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Network Effects on Trade in Intermediate Goods: Evidence from the Automobile Industry

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Abstract

Growing production fragmentation makes analysis of network effects on trade in parts and components more important than ever. This study examines network effects on auto parts exports from six major auto producing countries using a panel dataset covering 49 destinations and 31 products over the period from 2002 to 2008. Unlike previous research, this study finds that, in the case of Japanese automakers, overseas production by subsidiary plants is less important in determining auto parts exports from Japan than it is for the other major auto producing countries. Japanese auto parts suppliers, unlike their counterparts in other countries, have a tendency to follow the Japanese auto makers in internationalizing their operations. This practice of meeting the need of automakers from overseas production plants weakens the network effects on auto parts exports from Japan.

Keywords:
Network effect, International trade, production fragmentation, *keiretsu*, automobile industry, Japan

***JEL* classification**: F14, L23

1. Introduction

It is well held in trade literature that business and social networks are important driving forces of international trade (Rauch and Feenstra, 1999). Networks that were domestically forged are now being internationalized through cross-border migration and foreign direct investment, helping to alleviate informal trade barriers. Previous research has predominantly examined the implications of Japanese *keiretsu* and overseas Chinese networks for international trade. One consensus is that relationships between sellers and buyers matter in an environment where enforcement of international contracts is weak and information about international trade opportunities is not adequate (Rauch and Feenstra, 1999). The magnitude of these networks is an ongoing empirical issue in international trade. The stronger network effects are, the worse the standard trade models are expected to perform under the assumptions of anonymous agents trading through arms-length transactions (Greaney, 2009).

Given the growing importance of production fragmentation[1] in international trade, analysis of the network effects on trade in intermediate goods has become more important than ever. The geographically integrated production process began to separate as technological developments in transportation and communication made long-distance transactions feasible. Furthermore, the development of information technology and liberalization of trade and investment have dramatically reduced communication and transaction costs, enabling multinational enterprises (MNEs) to outsource an increasing amount of their production process across multiple countries based on factor endowments and organize their value chains globally. This has resulted in a steady rise in trade in parts and components across national borders (Yeats, 1998; Kimura and Ando, 2005; Athukorala and Yamashita, 2006).

[1] Production fragmentation is defined as intra-product specialization where the production process is sliced into discrete activities, which are then allocated across multiple countries based on factor endowments such as labor, capital and technology. In the recent literature an array of alternative terms has been used to describe this phenomenon including ‘global production sharing’ and ‘international outsourcing’ (Jones and Kierzkowski, 1990; Helpman, 2006).

The objective of this paper is to broaden understanding of network effects in international trade by analyzing intermediate goods. In this paper, the following questions are explored: Do networks increase parts and components trade and, if so, to what extent? Are Japanese network effects distinctive? To answer these questions, I estimate the network effects on auto parts exports from 6 traditional auto-producing countries (hereafter, TPCs): Japan, the United States, Germany, France, Italy, and Sweden. The network effect is measured using overseas production by automakers headquartered in TPCs. My method involves estimating an augmented version of the Anderson and Wincoop (2003) gravity equation with a fixed effects model. I employ a large panel data covering 49 destination countries and 31 auto parts over the 7-year period from 2002 to 2008.

In accordance with expectations, the results suggest that on average, a 10% increase in overseas production by TPC automakers leads to an increase in auto parts exports from their home country by 4.3%.[2] An important finding, however, is that Japanese network effects are *less* important than those of other TPCs. I argue that such uniqueness could be led by the higher reliance on domestic procurements of overseas subsidiaries of Japanese automakers as a result of transfer of the vertical networks between automakers and parts suppliers formed in Japan. This is reflected in a general tendency of Japanese parts suppliers to internationalize their operations following Japanese automakers, which could weaken Japanese network effects.

This study adds to the literature measuring network effects in international trade and relates closely to Greaney (2005, 2009). The key extension is that this study analyzes *total* network effects including both *intra*- and *inter-firm* network effects with a newly-constructed product-level dataset. In contrast, Greaney focused on intra-firm network effects using firm-level data. The inclusion of inter-firm network effects matter, because the important aspect of production fragmentation is the splitting of production processes

[2] This is the simple average between the year 2002 and 2008 (See the lower part of Table 3).

across national borders beyond a firm's boundaries (Grossman and Helpman, 2002). In addition, as far as I am aware, this is the first paper to show empirical evidence of weaker Japanese network effects relative to other developed countries. Greaney's works present evidence that the Japanese network effect is, rather, stronger. The other contribution is that this paper demonstrates evidence that the standard gravity model might suffer from misspecification problems when determinants of intermediate trade are estimated, as argued by Baldwin and Taglioni (2013).[3]

The rest of this paper is structured as follows. Section 2 overviews the literature on network effects in international trade, with a particular focus on the role of Japanese *keiretsu*. Section 3 presents the empirical model and discusses data and estimation methods. Section 4 reports the estimation results. Section 5 discusses the key results. Section 6 concludes.

2. Japanese Network Effects: Theory and Evidence

Japanese *keiretsu* is among the business networks that have been paid the most attention by economists.[4] Unlike other networks, early research on Japanese *keiretsu* was motivated by how Japanese local business networks create trade barriers for outside competitors. Thus, both the theoretical and empirical literature has focused on an import-reducing effect of the domestic *keiretsu* network operating through the preferential choice of domestic *keiretsu* suppliers by assembly makers (Lawrence, 1991; Fung, 1991; Qiu and Spencer, 2002). This view was prominent in the policy debate on the US-Japan trade friction during the 1980s and 1990s. In recent years, there has been some research on the impact of the global *keiretsu* network, which has trade-creating effects. Empirical evidence in this literature is summarized in Table 1.

