Vertical Networks and U.S. Auto Parts Exports: Is Japan Different?*

Keith Head† John Ries ‡ Barbara J. Spencer§

July 6, 2002

Abstract

This paper develops a model in which upstream network "insiders" conduct relationship-specific investment that induces the downstream firm to transact within networks. The scale of destination-country production and part-specific measures of the importance of network relationships and engineering costs are used to explain the pattern of U.S. auto parts exports. Our results support the prediction that large scale promotes relationship-specific investment and reduces imports. Also, while Japan is a large parts importer, the composition of its imports is shifted away from parts where vertical *keiretsu* are prominent. Nations hosting U.S.-owned automakers import more U.S. parts.

*We appreciate the very helpful comments of Bruce Blonigen, Jerry Hausman, and Hodaka Morita and we also thank Thomas Krier, Kirk Monteverde, David Teece, and Douglas Marcouiller for providing data. The paper has also benefited from presentations at Yale School of Management, University of Toronto, Sydney University, University of Calgary, and the Claremont Colleges. Barbara Spencer is grateful for financial support from the Social Sciences and Humanities Research Council of Canada.

†UBC-Commerce, Email: keith.head@ubc.ca

‡UBC-Commerce, Email: john.ries@ubc.ca

§UBC-Commerce and NBER, Corresponding Author: 2053 Main Mall, Vancouver, BC, V6T1Z2, Canada. Fax: (604)822-8477, Email: barbara.spencer@commerce.ubc.ca

1 Introduction

Despite decades of tariff reductions and infrequent use of contingent protection, many observers continue to regard the Japanese market as "closed" to foreigners. In support of this claim, they point to persistent trade surpluses and a relatively low import to GDP ratio (7% in 1999). Since formal trade barriers seem too small to explain the alleged lack of market access, commentators point instead to special business practices. As noted by the World Trade Organization's 1998 *Trade Policy Review*, "Concern remains about the effects on foreign access to Japan of horizontally and vertically integrated groups (*kigyo-shudan* and *keiretsu*)."

Keiretsu are well-known and controversial but not the only business networks with the potential to influence international trade. Rauch's (2002) recent survey discusses the trade-creating activities of networks comprising members of ethnic groups and affiliates of multinational corporations. Rauch describes how such networks promote trade by disseminating information on market opportunities and the trustworthiness of potential trade partners. An additional role seems relevant for vertical networks: the facilitation of investment by upstream firms that generates benefits for downstream firms.

This paper investigates the role of business networks in trade by examining the pattern of U.S. auto parts exports to 26 countries from 1989 to 1994. We develop the model of Spencer and Qiu (2001) that identifies vertical networks as arising from the decision of suppliers to conduct relationship-specific investment. The theory contains implications for trade by identifying the parts likely to be produced within the network and those likely to be procured at arms-length from "outsiders." We find evidence consistent with the model's proposition that a lager scale of local production reduces imports by encouraging local insiders to conduct relationship-specific investment. Our results indicate that Japan's imports of a part tend to be lower for parts where vertical *keiretsu* are prominent. On average, though, Japan imports *more* parts from the U.S.

than one would expect from its observed economic characteristics. We also find higher imports by countries with a larger amount of production by U.S. automobile affiliates—especially for parts with high engineering costs.

Our study contributes to the debate on whether Japan's imports are "too low" and whether vertical *keiretsu* are exclusionary. Lawrence (1993) cites studies showing that Japanese manufacturing imports are lower than the levels predicted by trade models. Moreover, Lawrence (1991) finds that import penetration decreases in Japan with increases in the share of both horizontal and vertical *keiretsu* sales across industries. Fung (1991) reports a negative relationship between U.S. exports to Japan and the combined share of horizontal and vertical *keiretsu* sales. Saxonhouse (1993) identifies problems in the papers supporting the Lawrence position and presents his own evidence showing that Japan's distinctive trade structure can be explained by its pattern of factor endowments.

Saxonhouse also points out that any import-reducing effects of *keiretsu* may to be due to efficiency rather than collusion. The Spencer and Qiu (2001) model provides a theoretical basis for networks as a vehicle for increasing efficiency. In this paper, U.S. firms find it difficult to sell intermediate goods in Japan because *keiretsu* suppliers make efficiency-enhancing investments in parts that strongly benefit from relationship-specific investment.

Miwa and Ramseyer (2000) review the theoretical and empirical work on the economic role of relationship-specific investment and *keiretsu* in the automobile industry. Countering views to the contrary expressed by Asanuma (1989) and Aoki (1988), they argue that relationship-specific investment and extra-contractual governance mechanisms do not appear to play important interrelated roles in Japan's automobile industry. Further arguments downplaying the role of relationship-specific investment are provided by Casadesus-Masanell and Spulber (2000) who find that General Motor's acquisition of Fisher Body was not an effort to avoid opportunism in the presence of asset specific investment. However, other research provides empirical evidence showing that U.S. automakers tend to internalize the production of parts for which relationship-specific investment is important. Monteverde and Teece (1982), the source of some of the data used in this study, find that the likelihood that General Motors and Ford produce a part in-house is positively associated with the engineering costs of part development and a measure of model-specificity. Klier (1994) and Masten, Meehan, and Snyder (1989) also conclude that concerns about opportunism influence the vertical integration decisions of U.S. automakers. We extend this literature by testing the implications of our model linking the decision to conduct relationship-specific investment to international trade.

The paper proceeds as follows. Section 2 models how ex-post bargaining with an assembler affects the incentive of a parts supplier to make relationship-specific investments. It predicts that network firms will only produce parts for which the marginal product of relationship-specific investment exceeds a critical level with "outsiders" supplying the remaining parts. Section 3 describes our data set on U.S. exports of 53 different vehicle parts to 26 importing countries over the period 1989 to 1994. We present and interpret the econometric results in section 4. Finally, section 5 summarizes the implications of these results for our understanding business networks.

2 A Model of Vertical Networks

The model is an adaptation of Spencer and Qiu (2001).[1] An automaker (sometimes abbreviated to "maker") chooses between purchasing parts from a member of its "network" or from independent firms. We will refer to the former as "insiders" and the latter as "outsiders."

Insider suppliers have an advantage because, based on long-term relationships, they can each make relationship-specific investments, referred to as RSI, so as to reduce the cost of as-

[1]Qiu and Spencer (2002) also extend this model to examine the effects of trade policy aimed at opening the Japanese market.

sembly for the maker. This cost reduction applies only to the maker for which the part is designed and not for other makers. Membership of the network is necessary for these investments because of the need for a very high level of information concerning not only the design of the part itself, but also with the way the part can be modified to better fit with other connecting parts in the assembly process.[2] In addition to insiders, we assume that there are a large number of potential outsider suppliers that do not undertake RSI for the maker within the particular network and hence are able to provide only "generic" parts at competitive prices based on their cost of production plus transport costs. Despite the advantage of RSI conducted by insiders, the maker may nevertheless select outsiders because of their potentially lower cost of production.

For simplicity, we present the analysis for a representative maker with an exogenously set output of cars, denoted y. This will allow us to focus on the cost minimization problem associated with sourcing components without fully specifying the downstream product market.[3]

A large number, N, of parts is required to produce an auto, with parts and labour combined in fixed proportion in final assembly. Each assembled auto requires β_i units of part i. For each part i, there is a single insider supplier also referred to with subscript i that potentially makes a relationship-specific investment, denoted k_i. This investment creates a rent, denoted r_i, for the maker in the form of a reduction in the labour part of the assembly cost for each auto produced using the part from supplier i. Different parts have different potential for RSI. Letting $\rho_i = \rho(i) > 0$ denote a measure of the efficacy of RSI for part i, we assume that the

[2] Branstetter (2000) finds strong empirical evidence for the importance of the flow of technological information within vertical *keiretsu* in enhancing efficiency.

[3] Spencer and Qiu's (2001) specification of the product market for cars as a Cournot duopoly with segmented markets reveals that the main insights of the model are robust to relaxing the single assembler assumption.

relationship between the rent, r_i, created per auto and the level of k_i is given by

$$r_i = \rho_i \sqrt{k_i}. \tag{1}$$

Higher levels of RSI create more rent for the maker, but at a decreasing rate. We exploit the fact that N is large by ordering the parts on a continuum $i \in [0, N]$, with the parts varying from low to high values of RSI efficacy, ρ_i. We assume that $\rho(i)$ is strictly increasing in i and hence $\rho'(i) > 0$ for all $i \in [0, N]$. The magnitude of ρ_i—but not the ranking of parts—may vary internationally so as to capture country-specific differences in the efficacy of RSI. For example, if the nature of institutions and culture in Japan would better facilitate the kind of information transfer that enhances RSI, then ρ_i would be larger there.

