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Foreign direct investment and host country productivity: the American automotive component industry in the 1980s

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Abstract

Although several studies have shown that inward foreign direct investment (FDI) often leads to greater host country productivity, researchers have yet to determine the relative importance of direct technology transfer and competitive pressure. To assess the relative importance of the two channels, we examine the US auto-component industry between 1979 and 1991. During this period, Japanese automobile assemblers began to produce vehicles in North America, and began to purchase inputs from US auto-component manufacturers. Those US manufacturers that sold components to Japanese transplants would be the direct recipients of any technologies transferred from the Japanese. Although we find that the direct investment by Japanese assemblers was associated with overall productivity improvement in the US auto-component industry, we find little evidence of direct technology transfer. The productivity growth of US suppliers affiliated with Japanese assemblers was no greater than that of other, non-affiliated US suppliers. Further, we find that the Japanese assemblers tended to purchase components from less productive US suppliers and, moreover, that low-productivity suppliers that sold goods to Japanese assemblers had a higher survival rate than low-productivity suppliers that did not sell to Japanese firms. The results suggest that increased competitive pressure in the auto-sector was the main cause of overall productivity improvement, at least during the initial stages of FDI of the 1980s.
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Introduction

A classic line of inquiry in international strategy research is the origins and outcomes from foreign direct investment (FDI). In *The Future of the Multinational Enterprise*, Buckley and Casson (1976) explored why multinationals exist. By addressing why firms conduct FDI, they raised critical issues for policymakers. Notably, what stance should host country governments take towards FDI, as FDI causes social and environmental externalities? Buckley and Casson suggested that entering foreign firms might train labor, cause greater worker migration, and exhaust critical inputs. They asked whether the net welfare outcome for the host country is positive. Even after several decades of research this remains a challenging question.

In exploring this question, we focus on a particular dimension of outcome: host industry productivity. Productivity is a particularly useful barometer, because FDI's numerous effects will be directly or indirectly reflected: training of labor will increase productivity, for instance, while transfer of unique knowledge will also increase productivity. Several studies have examined the productivity issue. Prominently, Caves (1974) suggested that FDI improves host country productivity in two ways: (1) by stimulating better resource allocation among firms and industries, and (2) by transferring technology from foreign firms to local firms in the host country.

Following Caves, other studies have consistently found that inward foreign investment increases host industry productivity. Globerman (1979) used industry aggregate data, whereas Blomström and Persson (1983) and Blomström (1986) used establishment-level data to study the relationship between productivity and FDI in Canada, Mexico, and the USA. Using cross-sectional regressions, these studies found that foreign-owned subsidiaries' production share in an industry relates positively to value-added per employee and weakly negatively to average profitability.

Using firm-level data for Morocco from the late 1980s, Haddad and Harrison (1993) found that greater foreign presence reduces dispersion in productivity among local firms, because the firms converge towards best practices, even though the study also found that foreign presence is unrelated to productivity growth in domestic firms. Using Mexican establishment-level data in the 1970s, Kokko (1994) found that local establishments' productivity level significantly lags in industries that use complex technologies and have a high foreign share of production, with large technology gaps in conjunction with high foreign ownership that inhibits knowledge spillovers. For a panel of Venezuelan plants, Aitken and Harrison (1999) found that foreign equity participation is positively correlated with plant productivity for small enterprises. They also found that foreign investment negatively affects the productivity of domestically owned plants. Taking into account these two offsetting effects, the net impact of foreign investment is quite small. Hence studies using firm and plant-level data reveal a more complicated picture, which suggests a multitude of FDI effects on productivity. In addition, the existing research does not clearly delineate the relative importance of Caves' two explanations.

The relative importance of the competing explanations has significant policy and strategy implications. From a policy perspective, if increased host productivity is primarily the result of direct technology transfer, then attracting FDI is crucial for productivity growth. If, instead, increased host productivity is the result of greater competition, then attracting FDI is secondary to the question of why competition was not originally intense enough to ensure high productivity. From a strategy perspective, the key issue is whether establishing direct commercial linkages with specific productive foreign firms tends to help a firm become more productive itself or, instead, whether the firm must respond to more diffuse competitive pressures in order to gain improved productivity. Therefore we investigate the relative importance of the channels through which FDI might influence host industry productivity using an industry study in which we can observe linkages between firms.

Our experimental setting is the US auto-component industry from 1979 to 1991. We focus our attention on Japanese FDI's influence on US suppliers' productivity during this period. The North American auto-sector in the 1980s had several features that made it an attractive setting. Unlike the end-product automobile sector, where there were only the Big Three US assemblers (General Motors, Ford, and Chrysler), the large number of firms that operated in the auto-component supply sector provides the opportunity to examine how differences in supply relationships and other firm-level variables affected firm productivity. There was substantial inward FDI, which originated predominantly from a single country, Japan. This Japanese investment probably increased competition, which then led to productivity changes. In addition, the Japanese entrants possessed superior production techniques and management practices, which created the potential for technology transfer. Japanese transplant assemblers and some US component manufacturers had direct contact via supply contracts. These relationships might have facilitated the direct transfer of production processes, operating systems, and management skills.

We compare the productivity and the survival of US component firms that did and did not supply Japanese transplants. The comparison allows us to differentiate among the channels through which Japanese FDI in the automobile sector might affect productivity in the auto-component industry. Because of the vertical assembler–supplier nature of our investigation, we add a third channel to the two that Caves discussed. The three channels are:

(1) direct technology transfer from foreign firms to host country firms, which would increase firm-level productivity;
(2) competitive pressure, which would improve industry-level resource allocation and utilization; and
(3) adverse selection, which would retard improvement of industry-level resource allocation.

Adverse selection might arise if transplants were less knowledgeable than US assemblers of US suppliers' capabilities, and if relatively fewer productive suppliers were more inclined to seek supply contracts from the Japanese transplants.

Of note is the fact that we examine FDI's influence across vertically related industries: FDI at the assembler level changing productivity at the supplier level. This contrasts with existing research that examines FDI and productivity change within the same industry. To evaluate whether FDI's net welfare outcome for the host nation is positive, examining vertically related industries is a natural extension. Additionally, the presence of buyer–supplier relationships provides a unique instrument to capture direct technology transfer. As far as we know this is one of the few studies to extend the investigation of FDI's effects across related industries.

Several results stand out. First, the productivity of US component firms in our sample rose with the share of vehicles that Japanese transplants assembled in the USA. Second, the Japanese transplants tended to source from US component suppliers that had lower initial productivity levels. Third, the less productive suppliers that sold components to Japanese transplant assemblers had a higher survival rate than other, less productive suppliers. Fourth, US component firms that supplied transplants did not experience faster productivity growth, although they were the most likely to receive any technology that was transferred. Together, our results suggest that increased competitive pressure was more responsible than technology transfer for the observed industry productivity growth, whereas adverse selection at least temporarily inhibited industry productivity growth.

The paper proceeds as follows. We present a brief history of Japanese FDI in the North American automobile sector during the 1980s. We then discuss the three ways in which FDI may influence host industry productivity, and outline their empirical implications for the auto-component industry. The subsequent sections describe the data, the empirical analyses, the results and their robustness. We conclude by identifying the major implications of the results.

Japanese automotive transplants in North America during the 1980s

During the 1970s and 1980s, Japanese auto-companies became increasingly important international manufacturers. By the 1980s, better production techniques, more effective management skills, and more efficient use of process automation made many Japanese assemblers superior to their American and European counterparts in productivity and quality (e.g., Lieberman *et al.*, 1990; Womack *et al.*, 1990). These superior capabilities helped the Japanese manufacturers to achieve sizable import penetration in the North American market. North American car and light truck imports from Japan grew from 500,000 vehicles in 1970 to 2.6 million vehicles in 1981 and 3.7 million vehicles by 1986.

The growth of Japanese car imports led the USA to create import barriers. In addition to existing tariffs on imported light trucks (25%) and passenger cars (2.5%), the 1981 Voluntary Restraint Agreement (VRA) and the 1986 Voluntary Export Restraints (VER) limited both the total volume of imports and each manufacturer's share of that volume. Because Toyota held the greatest import share from Japan when the restraints were established, the agreement guaranteed that Toyota would continue to hold the largest import share. The only way in which other Japanese manufacturers could gain North American market share was to produce cars locally. Thus these barriers contributed to several Japanese motor vehicle assemblers establishing production facilities in North America.

During the 1980s, eight Japanese assemblers that set up North American production facilities account for almost all inward assembler FDI.[1] Honda and Nissan were the first arrivals, in 1982 and 1983, respectively. Toyota, Mazda and Mitsubishi arrived in the mid-1980s. Subaru, Isuzu and Suzuki started North American production in the latter part of the decade. Through these transplant facilities the Japanese accounted for a growing share of production volume in North America. Big Three car and light truck production in the USA and Canada grew from 8.9 million vehicles in 1981 to 12.9 million in 1985 and then decreased to 8.7 million in 1991. At the same time, Japanese transplant production volume in North America grew steadily from zero units in 1981 to 1.9 million units in 1991. The transplants held about 17% of North American car and light truck production by 1991, almost all of which they sold in the North American market. Together, transplant production volume and Japanese imports reached close to 30% market share by the early 1990s, which substantially increased competitive pressure in the US auto-sector.