[3] Previous studies such as Kimura and Ando (2005) and Athukorala and Yamashita (2006) use GDP as the mass variable, despite the fact that they rely on the consumer good version of the gravity model to describe parts and components trade. This study shows that value-added could underestimate the role of the mass variable in explaining trade in intermediate products.

[4] See Rauch (2001) for an overview of network effects in international trade.

Qiu and Spencer (2002) postulate that the domestic *keiretsu* networks have import-reducing effects from the relation-specific investment (RSI) that improves the fit or ease of assembly with other parts produced by *keiretsu* suppliers.[5] Hence, efficiency-raising RSI causes Japanese assembly makers to choose domestic procurement within the *keiretsu* network rather than imports from local suppliers in a foreign country even if produced at a cheaper cost. This theoretical observation is consistent with empirical results. Lawrence (1991) and Fung (1991) examine the role of the domestic *keiretsu* network for US-Japan trade and find that it negatively affects import penetration in Japan by foreign sellers. Fung (1991) concludes Japanese *keiretsu* may be an important determinant of US-Japan trade.[6]

Subsequent work by Baldwin and Ottaviano (2001) and Greaney (2003) has emphasized that the global *keiretsu* network promotes international trade by helping to overcome informal trade barriers. The cost here reflects the expenditure required to penetrate the market by creating a connection with buyers. This cost becomes higher when agents have a different nature such as culture, language, nationality, and business customs. However, if the seller and buyer belong to the *keiretsu*, the costs could be much lower compared with non-*keiretsu* members because they already have mutual trust based on a close and long-standing business relationship.

This theoretical prediction is supported by the empirical results of Head et al. (2004) and Greaney (2005, 2009). Head et al. (2004) explicitly investigate the impact of both the domestic and global *keiretsu* network on the pattern of auto parts imports from the US in Japan. They find the global *keiretsu* network

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[5] There are several forms of RSI such as physical asset specificity (e.g. customized machinery), site specificity (e.g. improvements in coordination to economize on inventory or transportation costs), and human asset specificity (e.g. gains in know-how from experience and information sharing). For applications within *keiretsu*, see Aoki (1988).

[6] Saxonhouse (1989) takes an opposite position, arguing that Japan's trade pattern can be explained by factor endowments in a similar way as for other advanced countries. Also, Ueda and Sasaki (1988) investigate whether the *keiretsu* affects manufacturing imports in Japanese manufacturing and find evidence that the domestic *keiretsu* network has an import-creating effect especially for vertical *keiretsu* such as Toyota, Nissan, Sony, and Fujitsu.

positively works for auto parts imports in Japan through "reverse imports" (i.e. imports from overseas affiliates of that country's own firms) however it is smaller than the import-reducing effect of the domestic *keiretsu* network. Using firm-level data, Greaney (2005, 2009) finds that Japanese affiliates in the United States display a stronger home bias in their international trade pattern than any other foreign affiliates located in the United States, suggesting that production networks between headquarters and overseas subsidiaries play an more important role in determining Japan's trade.

This study builds on the works of Greaney (2005, 2009) by investigating network effects on auto parts exports from TPCs and the uniqueness of Japanese network effects.[7] The first development is to analyze total network effects in international trade with an emphasis on inter-firm network effects, which Greaney has not explored. To do so I analyze the automobile industry, which is characterized by a vertical integration between automakers and auto parts suppliers. It is expected that the expansion of overseas production by Japanese automakers increases auto parts exports from suppliers (and automakers) in Japan more than in the case of other TPCs due to global *keiretsu* networks (Baldwin and Ottaviano, 2001; Greaney, 2003). Second, the dataset in this study includes 49 trading countries (Appendix 1), allowing for an investigation of differences in network effects among destinations. It is postulated that network effects are stronger in developing countries where enforcement of international contracts is weak and information about international trade opportunities is not adequate (Rauch and Feenstra, 1999). On the other hand, Greaney's works include only the United States as a host country. Third, this paper employs a new measurement approach for network effects. Instead of using dummy variables, I measure network effects using the overseas production in each trading country by automobile producers headquartered in the TPCs.

[7] Data limitations do not allow for measuring network effects on auto parts imports to TPCs. It is difficult to obtain information on overseas activities of suppliers headquartered in TPCs.

3. Empirical Analysis

3.1. Estimation strategy

The estimation of the determinants of auto parts exports draws on the "gravity with gravitas" model developed by Anderson and Wincoop (2003):

$$\ln EX_{i,j,k} = \ln GDP_{i,k} + \ln GDP_{j,k} - \ln WGDP_k + (1-\varphi_k)[\ln \Phi_{i,j,k} - \ln\delta_{i,k} - \ln\theta_{j,k}] \quad (1)$$

$$\delta_{i,k} = \sum_{j=1}^{c}\left(\frac{\Phi_{i,j,k}}{P_{j,k}}\right)^{1-\varphi_k}\frac{GDP_{j,k}}{WGDP_k} \quad (2)$$

$$\theta_{j,k} = \sum_{i=1}^{e}\left(\frac{\Phi_{i,j,k}}{\delta_{i,k}}\right)^{1-\varphi_k}\frac{GDP_{i,k}}{WGDP_k} \quad (3)$$

where subscripts i, j, and k stand for exporters, importers, and products, respectively. The ln before variables is the natural logarithm. The dependent variable (*EX*) is auto parts exports. *GDP* is gross domestic product for each product, and *WGDP* is the aggregated gross domestic product in the world. φ is the intra-product elasticity of substitution between varieties, and Φ stands for trade costs. The most important feature of the Anderson and Wincoop (2003) model is the inclusion of multilateral resistance terms (δ and θ) that account for unobserved price indices. The inclusion of these two variables has a significant implication for estimating the gravity model, as an omitted variable bias could be corrected.