Let c_i represent the constant unit cost of production of part i for insiders. Outsiders supply a homogeneous version of the part in a competitive spot market at price p_i^*. Both c_i and p_i^* include all relevant transport costs to the maker's facility (as well as tariffs if the part is imported). We define δ as the cost advantage of sourcing from an outsider:

$$\delta = c_i - p_i^*.$$

Note that this cost advantage does not include the rent generated by RSI. We assume for simplicity that δ is constant across parts.[4]

Although parts can be produced more cheaply by outsiders, the maker can gain from the local purchase of part i from an insider supplier due to the effect of RSI in reducing assembly costs. Supposing that part i is purchased at a price, $p_i \geq c_i$, the rent, r_i, created by RSI reduces the maker's net cost to $p_i - r_i$. Consequently, it is possible that $p_i - r_i < p_i^*$, reflecting an

[4] Spencer and Qiu (2001) show that the theory can accommodate $\delta'(i) \leq 0$ and small values of $\delta'(i) > 0$. The empirical specification could also accommodate δ that varies across parts in the part fixed effects.

overall cost advantage to the maker from the use of insider-made parts. Since $\beta_i y$ represents the demand for each part (β_i units of each part are required per auto), the resulting profit for insider supplier i is given by:

$$\pi_i = \beta_i y(p_i - c_i) - k_i. \tag{2}$$

An important aspect of RSI is that the supplier cannot be guaranteed a return based on a contract that is conditional on the amount, k_i, of investment. This is due to the difficulty of actually observing k_i, which would include non-observable costs (or at least non-verifiable by courts), such as the costs of obtaining the information and coordination with other suppliers. Consequently, we assume that the investment, k_i, is sunk prior to bargaining between each supplier and the maker as to the price, p_i. The resulting price, p_i, can be based on r_i, but not on k_i.

The order of moves is as follows: At stage 1, each supplier i commits to its investment $k_i \geq 0$, and simultaneously the maker specifies its output, y. Since each firm sets its choice variable to maximize own profit taking the other choice variables as given, this gives rise to a Nash equilibrium in k_i and y. In making these decisions, the maker and its suppliers correctly anticipate the outcome of the stage 2 bargaining process determining the prices, p_i, for parts. We assume the maker will at least break even, but suppliers have to consider the possibility that, if the agreed upon price is too low, RSI at stage 1 could result in a loss. At stage 2, the maker engages in Nash bargaining over the price, p_i, simultaneously with each remaining supplier. If an agreement is reached with the supplier of part i, the maker orders the $\beta_i y$ parts needed to produce output y. Otherwise, the maker buys the same quantity of part i from an outsider firm.

The maker's marginal cost due to part i is given by $p_i - r_i$ if it reaches an agreement in its bargaining with supplier i. It has a 'threat point' of buying the part from outsiders at a price of p_i^* if bargaining breaks down. Thus, the maker's net payoff from reaching agreement is given by $(p_i^* - (p_i - r_i))\beta_i y$, i.e. the difference between the price of outsiders and the net cost of parts procured from insiders multiplied by the quantity of parts produced. Correspondingly, since investment, k_i, is sunk by stage 2, supplier i's surplus from reaching an agreement is its variable profit, $(p_i - c_i)\beta_i y$. The combined surplus from agreement is

$$(p_i^* - (p_i - r_i) + (p_i - c_i))\beta_i y = (r_i - \delta)\beta_i y.$$

Letting $\alpha \in [0, 1]$ represent the bargaining power of the maker, the Nash bargaining solution awards a share $1 - \alpha$ of the combined surplus from agreement to the supplier. Taking into account the cost of RSI, post-agreement supplier profit is

$$\pi_i = (1 - \alpha)(r_i - \delta)\beta_i y - k_i. \tag{3}$$

If $r_i - \delta < 0$, bargaining breaks down, the maker sources part i from outsiders, and the insider's profit would be $\pi_i = -k_i$. Note from (3) that suppliers must have at least some bargaining power, i.e. $\alpha < 1$, if they are to obtain a profit in stage 2. And, since suppliers would not do RSI without an expected profit, it is actually beneficial to the maker to have less than complete bargaining power.

At stage 1, supplier i determines the optimal value of k_i in the event that it would produce the part by maximizing π_i as in (3), taking y as given. Choosing k_i to maximize profit subject to (1) leads to

$$k_i = (\beta_i y(1 - \alpha)\rho_i)^2/4 \text{ and } r_i = \beta_i y(1 - \alpha)\rho_i^2/2. \tag{4}$$

Even if $k_i > 0$ from (4), it is possible that revenue would not be sufficient to cover k_i and hence would lead to a loss. In that case supplier i would set $k_i = 0$ and not produce the part. Since parts are ordered on the basis of increasing efficacy of RSI (i.e. since $\rho'(i) > 0$ for $i \in [0, N]$), it follows from (4) that k_i and r_i are strictly increasing in i for $k_i > 0$. We obtain the closed form for local suppler profits by substituting the solutions for k and r from (4) into equation (3), yielding

$$\pi_i = \beta_i y(1-\alpha)[\beta_i y(1-\alpha)\rho_i^2/4 - \delta]. \tag{5}$$

From this equation it is apparent that the greater is i, the greater are potential insider profits:

$$d\pi_i/di = (\beta_i y(1-\alpha))^2 \rho'(i)/2 > 0. \tag{6}$$

Define part $i = T$ as the critical part for which $\pi_T = 0$. Parts are produced by insiders with RSI for $i \geq T$ and by outsiders for $i < T$. Expressing this idea in terms of ρ_i , it follows that local production takes place if and only if $\rho_i \geq \rho_T$. Solving for the level of ρ that sets π equal to zero we obtain

$$\rho_T = 2\sqrt{\delta/(\beta_i y(1-\alpha))}. \tag{7}$$

We illustrate these results using Figure 1, which shows parts $i \in [0, N]$ ordered in terms of increasing ρ_i on the X-axis. The upward sloping curve representing r_i corresponds to the hypothetical reduction in assembler costs if the supplier chose k_i according to equation (4). The possible profit (or loss) of supplier i if it chooses to produce is shown by the solid line, denoted π. For $r_i \geq \delta$, profit is given by equation (3) which is increasing in i. For $r_i < \delta$, the supplier anticipates that bargaining will break down and it will suffer a loss equal to the amount of RSI (k_i). Since the lines denoting r_i and δ cross at $i = A$, the maker would prefer insiders for all parts $i \geq A$. However, supplier i's share of the return for parts $i \in [A, T)$ is not sufficient to cover the cost of RSI, with the outcome that these parts are sourced from outsiders. Profit is zero (the π line cuts the X-axis) at part $i = T$, which is the lowest value of RSI importance at which insiders can expect to break even. Each supplier i will commit to its RSI and choose to

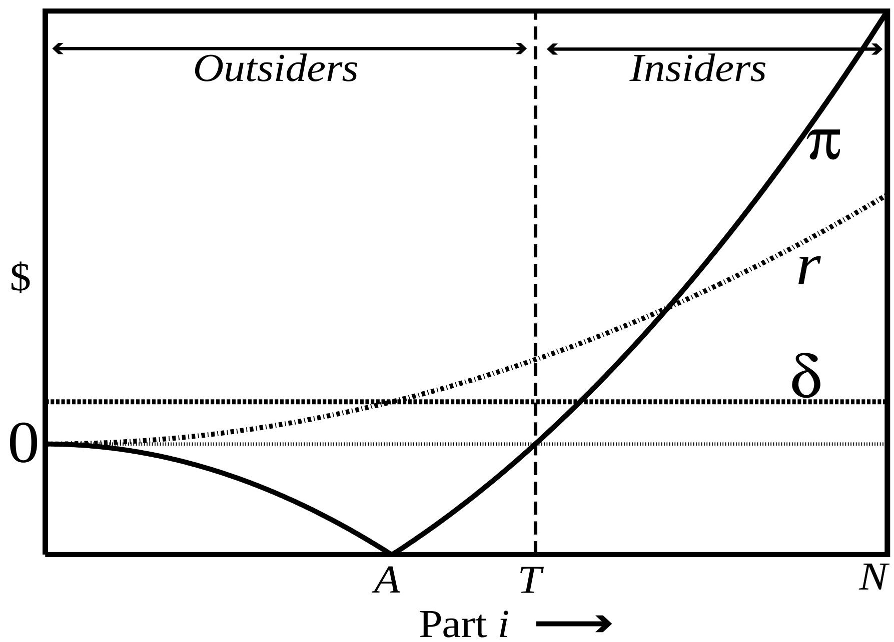

Figure 1: The determination of which parts are sourced from insiders

produce for $i \geq T$, but will set $k_i = 0$ and be inactive for $i < T$.

