Global Production Sharing in the Automobile Industry: The Case of Japan

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Declaration

Except where otherwise indicated, this dissertation is my own original work.

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To dearest Chisato and my parents, Koichi and Hisako

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Abstract

The purpose of this thesis is to contribute to the literature on global production sharing by examining the case of the Japanese automobile industry in the global context. The key hypothesis is that the unique characteristics of the production system and supplier relationships in Japan matter in determining the extent and modality of production sharing. The analysis focuses specifically on the implications of the 'following-leader' pattern (that is, parts and components suppliers following car producers) of Japanese overseas investment and of the interlocking relationships among firms (*keiretsu* networks).

The analysis is conducted at both the macro and micro levels. The macro-level analysis examines whether the following-leader investment and *keiretsu* network serve to differentiate patterns of Japan's parts and components and final trade from that of the other five major auto-producing nations (the United States, Germany, France, Italy, Sweden). The methodology involves estimating an augmented gravity model using a newly-constructed three-dimensional (country-partner-product) panel dataset. The micro-level analysis focuses on exports and imports separately. The export-side analysis examines whether the following-leader investments by Japanese suppliers substitute or complement auto parts exports from Japan. The import-side analysis probes the role of *keiretsu* networks through an in-depth case study of the supplier network of Toyota Motors, focusing specifically on the role of domestic and overseas parts suppliers in determining Toyota's global procurement patterns of parts and components. The analysis makes use of a unique product-level dataset compiled from customs records.

The thesis begins with an overview of the globalisation process of the automobile industry, with emphasis on the comparative performance of Japanese automakers in the global automobile

industry. Chapter 3 undertakes a comparative analysis at the macro-level to investigate unique features of global production sharing by Japanese automakers. Chapters 4 to 6 report the results of micro-level analyses. Chapter 4 provides a profile of the Japanese automobile industry with a particular focus on Toyota, including its history, management, and production networks in order to set the stage for the empirical analyses in subsequent chapters. Chapter 5 explores the effect of the following-leader investment by Japanese suppliers on auto parts exports from Japan. Chapter 6 examines how domestic and global *keiretsu* networks impact on auto parts imports. Chapter 7 summarises the key findings and policy implications.

A number of interesting results emerge from the analyses. First, there is clear evidence of a following-leader pattern in foreign direct investment (FDI) by Japanese auto parts suppliers, and therefore the magnitude of the relationship between Japanese auto parts exports and FDI is much smaller compared to the other major auto-producing countries. Second, the micro-level analysis shows that the following-leader investment by Japanese auto parts suppliers plays an important role in increasing exports from Japan. Third, in contrast with previous studies, there is no evidence to support the hypothesis that the domestic *keiretsu* network constrains auto parts imports to Japan: there seems to be a clear division of labour between local auto parts producers and their overseas counterparts operating within global automobile networks.

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Abbreviations

2SLS	Two Stage Least Squares
ASSB	Assembly Services Sdn. Bhd.
BEC	Broad Economic Categories
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CAPTIN	Canadian Autoparts Toyota Inc.
CBU	Completely-Built Units
CEEC	Central and Eastern European Countries
CEPII	Centre d'Etudes Prospectives et d'Informations Internationales
CES	Constant Elasticity of Substitution
EEC	European Economic Community
EU	European Union
FDI	Foreign Direct Investment
FEM	Fixed Effects Model
GDP	Gross Domestic Product
GHQ	General Headquarters
GM	General Motors
HOV	Hecksher-Ohlin-Venek
HS	Harmonised System
IIT	Intra-Industry Trade
IMV	Innovative International Multi-Purpose Vehicle
I-O	Input-Output
IPT	Inward Processing Trade
IPX	Inward Processing Exports
IRC	Industry Research and Consulting
IV	Instrumental Variable
JAMA	Japan Automobile Manufacturers Association
JAPIA	Japan Auto Parts Industries Association
JNX	Japanese Automotive Network Exchange
KD	Knock-Down
LSDV	Least Squares Dummy Variables