The empirical issue is how to estimate the Anderson and Wincoop (2003) model in a consistent manner. The standard approach is the use of the fixed effects estimation technique. Grouping terms together for exporters and importers allows for equation (1) to be rewritten as follows:

$$\ln EX_{i,j,k} = C_k + F_{i,k} + F_{j,k} + (1-\varphi_k)\left[\ln \Phi_{i,j,k}\right] \quad (4)$$

$$C_k = -\ln WGDP_k \quad (5)$$

$$F_{i,k} = \ln GDP_{i,k} - \ln\delta_{i,k} \quad (6)$$

$$F_{j,k} = \ln GDP_{j,k} - \ln\theta_{j,k} \quad (7)$$

The equations indicate that three fixed effects should be controlled for. One is product fixed effects (C_k). Indeed, auto part fixed effects matter in controlling for omitted variable biases (Head et al., 2004). For example, auto parts with higher asset specificity and engineering costs (e.g. catalytic converters, variable valve lift systems) are probably exported from headquarters' plants in a home country to avoid breaches of technology and information. The others are exporter-product fixed effects ($F_{i,k}$) and importer-product fixed effects ($F_{j,k}$). Because trade costs potentially vary by products, the multilateral resistance terms also vary across not only exporters and importers but also products.

For the purpose of this study the standard gravity equation (4) is augmented by adding a number of other variables. Overseas production in an importing country by automobile producers headquartered in the TPCs (*OSP*) allows for the measurement of network effects on auto parts exports from TPCs. Four variables are included as representatives of trade costs (Φ): the geographical distance (*DIS*), adjacency (*ADJ*), common language (*LAN*), and colonial tie (*COL*) between exporters and importers. The augmented version of the gravity equation is:

$$\ln EX_{i,j,k} = \beta_1 \ln OSP_{i,j} + \beta_2 \ln DIS_{i,j} + \beta_3 ADJ_{i,j} + \beta_4 LAN_{i,j} + \beta_5 COL_{i,j} + C_k + F_{i,k} + F_{j,k} + \varepsilon_{i,j,k} \quad (8)$$

Estimation is carried out in three steps. The first is to estimate equation (8) separately for products (k) in a single period. This is the most feasible approach to estimating the Anderson and Wincoop (2003) model consistently. All that is needed is a full set of exporter and importer fixed effects. The superiority of this approach allows two multilateral resistances (δ, θ) and the elasticity of substitution (φ) to vary accordingly. The second step is to estimate equation (8) directly for each year (2002-2008). However, the shortcoming of this approach is to rely on the assumption that the elasticity of substitution is constant across products. Lastly, additional examinations are undertaken with the four-dimensional panel dataset pooling all dimensions (exporters, importer, products, and periods) together. The use of the four-dimensional panel data not only enhances the efficiency of estimation due to the increase in the number of observations but also allows for additional control variables and a different estimation method. The additional variables include domestic output in the automobile industry (*DAP*) to represent economic mass, the value/weight ratio (*VWR*), and the nominal exchange rate (*NER*). The Poisson pseudo-maximum-likelihood (PPML) technique is employed to investigate the possibility of estimation biases emanating from missing values (Silva and Tenreyro, 2006).

Careful attention needs to be paid to mass variables (*DAP*). Conceptually, the expenditure and output for each product should be included instead of GDP, as the product-based gravity model is estimated in this study. In addition, mass variables should be measured in gross term rather than value-added terms when determinants of trade in parts and components are examined using the Anderson and Wincoop (2003) framework (Baldwin and Taglioni, 2013). The Anderson and Wincoop (2003) model is based on consumer demand rather than intermediate demand, and is therefore less appropriate in explaining determinants of trade in intermediate goods. Furthermore, to capture the market size for auto parts exports properly, not only car production but also auto parts production should be included, as intra-industry trade within the auto parts industry becomes an important driver of bilateral trade given the growing production fragmentation in recent years. Taking into account these points, mass variables are constructed and their performance are examined (see below for details).

One advantage of the use of product-level data is to allow for constructing a unit value ratio (*VWR*) for each auto part. Controlling for this variable is important because product characteristics such as bulkiness could influence the firm’s internationalization strategy (i.e. exporting or foreign direct investment): bulky parts such as body and chassis components are expected to be directly supplied in a host country rather than exported from a home country because of higher transportation costs. In addition, the nominal exchange rate (*NER*) is an important variable to influence the firm’s internationalization strategy and so is an important control.

3.2. Variable Construction and Data Sources

Data on overseas production are obtained from the International Organization of Motor Vehicle Manufacturers, which provides information on production volume by manufacturer and country. Using these data, I calculate overseas production in each importing country by automobile producers headquartered in the TPCs (Appendix 2). While a classification based on ownership would be more appropriate, this study does not employ such a classification due to the difficulty of measuring ownership in a consistent manner. One reason is that there are wide varieties of degree of ownership and alliances.[8] In addition, the degree of ownership changes over time, and alliances between automakers have sometimes been dissolved.[9] On the other hand, the locations of their headquarters can be easily identified, because they normally do not move even when merged into another company (e.g. Opel has continued to be headquartered in Germany).

