless for this variable.

3. Competitiveness of Foreign-Owned Firms in Ohio

Regardless of their own R&D intensities and innovativeness, foreign-owned firms, relying on their existing store of knowledge or infusion of new technologies from their foreign parents, could witness changes in the location of their competitors, in their sources of competitiveness, and in the levels of their competitiveness over time.

When we asked our respondents to specify the location of their major competitors, "the United States" (excluding Ohio) was by far the most frequently specified location of major competitors, followed by "Ohio" and then "other foreign countries." "Foreign parent company's country" was the least important region of competitors. In CHAID analysis, EJTGRANT (expected job training grants as an incentive to locate in Ohio), merged into two groups, is the best predictor of MAJCOMP.

We asked our respondents to rank separately the following sources of their competitiveness:

i. Lower prices of products (LOWPRICE)
ii. Higher quality of products (HIQUALIT)
iii. Prompt and reliable service (SERVICE)
iv. Product innovation (PRODUCT)
v. Process innovation (PROCESS)
vi. Other source of competitiveness (OTHSOURS)

According to the Friedman Two-Way ANOVA and Kendall's W tests, which determine whether k samples have been drawn from the same population by comparing the distributions of k variables, the responses to the six sources of competitiveness were significantly different from each other.

The three most important questionnaire-specified sources of competitiveness for the respondents were HIQUALIT, SERVICE, and PRODUCT, based on a large sample of 163 responses that ignored OTHSOURS, to which only 17 companies had responded out of 180 total companies in our sample. However, based on a much smaller sample of 15 companies that had responded to all sources of competitiveness, including OTHSOURS, OTHSOURS ranked the highest among all six factors, followed by HIQUALIT, SERVICE, and PRODUCT. "Name and reputation of the company," "marketing creativity," and "delivery" were the most important respondent-specified "other sources" of competitiveness.

When we asked our respondents to tell us what happened to their competitiveness (COMPETIT) since the time of ownership by their present major foreign parents, almost two-thirds of the respondents indicated that their competitiveness had increased since the time of ownership by their present major foreign parents. Only about 6% reported that their competitiveness had decreased.

This result is consistent with the finding of Li and Guisinger (1991) that foreign-controlled firms in the United States had, both in the aggregate and by major industry group, lower business failure rates than domestically owned firms. These are both empirical findings that we would expect on the basis of the ownership-advantage argument for DFI.

The best overall CHAID predictor of COMPETIT is FOUNYEAR (foundation year of the Ohio company), merged into four groups. Although the relationship between the two is not monotonic, it appears that the older firms were able to improve their competitiveness relatively more than the younger firms.

V. Summary of Empirical Results

Our empirical results can be summarized as follows:

1. Majorities of the respondents had neither R&D employees nor R&D expenditures, reflecting their R&D dependence on their foreign parent companies. Moreover, majorities of the respondents had neither payments nor receipts for technology. As expected, R&D employment and R&D expenditures, as well as the R&D employment and sales ratios, were highly and positively correlated.

2. The best CHAID predictor of R&D employment was total employment. Among the larger companies, the more export-oriented ones had a greater number of R&D employees. The best CHAID predictor of R&D expenditures was R&D employment. Among the companies with smaller R&D employment, those with larger R&D sales ratios had larger R&D expenditures. In logistic regressions, the likelihood of R&D employment increased, as expected, with R&D expenditures but decreased, contrary to our expectations, with exports. Perhaps the most interesting result was that Japanese-owned companies were significantly less likely and Dutch-owned companies significantly more likely to have R&D employment. The likelihood of R&D expenditures increased, as expected, with R&D employment, but not with exports and total employment. Moreover, Japanese-owned companies were significantly less likely to have R&D expenditures.

3. Our 7% estimate of the R&D employment ratio was greater than the U.S. Department of Commerce 1992 benchmark estimate of 4.8% for all foreign-owned nonbank firms in the United States. The best CHAID predictor of R&D employment ratio was R&D employment. Among the companies with larger R&D employment, those with higher R&D sales ratios had higher R&D employment ratios. Our 2.62% estimate of the R&D sales ratio was the same as the U.S. Department of Commerce 1992 benchmark estimate of 2.6% for all foreign-owned nonbank firms in the United States. The best CHAID predictor of R&D sales ratio was R&D expenditures. Among the companies with larger R&D expenditures, those with higher R&D employment ratios had higher R&D sales ratios.