MNEs	Multinational Enterprises
NAFTA	North American Free Trade Agreement
NPCs	New Auto-Producing Countries: China, India, Thailand, Indonesia, Malaysia, the Philippines, Vietnam, Brazil, Argentina, Mexico, Russia, Poland, the Czech Republic and South Africa
NUMMI	New United Motor Manufacturing, Inc
ODM	Original Design Manufacturing
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturing
OICA	International Organisation of Motor Vehicle Manufacturers
OLS	Ordinary Least Squares
OPM	Outward Processing Imports
OPT	Outward Processing Trade
OPX	Outward Processing Exports
P&C	Parts and Components
PPML	Poisson Pseudo-Maximum-Likelihood
R&D	Research and Development
REM	Random Effect Model
RSI	Relation-Specific Investment
SC	Toyota Caetano Portugal, S.A.
SCAP	Supreme Commander for the Allied Powers
SITC	Standard International Trade Classification System
SOFASA	Sociedad de Fabricacion de Automtores S.A.
STM	Siam Toyota Manufacturing Co., Ltd
SUR	Seemingly Unrelated Regression
TAM	P.T. Toyota-Astra Motor
TAP	Toyota Autoparts Philippines Inc.
TASA	Toyota Argentina S.A
TDB	Toyota do Brazil Ltda.
TDV	Toyota de Venezuela Compania Anonima
TFAP	Tianjin Fengin Auto Parts Co., Ltd.
TMCA	Toyota Motor Corporation Australia Ltd
TMMC	Toyota Motor Manufacturing Canada Inc
TMMF	Toyota Motor Manufacturing France S.A.S.
TMMI	Toyota Motor Manufacturing Indiana Inc
TMMIN	P.T. Toyota Motor Manufacturing Indonesia Inc
TMMK	Toyota Motor Manufacturing Kentucky Inc
TMMP	Toyota Motor Manufacturing Poland SP.zo.o.
TMMT	Toyota Motor Manufacturing Turkey Inc
TMMTX	Toyota Motor Manufacturing Texas Inc
TMMWV	Toyota Motor Manufacturing West Virginia Inc
TMP	Toyota Motor Philippines Corp.
TMT	Toyota Motor Thailand co., Ltd.

TMUK	Toyota Motor Manufacturing UK Inc
TPCs	Traditional Auto-Producing Countries: Japan, United States, Germany, France, Italy and Sweden
TPS	Toyota Production System
TSAM	Toyota South Africa Motors Ltd
TTFC	Tianjin Toyota Forging Co., Ltd
UN	United Nations
USA	United States of America
VERs	Voluntary Export Restraints

CHAPTER 1

Introduction: Purpose, Scope and Preview

1.1 Purpose

The purpose of this thesis is to contribute to the literature on global production sharing by examining the case of the Japanese automobile industry. The key hypothesis is that the unique characteristics of the production system and supplier relationships in Japan are important in determining the extent and modality of production sharing. The analysis focuses specifically on the implications of the 'following-leader' pattern (that is, parts and components suppliers following car producers) of Japanese overseas investment and of interlocking relationships among firms (*keiretsu* networks).

The analysis is conducted at both the macro and micro levels. The macro-level analysis examines whether the following-leader investment and *keiretsu* network serve to differentiate patterns of Japan's parts and components and final trade from that of the world's other five major auto-producing countries in the world (the United States, Germany, France, Italy, and Sweden). The methodology involves estimating an augmented gravity model using a newly-constructed three-dimensional (country-partner-product) panel dataset. The micro-level analysis is an in-depth case study of the supplier network of Toyota Motors, focusing specifically on the role of domestic and overseas parts suppliers in determining Toyota's global procurement patterns of parts and components (P&C, hereafter). The analysis makes use of a unique product-level dataset put together from the customs records of ports in Aichi prefecture.

The next section defines global production sharing. The following two sections overview the existing literature and discuss the research gaps. The final section previews the structure of this thesis and summarises each chapter.

1.2 Global Production Sharing

Global production sharing is defined as intra-product specialisation in which the production process of a good (or a service) is sliced into discrete activities (tasks) which are then allocated across multiple countries. This phenomenon can be observed across industries such as electronics, clothing, television, radio receivers, office equipment, power and machine tools, cameras, watches, pharmaceuticals, and automobiles. In the recent literature an array of alternative terms have been used to describe this phenomenon including 'fragmentation', 'slicing the value chain', 'disintegration of production', 'vertical specialisation' and 'international outsourcing' (Jones and Kierzkowski 1990, Krugman 1995, Feenstra 1998, Hummels et.al 2001, Spencer 2005, Helpman 2006, Grossman and Rossi-Hansberg 2008).

At the formative stage in the 1960s, production sharing involved multinational corporations locating small fragments of the production process in a low-cost country and re-importing the assembled components to be incorporated in the final product in the home country. Over time, production networks have become more widespread, encompassing more extensive production processes undertaken across borders of many countries. Multinational corporations are now organising their value chains globally by allocating not only parts and components assembly, but also final assembly, product designing, marketing and headquarter functions to multiple countries.

Global production sharing takes two forms. One is intra-firm production sharing, in which the production process is split across borders within a single multinational firm. This takes the form of division of labour between the headquarter and an overseas subsidiary and among overseas subsidiaries. Another form is inter-firm production sharing, in which the production process is split across national borders beyond a firm's boundaries. This takes the form of subcontracting a component of the production process to independent firms. Global production sharing has developed over time with combinations of these two forms. The modality and intensity vary among products and industries reflecting product and industry-specific characteristics, trade costs, firm strategies, relative costs, market factors, economies of scale, and policy environments.

The focus of this thesis is limited only to the production process related to the vertical linkage between production of P&C and final assembly in the automobile industry. Given the nature of data availability, it is difficult to quantify the whole process of global production sharing.