Auto parts exports from TPCs are obtained from UN Comtrade. Exports are measured in nominal US dollars. Distance, adjacency, common language, and colonial ties between countries are obtained from the CEPII database. Distance is measured using the geographical coordinates of the capital cities. The adjacency dummy indicates whether two countries are contiguous. The common language variable is a dummy variable indicating whether countries share a common official language. The colonial dummy variable is measured in the same manner. Data on nominal exchange rates are from the World Development Indicators. The nominal exchange rate is calculated by local currency units per US dollars (period average), and indexed by making the year 2002 a base year. The value/weight ratio is constructed as

$$VWR_{i,j,k,t} = EX_{i,j,k,t} / NW_{i,j,k,t}$$

[8] For example, while Opel, a German carmaker, has been a complete subsidiary of General Motors since 1929, Mazda, a Japanese automobile producer, has been more loosely allied with Ford.

[9] For example, Chrysler, a US carmaker, was purchased by Daimler Benz, a German car maker, creating a combined entity, DaimlerChrysler, in 1998. However, this alliance was dissolved in 2007.

where EX stands for nominal export value and NW stands for net weight, respectively.[10] These data are obtained from UN Comtrade.

Data on domestic output in the automobile industry are obtained from the International Yearbook of Industrial Statistics of the United Nations Industrial Development Organization (UNIDO) for various years. As discussed above, gross output in the automobile industry including both auto production and parts and components production is constructed in nominal terms.[11] For an international comparison, the output is converted to US dollars in purchasing power parity (PPP) terms, as they are measured in local currency. Data on the PPP are downloaded from the Penn World Table. A detailed list of variable definitions and data sources is provided in Appendix 3. Summary statistics are presented in Table 2.

4. Results

4.1. Do networks increase auto parts exports from TPCs and, if so, to what extent?

Table 3 reports fixed effect estimates of network effects. The upper part of the table shows the results when equation (8) is separately estimated by products for the year 2008.[12] Overall the goodness-of-fit of each regression is sufficient. The result clearly suggests that network effects on auto parts exports from TPCs exist for a wide variety of products. Positive and significant coefficients (at the 10% level or higher) of overseas production by TPC automakers are found for 23 auto parts (out of 31). The coefficients range from 0.11 to 0.61. The lower part of the table shows the results, in which equation (8) is estimated directly for each year with pooled data covering around 3,200-3,500 observations. The overall goodness-

[10] The weight/unit could be more appropriate than value/weight ratio in this context. However, while weight is measured for almost all of the products in a consistent manner, unit data are not available for a large share of the products analyzed in this study.

[11] Domestic output in the automobile industry includes the manufacture of motor vehicles (ISIC 341), manufacture of bodies for motor vehicles (ISIC 342), and manufacture of parts and components and accessories for motor vehicles and their engines (ISIC 343).

[12] The year 2008 is the latest year of the sample. The estimation result is consistent with that for the other periods (2002-2007).

of-fit of the regression is around 0.70. The results are consistent with those of the product-by-product analyses. The coefficients of overseas production by TPC automakers are positive and statistically significant for all periods. The coefficients range from 0.38 to 0.50 across years.

Table 4 demonstrates additional evidence of the network effects analyzing four-dimensional panel data.[13] The first column shows that the coefficient of overseas production (*OSP*) is positive and statistically significant at the 1% level. The result suggests that overall, a 10% expansion of overseas production by TPC automakers leads to a 4.3% increase in auto parts exports from their home country. Next, splitting the sample into developed and developing countries, the model is estimated separately (Columns 2 and 3). In accordance with expectations, the results suggest that the network effect for developing-country destinations (0.45) is stronger than that for developed countries (0.37).[14] This finding is consistent with the view that developing countries are subject to weaker enforcement of international contracts and greater asymmetric information between exporters and importers compared with developed countries (Rauch and Feenstra, 1999). The network effects on auto parts exports from TPCs remain robust even after including controls (Columns 4 and 5) and estimating by PPML instead of OLS (Column 6).

The negative coefficient of distance reflects the importance of proximity for trade, and the positive coefficient of the adjacency dummy supports the importance of geographical clusters in the automobile industry. On the other hand, there is no evidence that common language and colonial ties are determinants of auto parts exports from TPCs. The size of the automobile industry for exporter and importer are highly significant predictors of auto parts exports from TPCs (Columns 4 and 5). The important finding is that the mass variables in value-added terms are underestimated compared with gross outputs. This implies that once the equation is mis-specified, we are in the realm of omitted variables (Baldwin and Taglioni,

[13] Fisher-type unit root tests strongly reject the null hypothesis that all panels contain a unit root for time-variant variables: auto parts exports (*EX*), overseas production by automakers (*OSP*), gross outputs in automobile industry (*DAP*), value/weight ratio (*VWR*), nominal exchange rate (*NER*).

[14] Chow test rejects the null hypothesis that the slopes are identical across these two country groups.

2013). Interestingly, a high value/weight ratio product tends to be less associated with network effects suggesting that bulky products tend to be locally procured instead of being exported from home countries due to higher transportation costs (Column 4). However, this result appears not to be robust. The coefficient of nominal exchange rate is not reliable, as its sign and statistical significance vary with sample and estimation technique.