From the start, Japanese transplants purchased some of their components from US suppliers. Although more than 150 Japanese suppliers set up North American facilities during the 1980s to supply Japanese transplant assemblers, the assemblers also purchased many components from local North American suppliers (Martin *et al.*, 1995). Although some local sourcing decisions might have stemmed from desires to create political goodwill, many local sourcing activities also served operational needs, given the transportation distance and potential shipping delays from Japan.

The local sourcing activities created the potential for technology transfer from the Japanese assemblers to the local suppliers. For automotive manufacturing, substantial communication occurs between an assembler and its suppliers for production planning, engineering, costing, delivery, supervising, monitoring, and other ongoing activities. Many analysts have argued that Japanese auto-assemblers provide superior technical and operating support to their Japanese suppliers, which in turn improves their suppliers' productivity (e.g., Clark *et al.*, 1987; Clark and Fujimoto, 1991). Similarly, local US suppliers that sell components to the Japanese might also obtain physical and organizational technology, which then should increase the US suppliers' productivity.

Recent research that focuses on a small number of suppliers has examined the possibility of technology transfer from Japanese assemblers to US suppliers. Helper and McDuffie (1997) detailed Honda's attempts to have three of its US suppliers adopt its production system, and found that successful adoption was a function of the suppliers' learning ability and openness to ideas from outside of the firm. This suggests that the transfer of Japanese production processes, operating systems and management skills may assist some US suppliers. By contrast, however, Lieberman *et al.* (1999), using 1993 survey data, found that Japanese ownership in US parts suppliers was associated with above-average, rather than below-average, inventory. Their result suggests that the transfer of the Japanese 'just-in-time' inventory method might not be successful even within Japanese-owned suppliers in the USA.

Overall, the North American auto-sector in the 1980s presents an attractive setting for investigating inward FDI's influence on the productivity of a host country supply industry. The substantial inward FDI conducted by Japanese firms increased the competitive pressure on US assemblers and component suppliers. In turn, competitive pressure would be likely to improve productivity. Also, the presence of these Japanese firms, which possessed superior production techniques and management practices, created the potential for technology transfer. The direct contact between Japanese firms and some US component manufacturers might facilitate the transfer of technology. These features allow us to address the research questions described in the following section.

Research questions

We classify the influence of the Japanese transplants on US component supplier productivity into three general effects: direct technology transfer, increased competitive pressure, and adverse selection. To differentiate among the three effects we compare the productivity and survival of US component suppliers with and without a supply relationship with Japanese assembly transplants. We refer to suppliers that had direct sales relationships with Japanese transplant assemblers as *tie-in firms* and those that did not have such relationships as *non-tie-in firms*.

Caves (1974) suggested the first two productivity effects, direct technology transfer and competitive pressure. He argued that FDI might improve host country productivity through technology transfer. Technology transfer can occur when there is economic contact between foreign and local firms. If technology transfer is an important effect of FDI, tie-in firms would exhibit greater productivity gains than non-tie-in firms, because tie-in firms were direct and immediate recipients of technology from foreign firms. The Japanese transplants often encouraged or required their local suppliers to adopt operating practices similar to those used in Japan. Local suppliers sent production workers to Japan for training, and transplants sent teams of engineers to monitor and improve local suppliers' processes. Thus direct supply arrangements between Japanese transplants and American suppliers provided the potential for direct technology transfer, especially the transfer of managerial skills and operating practices.[2]

Caves (1974) argued that FDI also improves allocative and technical efficiency through competitive pressure. Foreign entrants break down entry barriers, compete for factor inputs and customers, and reduce the market power of entrenched firms. These changes make marginal firms exit or become more productive. With the vertical nature of the assembler–supplier relationship, such competitive pressure might be felt differentially. Overall, an introduction of foreign assemblers increases demand at the supplier level in the short term. Yet this greater demand originating from the Japanese transplants would not be universally available for all suppliers.

With increased competition from Japanese producers during the 1970s, US assemblers began to press their component suppliers for productivity gains during the late 1970s. The pressure intensified as Japanese transplant assemblers' market share rose during the 1980s. The Big Three auto-assemblers actively consolidated their supplier base during the 1980s and terminated purchases from marginal suppliers. Suppliers that did not improve sufficiently lost business, and often left the industry.

Although competitive pressure strongly influenced US auto-suppliers, certain suppliers benefited from the increased demand. In addition to Caves' direct technology transfer and increased competition effects, we suggest that there may also be an initial adverse selection effect that hinders improvement of allocative efficiency in sectors upstream of the industry in which FDI occurs. By increasing local end-product production, FDI often raises the local demand for upstream intermediate goods, such as auto-components. We suggest that, initially, marginal local suppliers may tend to meet the increased local upstream demand. The increased demand prolongs these marginal firms' survival, which hinders improved industry-level allocative efficiency.

Adverse selection may arise for two reasons: an information disadvantage, and a self-selection bias. Compared with incumbent firms, new foreign entrants often face an initial information disadvantage in selecting local suppliers (e.g., Zaheer and Mosakowski, 1997). In our case, with hundreds of component suppliers and no North American production experience, Japanese assembler transplants were less able than Ford, General Motors or Chrysler to screen out less capable suppliers in the North American market. Of course, as their North American production experience grew, the transplants' information disadvantage would disappear.

Together with the foreign entrants' information disadvantage is a self-selection bias among suppliers who sought new supply contracts from the foreign entrants. Forming a new supply relationship in auto-assembly requires the supplier to make a substantial investment in physical assets and in managerial and engineering efforts. Although production by Japanese assembly transplants accounted for much of the increase in North American motor vehicle output during the 1980s, each transplant's output share was much smaller than that of the Big Three firms. Many local suppliers might be reluctant to supply the transplants' new, relatively small-scale and uncertain needs, especially if they had little excess capacity or if supplying the transplants might damage their existing relationships with major customers. American automobile manufacturers substantially consolidated their component supplier base during the 1980s, ending relationships with many suppliers and deepening the purchases from suppliers they retained. Certainly, the US assemblers tended to retain the more productive suppliers. These retained suppliers, which gained increased sales to the Big Three firms, had reduced excess capacity and incentives to cater to the transplants. In turn, the weaker suppliers that were losing US assemblers' business were more likely to have the capacity and incentives to form supply relationships with the transplant assemblers. The joint impact of self-selection bias of the local suppliers and local knowledge limitations of the transplant assemblers might have led to an initial period of adverse selection in which the transplant assemblers purchased from less productive local suppliers.

The three possible effects of FDI in the US auto-sector during the 1980s suggest several research questions for local supplier productivity. The empirical outcomes depend on the relative strength of adverse selection, competitive pressure, and technology transfer.

Research question 1: Did transplant assemblers tend to form relationships with less productive suppliers?

A positive answer to question 1 would suggest that adverse selection occurred, in which transplants chose marginal suppliers because of the transplants' information disadvantage and the suppliers' self-selection bias.

Research question 2: Did low-productivity tie-in firms have a lower industry exit rate than low-productivity non-tie-in firms?

Although significant consolidation occurred among the supplier base of the Big Three, which led to the elimination of weak firms, a positive answer to question 2 would suggest that some low-productivity firms extended their survival by securing new business from transplants. We would expect the transplants to eventually replace marginal firms that failed to improve, though not necessarily within the period of our data.

Research question 3: Did tie-in firms exhibit greater productivity growth than non-tie-in firms?

A positive answer to question 3 would suggest that substantial direct technology transfer occurred, in which tie-in firms, as the direct vertical recipient of technology transfer from Japanese assemblers, increased their productivity by using the new knowledge. On the other hand, a negative answer would suggest that productivity growth in the US component sector in our sample period was not due to technology transfer.

Data

To answer these questions, we use three related analyses for local suppliers:

(1) the likelihood of tie-in formation;
(2) the hazard rate of exit; and
(3) productivity growth.

We need variables for the formation of tie-in relationships, firm exits, and productivity. A description of how we construct these variables, our data sources, and our sample follows.

We use a sample of firms from the Compustat data tapes between 1979 and 1991. As the first Japanese automotive transplant entered in 1982, we use 1979–1981 to establish pre-transplant benchmark measures. We include all corporations that listed their primary line of business in one of two SIC categories, SIC 3714 (automotive parts, new) or SIC 3465 (automotive stampings), any time between 1979 and 1991 inclusive. We also include firms whose primary business is not in auto-components but which have more than 10% of their sales in SIC 3714 or SIC 3465 (based on Compustat industry segment tapes). Because we are concerned with non-comparability of production function estimates, we exclude several other automotive-related SIC categories: SIC 2531 (institutional furniture), SIC 3499 (seating frames, metal), SIC 3647 (vehicular lighting equipment), SIC 3592 (carburetors, pistons, rings, and valves), and SIC 3694 (engine electrical equipment). Adding the excluded categories to our sample would yield only five additional firms.