1.3 Literature Review

1.3.1 Theory

Global production sharing has been studied by a number of trade theorists. In a series of papers, Jones and Kierzkowski (1990, 2000) applied the standard (comparative advantage-based) trade theory to the phenomenon of production sharing. Their framework identifies comparative advantage and increasing returns associated with 'service links' within global production networks as the driving forces of global production sharing. Here the term 'service links' implies "bundles of activities consisting of coordination, administration, transportation, and financial services" (Jones and Kierzkowski 1990, p.31) involved in linking various segments of the production process spread across national boundaries. The improvement of service links resulting from technological innovation in communication and transportation reduces the costs of connecting various segments of the production process. The liberalisation of trade and investment also reduces the cost of service links.

Global production sharing enables a company to locate production blocks across borders according to the comparative advantage of the countries involved. Since skills required for each production block differ, dispersion of activity could lower production cost. However, a cross-border spread of production blocks involves new fixed costs of establishing services links. The costs associated with service links increase as the production network spread across many national boundaries. So the degree of production sharing would be determined based on the fixed cost of services links and the benefits of the lower marginal costs arising from comparative-advantage based international specialisation.

Following Jones and Kierzkowski (1990, 2000), a number of authors have attempted to extend the standard trade theory to encompass the phenomenon of global production sharing. Arndt (1997) examines welfare implications of production sharing by decomposing a production process into a labour-intensive and capital-intensive stages. The model predicts that not only sub-contracting by the importable and labour intensive stage of a capital-intensive country (say the United States) but also sub-contracting by the exportable and capital-intensive stage of a labour-intensive country (say Mexico) has the effect of raising wages in both countries. The model also predicts that offshore sub-contracting improves national welfare of a capital abundant country (say the United States) through the Rybczynski effect.

In recent years, there have been some attempts to draw on the theory of industrial organisation and contract theory in order to explain the phenomenon of global production sharing (Spencer 2005, Helpman 2006). This new literature attempts to explain a firm's decision on production sharing in terms of organisation and location under incomplete contracts. The incompleteness of contract arises when it is impossible to assure the return to investment because the amount of investment is observable but unverifiable. Suppose an auto parts supplier undertakes relation-specific investment (RSI) for its customers (e.g. automakers).[1] The return of RSI is so uncertain and complicated that it is impossible to write a complete contract covering every possible event. Even if it is feasible, it is costly to write a complete contract. Even if the costs are

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[1] There are four types of relation-specific investments relating to four asset specificities (site, physical assets, human assets and dedicated assets). The example of site specificity is that a supplier builds its plant near the customer to achieve just-in-time delivery. The example of a physical asset is that a supplier purchases machines and tools so as to specialize to the needs of the customer.

acceptable, not every RSI can be observed, leading to moral hazard. Furthermore, even if all these are negligible, the RSI is not legally verifiable. This nature of incompleteness of contract could lead to a hold-up problem where the amount of RSI is lower than the optimal level, resulting in a decrease in total profit. Whether or not a hold-up problem occurs depends on the bargaining powers of agents (e.g. supplier and automaker) and their outside options. A property rights approach discusses the mechanism designed to minimise loss arising from a hold-up problem by affecting threat points with institutions such as property rights and law (Grossman and Hart 1986, Hart and Moore 1990, Hart 1995).

Antras (2003, 2005) studies the firm's choice between intra-firm production sharing (vertical integration) and inter-firm production sharing (arm's length transaction) by embedding the property rights approach into the general equilibrium model of trade based on monopolistic competition and differing factor endowments among countries. He finds that capital-intensive intermediate goods tend to be transacted within boundaries of firms (intra-firm production sharing), while labour-intensive products are transacted with unaffiliated firms (inter-firm production sharing). Antras (2005) develops a dynamic general equilibrium model of North-South trade in which the incompleteness of international contracts leads to the emergence of product cycles. The model predicts that intra-firm production sharing through FDI in the South initially occurs and is then shifted to inter-firm production sharing through outsourcing to independent firms in the South.

Focusing specifically on domestic production sharing (i.e. domestic vertical integration and arm's length arrangement), McLaren (2000) and Grossman and Helpman (2002) argue that "market thickness" plays an important role in determining a firm's decision on organisational form under the transaction cost approach.[2] McLaren (2000) analyses the effects of "market thickness" arising from international openness on the vertical integration between upstream firms (e.g. parts suppliers) and downstream firms (e.g. automakers). The results suggest that for upstream firms, opening a country makes arm's length arrangements more attractive because it enables them to find alternative business partners abroad, leading to larger bargaining power against downstream firms. Similar to McLaren (2000), Grossman and Helpman (2002) postulate that market thickness could facilitate a production sharing with independent firms by decreasing the costs of search for partners.

Grossman and Helpman (2005) deal with the firm's decision on inter-firm production sharing (i.e. domestic or cross-border production sharing) under incomplete contracts in a general equilibrium setting of monopolistic competition and trade. They find that a downstream firm tends to outsource to a country with a greater endowment of labour because it is more likely to have a larger market thickness that reduces search costs, and an improvement in a country's legal environment increases the country's share of outsourcing by reducing hidden transaction costs associated with inadequate institutions.