4. Among the three different components of total technology payments—payments to U.S. companies payments to the foreign parent company, and payments to nonparent foreign companies—the first component had the highest and the third component had the lowest mean rank, suggesting that the United States was the most

important source of technology for those companies making technology payments. Likewise, among the three different components of total technology receipts—receipts from U.S. companies, receipts from the foreign parent company, and receipts from nonparent foreign companies—the first component had the highest and the third component had the lowest mean rank, suggesting that the United States was also the most important source of technology receipts. Technology receipts from the foreign parent company were significantly lower than technology payments to the foreign parent company, suggesting that, in accordance with the theory of DFI, technology transfers have occurred to a greater extent from foreign-based MNCs to their Ohio affiliates than the reverse.

5. The best CHAID predictor of total technology payments as well as of total technology receipts was, not surprisingly, technology receipts-payments balance. Fifty-five percent of the respondents had a zero receipts-payments balance; only 11% had a positive balance. Our finding that most foreign-owned companies in Ohio had either zero or negative technology receipts-payments balance is consistent with a chronically negative balance at the national level.

6. The majority of respondents indicated “new products” as opposed to “new processes” as their major innovatory orientation. “The creation of a new enterprise” was the major contribution of 55% of the respondents. Another 12% reported that “starting a new industry” was their major contribution. This implies that two-thirds of the responding companies in our survey were started as greenfield investments. “Company’s customers” were the major beneficiaries of all but one of the 167 respondents’s innovativeness.

7. “The United States” (excluding Ohio) was by far the most frequently specified location of the major competitors, followed by “Ohio” and “other foreign countries.” “Foreign parent company’s country” was the least important region of competitors. The three most important sources of competitiveness for the respondents were higher quality of products, prompt and reliable service, and product innovation. Almost two-thirds of the respondents indicated that their competitiveness had increased since the time of ownership by their present major foreign parents. Only about 6% reported that their competitiveness had decreased.

On the whole, our empirical results suggest that most foreign-owned firms in Ohio appear to have contributed to the technological capabilities and innovativeness of the state’s economy, more through technology transfers from their foreign parents and less through their own R&D activities.

Footnotes

[1] The term "R&D" covers a continuum of organized activities that are aimed at the discovery, assimilation, transfer, or application of knowledge, and that consist of three categories: basic research, applied research, and development (Reid and Schriesheim [1996, 29].

[2] Analytically, DFI differs from portfolio foreign investment in terms of presence of foreign managerial control. Statistically, however, it is defined by the U.S. Department of Commerce in terms of 10% or more foreign ownership.

[3] This is the second in a series of papers containing our empirical findings derived from a comprehensive investigation of foreign-owned firms in Ohio. The issues investigated include locational factors, state and local incentives, production and sales, employment, technology, innovation, and competitiveness. In our first paper, Erdilek and Wolf (1997), we studied the country origins of the present and initial technologies of these firms. We found that, consistent with DFI theory, for most firms, both the present and initial technologies have been sourced from their parent-firm countries.

[4] For an example of the "Big Problem" that confronted and defeated one of Honda's suppliers, see Milbank [1990].

[5] The results reported here differ from those in Wolf [1993] which were not obtained through the use of CHAID (Chi-squared Automatic Interaction Detector) [Magidson, 1993] and logistic regression analyses [Norusis, 1994, 1-30].

[6] CHAID is a module of SPSS/Windows for segmentation modeling to divide a population into segments that differ in terms of a certain criterion. The CHAID algorithm has three stages: Merging, splitting, and stopping. It first divides a population into at least two mutually exclusive groups using the categories of the statistically most significant predictor variable. This variable is the one with the lowest p value, i.e., the probability that we would observe the sample relationship between the predictor variable and the dependent variable if they were statistically independent. The predictor variable that has the lowest p value is the one least likely to be unrelated to the dependent variable [Magidson, 1993].

[7] The rest of the CHAID figures, available on request, are not presented here due to space limits.

[8] Our remaining empirical results are not based on logistic regression analysis because either they involve other R&D related activities, derived from or closely related to R&D employment and R&D expenditures for which logistic regressions were reported, or they involve ordinal variables for which logistic regression analysis would not be meaningful.

[9] Acording to the U.S. Department of Commerce 1992 benchmark survey of IDFI, the R&D employment of non-bank U.S. affiliates was 4.8% of their total employment [Zeile, 1994, 165], much smaller than our estimate. In 1989, the ratio of R&D engineers and scientists (E&S) to the total labor force in the United States was 76 per 10,000 employees [National Science Board, 1993, 67]. The ratio of all S&E in the U.S. labor force, however, was 298 per 10,000 workers, compared to 380 per employees in Japan [National Science Board, 1993, 84].

[10] According to the U.S. Department of Commerce 1992 benchmark survey of inward DFI, the R&D sales ratio of non-bank U.S. affiliates was 2.6%[Zeile, 1994, 165], the same as our estimate. In 1991, the nondefense R&D/GDP ratio in the United States was 1.9% compared with 3.0% in Japan [National Science Board, 1993, 99].

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