Thus our sample includes most publicly traded firms in the auto-component industry, while excluding private and public companies with only marginal automotive component involvement. For the period 1979–1991, the sample contains 207 parent corporations with 1314 firm-year observations. The firms in our sample have an average of 49% of their corporate sales in the two auto-component SIC categories.

The Compustat data tapes provide needed corporate-level financial information, such as sales, assets, employees, R&D expenses, plant–property–equipment investment, depreciation expenses, and accumulated depreciation. We also examine business-level data in the tapes, but find that many firms do not consistently report business segment data. With our several years of data, we convert nominal corporate financial values across time into real values by deflating them using the yearly consumer price index (CPI). In turn, we deflate sales by SIC-specific Producer Price Indices (PPI).

For our first research question – Did transplant assemblers tend to form relationships with less productive suppliers? – we need to know who supplied whom and in which years. We identify supply relationships between our sample firms and Japanese transplants in two stages. We first develop a comprehensive list of component manufacturers that sold goods to transplants, using the transplants' press releases, official supplier lists obtained directly from the transplants, and several editions of the *ELM Guide to Automotive Sourcing*. Using these sources, we identify the specific year when tie-in relationships began for all transplants, except for NUMMI. Lacking exact information for NUMMI, but knowing that relationships began in either 1985 or 1986, we code all NUMMI tie-in relationships that were present in 1986 as beginning in 1986; any inaccuracy would affect only three tie-in relationships in our sample. We also use the above sources to determine how long the relationships persisted.

We record supply relationships at the corporate level of analysis. We identify suppliers' parent firms in three-steps. We first determine ownership in 1991 using the *Lotus OneSource – CD/Private* database, which provides the 1991 ultimate parent for private and public firms. This links almost every supplier to its ultimate parent. Second, we use *Who Owns Whom: Directory of Corporate Affiliations* to determine ownership at the start of a tie-in relationship. If the parent was the same at the start of a tie-in and in 1991, we assume that the parent was the same for the entire period. For cases where the parent was not the same at the start of a tie-in and in 1991, we search *Who Owns Whom* in all intervening years to find the year that ownership changed. In the third step, we search the Lexis/Nexis *Merger and Acquisition*, *Transportation/Automotive*, and *Newspapers* on-line libraries for information about ownership changes for those firms that did not appear in *Who Owns Whom*.

With the above procedure, we know which of our sample firms formed supply relationships with which Japanese transplant assemblers and for how long. We define a tie-in firm dummy variable (*TIEIN*) to denote the years in which a US supplier sold one or more components to Japanese transplant assemblers or to North American joint ventures between a Japanese transplant and an American assembler. We place no other definitional limits, such as threshold percent of sales or dollar value of components, on this variable because such proprietary information is unavailable. The *TIEIN* variable is either 1 or 0 in each firm-year. In addition, as a firm may have relationships with multiple Japanese transplants, we track the running total of tie-in relationships for each supplier (*TIE_CNT*), which is the count of relationships that existed in a firm-year.

Of the 207 parent firms in our sample, we identify 58 with at least one tie-in relationship, resulting in tie-in cases for 265 of the 1314 firm-year observations (20.2%). We find that all the tie-in relationships in our study persisted until the end of the study period or until the supplier exited the industry. This stability probably occurs because auto-component supply relationships tend to last for the several years of an automobile's production run.

For our second research question – Did low-productivity tie-in firms have a lower industry exit rate than low-productivity non-tie-in firms? – we need information on firm exits. We define exit as either ceasing as a going concern at the corporate-level or eliminating automotive component segments at the business level (a firm stops reporting that it has 10% or more of its overall corporate sales in the auto-component SIC categories 3714 and 3465). The dependent variable for the second research question is then how long a firm survived (*YRS_SURV*), which is the count of years a firm operated in the auto-supply sector after 1982, the first year a Japanese transplant entered. For instance, if a firm operated in the supply sector up to 1987, but not in 1988, then the firm's *YRS_SURV* equals 5 years.

All our research questions need productivity measures. The first and second questions link a firm's productivity level to its probability of becoming a tie-in firm and to firm survival. The third research question compares tie-in and non-tie-in firms' productivity growth. A logical choice for comparing productivity is each firm's residual from an industry-average production function.

We use the Compustat data to construct a multi-factor average production function. Recognizing that we have firms in SIC 3714 and SIC 3465, we initially estimate separate production functions for each SIC and then compare the production functions' regression coefficients. This comparison rejects the hypotheses that the two SICs' production functions differ significantly, and therefore we pool our firms' data to estimate a representative production function.

Following prior productivity research (Griliches, 1986; Hall, 1993), we estimate log-linear Cobb–Douglas production functions using output (sales) and real inputs for labor, physical capital, and R&D capital. As in Hall (1993), which also uses Compustat data, we use: the number of employees for labor; net plant, property, and equipment (*PPE*-net) deflated by the CPI for physical capital; and a perpetual inventory constructed from constant-dollar R&D expenses for R&D capital. To construct the R&D capital stock, we follow Hall (1993). We create a starting stock using a historic year's constant-dollar R&D expense scaled by a pre-sample growth rate of 5%. To obtain a firm's subsequent yearly running total R&D stock, we depreciate the starting stock at a 15% annual rate while adding annual R&D expense in constant dollar. We discuss alternate specifications in the robustness section of the paper.

Appendix 1 reports coefficient estimates for production functions calculated on a yearly basis. We obtain high adjusted R^2, always at least 97%, which is similar to what other researchers have obtained (Hall, 1993, 312). The factor coefficients are generally stable across time and add up to about 1, indicating that constant returns-to-scale prevails.

We use these coefficient estimates to calculate firms' productivity residuals. A firm's residual is the difference between its actual and expected output in year *t* based on the production function estimated for year *m*. Expected output is the dot product of the firm's inputs in year *t*, in natural logs, and the production function coefficient estimates for year *m*.

If *t* equals *m*, then the residual captures a firm's relative productivity level in that year; firms with positive (negative) residuals are relatively more (less) productive. For our analyses, we use two slightly different versions of relative productivity levels. *PROD_RES_AN* is the year-by-year measure of firms' relative productivity level, which we use when answering research question 1. *PROD_RES*0 is an estimate of firms' relative productivity level before 1982, the year the first transplant entered, which we use when answering questions 2 and 3.

*PROD_RES*0 for firms that exist before 1982 is the 3-year average of the residuals from 1979 to 1981. The averaging mitigates any transitory noise. Obtaining *PROD_RES*0 for firms entering after 1981 requires several additional steps. For late entrants, as data from 1979 to 1981 are unavailable, we use data in the firm's entry year and project backwards for a hypothetical measure of *PROD_RES*0 in 1981. We calculate a late entrant's residual by inputting its entry year output and inputs into the estimated 1979, 1980, and 1981 production functions shown in Appendix 1 and taking the average. This residual captures both the late entrant's relative productivity level in 1979–1981 and the industry-average productivity growth after 1981 up to the entry year. We assume that a firm does not enter unless it has incorporated industry productivity growth before its entry and is at least as productive as the prevailing industry average. To isolate the late entrant's relative productivity level in 1982, we subtract this industry-average productivity growth from the residual. We obtain the average industry productivity growth between 1981 and the entry year using data from non-late entrants, following the procedure for estimating productivity growth that the next paragraph describes.[3]

For our third research question – Did tie-in firms exhibit greater productivity growth than non-tie-in firms? – we need information on firms' productivity growth. To capture productivity growth, we let *t* be greater than *m*. The residual then indicates the firm's productivity growth between year *m* and *t* and the firm's initial relative productivity level in year *m*. Because we are interested in productivity growth after 1981, we estimate the benchmark production function using pooled firm-year data from 1979 to 1981.[4] Instead of being a single year, *m* is the period 1979–1981. We use the three pre-transplant years' data to reduce any transitory industry-level noise. Using this benchmark productivity function, we obtain a productivity residual for each firm in the last year it exists (*t* is the last year a firm exists in our sample). To isolate productivity growth (*PROD_GROW*), we subtract the firm's initial productivity level (*PROD_RES*0).

PROD_GROW represents productivity growth between 1981 to the final year when a firm appears in our data. If a firm exited before 1991, then *PROD_GROW* is its productivity growth between 1981 to the year before it exited. If a firm survived beyond 1991, then *PROD_GROW* is the firm's productivity growth from 1981 to 1991. Some firms in our sample entered after 1981. Assuming post-1981 entrants would not enter unless they had acquired at least industry-average productivity growth between 1981 to their entry year, *PROD_GROW* for post-1981 entrants captures industry-average growth between 1981 to their entry year plus firm-specific growth between the entry year to their final data year. For each firm *PROD_GROW* captures different years of industry and firm-specific productivity growth, as firms are in our data panel for a varying number of years. In our statistical analyses, we use firm-year dummy variables to account for this unbalanced nature. We describe the approach in detail in the productivity growth results section.