1.3.2 Empirical Evidence

In a pioneering study Yeats (1998) investigates the significance and patterns of global production sharing in foreign trade of developed countries (member countries of the Organisation for Economic Cooperation and Development (OECD)) using trade data based on the Revision 2 of the Standard International Trade Classification (SITC) during the period 1978 to 1995. He uses the share of P&C trade in machinery and transport equipment (products belonging to the SITC Section

[2] Williamson (1979) argues that the boundary of a firm is determined by characteristics of transactions: uncertainty, the frequency Williamson with which transactions between manufacturer and suppliers recur, and the degree to which durable transaction-specific investment by suppliers are incurred. On the one hand, it might be that the more idiosyncratic the investment characteristics by suppliers become and the more recurrent the transactions between manufacturer and suppliers become, the more likely the governance structure is to be vertical integration. On the other hand, it might be that the less specific the investment characteristics become, the more probable the transaction is governed by the market. Refer to Klein et al (1978) and Williamson (1979) for more details of the transaction costs approach.

7) as the indicator of global production sharing. His key finding is that trade in P&C accounts for 30% of total trade in SITC 7 and is growing faster than trade in final goods.

Using trade data based on SITC Revision 3 that allows the product coverage to be expanded to SITC Section 8 (miscellaneous manufactured goods), Athukorala (2005) and Athukorala and Yamashita (2006) analyse the trends and determinants of trade in P&C over 1992 to 2003 with a special focus on countries in East Asia.[3] Their findings confirm faster growth of trade in P&C than final goods in world trade. Furthermore they found that the dependence of P&C trade is particularly higher in countries in East Asia compared to those in the North American Free Trade Area (NAFTA) and the European Union (EU). Kimura and Ando (2005) and Kimura et al (2007) also find similar evidence.

Kimura et al (2007) examine characteristics of trade in P&C in East Asia in comparison with Europe over the period 1987 to 2003. The key findings are that trade in P&C in East Asia is growing faster than in Europe and intra-regional trade in P&C for East Asia is also growing faster than in Europe, although the share is still lower than that in Europe. Ando (2006) goes a step further by decomposing trade in P&C in East Asia into three types: vertical intra-industry trade (IIT), horizontal IIT and one-way trade. The findings indicate that horizontal rather than vertical product differentiation accounts for rapid growth in global production sharing in East Asia.

Using I-O tables for 14 OECD countries obtained from the OECD Input-Output Database, Hummels et al (2001) examine the significance of "vertical specialisation" measured by the value of imported inputs embodied in goods that are exported in international trade. The key findings are that the share of vertical specialisation of total exports in 14 countries was 16% in 1970 rising to 21% in 1990 and the growth in vertical specialisation accounts for 30% of the growth in overall exports between 1970 and 1990.

[3] 225 products are identified in SITC7 (168) and SITC8 (57) at 5 digit level.

Using processing trade data over 1988-1996 obtained from the Eurostat-Comext Database, Baldone et al (2001) examine the outward processing trade (OPT) – trade in goods being exported for reason of processing abroad and subsequently re-imported – in Europe's textile and apparel industry. They found that OPT relative to domestic production in Germany and the Netherlands was much higher compared to France and Italy while re-imports were much larger than final imports in all four countries. Egger and Egger (2005) explore further by decomposing the OPT into outward processing exports (OPX) – intermediate goods exports and outward processing imports (OPM) – re-imports of final goods in 12 countries in Europe. According to the findings of their regression analysis, relative cost differences measured by the real exchange rate and tax levels are important determinants of OPT. Using the same data source, Baldone et al (2007) analyse the processing trade in Europe more extensively, including not only OPT but also inward processing trade (IPT) – imports of intermediate goods to be processed in the European Union (EU) and subsequently re-exported outside the EU. The interesting findings are that the share of IPT is much larger than that of OPT in total trade in the EU. In addition, it is found that outward processing imports (OPM) are concentrated on America (in particular, the USA) and non-EU European countries (in particular, Central and Eastern European Countries (CEEC)) whereas inward processing exports (IPX) are concentrated on America and Asia. Furthermore, they find that OPM is concentrated in textiles and apparel and motor vehicles whereas IPX is concentrated on machinery and mechanical appliances and motor vehicles.