The implications of this model for trade depend on the locations of insiders and outsiders. The basic hypothesis used to develop the empirical specification is that insiders include local parts suppliers producing in the same country as the automaker. In particular, members of vertical *keiretsu* in Japan are viewed as insiders with respect to the production of auto parts for makers in Japan, but there may also be local vertical networks in other countries. This insider categorization is based on the logic that the information needed to design a part for a particular car model requires geographic proximity between upstream and downstream firms. However, we also consider the possibility that the coordination required for RSI can occur over longer distances if mediated by a multinational enterprise. Thus a supplier in the U.S. might be an insider when it transacts with a U.S. multinational firm operating a foreign market. Taking into account these two possibilities, the U.S. parts producers that export to non-U.S. car makers located abroad would be outsiders in these transactions. The empirical section will provide a test of the validity of these views of the boundaries of networks.

Since, as currently specified, the model predicts either zero sourcing of part i from outsiders or exactly $\beta_i y$ units, for the empirical specification, we adapt the model to reflect the greater continuity in export levels that we observe in the trade data. This involves relaxing our assumption of a representative maker so as to introduce heterogeneity across makers within each country as to whether to use a local insider or an outsider as a source for each part. Thus due to differences in characteristics, one maker might be using local insiders for a given part i, while another uses outsiders for the same part. Consequently each part will have a *probability* of being sourced from a local insider that is less than one, leading to non-zero import probabilities.

We introduce this heterogeneity by assuming that the cost advantage for outsiders, $\delta \equiv c_i - p_i^*$, varies randomly across the makers in each country. Since c_i, the costs of insiders, and p_i^*, the delivered price charged by outsiders, are both likely to vary across countries, we add j subscripts to identify the location of production. To determine the effect of variation in δ_j on the value of parts imported by country j, we first derive the probability, denoted Λ_{ij}, that a maker in country j sources part i from a local insider. From our model, Λ_{ij} equals the probability that δ_j is small enough to set $\pi_{ij} \geq 0$. Using the expression for π_{ij} shown in (5) we obtain

$$\Lambda_{ij} = \Pr[\pi_{ij} \geq 0] = \Pr[\delta_j \leq \beta_i y_j (1-\alpha)\rho_{ij}^2/4], \tag{8}$$

where y_j and ρ_{ij} now have j subscripts to reflect cross-country variation in output per maker and the efficacy of RSI.

The next step is to assume that δ_j is drawn from the Pareto distribution with scale parameter ϕ_j and shape parameter $\lambda > 1$. Thus, the expected value of δ_j, given by $\phi_j \lambda/(\lambda - 1)$, varies across countries but not across parts. The cumulative density function for a Pareto random variable is given by $F[x] = 1 - (\phi/x)^{\lambda}$, where ϕ is the minimum value. The use of the Pareto distribution allows us to express the probability of selecting a local insider in the following multiplicative form:

$$\Lambda_{ij} = F[\beta_i y_j (1-\alpha)\rho_{ij}^2/4] = 1 - [4\phi_j/(\beta_i y_j (1-\alpha)\rho_{ij}^2)]^{\lambda}. \tag{9}$$

As can be seen from (9), the probability of using a local insider is a continuous function of the parameters, .

Since our data involves the value of U.S. exports of auto parts, we let Υ_{ij} represent the probability that a maker in country j imports part i from the United States conditional on not purchasing the part from a local insider. The overall probability that country j imports part i from the United States is then given by (1 - Λ_{ij})Υ_{ij}. Thus, evaluating U.S. exports at their free-on-board (fob) prices, denoted p_i^{fob}, the expected value of U.S. exports of part i to country j is

$$\mathrm{E}[V_{ij}] = p_i^{\text{fob}}(1 - \Lambda_{ij})\Upsilon_{ij}\beta_i Y_j,$$

where Y_j is total car production in country j. The actual value of exports is given by expected exports multiplied by an error term, i.e. $V_{ij} = \mathrm{E}[V_{ij}]\exp(\xi_{ij})$, where ξ_{ij} is normally distributed. Dividing V_{ij} by Y_j, taking natural logs, and substituting in the expressions for Λ_{ij}, we obtain

$$\ln(V_{ij}/Y_j) = \lambda[\ln(4\phi_j) - \ln\beta_i - \ln y_j - \ln(1-\alpha) - 2\ln\rho_{ij}] + \ln(p_i^{\text{fob}}\beta_i) + \ln\Upsilon_{ij} + \xi_{ij}. \tag{10}$$

We combine the unobserved parameters that do not vary across countries, α, p_i^{fob} and β_i, into F_i. The country-specific unobserved variable, ϕ_j, joins ξ_{ij} in the regression's error term to yield

$$\ln(V_{ij}/Y_j) = F_i - \lambda\ln y_j - 2\lambda\ln\rho_{ij} + \ln\Upsilon_{ij} + \epsilon_{ij}, \tag{11}$$

where $F_i = \lambda(\ln 4 - \ln(1-\alpha)) - (\lambda - 1)\ln(\beta_i) + \ln p_i^{\text{fob}}$, and $\epsilon_{ij} \equiv \xi_{ij} + \lambda \ln(4\phi_j)$. Apart from the specification of $\ln \Upsilon_{ij}$, which is deferred until the regression analysis in Section 4, we discuss the data used to estimate this regression specification in the next section.

3 Data

Grouping the data into four categories—exports, car production, measures of the efficacy of relationship-specific investment and finally, concordance and description of parts,—we document the sources and measurement of the variables used in this study.

3.1 Export Data

We downloaded highly disaggregated U.S. export data from the Center for International Data maintained by Robert Feenstra at the University of California Davis. These data measure the fob *value* of parts exports, cover the 1989 to 1994 period, and are classified according to the Harmonized System (HS). We searched the HS descriptions to locate every ten-digit HS commodity category that involves automobile parts to obtain as complete a sample of exports as possible. Whenever possible, we confined the sample to parts specifically intended for passenger cars. In some cases even the most disaggregated HS codes do not distinguish between types of motor vehicles. A complete list of the HS codes that comprise our sample and their descriptions is available from the authors.

3.2 Car Production

Letting M_j denote the number of makers in country j, our model requires passenger car production, Y_j, and output per maker, $y_j \equiv Y_j/M_j$, by country. We estimate M_j based on a measure of the number of equal-sized makers as generated by the inverse of a Herfindahl index for each country. The Herfindahl index for country j, denoted H_j, is derived from output data for each maker in country j. Since we consider the possibility that U.S. parts exporters may be insiders in business relations with the foreign affiliates of U.S. makers, we also require the share of passenger car production by country accounted for by subsidiaries of the big three U.S.-based makers at that time (General Motors, Ford and Chrysler). We refer to this measure as BIG3. The Motor Vehicle Manufacturers Association of the United States provides annual car production data for 26 countries. We restrict our sample to that set of export markets. The same publication also provides the annual number of cars produced by each maker in each country, including production by the overseas subsidiaries of General Motors, Ford and Chrysler.

Table 1 lists the 26 countries with passenger car production together with an isocode used to identify each country. Column (1) shows the average number of individual parts imported by each of these countries across the six years of our sample. This average has an upper bound of the number of parts, which is 53. In the data, the average ranges from 7.8 to 52.5 with more than half of the countries importing on average at least 40 different parts each year. Column (2) lists each country's share of U.S. exports (to the 26 countries) and column (3) then provides each country's share of world car production outside the United States. Column (4) reports BIG3. As the column shows, General Motors, Ford and Chrysler produce cars in ten of the countries according to our data. Column (5) shows the number of makers, given by $M_j \equiv 1/H_j$. Our measure of local scale (in 1000s of cars per maker), y_j, appears in column (6).