Appendix 2 reports descriptive statistics for three key variables (*TIEIN*, *YRS_SURV*, and *PROD_GROW*). The appendix also reports descriptive statistics for other firm characteristic variables. 'Size' (*ASSETS*) is the log of real total assets. 'Capital intensity' (*ASSET*/*EMP*) is the log of the ratio of real total assets to the number of employees. 'Equipment wear' (*DEPR*/*PPE*) is the ratio of accumulated depreciation on plant, property, and equipment (*PPE*-gross−*PPE*-net) to *PPE*-gross. 'Automotive concentration' (*PCNT_AUTO*) is the fraction of a firm's corporate sales that derives from automotive sectors. 'Productivity level' (*PROD_RES*0) is the firm's relative productivity level in the pre-transplant era, as we described above. 'R&D intensity' (*R&D*/*EMP*) is the ratio of real R&D stock to the number of employees. 'Tie-in experience' (*YRS_TIEIN*) is the count of years between 1982 and 1991 inclusive for which the firm has a tie-in relationship.

Results

Before investigating our three research questions, we need first to establish that Japanese automotive FDI influenced supplier productivity in the USA. We regress local supplier productivity on measures of the transplants' local production presence.[5] For the main independent variable, we use the share of North American automobile production accounted for by Japanese transplants, defined as transplant unit output divided by total unit output of automobiles. The Japanese transplants' production share captures Japanese FDI at both the assembler and supplier levels, as both Japanese assemblers' and suppliers' FDI contributed to increasing Japanese transplants' production share. We include several control variables: a time-trend variable, Japanese import share, rest-of-the-world import share, and individual firm dummy variables (that is, a firm fixed-effect specification). We gather Japanese import and rest-of-the-world import shares from issues of *Wards' Automotive Yearbook*. Recognizing the positive correlation between transplant production share and the time trend, we also estimate the specification without the time trend with similar sign, magnitude, and significance for transplant share. The result is as follows:

$$\begin{aligned}
\text{Supplier productivity} &= \underset{(4.20)}{0.013}\ \text{Transplant production share} - \underset{(3.64)}{0.010}\ \text{Japan import share} \\
(t\text{-statistic}) \qquad & + \underset{(3.75)}{0.019}\ \text{World import share} - \underset{(0.64)}{0.003}\ \text{Time trend}
\end{aligned}$$

As expected, Japanese transplants' share of North American car output takes a positive and significant coefficient, showing that Japanese FDI correlates with productivity increases for our set of host country suppliers. The result suggests that the US component industry's productivity rose with inward Japanese FDI in the auto-sector. As the Japanese transplants' share of vehicle production increased from none to 17% during our study period, and given that the estimated coefficient is 0.013, the results suggest that transplant production led to about a 0.22% increase in productivity ($17\% \times 0.013 = 0.22\%$: that is, a 0.22% increase in output from the same inputs). Putting this in context, the *NBER Manufacturing Productivity Database* reports that total factor productivity in the auto-component sector grew by 5.9% from 1982 to 1991, compared with 4.7% for all US manufacturing. Thus the results suggest that the transplants might have accounted for about 18% of the extra productivity growth in the sector [0.22/(5.9–4.7)]. We turn now to the three research questions.

Differences between tie-in and non-tie-in firms before tie-in relationships began

If adverse selection occurs (question 1), then transplant assemblers would tend to form tie-in relationships with less productive local suppliers. We use binomial logistic regressions to test how suppliers' productivity influences the probability of forming a tie-in relationship.

In setting up the tests, the frequency of transplants' entry and the timing of their sourcing dictate the appropriate 'at risk' time-spell. Although we have yearly data, local suppliers are not 'at risk' for tie-in formation on a yearly basis. Typically, firms will form supply relationships when a transplant arrives and launches production of a new vehicle. Once sourced, the same suppliers typically provide the components for the entire model run of 4 years or more. Therefore local suppliers are usually only at risk in the year when, or the year after, new transplants arrive, or when an existing transplant begins production of a new model.

As new transplants entered every few years, we pool 3- and 4-year intervals by the timing and the type of Japanese assembler entrants to form time period regimes. We use three time period regimes. Regime 1, from 1982 to 1985, was the period when the earliest Japanese auto-assemblers, Honda and Nissan, first established North American auto-production. Regime 2, from 1986 to 1988, was the peak period of transplant entry with the arrival of Toyota-NUMMI, Toyota-Georgetown, Mazda, and Mitsubishi. These firms were all substantial players in their home market. Regime 3, from 1989 to 1991, was the period of later entrants, who were smaller auto-assemblers in Japan, including Subaru, Isuzu, and Suzuki. Transplant assemblers formed tie-in supply relationships during their entry regime and occasionally during subsequent regimes.

Our dependent variable is the establishment of tie-in relationships between a supplier and a Japanese transplant during a regime. If the tie-in count (*TIE_CNT*) variable for a firm increases by 1 or more in any year during a regime, the dependent variable for that regime is coded as 1. For example, Masco Industries had no tie-in relationships until 1987, when it established a relationship with Toyota, so we code Masco's dependent variable as equal to 0 in regime 1 and equal to 1 in regime 2. Of course, the same firm is repeatedly at risk across different regimes. If Masco also established relationships with Mazda and Honda in 1989, we would code the dependent variable as 1 in regime 3. We count cases in which a supplier formed multiple tie-ins during a regime as a single occurrence.

Our focal independent variable is a firm's relative productivity level before the start of a regime: a firm's pre-regime productivity residual. To reduce the impact of any transitory noise, we use the average of *PROD_RES_AN* in the 3 years before a regime. If a firm did not exist in all 3 years, we average *PROD_RES_AN* from those years available. This 3-year average of *PROD_RES_AN* is a firm's pre-regime productivity level relative to its peers. For example, in regime 3 we use the average of each firm's *PROD_RES_AN* from 1986 to 1988.

Although supplier productivity is of primary interest, we also include other control variables. If the Japanese transplants preferred stable component suppliers, we would expect size (*ASSETS*) to be a positive determinant because larger firms and businesses tend to be more likely to survive (Evans, 1987; Mitchell, 1994). If the transplants sought suppliers with a higher level of technological capabilities, we would expect R&D intensity (*R&D/EMP*) to be a positive determinant. Similarly, if the Japanese transplants preferred suppliers with more modern production facilities, then tie-in firms would have physical assets that are less worn (lower *DEPR/PPE*). We also include tie-in experience (*YRS_TIEIN*), because transplant assemblers might seek suppliers with prior tie-in experience. As the same firm is repeatedly at risk across different time regimes, we update these independent variables by using 3-year averages immediately preceding a regime.

We estimate a logistic regression for each of the three time regimes and for all regimes pooled together. For each regime's risk set, we include only those firms that were present in the year preceding the regime's start. For example, as regime 2 starts in 1986, only firms present in 1985 are in regime 2's risk set. Table 1 reports these results.

Column 1 in Table 1 reports the regression when we pool observations across time regimes. Columns

Table 1 Binomial logit estimates of likelihood of establishing a tie-in relationship

	Regimes pooled (1)	*Regime 1 (1982–85) (2)*	*Regime 2 (1986–88) (3)*	*Regime 3 (1989–91) (4)*
PROD_RES_AN	−1.390**	−1.630	−0.513	−1.859*
	(0.711)	(2.233)	(1.329)	(1.032)
YRS_TIEIN	0.451***		0.402*	0.492***
	(0.114)		(0.243)	(0.165)
ASSETS	0.199**	0.430*	0.104	0.257*
	(0.088)	(0.261)	(0.149)	(0.145)
DEPR/PPE	−0.926	−5.027	−3.836	1.075
	(1.687)	(5.556)	(2.975)	(2.369)
R&D/EMP	−0.154	−0.141	−0.355	−0.071
	(0.114)	(0.536)	(0.272)	(0.163)
Intercept	−1.630***	−2.162***	−1.622***	−1.585***
	(0.239)	(0.534)	(0.452)	(0.428)
n	180	54	58	68
Log likelihood	178.6	43.3	59.1	68.5
χ^2	34.1***	5.4	7.2	21.9***
d.o.f.	5	4	5	5
Concordant (%)	75.6	70.6	71.2	81.7

Positive coefficients indicate greater likelihood that a Japanese transplant manufacturer sourced parts from the firm (established a tie-in relationship). Variable values are 3-year averages preceding the start of a regime (for example, for regime 1, 1982–1985, the independent variable values are the average from 1979 to 1981.

*$p<0.10$; **$p<0.05$, ***$p<0.01$ (two-tailed tests; standard errors in parentheses).