The new literature goes a step further to investigate the forms of global production sharing, in particular which segments of the production process are done internally and which are done beyond firm boundaries. Antras (2003) examines the determinants of the share of intra-firm trade of US MNEs in total US trade at both the industry and country levels using panel data over the period 1987-1994. He finds the share of intra-firm imports of US MNEs in total US imports from the rest of world is positively correlated with the capital/labour ratio and R&D/total sales ratio in each domestic industry, and that the share of intra-firm imports of US MNEs in total US import from each country is positively associated with the capital/labour ratio in each country. These findings are consistent with theoretical predictions within a general equilibrium framework combined with a property-rights model of the boundaries of the firm and based on monopolistic competition and different factor endowments among countries. The findings of Antras (2003) are supported by those of Yeaple (2006). This study, based on cross-industry data for 1994, finds that US intra-firm imports as a share of US total imports is positively correlated with the capital/labour ratio. However, the more interesting finding is that intra-industry imports are more prevalent in capital intensive industries in relatively capital-scarce countries. Another key finding is that the extent of productivity dispersion across firms within an industry is positively associated with the parent firm's imports from overseas affiliates, suggesting an important role of firm heterogeneity in determining the modality of global production sharing as discussed by Antras and Helpman (2004) and Helpman et al (2004).[4]

Nunn and Trefler (2008) analyse US intra-firm imports of 5,423 products from 210 countries during the period 2000 to 2005 and examine three hypotheses proposed by an array of theoretical literature such as Antras (2003) and Antras and Helpman (2004, 2006). First, as predicted by Antras (2003), they find the more skill- and capital-intensive the industry, the higher is the ratio of intra-firm imports to total imports. This is consistent with Antras (2003) and Yeaple (2006). Second, it is found that industries with higher headquarters intensity and productivity dispersion tend to have a higher share of intra-firm imports in total US imports. Third, Nunn and Trefler (2007) find that higher contractual completeness in a trading country leads to a higher share of arm-length imports in total US imports.

Kimura and Ando (2005), Kimura and Kiyota (2006) and Tomiura (2007) investigate patterns and determinants of global sharing by Japanese firms. Using firm-level data, Kimura and Ando

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[4] The extent of productivity dispersion is measured by the standard deviation of firm sales across firms within an industry (Yeaple 2006).

(2005) identify the growing importance of not only intra-firm production sharing but also inter-firm production sharing. Kimura and Kiyota (2006) examine the determinants of firm' decisions on exports and FDI and find that productivity and R&D expenditure-sales ratio are positively correlated with both variables. In addition, they investigate the source of productivity difference and find interesting results: a firm that engages in exporting tends to have higher productivity than a non-exporter and a firm that engages in both FDI and exports tends to be more productive than a firm that engages in either FDI or exports. Tomiura (2007) also finds that FDI firms are distinctively more productive than exporting firms, which, in turn, are more productive than domestic firms.[5]

1.4 Gaps in the Literature: Why the Automobile Industry and Why Japan?

Previous research has substantially contributed to broadening our understanding of global production sharing. The theory has been enriched by incorporating in the standard trade theory insights from other areas such as contract theory and industrial organisation. Empirical evidence also has been rapidly accumulated due to improvements in data availability such as disaggregated bilateral trade data and firm-level trade data. However, little is known about inter-firm production sharing in spite of its important role (Price 2001, Hanson et al 2005, Kimura and Ando 2005, Helpman 2006). In fact, it is quite common that a firm subcontracts a part of the production process previously performed in-house to an external company. In electronics, a large number of final product firms outsource an assembly process to outsiders under original equipment manufacturing (OEM) arrangements, whereas other firms contract out not only assembly but also product design to external firms under original design manufacturing (ODM) contracts. In automobiles, an automaker subcontracts production and design of auto parts to independent suppliers.

Systematic analysis of inter-firm production sharing in the automobile industry is important because of the peculiar nature of its production process. First is the wide variety of

[5] Mayer and Ottaviano (2008) show that this is true of European firms.

components that constitute the automobile, ranging from engine components to power-train, steering, suspension, brake, wheels/tyres, exterior/interior trim, and body electronic components. It is inefficient for automakers to produce all these components in-house because of diseconomies of scale and capacity limitations. Therefore, it is natural for automakers to outsource components production to suppliers. The modality and effectiveness of the inter-firm relations between automakers and suppliers directly determine competitiveness. Second there are negative externalities in automobile production such as air pollution, greenhouse gas emissions and road accidents, which lead to strict regulations and standards imposed by governments (Parry et al 2007). In order for automakers to fulfil these regulations, close cooperation among final assemblers, and parts and components suppliers is essential. One way to reduce vehicle exhaust emissions would be to improve engine design, which, in turn, requires parts suppliers to design new parts. Another is to develop new technologies such as catalytic converters and evaporative emissions control in cooperation with suppliers (OICA 2011).

It is well documented that the inter-firm production sharing between Japanese automakers and suppliers developed over a long period of time is an important source of global competitiveness of Japanese automobile industry. The adaptation of inter-firm production sharing between Japanese automakers and suppliers is based on a long-term relationship coupled with cross-stake holding and information sharing. This locally forged inter-firm relationship is transferred to host countries when Japanese automakers build production plants abroad, encouraging suppliers to follow automakers' overseas investments. In addition, increasing overseas investments by suppliers facilitate inter-firm trade in P&C within their global production networks.