4.2. Are Japanese network effects distinctive?

Table 5 demonstrates that the network effects are heterogeneous for exporting countries. The striking finding is the weaker Japanese network effect relative to that of other TPCs. As can be seen in row 3, the negative coefficients of the interaction term between the country dummy and overseas production is found only for Japan. The result predicts that the magnitude of the interlink between auto part exports from Japan and overseas production by Japanese automakers is 0.12 percentage points *smaller* compared with the magnitude of the average relationship estimated for all TPCs.[15] On the other hand, the result suggests that the network effects for the United States (0.32) and Sweden (0.24) are larger relative to those of other TPCs. There is no evidence that network effects for France, Italy, and Germany differ from the average effect for other countries.

That the findings are robust is demonstrated in Table 6 which presents product-by-product analyses for Japan, the United States, and Sweden. Negative and significant coefficients of the interaction term between the Japan dummy and overseas production by Japanese automakers are found for a wide variety of products. 19 estimates of the interaction term are negative and significant with at least a 10% significance level, whereas no positive and significant estimate is found. On the other hand, positive and

[15] The smaller Japanese network effects do not necessarily mean there is a substitution relationship between overseas production and exports. In fact, the result shows that overseas production by Japanese automakers and auto parts exports from Japan are complementary (Table 5). These two variables are statistically assessed as "complementary" when the sum over the two coefficients of overseas production by automakers (+0.26) and its interaction terms with country dummy (-0.12) is positive (Wooldridge, 2002).

significant coefficients are found for almost half of the products for the United States (15) and Sweden (16).

5. Discussions

Why are Japanese network effects weaker? One explanation is that the export-reducing effects of the following-leader investments are more significant in the case of Japan than other TPCs. Following-leader investment – auto parts suppliers' investments following their customers' investment abroad – is a common phenomenon in the automobile industry. Modularity, for example, results in large modules (e.g. cockpit and chassis modules), which are more difficult and expensive to ship over long distances and are more likely to be coordinated tightly with the final assembly process, leading to the co-location of automaker and parts suppliers (Sturgeon et al., 2008). In addition, MNEs have generally attempted to be localized in host countries due to transportation costs and foreign currency risks. Import-substitution policies in host countries also affect the investment decision not only by automakers but also by parts suppliers. For example, local content requirements combined with a high tariff on automobile imports are popular among developing countries such as India, Thailand, Vietnam, Indonesia, Brazil, Argentina and Mexico. Thus, it could be that while overseas production by automakers increases export demands for intermediate goods produced at home, overseas production by parts suppliers could offset such a trade-creating effect to the extent that exporting and investments are alternative strategies.[16]

The stronger export-reducing effects of the following-leader investments by Japanese parts suppliers could emanate from the unique modalities of inter-firm relationships. The Japanese automobile industry is characterized by vertical integration between automakers and parts suppliers. As Qiu and Spencer (2002) discussed, the RSI by Japanese parts suppliers encourages Japanese automakers to choose domestic

[16] Analyzing the Japanese automobile industry, Nishitateno (2013) presents evidence that overseas production by parts suppliers offsets increased demands for intermediate goods resulting from overseas production by automakers.

procurement within the *keiretsu* network, resulting in relatively low dependence on imported parts and components.[17] The important point is that when Japanese automakers build production plants abroad, this locally forged inter-firm relationship is transferred to host countries (Kimura and Pugel, 1995).[18] Therefore, overseas subsidiaries of Japanese automakers are also expected to rely on domestic procurements rather than cross-border sourcing including importing from Japan. On the other hand, overseas subsidiaries of the other TPCs tend to outsource their auto parts production globally, as their industrial organizations are more market-oriented (IRC, 2004, 2008).

The smaller Japanese network effect contrasts with the finding of Greaney (2005, 2009) that the Japanese network effect is *stronger* than those of other developed countries. However, care is needed in comparing this study with Greaney's work, as data and measurement of network effects are different.[19] Moreover, the different scope of the network effects leads to difficulties in comparing the results: this study examines total network effects, mainly focusing on inter-firm network effects between automakers and parts suppliers, whereas Greaney only analyzes intra-firm network effects.

6. Conclusion

In this paper, I explored whether networks could be a leading determinant of trade in auto parts, and whether Japan is unique. The results clearly suggest that overseas production by automakers

[17] The value of auto parts imports to Japan relative to domestic auto production is quite low compared with the other TPCs. The ratio of auto parts imports (22 billion US dollars) to domestic auto production (12 million units) for Japan was 1,899 in 2008. On the other hand, the counterparts for the other TPCs are 10,784 for the United States, 13,216 for Germany, 14,327 for France, 19,931 for Italy, and 41,543 for Sweden.

[18] The incentive is to utilize agglomeration externalities including easier information sharing among *keiretsu* members, greater advantages of proximity due to the use of just-in-time delivery, and the use of specialized components for which the specifications are developed within long-term supplier-assembler relationships in Japan (Head et al., 1995, 1999; Blonigen, 2005).

[19] Greaney (2009) employs firm-level data for nonbank foreign affiliates during the year 1992, 1997, 2002. The information relates to exports and imports of overseas subsidiaries in the United States from 8 developed countries including Japan.

headquartered in TPCs increases auto parts exports from their home country. The elasticity ranges from 0.38-0.50. The results also suggest that in the case of Japanese automakers overseas production by their subsidiary plants is less important in determining auto part exports from Japan. I argue that the results perhaps reflect a general tendency of Japanese part suppliers to internationalize their operations following Japanese automakers, which could weaken Japanese network effects.