2–4 report the results for tie-in relationships that suppliers established during regimes 1–3. *PROD_RES_AN* is consistently negative, and is significant in the pooled regression and in regime 3. Tie-in experience (*YRS_TIEIN*) is positive and significant in the pooled test and regimes 2 and 3; tie-in experience is not relevant in regime 1 because no suppliers had prior tie-in experience. Size (*ASSETS*) is positive and significant in the pooled case and in regimes 1 and 3. Both R&D intensity (*R&D/EMP*) and wear on physical assets (*DEPR/PPE*) are uniformly insignificant.

Table 1 indicates that tie-in firms tended to be less productive than non-tie-in firms before tie-in relationships began, and that this relationship is stronger in the period when marginal Japanese auto-assemblers started production in the US. This finding is consistent with adverse selection, suggesting that transplants chose less productive local firms as suppliers. In addition, Table 1 suggests that transplants often sought suppliers that already had tie-in relationships with other transplants, and that tie-in firms tended to be larger firms.

Exit rate of tie-in and non-tie-in firms

We turn now to whether lower-productivity tie-in firms have a lower exit rate (question 2): that is, whether marginal firms may have extended their survival by securing new business from transplants. We use a Cox Proportional Hazard model to test how the presence of a tie-in relationship influenced a firm's hazard rate of exit. The model specifies that an event's hazard rate is the product of an underlying, unspecified hazard function, $\lambda_0(t)$, multiplied by an exponentiated set of independent variables. Our event is a firm's exit, which the dependent variable *YRS_SURV* indicates. *YRS_SURV* is the count of years for which a firm survived between 1982 and 1991. Thus, for firms present from before 1982, if *YRS_SURV* is less than 9 (1991–1982 = 9), then we know that the firm exited and when it exited; for post-1981 entrants *YRS_SURV* in combination with the entry year indicates whether and when an exit occurred. The Cox model uses this information to construct the likelihood function.

To determine the influence of independent variables on *YRS_SURV*, the Cox model maximizes the product of likelihoods for all the exits observed. The likelihood of a specific observed exit is the hazard rate for the exiting firm scaled by the sum of hazard rates for all firms at risk when the exit occurs. The likelihood function is the product of the separate likelihood of every observed exit. The coefficient estimates for the independent variables are those that maximize the likelihood function.

Beyond this basic Cox specification, we set up the model to handle late entrants and right-censoring. A firm that entered after 1982 was not at risk for as many year spells as a firm that existed in 1982. Therefore we implement the model with left-truncation by excluding late entrants from the risk set in years prior to their entry. Also, as our panel ends in 1991, we implement the Cox model with right-censoring of *YRS_SURV* for firms that remained in 1991.

The focal explanatory variable is *TIEIN*, which denotes whether the presence of a tie-in relationship affects a firm's survival chances. We implement *TIEIN* as time varying in the Cox model. Between 1982 and 1991, *TIEIN* can change from 0 to 1 if and when a tie-in relationship is formed. Essentially, within the Cox model, *TIEIN* becomes indexed by time for when the risk sets are evaluated.

We include several control variables that might influence exit. We include firms' relative productivity level from the pre-transplant years of 1979–1981 (*PROD_RES*0). We include size (*ASSETS*), capital intensity (*ASSET/EMP*), and a firm's focus on the automotive industry (*PCNT_AUTO*). Size is an important determinant of survival (Evans, 1987; Mitchell, 1994). As input stocks with limited second-best uses become barriers to exit (Caves and Porter, 1976), higher capital intensity might reduce exit if capital has fewer alternative uses than labor. Firms more vested in the automotive industry may be less likely to exit from this line of business. Because there is little variation across time in firm size, capital intensity, and automotive focus, we use fixed values from before the start of the risk set, that is, before 1982. The values are 3-year averages from 1979 to 1981. If a firm enters after 1981, we use the values in the year of entry.

Table 2 reports the results from the Cox hazard model. We report both pooled results and separate analyses for high- and low-productivity firms, as we discuss below.

Column 1 in Table 2 reports the pooled sample hazard models. Positive coefficients indicate that the covariate increases the hazard rate of exit, whereas negative coefficients indicate that the covariate reduces the hazard rate. The pooled result in column 1 indicates that *TIEIN* is negative; moreover, the result is borderline significant (at the 10% level for a one-tailed test), which implies that the presence of a supply relationship with a

Table 2 Cox proportional hazard estimates of forms' rate of exit, 1982–1991

		Obs split by productivity	
	All obs pooled (1)	*High only (2)*	*Low only (3)*
TIEIN	−0.955	−0.211	−1.531**
	(0.594)	(1.224)	(0.767)
*PROD_RES*0	−0.629	1.333	−0.442
	(0.396)	(1.563)	(0.485)
ASSETS	−0.236**	−0.097	−0.263**
	(0.093)	(0.196)	(0.122)
ASSET/EMP	0.876	−0.466	1.502**
	(0.533)	(1.242)	(0.627)
PCNT_AUTO	−1.112*	−2.597*	−1.038
	(0.607)	(1.611)	(0.670)
Cases	90	44	46
Exit	36	9	27
Censored	54	35	19
Log likelihood	156.7	41.8	91.8
χ^2	15.2**	5.0	15.9**
d.o.f.	6	6	6

Positive coefficients indicate greater hazard rate of exit. *TIEIN* is a time-varying covariate coded as 0 for no tie-in relationship and 1 for a tie-in relationship. Other variables are time invariate. If the firm existed before 1982, values are 3-year averages from 1979 to 1981. Firms entering after 1982 take the values in the year of entry.
*$p<0.10$, **$p<0.05$, ***$p<0.01$ (two-tailed tests; standard errors in parentheses).

Japanese transplant slightly extends a supplier's survival. The pooled results also indicate that larger firms (*ASSETS*) with a greater concentration in the automotive sector (*PCNT_AUTO*) have lower exit rates.

If adverse selection occurs in the auto-component sector, tie-in relationships would reduce the exit rate among low-productivity firms and not affect the exit rate of high-productivity firms, which can survive on their own merits. Therefore, using median *PROD_RES*0, we split the sample into two subsets and fit the Cox Proportional Hazard model for above and below median productivity firms. Columns 2 and 3 of Table 2, respectively, report the results for the high- and low-productivity subsets. As expected, tie-in relationships do not affect the exit rate of high-productivity suppliers (column 2), but do significantly reduce the exit rate of low-productivity firms (column 3).

Several control variables also have a differential influence among high- and low-productivity firms. Greater size (*ASSETS*) decreases the exit rate among lower-productivity firms but not among higher-productivity firms. Also among lower-productivity firms, greater capital intensity (*ASSET/EMP*) increases likelihood of exit, which is equivalent to more labor-intensive firms having lower exit rates. This finding, which is the opposite of prior results across all US manufacturing industries, may fit the automotive sector given the strong presence of union labor. Unionized labor may be more difficult to shift to alternative uses than capital equipment, thereby inhibiting exit from the automotive sector. These two results suggest that greater scale- and labor-based exit barriers have little influence on survival once a firm achieves some critical level of productivity. Conversely, greater automotive concentration (*PCNT_AUTO*) reduces high-productivity firms' exit rate but does not affect low-productivity firms. This result suggests that, among high-productivity firms, focused firms are more likely to remain in the components business.

Overall, tie-in relationships significantly increased survival chances among lower-productivity suppliers. Thus the results provide evidence for the occurrence of adverse selection. From the prior section we know that transplants initially tended to source from lower-productivity suppliers. The current section suggests that the sourcing relationships often extended the survival of these lower-productivity suppliers.

Productivity growth of tie-in and non-tie-in firms

We now examine differences in the productivity growth of tie-in and non-tie-in firms (question 3), to determine whether the overall positive influence of FDI on productivity growth that we identified earlier stems from technology transfer or from competitive pressure. If technology transfer was the primary cause of the productivity growth, then tie-in firms as the immediate recipients should exhibit greater productivity improvement than non-tie-in firms. We use ordinary least-squares regressions to test how a tie-in relationship influenced a firm's productivity growth.

The dependent variable is a firm's productivity growth, *PROD_GROW*. As we described in the data section, for a firm that existed in or before 1981, *PROD_GROW* measures productivity growth from 1981 to 1991 or to the year the firm exited, whichever is earlier. For a post-1981 entrant, *PROD_GROW* captures the firm's own growth between the entry year and its final data year, plus the average industry productivity growth between 1981 to the firm's entry year.

Because firms benefit from industry-average growth in years that they are present, we need to include yearly dummy variables to account for average yearly industry growth. With panel data running from 1982 to 1991, all firms have 10 yearly dummy variables. We set firm-year dummy variables equal to 1 if the firm benefited from average industry productivity growth in that year. Thus, for firms present from 1982 to 1991, all the firm-year dummies equal 1. For post-1981 entrants, while all firm-year dummies from the entry year to their last year are equal to 1, we also code their yearly dummies from 1982 to their entry year as equal to 1 assuming that late entrants have incorporated these years' industry productivity growth before their entry. For firms that exit before 1991, firm-year dummies become 0 in the post-exit years. Of course, in our OLS regressions, we collapse perfectly collinear yearly dummies to a vector of all 1's.