Spencer and Qiu (2001) and Qiu and Spencer (2002) have theoretically analysed the mechanism of inter-firm production sharing between Japanese automakers and suppliers with a particular focus on *keiretsu* networks. Their work analyses automakers' procurement decisions between the purchase of customised components from *keiretsu* suppliers under incomplete contracts and the purchase of generic components from a spot market. The work of Spencer and Qiu (2000) and Qiu and Spencer (2002) has established in the literature the idea that 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.[6] Hence, the efficiency-raising RSI causes Japanese assembly makers to choose domestic procurement within the *keiretsu* network rather than importing from local suppliers in a foreign country even if producing at cheaper costs. This postulate is consistent with empirical results. Lawrence (1991) and Fung (1991) examine the role of the domestic *keiretsu* network for US-Japan trade and find it negatively affects import penetration in Japan by foreign sellers. Fung (1991) concludes Japanese *keiretsu* may be an important determinant of US-Japan trade.[7]

More recent works by Baldwin and Ottaviano (2001) and Greaney (2003) have emphasised that the global *keiretsu* network promotes international trade by providing *keiretsu* members with a cost advantage in market access. 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 both belong to the *keiretsu*, the costs could be much lower compared to non-*keiretsu* members because they already have mutual trust based on a close and long-standing business relationship. This theoretical work is supported by Head, Ries and Spencer (2004), who explicitly investigate the effects of both domestic and global *keiretsu* networks on the pattern of auto parts imports from the US in Japan. They find the global *keiretsu* network increases auto parts imports in Japan through "reverse imports" (i.e. imports from overseas affiliates of that country's own firms)

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

[7] Saxonhouse (1989) takes an opposite position, arguing that Japan's trade pattern can be explained by factor endowment as with 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.

however it is smaller than the import-reducing effect of the domestic *keiretsu* network. Using firm level data, Greaney (2005, 2009) find that Japanese overseas affiliates in the United States demonstrate by far the strongest home bias in their trade partners highlighting the existence of stronger network effects on trade among Japanese firms.

1.5 Structure and Preview

The thesis comprises seven chapters. Chapters 2 and 3 are macro level analyses. Chapter 2 overviews the globalisation process of the world automobile industry by examining data on automobile production, sales and trade. The particular focus is on the period 2001/2 to 2007/8 when the global shift toward developing countries accelerated. It is shown that (1) the integration process accompanies a global shift from traditionally auto-producing countries to new auto-producing countries, (2) production networks formed by leading automakers from Japan, the United States and European countries is a main driving force of this integration process and (3) Japanese auto makers play a more important role in the integration process than any other automakers.

Chapter 3 undertakes an empirical analysis of the patterns and determinants of Japan's automobile trade from a comparative perspective. It begins with the comparison of Japan's trade performance with other traditionally auto-producing countries such as the United States and western European countries. Specifically, the roles of the 'following-leader' pattern (that is, parts and components suppliers following car producers) of Japanese overseas investment and of interlocking relationships among firms (*keiretsu* networks) for Japan's P&C trade are examined by analysing three-dimensional panel data (Reporter-Partner -Product) over a seven-year time period from 2002 to 2008.

Chapters 4, 5 and 6 are micro-level analyses. Chapter 4 provides a profile of the Japanese automobile industry with particular attention to Toyota Motors as a background for the empirical analysis in subsequent chapters. First I will set out the 70-year history of Toyota and overview its production system and suppliers relationship, which have implications for global production sharing. Subsequently, the trend and pattern of the following-leader investments undertaken by Toyota's *keiretsu* suppliers are examined. Finally, the trend and pattern of trade in P&C are investigated using trade data in Aichi prefecture, which are a proxy of trade related to Toyota and its suppliers.

Chapter 5 looks at whether the Japanese following-leader auto part suppliers in host countries substitutes or complements auto parts exports from Japan. To tackle this issue, a product-level dataset covering 79 auto parts and 34 countries over the period 1993 to 2008 is analysed. I calculated the number of employees of suppliers' overseas plants in a host country for each product as a proxy of the following-leader investment, using *Nihon no jidoshabuhin kogyo* [Japanese Automotive Parts Industry] compiled by the Japan Auto Parts Industries Association (JAPIA).

Chapter 6 investigates the role of *keiretsu* networks in auto parts import in Japan through an in-depth analysis of the case of Toyota. I will estimate separately the effects of domestic *keiretsu* networks and global *keiretsu* networks on auto parts import. The role of domestic *keiretsu* networks is analysed by estimating the share of domestic procurement from *keiretsu* suppliers for each auto part using "Automotive parts sourcing in Japan: Japanese car maker's procurement from domestic suppliers for 200 products lines" compiled by Industry Research and Consulting (IRC). The role global *keiretsu* network is quantified in the same way as in Chapter 5.

Chapter 7 summarises the findings and provides some policy implications.

CHAPTER 2

Globalisation of the Automobile Industry

2.1 Introduction

The globalisation process in the automobile industry has been at a turning point where the centre of the global automobile industry has shifted from developed countries to developing countries. This global shift began after World War II and, gradually proceeded over the second half of the 20th century. The beginning of the 21st century has witnessed the acceleration of this global shift and eventually, the share of automobile production in developed countries first fell below half of world production in 2010 (Figure 2.1). This unprecedented global shift suggests global automakers are rapidly expanding their production and distribution networks toward developing countries in recent years.