However, care is needed in generalizing the findings of this study due to the unique features of the automobile industry. The automobile industry is characterized by imperfect competition resulting from the important role of knowledge-based intangible assets produced by highly skilled labor and R&D. For example, since automobile production inevitably accompanies negative externalities such as air pollution, greenhouse gas emissions, and road accidents, a large amount of investment is required to mitigate these problems. The oligopolistic nature of the automobile industry resulting from such large investments may create network effects in international trade and smaller Japanese network effects, which may not exist to the same extent in other industries. This examination of network effects on intermediate goods in other industries could be an interesting research agenda to be explored.

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Table 1: Empirical evidence measuring network effects on international trade

Author	Variable Explained	Measurement/Data Source	Data/Technique	Network effects
Lawrence (1991)	Ratio of Japanese imports to domestic demand in 1985	Share of industry sales by vertical *keiretsu*/ Dodwell Marketing Consultants(1986)	Cross section/ OLS	Domestic network (-)
Fung (1991)	Net U.S export to Japan in 1980	Share of industry sales and employment by *keiretsu*/ Dodwell Marketing Consultants (1990)	Cross section/ OLS	Domestic network (-)
Ueda and Sasaki (1998)	Imports by Japanese manufacturing firms divided by inputs in 1993	A binary variable that takes on a value of 1 if a firm belongs to keiretsu/Nikkei (1993)	Cross section/ Tobit	Domestic network (+)
Head, Ries, and Spencer (2004)	U.S auto parts exports to Japan per car from 1989 to 1994	Share of *keiretsu* for each part in terms of the number of suppliers/Dodwell Marketing Consultants (1990)	Panel data/ OLS	Domestic network (-)
		Share of Japanese firm's employment for each part in U.S/ Dodwell Marketing Consultants (1997)		Global network (+)
Greaney (2005)	Exports of foreign affiliates in US to 8 major trade partners including Japan	A binary variable that takes on a value of 1 if trade is between foreign affiliates and their home country /Bureau of Economic Analysis (1987, 1992, 1997)	Panel data/ Fixed effects model	Global network (+)
		A binary variable that takes on a value of 1 if trade is between Japanese affiliates and Japan		Japanese network effect is more significant
Greaney (2009)	Exports and imports of foreign affiliates in US to 17 major trade partners including Japan	A binary variable that takes on a value of 1 if trade is between foreign affiliates and their home country/ Bureau of Economic Analysis (1987, 1992, 1997)	Panel data/ Fixed effects model	Global network (+)
		A binary variable that takes on a value of 1 if trade is between Japanese affiliates and Japan		Japanese network effect is more significant

Table 2: Summary statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max
Ln Export Value of Auto Parts (US dollars in nominal terms)	24,025	15.10	2.76	4.63	22.77
Ln Overseas Production (Volume)	24,025	10.84	2.34	0.69	15.03
Ln Gross Outputs in Automobile Industry, Exporter (US dollars in PPP terms)	23,331	26.04	0.90	23.70	26.86
Ln Gross Outputs in Automobile Industry, Importer (US dollars in PPP terms)	16,439	24.33	1.25	20.39	26.86
Ln Distance (Kilometers)	23,830	8.34	1.09	5.16	9.83
Ln Nominal Exchange Rate Index	23,737	0.50	2.97		17.99
Value/Weight Ratio (US dollars/ kg)	23,824	2.53	0.85		10.88
Adjacent Dummy	23,830	0.09	0.29	0	1
Language Dummy	23,830	0.06	0.24	0	1
Colony Dummy	23,830	0.04	0.19	0	1

Note: These are for the four-dimensional panel dataset.

Table 3: Fixed effects estimates of network effects

	Products	Coefficients	Standard Errors	R^2	Observations
1	Tyres	0.12	(0.08)	0.92	112
2	Glasses	0.25***	(0.08)	0.83	114
3	Leaf springs	0.14**	(0.06)	0.94	114
4	Mountings	0.38***	(0.07)	0.91	113
5	Engines	0.38***	(0.09)	0.86	115
6	Air Conditioners	0.09	(0.08)	0.86	114
7	Filters	0.11**	(0.05)	0.91	115
8	Jacks/hoists	0.13	(0.41)	0.76	63
9	Gaskets	0.25***	(0.08)	0.92	115
10	Mechanical seals	0.14*	(0.08)	0.91	115
11	Engine parts	0.14	(0.08)	0.86	115
12	Lighting/signaling equipments	0.30***	(0.09)	0.86	114
13	Lamps	0.16	(0.12)	0.82	104
14	Wire harness	0.27**	(0.11)	0.84	113
15	Chassis and bodes	0.61**	(0.24)	0.69	100
16	Bumpers	0.30***	(0.08)	0.9	113
17	Seat belts	0.23**	(0.11)	0.76	104
18	Body parts	0.34***	(0.07)	0.87	115
19	Gear boxes	0.43***	(0.09)	0.89	115
20	Bearings	0.33**	(0.15)	0.8	114
21	Wheels	0.38***	(0.10)	0.9	114
22	Transmission	0.41***	(0.08)	0.88	115
23	Radiators	0.26***	(0.09)	0.83	113
24	Mufflers and exhaust pipes	0.43***	(0.10)	0.88	112
25	Clutches	0.27***	(0.10)	0.85	115
26	Steering wheels	0.41***	(0.07)	0.86	114
27	Other parts of motor vehicles	0.22***	(0.07)	0.89	115
28	Clocks	0.26	(0.22)	0.85	51
29	Seats	0.14	(0.16)	0.78	106
30	Floor mats	0.22**	(0.09)	0.9	115
31	Turbines	0.01	(0.08)	0.86	114
Pooled Estimates					
Year 2008		0.41***	(0.08)	0.71	3,381
Year 2007		0.50***	(0.06)	0.73	3,256
Year 2006		0.47***	(0.07)	0.74	3,371
Year 2005		0.48***	(0.06)	0.73	3,393
Year 2004		0.38***	(0.05)	0.69	3,500
Year 2003		0.38***	(0.07)	0.7	3,405
Year 2002		0.42***	(0.05)	0.72	3,524