Our analysis focuses on whether the presence of a tie-in relationship increases or decreases the tie-in firm's productivity growth. We examine three separate tie-in relationship specifications. In the first specification, we use a binary independent variable (*D_TIEIN*), which indicates whether a firm ever had a tie-in relationship during 1982–1991 (that is, whether *TIEIN* was ever 1). Second, recognizing that longer tie-in relationships may lead to more technology transfer, we use as a regressor the number of years for which a tie-in relationship existed (*YRS_TIEIN*). Third, for a more detailed investigation that allows the value of a tie-in relationship to differ by year, we use annual tie-in dummy variables to specify the years for which a tie-in relationship existed for each firm (*TIE*82, *TIE*83, *TIE*84,…,*TIE*91). In the last specification, the tests would be whether these annual tie-in dummies are jointly significant and whether their sum is equal to zero.

We also include other variables that might affect productivity growth. If 'more able' firms experience greater productivity growth, then firms with higher initial productivity levels should experience greater growth. Or, if productivity exhibits regression towards the mean, firms with low initial productivity levels would have higher productivity growth. Therefore we include *PROD_RES*0, which captures a firm's initial productivity level; recognizing that the procedure used to obtain *PROD_RES*0 for post-1981 entrants may cause a common error term between *PROD_RES*0 and the dependent variable, we also try alternative specifications, which are discussed in the robustness section.

Because there is some evidence, albeit mixed, that firm sales growth is negatively related to existing firm size (Hall, 1987; Dunne *et al*., 1989), we include firm size (*ASSETS*). If a firm's productivity growth is related to its size growth, then its productivity growth might also be related negatively to the existing firm size. We also include equipment wear (*DEPR*/*PPE*), as firms with older physical assets would understate their capital inputs because of historical cost accounting, thereby leading to overestimation of their productivity. Finally, as we construct the productivity growth measure at the corporate parent level, firms with varying degrees of economic activity within the automotive sector may experience different overall productivity growth at the parent level. For example, if productivity in overall manufacturing grew more slowly than within the automotive sector (as the *NBER Manufacturing Productivity Database* suggests), then firms with less business in the automotive sector should have lower growth. Therefore we also include automotive concentration (*PCNT_AUTO*). These independent variables take the pre-1982 value for firms that existed before 1982 and the values in the entry year for post-1981 entrants.

Table 3 reports the results from the OLS regressions of productivity growth. Column 1 in Table 3 reports the results for the baseline model. Columns 2–4 report results when we introduce *D_TIEIN*, *YRS_TIEIN*, and the yearly tie-in dummy variables, respectively. Each specification permits a finer-grained test of the effect of tie-in relationships than the immediately preceding specification.

Table 3 results suggest that tie-in relationships neither increased nor decreased the productivity of supplier firms. Our main variables of interest, *D_TIEIN* and *YRS_TIEIN*, are respectively, positive and negative, but not significant, in columns 2 and 3. In column 4, the coefficients for the yearly tie-in dummies do not have a stable sign and are mostly insignificant. An *F*-test indicates that they are jointly insignificant; the sum of all the dummy variables is not significantly different from zero. Thus we find no evidence of direct technology transfer.

All other control variables in Table 3 are insignificant, except the initial productivity level, *PROD_RES*0, which has a consistent and significant negative influence on productivity growth. This suggests that surviving firms with low initial productivity tended to catch up during the study period.

One possibility for not finding evidence of technology transfer among tie-in firms is that

Table 3 OLS estimates of factors affecting firms' accumulated productivity growth 1982–1991

	(1)	(2)	(3)	(4)	
PROD_RES0	−0.638***	−0.636***	−0.645	−0.629***	
	(0.068)	(0.071)	(0.071)	(0.075)	
ASSETS	−0.016	−0.016	−0.014	−0.014	
	(0.016)	(0.016)	(0.016)	(0.017)	
DEPR/PPE	0.168	0.164	0.183	0.290	
	(0.216)	(0.220)	(0.220)	(0.237)	
PCNT_AUTO	−0.052	−0.052	−0.047	−0.015	
	(0.101)	(0.101)	(0.102)	(0.105)	
D_TIEIN		0.006			
		(0.073)			
YRS_TIEIN			−0.005		
			(0.013)		
*TIE*82				0.133	(0.368)
*TIE*83				−0.401	(0.246)
*TIE*84				0.428	(0.228)*
*TIE*85				−0.358	(0.233)
*TIE*86				0.217	(0.214)
*TIE*87				−0.403	(0.258)
*TIE*88				0.342	(0.246)
*TIE*99				−0.018	(0.508)
*TIE*90				0.159	(0.527)
*TIE*91				−0.207	(0.168)
Sum (all annual tie-in coefficients)				−0.109	
F-value (10,99) 'each and every annual tie-in coefficient = 0'				0.78	($p=0.64$)
F-value (1,99) 'the sum of all annual tie-in coefficients = 0'				0.12	($p=0.73$)
n	104	104	104	104	
Adjusted R^2	0.83	0.83	0.83	0.83	
F-statistic	44.0***	40.2***	40.3***	23.8***	
d.o.f.	12	13	13	22	

Positive coefficients indicate greater accumulated productivity growth by 1991 or by the last year a firm exists in the panel. Accumulated productivity growth is the output residual in 1991 or the exit year. Output residual is growth in output unexplained by input growth. A benchmark function is estimated using capital, labor, and R&D capital stock input data from 1979 to 1981. Other variables are 3-year averages from before the panel starts, 1979–1981, if the firm existed before 1982. For firms entering the set after 1982, the values in the year of entry are used.The analysis includes dummy variables for which years a firm is present, because productivity growth might vary by the years for which a firm is in the dataset; in order to conserve space, we do not report the individual coefficient estimates.
*$p<0.10$, **$p<0.05$, ***$p<0.01$ (two-tailed tests; standard errors in parentheses).

significant technology transfer might occur only for 'high tech' components: that is, only tie-in firms selling more complicated components to Japanese transplants would benefit, whereas suppliers of commodity-like lower-technology parts would not. To address this possibility, in sensitivity analysis we repeat the regressions in Table 3, but split the sample into two groups: firms with above- and below-median capital intensity. The results for the above- and below-capital intensity groups are similar to each other, as well as to the results that we report in Table 3.

What then explains the positive relationship between the US component industry's productivity growth and the Japanese auto-sector FDI during the 1980s? As tie-in relationships do not affect productivity growth, direct technology transfer is not a likely explanation. From the prior two analysis sections, we also find that adverse selection occurred: some tie-in firms were initially less productive suppliers, and transplant supply relationships extended the survival of low-productivity firms. This pattern of exit hazard rates suggests that non-tie-in firms experienced more severe competition, which forced less productive non-tie-in firms to exit. Given the lack of evidence for direct technology transfer and the occurrence of adverse selection, we conclude that competitive pressure was mainly responsible for the positive correlation between FDI and productivity increase in the upstream host industry.

Robustness

We recognize several possible limitations to the way our productivity measure estimates output and capital inputs. Our first concern is whether our results are affected by noise in the input variables. For example, *PPE*-net (net plant and equipment), which is based on book value and accounting depreciation, is an imperfect proxy for capital inputs. A more desirable measure would be the replacement cost for each asset item on a company's balance sheet. Unfortunately, such information is unavailable. As tie-in and non-tie-in firms have similar 'equipment wear' (accumulated depreciation/gross plant and equipment), the noise in *PPE*-net should not cause any systematic bias when comparing tie-in and non-tie-in firms.

To check whether our results are robust to the definition of productivity, we vary the productivity function's inputs in three ways. First, for physical input instead of *PPE*-net, we use gross plant and equipment or total constant dollars of assets. Second, in deriving the R&D stock, we try varying the pre-sample growth rate and the depreciation rate from 5 to 15%, respectively, which systematically increases or decreases a firm's annual R&D capital stock. Third, we drop R&D stock as an input and use only a two-factor instead of a three-factor production function. These alternatives do not materially change our reported results.

A second possible limitation is in our output measure. As we measure output using revenue rather than quantity, we may be capturing differences in merchandise prices. As sales equals price times quantity, productivity differentials based upon sales as output might reflect price differences. The labor economics literature indicates that the real wage for high-skilled labor increased relatively more than the real wage for low-skilled labor during the 1980s (Cutler and Katz, 1991). Also, discussions with auto-industry engineers suggested that Japanese transplants initially sourced more standardized and lower-skill components from US suppliers. The results in Table 3 might then reflect the difference in gains in the relative price between capital-intensive and labor-intensive products, even though the products are within the same industry class.