This chapter investigates the global shift in the automobile industry by analysing data on automobile production, sales, and trade. The emphasis is on the role of production networks spread by leading automakers originating from the traditionally auto-producing countries (hereinafter, TPCs): Japan, United States, Germany, France, Italy and Sweden. It is shown that the center of the global automobile industry is shifting from TPCs to the new auto-producing countries (hereinafter, NPCs): China, India, Thailand, Indonesia, Malaysia, the Philippines, Vietnam, Brazil, Argentina, Mexico, Russia, Poland, the Czech Republic and South Africa. The leading automobile producers originating from TPCs, especially Japanese automakers, have been the key driving force of this rapid global shift in the early 21st century.

The analysis covers the period 2001 to 2008 for two reasons. First, the beginning of the 21st century saw a global shift at an unprecedented pace. Second, data availability on automobile production and sales are limited to 2001 onward. 2009 and 2010 are excluded due to the automobile industry being severely affected by the global financial crisis.

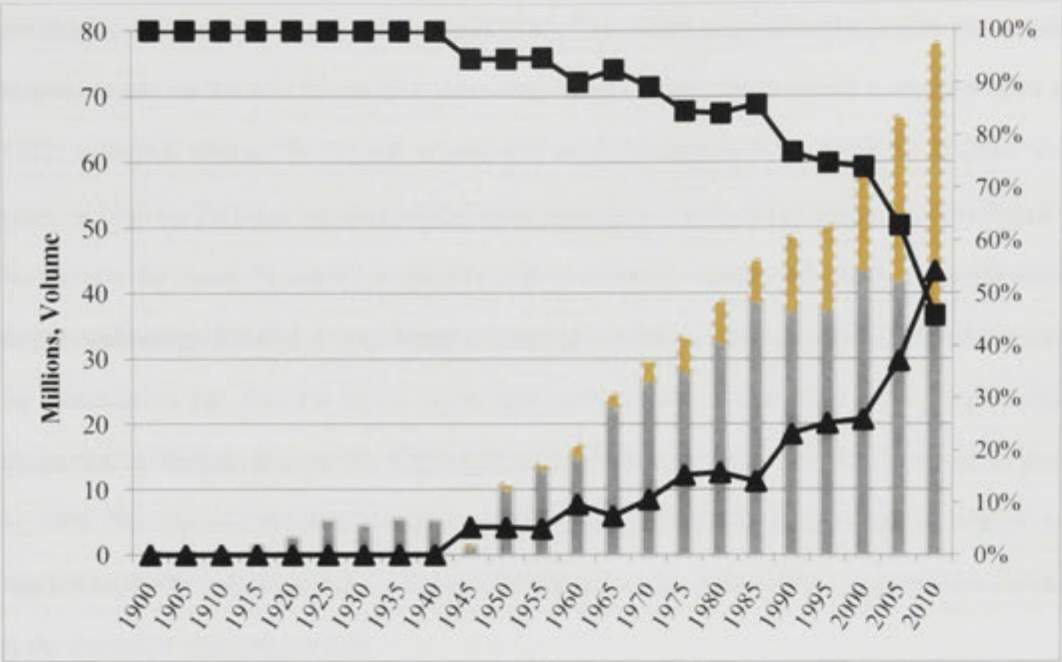
The plan of this chapter is as follows. The next section provides an overview of the globalisation process in automobile industries prior to the 21st century. First, I describe the global shift from developed countries to developing countries over the 20th century followed by a more detailed break down into regions.[8] Section 2.3 reveals the characteristics of the global shift by breaking it down into countries and examining data on production, sales, and trade during the period 2001 to 2008. Section 2.3 examines the role of the global production networks established by automakers originating from the TPCs in developing the global shift. Section 2.4 concludes.

2.2 Overview: The Process

Figure 2.1 shows the trend of world automobile production and its distribution from 1900 to 2010. At the first half of the 20th century automobile production developed to some extent however its development was so limited that production volume remained below 6 million units. Production was completely dominated by developed countries. The post-war period experienced a dramatic increase in world automobile production from 10 million units in 1950 to nearly 80 million units in 2010. Although the developed country share had continued to fall since 1945, it was still significant: 75% in 2000. The beginning of the 21st century saw both the most rapid growth in world production and a dramatic decline in the developed country share. While world production increased by nearly 20 million units from 2000 to 2010, the developed country share declined from 74% to 46%. This unprecedented transformation indicates that the centre of the global automobile industry is shifting from developed countries to developing countries.

[8] The developed countries include North America, Western Europe and Japan that have traditionally produced automobiles. On the other hand, for simplicity, the developing countries are the rest of the world.