The relationship between each country's share of car parts exports from the U.S. and its share of non-U.S. car production (from columns (2) and (3) respectively of Table 1) is shown in Figure 2. If each country imported U.S. parts in the same fixed proportion to output then the points would line up on the 45-degree line. We code each country into three categories of BIG3, namely "No Big 3 Production", "Minority Big 3" (less that 50% of output produced by Ford, GM, and Chrysler affiliates) and "Majority Big 3." Canada and Mexico are well above

Table 1: Imports of U.S. Parts by Auto-Producing Countries

	(1)	(2)	(3)	(4)	(5)	(6)
Country (ISO code)	**# Parts**	**% of Exp.**	**% of Cars**	**% of Big3**	**# Makers**	**Scale**
		V_j/V	Y_j/Y	Y_j^{BIG3}/Y_j	$M_j = 1/H_j$	y_j
Canada (ca)	50.7	63.84	3.84	80.59	3.9	290
Mexico (mx)	52.5	21.8	2.4	57.09	4.8	146
Japan (jp)	52.2	4.22	30.85	0	5.2	1734
United Kingdom (uk)	52	1.84	4.51	42.86	4.4	299
German (de)	51.8	1.7	15.11	34.74	4.9	907
Austral (au)	52.2	1.24	1.07	60.75	3.6	87
Korea, South (kr)	49.7	0.88	4.38	0	2.7	475
Belgium (be)	50.5	0.83	1.05	100	1	308
France (fr)	50	0.64	10.9	0	2.8	1162
Brazil (br)	45.2	0.57	2.98	37.04	3.6	242
Netherlands (nl)	49.3	0.56	0.34	0	1	101
Taiwan (tw)	49.5	0.42	0.97	30.41	5	57
Italy (it)	48.2	0.32	5.34	0	1.7	907
Sweden (se)	46.5	0.23	1.09	0	1.7	188
China (cn)	37.5	0.16	0.45	0	2	68
Austria (at)	33	0.15	0.08	0	1	24
Spain (es)	43.2	0.15	6.14	38.44	4.8	373
Argentina (ar)	42.3	0.14	0.65	12.58	2.7	71
Turkey (tr)	38.3	0.12	0.74	2.36	2.2	101
USSR / CIS (ru)	24	0.06	3.97	0	3	386
India (in)	30	0.05	0.64	0	1.7	114
Malaysia (my)	24.5	0.04	0.39	0	1	114
Yugoslavia (yu)	19.7	0.02	0.48	0	2.8	52
Poland (pl)	20	0.01	0.89	0	1.8	143
Hungary (hu)	9	0.01	0.1	0	1	30
Czechoslovakia (cz)	7.8	0	0.65	0	1	188

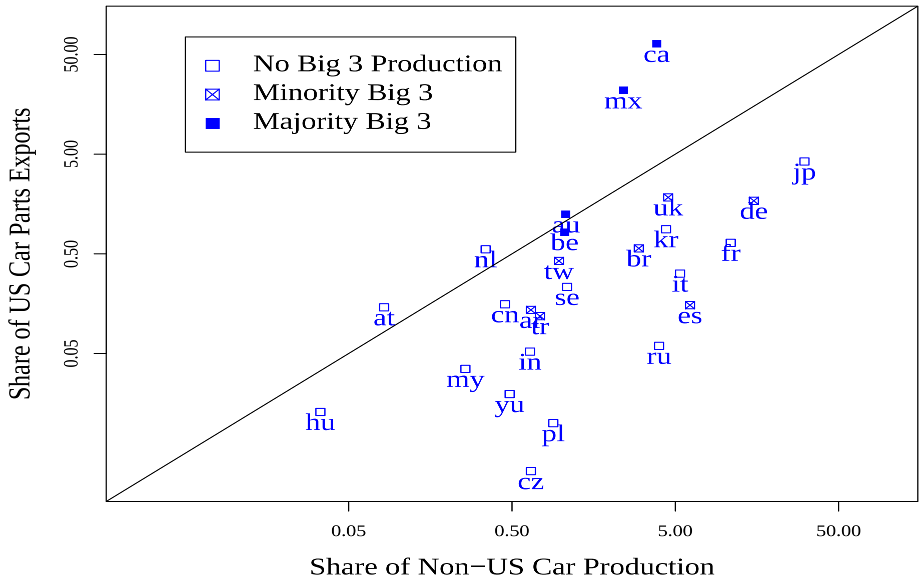

Figure 2: Car Production Shares and Shares of US Parts Exports

the 45-degree line, and therefore have import shares much greater than production shares. On the other hand, the former communist nations, the C.I.S. (ru), Czech Republic (cz), China (cn), Hungary (hu), and Yugoslavia (yu) import less than their car production share of U.S. parts. Japan also lies below the 45-degree line.

3.3 Determinants of the efficacy of RSI

Our formal theory does not specify the criteria determining which parts have high efficacy of RSI. One hypothesis is that vertical networks form to produce parts that have certain technical characteristics associated with a greater need for RSI. This group would include parts, such as engines, which involve costly investments in engineering and design that are relevant mainly to a particular auto-maker. We implement this idea by using a rating of the cost of engineering per part developed by Monteverde and Teece (1982) on the basis of information provided by a design engineer. This engineering cost rating, which we refer to as ECR, rates the engineering cost of developing a given part for a new car model on a 1 to 10 scale with 10 corresponding to the highest level. To the extent that these engineering costs are specific to a maker, they would represent relationship-specific investments and hence ECR can serve as a proxy for the efficacy of RSI. There are no doubt other possible technical characteristics that enhance the potential for RSI for a particular part. For example, relationship specific investments could be important for achieving "just-in-time" delivery, with the nature and extent of these investments varying over parts due to differing requirements for packaging and transport. Since the Japanese auto producers were pioneers in developing "just-in time" delivery, this type of RSI could be relatively more important for Japan. We do not consider this possibility due to lack of data. Spencer and Qiu (2001) propose a further possibility (also not considered) that a higher efficacy of RSI is associated with parts that are more important part in the sense that they represent a greater share of the cost of an auto.

A second hypothesis of particular relevance for our analysis of *keiretsu* in Japan is that a greater strength of network involvement in the production of a part may itself raise the efficacy of RSI for that part. Two features of vertical networks could be significant here. First, as detailed in our model, the formation of a vertical network ameliorates the hold-up problem and hence raises the incentives for suppliers to engage in RSI. Secondly, the effect of vertical networks in increasing the flow of information between suppliers could suggest new possibilities for relationship-specific investments and generally improve the efficiency with which these investments are made. For any particular part, we hypothesize that the strength of these effects will vary with the strength of network involvement as measured by the degree to which producers of that part participate in the network. Taking this approach, we can include the possibility that the group of parts produced with RSI in a vertical network may be determined by historical or cultural factors in a particular country, not just the technical characteristics of parts. Thus, under this hypothesis, a vertical network such as *keiretsu*, could potentially raise the efficacy of RSI for the parts they produce in Japan, but these parts need not be the same as the parts produced by other vertical networks, such as in the United States. Of course, there is also an alternative possibility, which we cannot address with our data, namely that the vertical network is based on cronyism and does not generate RSI. In this case, the preferential sourcing of parts from insiders would reduce rather than raise the efficiency of production.

We develop three measures for the strength of network participation by part. Two of these measures, INH-U and INH-J, measure the extent to which a part is produced in house in the U.S. and Japan respectively and the third, KEI measures *keiretsu* involvement by part in Japan. Monteverde and Teece (1982) provide estimates of the share of in-house sourcing for each part by General Motors and Ford. INH-U is then a single measure (by part) of in-house production shares in the U.S., generated by taking a weighted average of the Monteverde and Teece (1982) measures in which GM has two-thirds weight so as to roughly reflect its production volume.

Our measures, INH-J and KEI, are derived using data from *The Structure of the Japanese Auto Parts Industry*, 1990, by Dodwell Marketing Consultants. This book lists the major Japanese suppliers of individual auto parts for each automobile manufacturer in Japan. It identifies whether the part is produced "in-house" and provides information as to the "grouping" of each supplier. A supplier is considered to be in a particular maker's group based on the equity holdings of the maker, supplier reliance on the maker for 50% of its sales, or other factors such as historical relationships or personnel ties. Following standard terminology in the literature cited in the introduction, we refer to Dodwell's "groupings" as vertical *keiretsu*.

Defining a "link" as a unique pairing of a maker and a major supplier, we count the respective numbers of links involving in-house production and *keiretsu* for a given maker and part. Dividing by the total links for each maker, we then obtain the share of in-house links and *keiretsu* links per maker. Finally, to generate INH-J and KEI as single measures per part, we calculate the weighted average across makers of the shares of in-house links and *keiretsu*

Table 2: Major suppliers of mufflers to the six largest automakers

Maker:	Toy.	Nis.	Hon.	Maz.	Mit.	Suz.
Toyota						
Nissan						
Honda						
Mazda						
Mitsub.						
Suzuki						$\oplus$
Sango	$\otimes$					
Futaba	$\otimes$		$\odot$		$\odot$	$\odot$
Calsonic		$\otimes$				
Sankei GK			$\otimes$			$\odot$
Niho				$\otimes$		
Sankei K				$\odot$	$\otimes$	
Hoei					$\otimes$	
Comex				$\odot$		
Miyoshi				$\odot$		
Fraction in-house	0	0	0	0	0	1/3
Fraction *keiretsu*	2/2	1/1	1/2	1/4	2/3	0/3
Weight:	36%	18%	12%	8%	10%	8%

respectively using car production in 1996 as the weight. Since the links that form the basis of our measures involve only suppliers located in Japan, our measures do not depend directly on the level of imports of each part.