Three sensitivity analyses address the output measure concern. First, we repeat the logistic regressions in Table 1 after adding capital intensity (*ASSET*/*EMP*) as another explanatory variable. *ASSET*/*EMP* is insignificant, indicating that tie-in and non-tie-in firms have similar capital intensity. Second, we repeat all analyses shown in Table 3, but also add capital intensity (*ASSET*/*EMP*) to control for potential technology differences in component firms' products. The results are similar, with the coefficient estimates retaining their directions and significance levels. Third, we split the sample into above- and below-median capital intensity, obtaining results similar to those in Table 3 for both groups.

We also recognize the possibility of an econometric issue in the results that Table 3 reports. The dependent and an independent variable may have a common noise term, making the regressions biased and inconsistent. We obtain *PROD_GROW* by subtracting *PROD_RES*0 (initial relative productivity) from an initial residual. To check the reliability of our results, we rerun the regressions using the initial residual as the dependent variable: that is, we do not subtract *PROD_RES*0 from the initial residual. This check produces regression coefficients for *PROD_RES*0 that are essentially 1.0 plus those reported in Table 3, while the other coefficients' signs and significance levels remain unaffected.

A similar correlation of noise terms might arise from the way we obtain *PROD_RES*0 for post-1981 entrants. To obtain late entrants' *PROD_RES*0, we use their entry year input/output and the pre-transplant era production function to obtain an initial residual. Then, from this residual we subtract industry-average productivity growth, which is the average of individual firms' productivity growth for those that existed between 1981 and the late entrant's entry year. Thus, for late entrants, noise in their independent variable becomes correlated with noise in some observations of the dependent variable. Concerned that this might affect our results, we redo our Table 3 regressions while excluding post-1981 entrants. This reduces the number of observations from 104 to 54. Our results for Table 3 are unchanged, with identical coefficient signs and equivalent significance levels.

A final concern is the possibility that rent extraction might camouflage productivity growth. Whereas the Japanese transplants might successfully transfer technology to tie-in firms, resulting in considerable productivity growth, they might also then extract the rents from the tie-in firms, possibly in the form of low and declining prices. There is some evidence that Japanese transplants obtain greater cost reductions from their suppliers than US assemblers (Cusumano and Takeishi, 1991).[6]

To examine the rent extraction possibility, we conduct several analyses of wage expense and capital earnings. If rent extraction took place, the extraction should lead to lower wages and/or capital earnings. First, we ask whether tie-in firms experienced abnormal decline in their capital earnings after the formation of a tie-in relationship. We find that return on assets and on sales in excess of the industry average for tie-in firms were positive but insignificantly different from zero.[7] Second, we inquire about wage rates and find no discernible difference between the tie-in and non-tie-in firms' 'wage expenses/employee,' based on a smaller sample of firms for which we have wage expenses data (15% of the total). We regressed the 'wage expenses/employee' on a dummy indicating the presence of a tie-in relationship. We conduct the regressions both by using only year-by-year data and by pooling all observations while including year dummies. In all cases the tie-in dummy attracts an insignificant coefficient, indicating that employees of tie-in firms did not receive lower wages. We conclude that there is no evidence of significant rent extraction by Japanese auto-assemblers from tie-in auto-component suppliers.

Conclusion

Earlier research has established that inward FDI typically raises host industry productivity, but the relative importance of the two mechanisms responsible – technology transfer and competitive pressure – has been unclear. Using unique data on interfirm links, we assess these two mechanisms' relative importance by investigating the productivity of US component suppliers from 1982 to 1991. Japanese auto-transplants' increased production presence in North America significantly influenced the industry's productivity growth during this period. We differentiate between local firms that are more likely and less likely to be recipients of technology transfers from the Japanese transplants. As suppliers and assemblers necessarily interact during the production and sale of these intermediate goods, those suppliers that sell goods to foreign-owned assemblers will be the likely recipients of any direct technology transfers.

We find that the productivity of local suppliers that sold components to the Japanese transplants did not grow faster than the productivity of unaffiliated suppliers. Thus we find no evidence of direct technology transfer affecting these US suppliers' productivity during this initial stage of inward FDI. Further, we find evidence of adverse selection. Japanese assemblers often purchased components from local suppliers that had lower initial productivity levels and, in turn, the relationship with the Japanese transplants extended the survival of low-productivity tie-in suppliers. Despite the lack of evidence for direct technology transfer increasing productivity, and the occurrence of adverse selection, overall industry productivity in the auto-component supply sector did increase during this period. In the absence of significant technology transfer, competitive pressure appears to be the primary cause of the productivity growth. Increased competitive pressure led to the exit of less productive non-affiliated firms.

Although the results indicate that competitive pressure overshadowed any direct technology transfer during early stages of FDI, the extent of technology transfer might increase over time. First, the benefits of technology transfer might emerge only after our sample period. Some tie-in relationships were formed only 2 years before the end of our sample period. Second, especially early in the period, the Japanese transplants inadvertently or by necessity sourced from less productive North American suppliers. With greater North American production experience, transplants eventually would be able to purchase from stronger host country suppliers, which had greater potential to benefit from technology transfer.

The type of supplier in our sample might also decrease the likelihood of technology transfer occurring. Helper and McDuffie (1997) note that, for successful transfer of Honda's 'best practices' to indigenous suppliers, target suppliers need both the proper technical skills (high absorptive capacity) and the proper inclination (low organizational identity). The suppliers in our sample are publicly owned firms, which are typically larger companies. Such firms might have stronger organizational inertia, which might inhibit successful transfer.

Although we find no evidence for technology transfer affecting US suppliers' productivity, the results do not exclude successful technology transfer at the assembler level. US assemblers also had direct and indirect opportunities to observe, learn, and employ Japanese production methods. For instance, NUMMI provided General Motors' managers and engineers with first-hand experience with Toyota production practices. In addition, Big Three managers and engineers also made numerous visits to the Japanese transplants and vice versa (Womack *et al.*, 1990; Helper and McDuffie, 1997).

Several restrictions limit the generality of our results. We rely on data from the US auto-industry, an industry that experienced years of oligopolistic competition, and which could benefit substantially from increased competition. Additionally, the advanced state of US physical technology reduces the potential for technology transfer relative to environments with lower levels of both physical technology and production methods.

In spite of these caveats, we find that competitive pressure is the main reason for the productivity growth in the supply sector that occurred following inward FDI. Our results complement findings such as those by Nickell (1996) that competition tends to increase total factor productivity growth. Further, the result that competitive pressure extends beyond the focal industry to the vertically related supply sector highlights the importance of accounting for firm-level behavior. These interfirm links lead to impact beyond just the focal industry. The fact that tie-in suppliers' productivity growth lagged behind reinforces the growing assessment of the strategic management literature that the transfer of tacit, organizationally embedded skills is a difficult process, requiring substantial hands-on effort rather than simple commercial linkages (Martin *et al.*, 1998).

Scholars including Buckley and Casson (1976) and Caves (1974) have raised the question of how inward FDI affects the host. This is a classic question, but gaps in our understanding persist. Our findings highlight the importance of firm behavior in addressing this classic question. Identifying the variation and dynamics in behavior among firms and across sectors is crucial in understanding how FDI affects the host country. More firm-level inquiries that emphasize variations in investment motives and variations in within-country locations and mode of entry choice (e.g., Chung and Alcacer, 2002) would further close the gap. These studies, including the current paper, illustrate contributions that international business and strategy research can make to economics, besides being of interest on their own.

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Notes
[1]A few other foreign-owned assembly facilities operated during the study period. Volkswagen opened a facility in Pennsylvania in 1974 but had low sales volumes from the start and closed it in 1988. In Canada, Volvo opened a small facility during the 1970s, and Hyundai established a plant at the end of the study period. We exclude the Volkswagen, Volvo and Hyundai investments in our study because of the facilities' small volumes and the difficulty in obtaining the necessary supplier information. Overall, we expect that they had little impact.

[2]Another potential channel for direct technology transfer is a supplier-to-supplier channel between Japanese-owned suppliers and American-owned suppliers. About 150 Japanese auto component suppliers entered the USA during the 1980s and about 25 Japanese-owned suppliers entered the USA even earlier, during the 1960s and 1970s (Martin *et al.*, 1995, 1998). Some of the Japanese suppliers formed joint ventures with US parts suppliers. However, all the US–Japanese supplier joint ventures sold goods to Japanese assembly transplants during the 1980s, so that the supplier-to-supplier channel also involves direct sales relationships between American-owned suppliers and Japanese-owned assembly transplants. Thus the presence of a tie-in supply relationship between a Japanese assembler and a US supplier provides a single indicator that denotes possible direct technology transfer from Japanese automobile manufacturers to American suppliers.

[3]For a firm entering in 1988, we use the firm's 1988 input and output data to obtain residuals from the estimated 1979, 1980, and 1981 production functions. We take the average, and then subtract the average productivity growth between 1981 and 1988 for all non-late entrants that survived in the period. The result is *PROD_RES*0 for the firm.