Notes: ***, **, and * indicate statistical significance at 1%, 5%, and 10%. Coefficients are for overseas production by automakers headquartered in TPCs. Figures in parentheses are cluster-robust standard errors by distance. The upper part of the table shows when equation (8) is separately estimated by products for the year 2008. Coefficients on constants and other variables (exporter dummies, importer dummies, distance, adjacency, language, colonial tie) are not reported. The lower part of the table shows the results when equation (8) is directly estimated for each year. Product dummies, exporter-product dummies, importer-product dummies, distance, adjacency, language, colonial tie are included into the model, but their results are not reported.

Table 4: Determinants of auto part exports from 6 major auto producing countries with four-dimensional panel data

Dependent variables: Ln Exports of auto parts from 6 major auto producing countries (*EX*)	(1)	(2)	(3)	(4)	(5)	(6)
Ln Overseas Production (*OSP*)	0.43***	0.37***	0.45***	0.32***	0.34***	0.27***
	(0.05)	(0.08)	(0.05)	(0.06)	(0.06)	(0.07)
Ln Distance (*DIS*)	-0.81***	-0.87***	-0.75***	-0.99***	-0.94***	-0.63***
	(0.14)	(0.15)	(0.24)	(0.10)	(0.11)	(0.08)
Adjacent Dummy (*ADJ*)	0.80***	0.14	1.61**	0.38	0.47*	0.44***
	(0.29)	(0.34)	(0.62)	(0.30)	(0.30)	(0.18)
Language Dummy (*LAN*)	0.22	0.63	0.16	0.21	-0.04	-0.05
	(0.31)	(0.40)	(0.41)	(0.43)	(0.42)	(0.25)
Colony Dummy (*COL*)	-0.17	-0.71	-0.16	-0.45	-0.45	-0.36
	(0.38)	(0.57)	(0.51)	(0.40)	(0.40)	(0.26)
Ln Gross Outputs in Automobile Industry, Exporter (*DAP*)				0.68***	0.60***	0.25**
				(0.13)	(0.09)	(0.11)
Ln Gross Outputs in Automobile Industry, Importer (*DAP*)				0.39***	0.18**	0.39***
				(0.09)	(0.09)	(0.09)
Value/Weight Ratio (*VWR*)				0.06	-0.02	-0.07
				(0.15)	(0.15)	(0.29)
Ln (*OSP*) × Ln (*VWR*)				-0.03*	-0.02	-0.001
				(0.01)	(0.01)	(0.03)
Ln Nominal Exchange Rate (*NER*)				-0.02	-0.10**	0.09*
				(0.05)	(0.05)	(0.05)
Exporter-Product Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Exporter-Product Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Product Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Sample	All	Per Capita GNI >$12,616	Per Capita GNI <$12,616	All	All	All
Estimation Technique	OLS	OLS	OLS	OLS	OLS	PPML
R-Squared	0.69	0.75	0.69	0.74	0.73	n.a.
Observations	23,830	10,226	13,604	15,496	15,844	15,496

Notes: ***, **, and * indicate statistical significance at 1%, 5%, and 10%. Figures in parentheses are cluster-robust standard errors by distance. I analyze four-dimensional panel data, which is made of exporter, importer, product and year. Exporter includes 6 countries (Japan, United States, Germany, France, Italy, and Sweden), Importer covers 49 countries listed in Appendix 1, product include 31auto parts presented in Table 3 and time period is 7 years from 2002 to 2008. According to the World Bank, a country with GNI per capita $12,616 or more is classified as high income country. The natural logarithm of value-added in automobile industry is included instead of gross outputs in Column (5). OLS stands for ordinary least squares, and PPML stands for Poisson pseudo-maximum-likelihood. Fisher-type unit root tests strongly reject the null hypothesis that all panels contain a unit root for every time-variant variable.

Table 5: A comparison of the interaction term between country dummies and overseas production

	Japan	USA	France	Sweden	Italy	Germany
Ln Overseas Production (*OSP*)	0.26***	0.22***	0.23***	0.20***	0.24***	0.24***
	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)
Country Dummy	1.46**	-4.52***	-0.93*	-4.28***	-0.07	2.01**
	(0.65)	(1.53)	(0.51)	(0.73)	(0.74)	(0.83)
Country Dummy × Ln (*OSP*)	-0.12**	0.32**	0.01	0.24***	-0.08	-0.10
	(0.05)	(0.13)	(0.05)	(0.08)	(0.07)	(0.07)

Notes: ***, **, and * indicate statistical significance at 1%, 5%, and 10%. Figures in parentheses are cluster-robust standard errors by distance. I analyze four-dimensional panel data, which is made of exporter (6), importer (49), product (31) and year (2002-2008). Coefficients on constants and other variables (distance, language, adjacency, colonial ties) are not reported. Importer fixed effects, product fixed effects, and year fixed effects are controlled, but not reported.