Using the example of mufflers, which has a large *keiretsu* presence, Table 2 illustrates the derivation of our INH-J and KEI variables. The table sets out the main suppliers of mufflers (as defined by Dodwell) for the makers (Toyota, Nissan etc) in Japan. We illustrate supply links by in-house production with $\oplus$, supply by a *keiretsu* member, with $\otimes$, and supply by an outsider with $\odot$. The first section lists the makers to show production in-house. For the case of mufflers, Suzuki is the only maker to produce in-house. Since for Suzuki, there are two other suppliers (Futaba and Sankei GK), its ratio of in-house links to total links is 1/3. Weighting by the fraction of output (8%) produced by Suzuki, INH-J (not shown) for mufflers is 2.67%. The next group of suppliers, Sango to Hoei, represent firms that are part of one of the makers' *keiretsu*. However, it is interesting to note that some of these suppliers also produce for makers outside their own *keiretsu*. Thus Futaba is part of the Toyota *keiretsu*, but also produces for Honda, Mitsubishi and Suzuki. The final two suppliers, Comex and Miyoshi, are outsiders that supply only Mazda. As can be seen from the table, there are only two suppliers for Toyota (Sango and Futaba) and since they are both member of the Toyota *keiretsu*, the number of *keiretsu* links relative to total links is 2/2 = 1. Weighting this fraction by the share of output across the makers listed in the table (covering 92% of auto output), we obtain KEI = 68.67/0.92 = 74.6%. [5]

In all, we have four proxies for the efficacy of relationship-specific investment in the study. None of these variables contains time-series variation. Table 3 defines the variables and displays their correlations. Monteverde and Teece (1982) establish that the technical measure, ECR, is positively related to GM and Ford's decision to produce in house.[6] We also observe this positive association in our correlations: the weighted sum of the Ford and GM in-house production share, INH-U, has a significant and positive correlation with ECR. Interestingly, Japanese in-house production as measured by INH-J has even stronger positive relationship with ECR. These correlations indicate that parts with high engineering cost ratings tend to be produced in-house. In contrast, the table shows that our other measure of the strength of network participation, KEI, has virtually no correlation with ECR and a negative, but insignificant, correlation with INH-J and INH-U. If all four proxies are driven by the same underlying reason for RSI, then they should all be positively correlated. Leaving aside problems of measurement, this suggests that parts produced with high *keiretsu* involvement are not associated with high costs of engineering. *Keiretsu*-produced parts may be associated with some other technical characteristics, such as those involved with "just-in-time" delivery, but it is also possible that

[5]Accounting for links with the makers (Daihatsu, Fuji, Hino and Isuzu) not shown in the table, we obtain KEI = 72.4% for mufflers. For concordance with the trade data, we combine mufflers with exhaust pipes. Since KEI = 73.4% for exhaust pipes, we obtain KEI = 72.9% for the combined category.

[6]Monteverde and Teece (1982) convert the in-house production share into a binary variable and conduct probit regression analysis.

Table 3: Correlations between proxies for RSI importance

	INH-J	KEI	INH-U	ECR
INH-J: share of in-house links in Japan	1.000			
	(50)			
KEI: share of *keiretsu* links in Japan	-0.061	1.000		
	(50)	(50)		
INH-U: share of in-house purchases by GM and Ford	0.295[c]	-0.147	1.000	
	(39)	(39)	(41)	
ECR: engineering cost rating (1-10)	0.602[a]	0.015	0.333[b]	1.000
	(40)	(40)	(41)	(42)

Note: Significance at the 1%, 5%, and 10% level shown with the superscripts *a*, *b*, and *c* respectively. The number of observations used in the pairwise correlations are shown in parentheses.

they mainly reflect the outcome of historical and cultural factors in Japan.

3.4 Concordance and Description of Parts

The different sources have unique ways of categorizing parts. The export data is identified according to the Harmonized System (HS), whereas the data from Dodwell (1990) and Monteverde and Teece (1982) reflect the categorization of the authors. We created a concordance to combine the information from the difference sources. Based on an examination of the data, we formed the 53 parts categories shown in Tables 4 and 5. These categories reflect a level of aggregation equalling or exceeding the aggregation level in the various sources. Thus, each of the part categories used in the different sources of data mapped to one of the categories we devised. In cases where multiple part categories mapped to a single category of ours, we summed the HS-level exports and averaged the RSI proxies.

Tables 4 and 5 portray some characteristics of the 53 parts. Column (1) shows the average number of countries that imported the part in the six years of our data. The column reveals

Table 4: Top 25 Exported Parts Categories

	(1)	(2)	(3)	(4)	(5)	(6)
Part	**# Mkts**	**% of Total**	**% to JPN**	INH-J	KEI	ECR
		V_i/V	V_{iJ}/V_i	(Dodwell)		(M&T)
Engines	22	15.4	1.3	53.4	25	9
Transmissions	20.5	8.1	0.4	24	54.6	10
Body Stampings	14.2	8	0.2			8
Engine Parts	23.2	7.2	3.3	16.1	22.6	7.3
Wiring Sets	22	6.7	0.8	0	0.8	4
Tires	22.3	5.4	22.7	0	0	
Brakes	21.3	5.2	1.6	5.2	34.8	5.7
Axles	22.3	4.9	0.6	49.2	31.3	10
Seat Parts	13.8	3.9	3.8	0	48.5	4
Bumpers	21.8	2.8	12.3	31	17.6	7
Wheels	21.2	2.6	9.7	7.3	29.2	5.7
Steering	20.2	2.5	0.5	13.8	38.5	7.1
Catalytic Converters	22.5	2.3	26.2	22.3	20.5	9
Mufflers+Exhaust Pipes	16.5	2	13.9	1.3	72.9	3
Safety Belts	14	1.7	0.4	0	17.8	3
Radios	22.5	1.7	4.5	0	4.5	5.7
Windshield Wipers	21.2	1.4	0.8	0	13.5	7
Gaskets	22.8	1.3	1.9	0	14.9	
Radiators	19.5	1.2	1.2	0	27	8
Windows	19.8	1.2	5.9	0	6	1
Lighting	21	1.2	0.5	0	33.1	3.5
Fuel Pumps	22.8	1.1	0.9	1.3	49.9	6
Climate Control	19.7	1.1	7.2	6.6	47.5	5.7
Shock Absorbers	20.5	1.1	1.9	11.9	12	2
Starter Motors	20.5	1	16.1	0	35.8	7

Table 5: Export Patterns for Other Parts

	(1)	(2)	(3)	(4)	(5)	(6)
Part	**# Mkts**	**% of Total**	**% to JPN**	INH-J	KEI	ECR
		V_i/V	V_{iJ}/V_i	(Dodwell)		(M&T)
Alternators	20	0.8	1	0	35.8	7
Oil/Fuel Filters	22	0.7	2.1	0	51.6	1
Flasher Units	18.7	0.6	3.5	0	59.5	
Intake Air Filters	22.3	0.5	12.2	0	34	4.3
Diesel Fuel Injectors	22.7	0.5	4.5	0	35.6	
Batteries	17.2	0.5	0.7	0	0	2
Seats	18	0.5	2.8	12	42.7	
Clutches	20.5	0.5	4.1	9.7	44.4	
Mirrors	14	0.5	1.1	0	26.2	5
Meters	21.2	0.4	2.9	0	23.8	8
Brake Linings	18	0.4	0.9	0	11.9	
Drive shafts	19.7	0.4	0.8	20.4	32.6	3
Cam/Crankshafts	18.7	0.3	0.8	39.7	16.9	9
Hinges	15.7	0.3	0.5	0	60.5	5
Locks	14.2	0.3	0.2	0	58.5	5.5
Spark Plugs	20.3	0.3	5.1	0	17.8	1
Ignition Coils	17.7	0.3	0.7	0	47.6	2
Distributors	11.5	0.3	0.4	0	41.6	6
Coil Springs	11.7	0.2	0.2	0	11.9	3
Fans	19.3	0.2	0.4	0	53.2	4
Body Shells	17.3	0.2	7.9			
Horns	20.5	0.1	0.8	0	47.8	2
Furniture Parts	14.5	0.1	2.6	4.9	44.5	4.7
Flywheels+Pulleys	17.3	0.1	0.6	6.8	64.4	
Rubber Mechanical Articles	14.2	0	6.4	0	0	
Clocks	14.5	0	1.7	0	32.3	2
Chassis	13.8	0	1.8			6.8
Brake Hose	4.3	0	0.3	0	40.5	