[4]The estimated three-factor productivity function is (adjusted $R^2 = 0.97$):

$$\begin{array}{lcllcll} \text{Output} & = & 3.362 & \text{Intercept} & + & 0.273 & PPE\text{-net} \\ (t\text{-statistic}) & & (22.696) & & & (5.206) & \\ & + & 0.674 & \text{Labor} & + & 0.042 & \text{Capital} \\ & & (9.459) & & & (1.117) & \end{array}$$

[5]We construct a basic productivity measure similar to *PROD_RES_AN*. Instead of estimating three-factor production functions every year, we pool all firm-years and estimate a single function for the entire panel. A

firm-year residual from this single function then represents how far a firm falls from the overall panel average in a given year. This measure allows us to ask how each firm responds across time on a yearly basis from an absolute reference. The estimated equation is (adjusted $R^2 = 0.97$):

Output	=	3.439	Intercept	+	0.300	*PPE*-net
(*t*-statistic)		(45.124)			(12.237)	
	+	0.676	Labor	0.049	R&D capital	
		(23.198)		(3.701)		

[6]Richard Caves drew our attention to the rent-extraction interpretation. Cusumano and Takeishi (1991) used a survey of two US assemblers, five Japanese transplant assemblers, and three Japanese-owned auto assembly facilities in Japan; they reported several findings pertinent to the possibility of rent extraction. First, Japanese transplants focused more on a supplier's capability to meet a buyer's target price in selecting component suppliers than US assemblers did. Second, US assemblers and Japanese transplants reported almost identical target-price ratios, which is the actual part price at market introduction divided by the target price the auto maker set when the part's major supplier was selected. Third, the transplants performed somewhat better than the US firms in obtaining price decreases from US suppliers (–0.6% vs an increase of 0.9%) (Cusumano and Takeishi, 1991, 573).

[7]We measured capital earnings as net income after taxes with depreciation and interest expenses added back. We then scaled annual earnings by sales or total assets to measure yearly return on sales (ROS_t) and return on assets (ROA_t). We defined the change in return on sales in year *t*, $DROS_t$, as the yearly difference between 2-year averages: $(ROS_{t+1}+ROS_{t+2})/2-(ROA_{t-1}+ROA_{t-2})/2$. (We use multiple year averages to reduce transitory shocks in capital return data. Our results are equivalent when we use 3-year averages, though the number of observations declines because there were insufficient data to obtain 3-year averages for some late tie-in firms.) We defined change in the rate of return on assets, $DROA_t$, similarly.

To determine whether tie-in relationships adversely affected change in capital earnings, we constructed an 'abnormal change in capital earnings' measure for tie-in firms. First, we obtained the average change in capital earnings for non-tie-in firms (average of $DROS_t$ and $DROA_t$) for each year t. Then we subtracted the average from the $DROS_t$ and $DROA_t$ of firms forming a tie-in relationship in year *t*. We call the differences $ADROS_t$ and $ADROA_t$ 'abnormal change' in the rate of return on sales and on assets among firms forming a tie-in relationship in year *t*. Third, we pooled $ADROS_t$ and $ADROA_t$ over all years *t* and all firms forming a tie-in relationship in year *t*.

We tested whether the average values of *ADROS* and *ADROA* differ significantly from zero. If rent extraction occurs, then the coefficient on $ADROS_t$ and $ADROA_t$ will be negative, suggesting that tie-in firms' capital earnings would decrease after the firms formed tie-in relationships. Instead, we found that $ADROS_t$ and $ADROA_t$ were insignificantly positive (0.0136 with a *t*-statistic of 1.602 and 0.0064 with a *t*-statistic of 0.595).

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Appendix 1

In Table 4, year-by-year productivity regression coefficient estimates are made.

Table 4 Year-by-year productivity regression coefficient estimates

	Intercept	*Log K*	*Log L*	*Log R&D*	*Sum K, L and R&D*	*Adj R^2*
1979	3.322***	0.256**	0.668***	0.070	0.99	0.97
	(0.281)	(0.103)	(0.137)	(0.069)		
1980	3.412***	0.269***	0.716***	0.013	1.00	0.97
	(0.242)	(0.086)	(0.113)	(0.063)		
1981	3.637***	0.228***	0.753***	−0.002	0.98	0.98
	(0.255)	(0.084)	(0.124)	(0.065)		
1982	3.595***	0.234***	0.801***	−0.018	1.02	0.97
	(0.274)	(0.087)	(0.123)	(0.073)		
1983	3.146***	0.373***	0.706***	−0.018	1.06	0.99
	(0.289)	(0.095)	(0.113)	(0.062)		
1984	2.997***	0.437***	0.433**	0.126	1.00	0.98
	(0.361)	(0.123)	(0.172)	(0.082)		
1985	3.052***	0.428**	0.455*	0.091	0.97	0.98
	(0.567)	(0.194)	(0.238)	(0.076)		
1986	3.413***	0.238	0.517**	0.228***	0.98	0.98
	(0.498)	(0.165)	(0.203)	(0.071)		
1987	3.613***	0.174	0.634***	0.203***	1.01	0.98
	(0.357)	(0.116)	(0.155)	(0.067)		
1988	3.741***	0.216**	0.691***	0.118**	1.02	0.98
	(0.282)	(0.099)	(0.121)	(0.047)		
1989	3.748***	0.265**	0.769***	0.026	1.06	0.98
	(0.336)	(0.116)	(0.139)	(0.053)		
1990	3.714***	0.339**	0.715***	−0.004	1.05	0.98
	(0.380)	(0.132)	(0.148)	(0.064)		
1991	3.628***	0.344***	0.599***	0.053	1.00	0.99
	(0.271)	(0.091)	(0.097)	(0.044)		

Dependent variable is log(sales), which is deflated by the appropriate sector's PPI. Capital input, *K*, is net plant, property and equipment. Labor input, *L*,

Appendix 2

Descriptive statistics is shown in Table 5.

Table 5 Descriptive statistics

	Correlations[a]									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1 *TIEIN*	1.00	0.32	0.11	0.25	−0.07	0.05	0.01	−0.10	−0.01	0.84
	207	190	117	198	188	198	197	113	113	207
2 *YRS_SURV*	0.32	1.00	0.36	0.02	−0.09	−0.07	0.09	−0.03	0.05	0.34
	190	190	109	182	172	182	181	105	105	190
3 *PROD_GROW*	0.11	0.36	1.00	0.16	0.14	0.19	−0.05	0.42	0.07	0.07
	117	109	117	116	113	116	116	104	104	117
4 *ASSETS*	0.25	0.02	0.16	1.00	0.35	−0.01	−0.48	0.35	−0.33	0.251
	198	182	116	198	188	198	197	113	113	198
5 *ASSET/EMP*	−0.07	−0.09	0.14	0.35	1.00	−0.07	−0.21	0.15	0.15	−0.06
	188	172	113	188	188	188	187	113	113	188
6 *DEPR/PPE*	0.05	−0.07	0.19	−0.01	−0.07	1.00	0.05	0.38	−0.04	0.06
	198	182	116	198	188	198	197	113	113	198
7 *PCNT_AUTO*	0.01	0.09	−0.05	−0.48	−0.21	0.05	1.00	−0.18	0.26	0.01
	197	181	116	197	187	197	197	112	112	197
8 *PROD_RES0*	−0.10	−0.03	0.42	0.35	0.15	0.38	−0.18	1.00	−0.50	−0.12
	113	105	104	113	113	113	112	113	113	113
9 *R&D/EMP*	−0.01	0.05	0.07	−0.33	0.15	−0.04	0.26	−0.50	1.00	−0.05
	113	105	104	113	113	113	112	113	113	113
10 *YRS_TIEIN*	0.84	0.34	0.07	0.25	−0.06	0.06	0.01	−0.12	−0.05	1.00
	207	190	117	198	188	198	197	113	113	207
Summary statistics										
Cases	207	190	117	198	188	198	197	113	113	207
Mean	0.28	6.75	0.37	−0.32	0.10	−0.04	0.49	−0.18	0.72	1.20
Standard deviation	0.45	3.05	0.41	2.35	0.51	0.16	0.68	0.55	3.76	2.31

[a]The second number in each cell is the number of pairwise cases.
Dependent variables (*TIEIN*, *YRS_SURV*, and *PROD_GROW*) vary from 1982 to 1991.
The independent variables are 3-year averages from 1979 to 1981 (except *YRS_TIEIN*) if the firm existed before 1982. Entrants take the values in the year of entry.
For *ASSETS*, *ASSET/EMP*, *DEPR/PPE*, and *R&D/EMP*, we subtracted SIC-specific annual averages from the corresponding firm-year values before calculating the 3-year averages, as our data consist of firms from SIC 3714 and 3465. This de-meaning explains the potentially confusing negative mean values for *ASSETS* and *DEPR/PPE*.

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