Table 6: Coefficients of interaction term of overseas production with country dummy for Japan, the United States, and Sweden

	Products	Japan	United States	Sweden
1	Tyres	-0.20***	0.57***	0.36**
2	Glasses	-0.16**	0.50***	-0.03
3	Leaf springs	0.03	0.25*	0.10
4	Mountings	-0.02	0.26*	-0.03
5	Engines	-0.32***	0.28	0.54***
6	Air Conditioners	-0.15***	0.56***	0.16
7	Filters	-0.14***	0.32***	0.08
8	Jacks/hoists	0.06	0.20	0.53**
9	Gaskets	-0.28***	0.27*	0.33***
10	Mechanical seals	-0.31***	0.23	0.32***
11	Engine parts	-0.03	0.34**	-0.11
12	Lighting/signaling equipments	-0.11**	0.46***	-0.01
13	Lamps	-0.06	0.33	0.19
14	Wire harness	-0.04	0.17	0.32***
15	Chassis and bodes	-0.46***	0.20	0.75***
16	Bumpers	-0.23***	0.31**	0.29**
17	Seat belts	-0.28***	0.40	0.40***
18	Body parts	-0.14***	0.10	0.07
19	Gear boxes	-0.35***	0.47**	0.50***
20	Bearings	-0.17**	0.23	0.95***
21	Wheels	-0.28***	0.30	0.10
22	Transmission	-0.30***	0.26	0.14
23	Radiators	-0.29***	0.17	0.27*
24	Mufflers and exhaust pipes	-0.09	0.36	0.41***
25	Clutches	-0.06	0.39*	0.13
26	Steering wheels	-0.23***	0.39	0.06
27	Other parts of motor vehicles	0.04	0.20*	0.05
28	Clocks	n.a.	0.25	0.25*
29	Seats	0.003	0.31	0.34*
30	Floor mats	-0.24***	0.33**	0.30***
31	Turbines	-0.06	0.40**	0.01

Notes: ***, **, and * indicate statistical significance at 1%, 5%, and 10%. Figures in parentheses are cluster-robust standard errors by distance. Coefficients on constants and other variables (distance, language, adjacency, colonial ties) are not reported. Importer fixed effects, product fixed effects, and year fixed effects are controlled, but not reported. The coefficient for clocks is not available due to a large number of missing observations for Japan.

Appendix 1: List of trading countries

Asia	Americas	Europe	Others
China	Argentina	Austria	Australia
India	Brazil	Belgium	Botswana
Indonesia	Canada	Czech Republic.	Egypt
Iran	Chile	Finland	Kenya
Japan	Colombia	France	Morocco
Malaysia	Ecuador	Germany	Nigeria
Pakistan	Mexico	Hungary	South Africa
Philippines	Uruguay	Italy	Tunisia
South Korea	United States	Netherlands	
Thailand	Venezuela	Poland	
Viet Nam		Portugal	
		Romania	
		Russian Federation	
		Slovakia	
		Slovenia	
		Spain	
		Sweden	
		Turkey	
		United Kingdom	
		Uzbekistan	

Note: The selection of trading countries is based on whether TPC automakers have one or more overseas subsidiaries.

Appendix 2: List of automobile producers according to locations of headquarters

Japan	United States	Germany	France	Italy	Sweden
Daihatsu	Cadillac	Audi	Bugatti	Alfa Romeo	Saab
Hino	Chevrolet	BMW	Citroen	Ferrari	Scania
Honda	Chrysler	Evobus	Renault	Fiat	Volvo
Isuzu	Ford	MAN	Peugeot	Iveco Trucks	
Mazda	Freightliner	Mercedes-Benz	Renault Trucks	Lamborghini	
Mitsubishi	General Motors	Mini		Lancia	
Mitsubishi Fuso	Hummer	Neoplan		Maserati	
Nissan	Jeep	Opel			
Subaru	Navistar	Porsche			
Suzuki	Paccar	Smart			
Toyota	Pontiac	Unimog			
	Sterling	VolksWagen			
	Western Star				

Source: International Organization of Motor Vehicle Manufacturers (OICA): http://www.oica.net/

Appendix 3: List of definitions and data sources of variables

Variables	Definition	Data Source
EX	Export value of auto parts measured in nominal US dollars	UN Comtrade: (http://comtrade.un.org/)
VWR	Value/weight ratio, $VWR = EX / NW$ where *EX* is nominal export value and *NW* is net weight for each auto part	As above
DAP	Gross output (converted to US dollars in purchasing power parity terms) in the automobile industry including manufacture of motor vehicles (ISIC 341), manufacture of bodies for motor vehicles (ISIC 342), and manufacture of parts and components and accessories for motor vehicles and their engines (ISIC 343).	The International Yearbook of Industrial Statistics of the United Nations Industrial Development Organization (UNIDO) for various years
OSP	Volume of overseas production by automobile producers headquartered in traditional auto-producing countries (TPCs)	International Organisation of Motor Vehicle Manufacturers: (http://oica.net/category/about-us/)
NER	Nominal exchange rate (calculated by local currency units per US dollars) index (the year 2002 is a base year)	World Development Indicators: (http://www.worldbank.org/)
DIS	Geographical distance between the capital cities in kilometers	CEPII database: (http://www.cepii.fr/anglaisgraph/bdd/fdi.htm)
ADJ	Dummy variable indicating whether the two countries are contiguous	As above
COL	Dummy variable indicating whether the two countries are colonially tied	As above
LAN	Dummy variable indicating whether the two countries share a common official language	As above

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