that the majority of parts were shipped to most of the 26 countries that produce automobiles. The parts are ordered by their share of the value of U.S. parts exports, as shown in column (2). Engines top the list at 15.4%, followed by transmissions (8.1%) then body stampings (8.0%). Column (3) displays Japan's share of U.S. parts exports for each part. This column reveals high Japanese imports of catalytic converters (26.2%), tires (22.7%), and starter motors (16.1%). In contrast, Japanese purchases account for less than 1.3% of engines, transmissions, and body stampings exports from the United States. The last three columns contain data on the share of in-house links in Japan (INH-J), *keiretsu* links in Japan (KEI) and engineering cost ratings (ECR). Due to incomplete data for our measures of engineering cost and network participation (indicated by blanks in the table), the regressions we estimate use at most 50 parts categories.

4 Regression Analysis

Recall that the model generated the following equation for the ratio of the value of U.S. exports of part i to country j to total production in country j:

$$\ln(V_{ij}/Y_j) = \mathrm{F}_i - \lambda \ln y_j - 2\lambda \ln \rho_{ij} + \ln \Upsilon_{ij} + \epsilon_{ij}, \tag{12}$$

where y_j is the number of vehicles produced per maker in country j, Υ_{ij} represents the probability that country j imports part i from the United States conditional on the part not being purchased from a local insider and $\mathrm{F}_i = \lambda(\ln 4 - \ln(1-\alpha)) - (\lambda - 1)\ln(\beta_i) + \ln p_i^{\text{fob}}$.

A central parameter in the analysis is the efficacy of RSI, ρ_{ij}. Letting NET_i take on the values given by our measures, KEI or INH-J, of network intensity in Japan, we assume that the log of ρ_{ij} is given by

$$\ln \rho_{ij} = E_i + \theta_1 \mathrm{JPN}_j + \theta_2 \mathrm{NET}_i \cdot \mathrm{JPN}_j + \theta_3 \mathrm{ECR}_i \cdot \mathrm{JPN}_j, \tag{13}$$

where JPN$_j$ equals one for Japan and zero otherwise. In estimating (12), the first term, E_i will be absorbed into a fixed effect for each part. We hypothesize that long-term relationships between suppliers and makers allow for higher efficacy of RSI in Japan. If so, both θ_1 and θ_2 will be positive. The interaction term, θ_2, will be positive if a greater strength of network involvement in the production of a part is associated with an increase in the Japanese advantage with respect to the efficacy of RSI. It is possible that Japanese vertical networks represent unique institutions that are particularly useful for facilitating communication in the design or delivery of parts, leading to greater investment in RSI and an increase in local production. This effect may be larger for parts that have certain technical characteristics associated with a greater need for coordination and communication to meet maker specifications. We interact ECR with JPN to test whether our rating of engineering costs is associated with a higher efficacy of RSI in Japan as would be indicated by a positive value of θ_3. As previously mentioned, it is possible that the involvement of Japanese vertical networks in the production of a part may itself raise the efficacy of RSI for that part by increasing the flow of information and ameliorating the hold-up problem associated with RSI. In this case the association between RSI efficacy and technical characteristics of parts, including engineering cost, may be weak or non existent.

We now examine the elements of Υ_{ij}, which is the probability that a maker in country j would import part i from the United States conditional on not purchasing part i from a local insider. Υ_{ij} reflects the comparative advantage of the U.S. in each part together with the trade costs associated with shipment to country j. In addition, car makers may find it easier to meet U.S. safety and environmental standards if they obtain the relevant components from U.S. based suppliers. Hence, we hypothesize that the propensity to import U.S. made parts is increasing in the share of national car output exported to the U.S., as denoted by X-US.[7]

We also include the possibility that U.S. parts exporters are insiders in business relations

[7]We thank Jerry Hausman for this suggestion.

with the foreign subsidiaries of U.S. makers. Since U.S. subsidiaries would then preferentially import parts from the United States, we hypothesize that Υ_{ij} is increasing in the share of output made by U.S. subsidiaries in country j (represented by BIG3). A further implication of the theory is that these subsidiaries would import relatively more RSI-intensive parts. We test this proposition by interacting BIG3 with ECR as well as INH-U. If insiders produce RSI-intensive parts and if U.S. parts suppliers are insiders when trading with U.S. foreign affiliates, then we expect these interaction terms to be positive. Taking all these factors into account we obtain

$$\ln \Upsilon_{ij} = \nu_i - \tau_j + \omega_1 \text{X-US}_j + \omega_2 \text{BIG3}_j + \omega_3 \text{NET}_i \cdot \text{BIG3}_j + \omega_4 \text{ECR}_i \cdot \text{BIG3}_j, \tag{14}$$

where ν_i denotes a part-specific term reflecting U.S. efficiency in part i, τ_j is a country-specific term representing the trade costs of U.S. shipments to country j, and NET_i takes on the value INH-U_i.

We use a number of variables to capture trade costs, τ_j. Following standard practice in gravity equations, we calculate the log of great-circle distance in miles between country j's major city and the population centroid of the U.S. (Kansas City: latitude 40N, longitude 95W). We also include indicator variables for countries that are English-speaking (Australia, Canada, and the United Kingdom), communist in 1989 (China, Czechoslovakia, Hungary, Poland, USSR/CIS, and Yugoslavia). We also add indicators for Canada and Mexico to capture unique aspects such as trade arrangements (the 1965 Canada-U.S. Auto Pact and *maquiladora* program launched by Mexico in the same year) and adjacency to the U.S. that may explain their large volumes of imports as shown in Table 1. Finally we include the log of per capita GDP (1989–94 World Bank data), another standard variable in gravity equations.

Substituting (14) and (13) into (12), our full specification is

$$\ln(V_{ij}/Y_j) = \text{FE}_i - \lambda \ln y_j + \gamma_1 \text{JPN}_j + \gamma_2 \text{NET}_i \cdot \text{JPN}_j + \gamma_3 \text{ECR}_i \cdot \text{JPN}_j - \tau_j$$
$$+\omega_1 \text{X-US}_j + \omega_2 \text{BIG3}_j + \omega_3 \text{NET}_i \cdot \text{BIG3}_j + \omega_4 \text{ECR}_i \cdot \text{BIG3}_j + \epsilon_{ij}, \qquad (15)$$

where $\gamma_1 \equiv -2\lambda\theta_1$, $\gamma_2 \equiv -2\lambda\theta_2$, $\gamma_3 \equiv -2\lambda\theta_3$ and $\text{FE}_i \equiv F_i - 2\lambda E_i + \nu_i$ is the fixed effect for each part. This fixed effect captures U.S. comparative advantage across parts (ν_i) and fob prices (in F_i). The use of fixed effects precludes direct estimation of the effects of our proxies for the efficacy of relationship-specific investment (reflected in E_i from (13)). Based on the ideas outlined above that the coefficients on the Japan-specific terms (θ_i for $i = 1, 2, 3$) in (13) are positive, the coefficient on JPN and its interaction terms should be negative. Also, local scale, y_j, enters negatively. The coefficient (ω_1) on X-US and the coefficients (ω_i for $i = 2, 3, 4$) on BIG3 and its interaction terms are hypothesized to be positive. Determinants of trade costs, τ_j, include distance, per capita income, dummies identifying English speaking and communist countries and Canada and Mexico.

We estimate the model parameters using a panel of parts exports from 1989 to 1994 and report the results in Table 6. All regressions include year-specific intercepts and we calculate standards errors that are robust to the possibility of correlation across time for country-part combinations.[8] We begin with a "naive" specification that omits the local scale effect, $\ln y_j$, implied by the model. In this specification, shown in column (1), the log of the ratio of U.S. car imports to production is simply a function of trade costs, per capita income, and passenger car exports to the United States. It is consistent with the proposition that U.S. parts imports are proportional to production. As shown in column (1), this specification indicates that Japan imports are "too low." Column (2), portraying results when we add local scale, y_j, and BIG3,

[8] We use STATA's robust cluster command.

Table 6: Regressions with Part Fixed Effects

	Dependent Variable: ln U.S. Exports of Part i					
	(1)	(2)	(3)	(4)	(5)	(6)
ln miles from U.S.	1.593[a]	0.222	0.205	0.241	0.207	0.223
	(0.204)	(0.208)	(0.211)	(0.241)	(0.210)	(0.212)
ln income p.c.	0.266[a]	0.260[a]	0.257[a]	0.230[a]	0.256[a]	0.248[a]
	(0.051)	(0.049)	(0.049)	(0.056)	(0.049)	(0.049)
English speaking	0.976[a]	0.716[a]	0.781[a]	0.798[a]	0.781[a]	0.761[a]
	(0.107)	(0.111)	(0.111)	(0.126)	(0.110)	(0.112)
Communist	-0.259	-0.756[a]	-0.804[a]	-0.741[a]	-0.80[a]	-0.826[a]
	(0.162)	(0.155)	(0.157)	(0.175)	(0.158)	(0.158)
Mexico	6.322[a]	3.902[a]	3.770[a]	3.988[a]	3.771[a]	3.798[a]
	(0.364)	(0.373)	(0.373)	(0.428)	(0.372)	(0.374)
Canada	5.540[a]	2.951[a]	2.796[a]	3.044[a]	2.796[a]	2.980[a]
	(0.580)	(0.547)	(0.536)	(0.605)	(0.535)	(0.525)
X-US (car exports to U.S.)	0.90[a]	0.967[a]	1.047[a]	1.058[a]	1.051[a]	0.937[a]
	(0.339)	(0.309)	(0.313)	(0.351)	(0.314)	(0.302)
ln y (ln cars per maker)		-0.741[a]	-0.736[a]	-0.732[a]	-0.736[a]	-0.744[a]
		(0.038)	(0.039)	(0.045)	(0.039)	(0.039)
JPN	-1.441[a]	0.394[c]	0.834[b]	0.551	0.830[b]	1.075[a]
	(0.188)	(0.209)	(0.373)	(0.487)	(0.371)	(0.342)
BIG3		0.686[a]	0.691[a]	0.470	0.568[a]	0.599[a]
		(0.171)	(0.173)	(0.40)	(0.181)	(0.184)
KEI · JPN			-1.457	-1.310	-1.472	-2.341[a]
			(1.116)	(1.351)	(1.107)	(0.899)
ECR · JPN				0.650		
				(0.767)		
ECR · BIG3				0.700		
				(0.632)		
INH-U · BIG3				-0.228		
				(0.457)		
INH-J · JPN					0.078	0.258
					(1.182)	(1.172)
INH-J · BIG3					1.696	1.702
					(1.102)	(1.105)
N	6177	6177	5895	4639	5895	5791
R^2	0.560	0.634	0.637	0.636	0.638	0.644
RMSE	1.73	1.578	1.557	1.569	1.556	1.542

Note: Standard errors robust to correlation within part-country clusters, are in parentheses with [a], [b], and [c] denoting significance at the 1%, 5%, and 10% level. Sample period runs from 1989 to 1994. Year effects included but not reported.

reveals that the negative Japan effect is a consequence of failing to control for local scale effects which enter negatively and significantly. Once we add scale, Japan tends to import more than the model predicts (significant at the 10% level). The R^2 improves in this specification and the estimated distance coefficient, perversely positive in column (1), now enters insignificantly. We also find that a country's imports of U.S. auto parts rises with the BIG3 share of production. Columns (3)–(6) in Table 6 show results when we add various interaction terms involving BIG3 and JPN.

The result (from columns (2), (3), (5) and (6)) that Japan is a large importer of U.S. auto parts does not support the hypothesis that Japanese institutions promote insider trade at the expense of imports (from outsiders) for *all* parts. Japan's larger than expected imports may be explained by the fact that, relative to a number of the other countries which had high tariffs and domestic content requirements, Japan has low formal trade barriers.[9] Since tariffs and other formal trade barriers are not used as controls in the model, it seems likely that these omitted variables might help explain Japan's high level of imports. Another possibility is that Japan's imports from the U.S. were unusually high due to pressure from the U.S. government.[10]

Most of the coefficients of the trade cost variables are sensible and significant across the specifications. Higher per capita income leads to higher parts imports. Per capita income may capture differences in transportation infrastructure. English language contributes to trade, whereas communist countries import fewer parts. Once we control for local scale in columns (2)–(6), the distance coefficient always has a positive sign but is not significantly different from zero. In regressions without the Canada and Mexico indicator variables, the estimated coefficient on distance is negative and significant. Exports to the U.S., X-US, are associated with

[9] For example, starting in 1984, Australia introduced an 85% domestic content requirement for autos and tariffs on autos ranged from 45% in 1988 to 30% in 1994. See Truett and Truett (1997).

[10] In response to President George Bush's trip to Japan in January 1992, Japanese automakers announced a "voluntary" plan to double their 1990 purchases of U.S. auto parts by 1994. Actual purchases rose 30% from 1992 to 1993. See McMillan (1996).

greater imports of U.S. auto parts, a result consistent with the proposition that nations import U.S. auto parts partly in order to comply with U.S. technical regulations. It is also the case that Canada and Mexico import significantly more than average. This reflects a combination of geographic and trade policy factors.[11]

Column (3) displays results when we add KEI·JPN. It enters negatively but is not significant. These results indicate that Japan's "greater than expected" level of imports may not hold for parts with high levels of *keiretsu* participation. We add interactions using the Monteverde and Teece measures of engineering cost ratings and U.S. in-house production in column (4). None enter significantly. In column (5) we exclude the Monteverde and Teece variables that limit our sample (they are only available for 40 of our parts categories) and instead use INH-J, a variable we found to be strongly correlated with the engineering cost rating. Again, no interactions terms are significantly different than zero.

Column (6) shows results utilizing the previous specification but estimated without the parts category "Mufflers+Exhaust Pipes". From Table 4, "Mufflers+Exhaust Pipes" represents only 2% of the parts exported by the United States, but 13.9% of the parts imported by Japan. This high level of imports may reflect the importance of U.S.-made exhaust systems in ensuring that cars destined for the United States comply with U.S. emission standards. Any such effect would not be fully captured by X-US, since it corrects only for the "average" relationship between imports of parts and exports of cars to the United States. When "Mufflers+Exhaust Pipes" is excluded, we find that *keiretsu* participation has a negative and significant impact on Japanese imports. The results do not indicate, however, that imports of *keiretsu*-intensive parts are significantly lower in Japan than other counties. According to Table 4, the second highest KEI after "Mufflers+Exhaust Pipes" is for "Flywheels+Pulleys". Summing the coefficient on

[11] Note that our sample pre-dates NAFTA and that Canada and U.S. had essentially integrated markets in autos and their parts due to the 1965 Canada-U.S. Auto Pact.

JPN, 1.075, and the coefficient on the interaction, -2.341, multiplied by its value for KEI, 0.644, yields a small negative number -0.433.

The specification used in Table 6 has the advantage that information from 40-50 parts is combined to obtain the estimates of the responsiveness of U.S. exports to import-country characteristics. It imposes the restriction that the only differences in coefficients across parts lie in the fixed effect and the interactions with JPN and BIG3. This leads to efficient estimation if the assumption holds. However, there are plausible reasons to believe that coefficients on other variables might also vary across parts. For instance, as mentioned above, the import sensitivity to X-US may vary across parts. In addition, differences in transportability should, in all likelihood, lead to differences in distance and adjacency (Canada and Mexico) effects. This could change our results of interest if there were, for instance, a correlation between transportability and the proxies for the efficacy of RSI.

We investigate the robustness of our results by using the following two-step method that relaxes restrictions on the estimated coefficients. In the first step, instead of stacking the parts and estimating fixed effects, we estimate one equation per part. Thus all coefficients (not just the intercept) are allowed to vary from part to part. Since there is no variation in the RSI proxies for a given part, the interactions involving NET and ECR are omitted in the first step. In the second step, we regress the estimated coefficients for JPN and BIG3 on our network and engineering cost rating measures of the efficacy of RSI. These second-step regressions have only one observation per part. The JPN and BIG3 coefficients have different standard errors that we use as (inverse) weights to correct for heteroskedasticity in the second step regressions. [12]

The intercepts of the second-step regressions correspond to the coefficients on JPN and BIG3 shown in Table 6 and the slope coefficients on NET and ECR correspond to coefficients on the

[12] See Saxonhouse (1976) for a discussion of this method. We again use STATA's robust cluster command to obtain the first-step standard errors.

Table 7: Step 2 Regression Results

	(1)	(2)	(3)	(4)	(5)
JPN	0.424[b]	1.113[a]	1.282[b]	1.159[a]	1.164[a]
	(0.189)	(0.364)	(0.594)	(0.385)	(0.398)
BIG3	0.553[a]		0.173	0.484[a]	0.523[a]
	(0.159)		(0.533)	(0.173)	(0.174)
KEI· JPN		-2.232[b]	-2.894[b]	-2.255[b]	-2.279[b]
		(1.010)	(1.164)	(1.021)	(1.102)
ECR· JPN			0.230		
			(0.804)		
ECR· BIG3			1.231		
			(0.817)		
INH-U· BIG3			-0.311		
			(0.626)		
INH-J· JPN				-0.591	-0.587
				(1.491)	(1.509)
INH-J· BIG3				1.601	1.491
				(1.294)	(1.282)
	Summary statistics for JPN coef. regressions				
N	53	50	40	50	49
R^2	0.000	0.092	0.146	0.095	0.087
RMSE	1.378	1.328	1.294	1.34	1.357
	Summary statistics for BIG3 coef. regressions				
N	53		41	50	49
R^2	0.000		0.056	0.031	0.028
RMSE	1.154		1.162	1.087	1.075

Note: Estimated by weighted least squares (see explanation in text). Standard errors in parentheses with [a], [b], and [c] denoting significance at the 1%, 5%, and 10% level.

various interaction terms. To see this, note that the terms, $\gamma_1 \text{JPN}_j + \gamma_2 \text{NET}_i \cdot \text{JPN}_j + \gamma_3 \text{ECR}_i \cdot \text{JPN}_j$, from (15) can be re-expressed as $(\gamma_1 + \gamma_2 \text{NET}_i + \gamma_3 \text{ECR}_i)\text{JPN}_j$. Step one estimates the term inside the parentheses. The second-step regression of these estimated coefficients on NET and ECR recovers $\hat{\gamma}_1$, $\hat{\gamma}_2$ and $\hat{\gamma}_3$ as the intercept and slope estimates.

We evaluate the part-specific regressions in step one by examining the mean across parts of the estimated coefficients. In all cases, the mean value corresponds very closely to the estimates shown in Table 6 although we observe variation across parts in the estimates. Interestingly, we find evidence that the relationship between exports of “Mufflers+Exhaust Pipes” and the explanatory variables differs dramatically from the rest of the sample. Specifically, the estimates for every coefficient for this part fall outside the 95% confidence interval surrounding the mean of the estimates of the other part categories. As previously hypothesized, "Mufflers+Exhaust Pipes" exports are particularly sensitive to X-US.

Table 7 displays the results of second-step regressions that generate results corresponding to the five columns ((2)–(6)) of Table 6. For each column, the estimates are derived from two second-step regressions using estimated coefficients for JPN and BIG3 from the step-one regressions. The summary statistics (N, R^2, and RMSE) for each regression appear at the bottom of the table. The table indicates that the two-step procedure produces similar results to those found previously. The coefficient on JPN is positive and a bit larger and more significant than before. Now the variable KEI·JPN enters significantly negative (5% level) for the regressions that include "Mufflers+Exhaust Pipes" and this estimate does not change when this part category is excluded. BIG3 countries are shown to import significantly more U.S. parts. The positive coefficients on ECR·BIG3 and INH-J·BIG3 are consistent with the proposition that the BIG3 disproportionately import RSI-intensive parts but the these estimates are not significant.

5 Conclusion

We find evidence that networks do matter for trade and that Japan *is* different. Far from being a "closed" market, Japan imports more auto parts from the U.S. than its observable characteristics (car production, scale, distance from U.S., etc.) would predict. We find that greater scale of host-country auto production deters parts imports, a result supporting the model's prediction that local scale increases the returns to relationship-specific investment. Two results suggest that vertical networks matter for trade. First, U.S. exports to Japan decrease as the importance of *keiretsu* sourcing of a part rises. Second, countries where the Big 3 U.S. automakers account for large shares of car production tend to import more parts from the United States.

A preference for insiders over outsiders results in our model from endogenous decisions by insiders to conduct relationship-specific investment. Insider networks may reflect technical characteristics of parts that give rise to a high efficacy of RSI or may themselves generate greater efficacy of RSI. In this context, rather than being exclusionary, networks can be a source of greater efficiency in production. Our results are consistent with this view of networks but further evidence would be required to rule out the possibility that particular networks, such as *keiretsu* in Japan, are not based on cronyism. Since vertical *keiretsu* links are not correlated with engineering cost ratings, they do not appear to reflect technical efficiency, at least as far as we can measure it. Thus, the economic basis for cross-part variation in the prominence of *keiretsu* remains a puzzle that merits further investigation.

References

Aoki, Masahiko, 1988, *Information, Incentives, and Bargaining in the Japanese Economy* Cambridge: Cambridge University Press.

Asanuma, Banri, 1989, "Manufacture-Supplier Relationships in Japan and the Concept of Relation-Specific Skill," *Journal of the Japanese and International Economies* 3(1), 1-30.

Branstetter, Lee, 2000, "Vertical keiretsu and knowledge spillovers in Japanese manufacturing: An empirical assessment." *The Journal of the Japanese and International Economies* 14, 73-104.

Casadesus-Masanell, Ramon and Daniel F. Spulber, 2000, "The Fable of Fisher Body," *Journal of Law and Economics* 43, 67-103.

Center for International Data, University of California Davis, 2001, ⟨http://data.econ.ucdavis.edu/international/index.html⟩

Dodwell Marketing Consultants, 1990, *The Structure of the Japanese Auto Parts Industry*, Tokyo: Dodwell Marketing Consultants.

Fung, K.C., 1991, "Characteristics of Japanese industrial groups and their potential impact on U.S.-Japan trade," In: Baldwin, R., (Ed.), *Empirical Studies of Commercial Policy.* Chicago: University of Chicago Press, 137-168.

Klier, Thomas, 1994, "Lean Manufacturing and the Decision to Vertically Integrate: Some Empirical Evidence from the U.S. Automobile Industry," Federal Reserve Bank of Chicago Working Paper (wp-1994-1).

Lawrence, Robert Z., 1991, "Efficient or Exclusionist? The Import Behaviour of Japanese Corporate Groups," *Brookings Papers on Economic Activity*, 311-30

Lawrence, Robert Z., 1993, "Japan's different trade regime: An analysis with particular reference to keiretsu," *Journal of Economic Perspectives* 7(3), 3-19.

Masten, Scott E., James W. Meehan, and Edward A. Snyder, 1989, "Vertical Integration in the U.S. Auto Industry," *Journal of Economic Behavior and Organization* 12, 265-273.

McMillan, John, 1996, "Why does Japan resist foreign market-opening pressure?" In: Bhagwati, J., Hudec, R. (Eds.), *Harmonization and Fair Trade*, Cambridge: MIT Press, 515-541.

Miwa, Yoshiro and J. Mark Ramseyer, 2000, "Rethinking Relationship-Specific Investments: Contracting in the Japanese Automobile Industry," *Michigan Law Review* 98(8), 2636-2667.

Monteverde, Kirk and David J. Teece, 1982, "Supplier Switching Costs and Vertical Integration in the Automobile Industry," *Bell Journal of Economics* 13, 206-213.

Motor Vehicle Manufacturers Association of the United States, 1991–1996, *World motor vehicle data*, Detroit: MVMA.

Qiu, Larry D., and Barbara J. Spencer, 2002, "Keiretsu and Relationship-Specific Investments: Implications for Market-Opening Policy", NBER working paper w8279, May 2001, *Journal of International Economics*, forthcoming.

Rauch, James E., 2002, "Business and Social Networks in International Trade," *Journal of Economic Literature* forthcoming.

Truett, Dale B. and Lila J. Truett, 1997, "Australian Government Policies and the Balance of Trade Performance of the Transportation Equipment Industry: A Comparative Perspective", *Comparative Economic Studies* 39(1), 15-28.

Saxonhouse, Gary C., 1976, "Estimated Parameters as Dependent Variables", *American Economic Review*, 66(1), 178-183.

Saxonhouse, Gary C., 1993, "What Does Japanese Trade Structure Tell Us About Japanese Trade Policy", *Journal of Economic Perspectives*, 7(3), 21-43.

Spencer, Barbara J. and Larry D. Qiu, 2001, "Keiretsu and relationship-specific investment: A barrier to trade?", *International Economic Review*, 42(4), 871-901.