Figure 2.1: World Automobile Production and its Distributions, 1900-2010



Notes: The grey bar shows the total production volume of automobiles in North America and, Western Europe and the black line with squares represents its share in world productions. The orange bar shows the production volume of the rest of the world and the black line with triangles represents its share in world production. The production volume is presented in millions.
Source: *Nikkan Jidosha Shinbun* and *Nikkan Jidosha Kaigisho* [Automobile Newspaper and Automobile Business Association of Japan] (1999) and International Organisation of Motor Vehicle Manufacturers (OICA): http://www.oica.net/

The automobile industry first developed in Western Europe from the late 19th century to the early 20th century. In 1886, Karl Benz and Gottlieb Daimler in Germany invented viable automobiles which were developed into marketable commodities, as distinct from 'one-off' inventor's curiosities (Rhys 1972). This became the cradle of the automobile.[9] Applying Otto's four-stroke engine to a three-wheel vehicle, Karl Benz produced an automobile with an internal combustion engine named "*Motorwagen*" in 1886. The *Motorwagen* was first sold on the market in 1888, making it the first commercially obtainable automobile in history. Gottlieb Daimler initially

[9] Note that here the automobile is defined as motor vehicles powered by internal combustion engines excluding steam-propelled vehicles and electric vehicles. Steam-propelled vehicles have a longer history, dating back to 1665 when the Jesuit Ferdinand Verbist produced a model steam car (Rhys 1972).

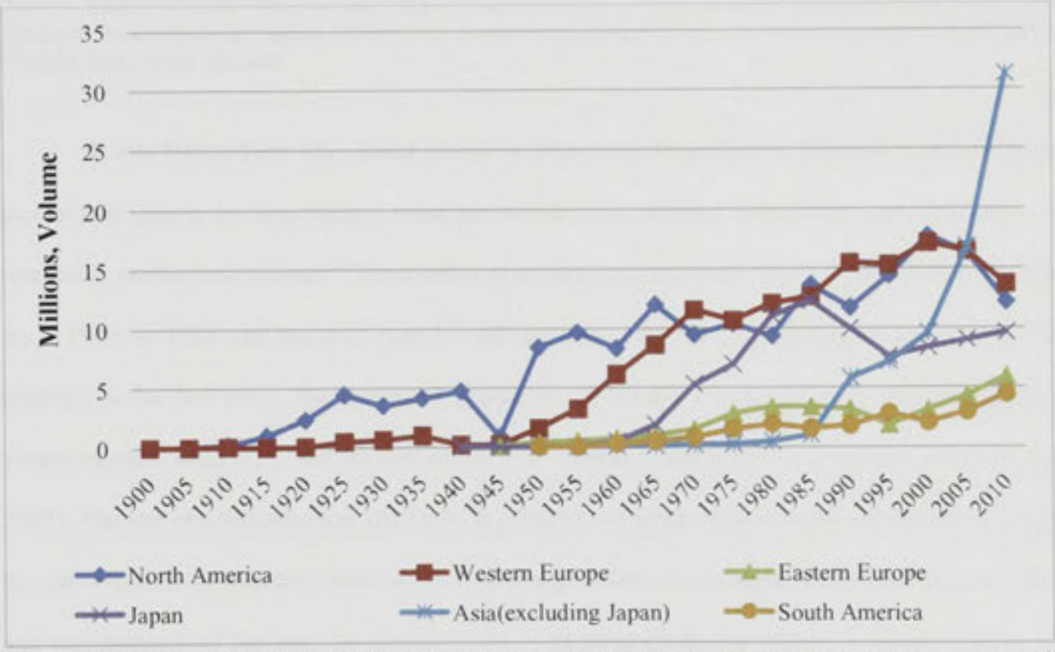
specialised in the development of high-speed and light-weight engines and succeeded in developing an innovative engine (Bloomfield 1978).[10] Mounting this innovative engine on a coach, Daimler produced the first four-wheel automobile in history in 1886 and sold it on the market in 1892. A further advance in internal combustion engine technology developed by Daimler was made in 1895 by De Dion and Bouton in France, leading to a high-speed engine that developed 1 horsepower for every 25 pounds at speeds of up to 1,500 revolutions per minute. This advanced engine technology diffused among Western European countries and was widely adopted not only for automobiles but also for motor cycles and early airships (Bloomfield 1978). Automobile production in Western Europe was 6 thousand units in 1900 but rapidly grew to 38 thousand units in 1905. The share of Western Europe in world production during these periods accounted for nearly two thirds, indicating that the centre of the global automobile industry was Western Europe at the formative stage (Figure 2.3).

Development of the automobile industry in Western Europe was underpinned by two factors. The first is that the carriage and coach had played roles as important means of transportation in Europe. The long-standing carriage tradition developed infrastructures such as paved roads and supporting industries such as wheels, axles, bodies, doors and seats. These developments allowed Western Europe to establish the first automobile industry in the world. Second, the existence of technological accumulation prior to the invention of automobiles by Karl Benz and Gottlieb Daimler in 1886 was extremely crucial in developing automobiles. In 1804 Isaac de Rivoz, a Swiss, propelled a carriage by exploding hydrogen and air inside a cylinder. While French man, Etienne Lenoir, patented a two-stroke internal-combustion engine in 1860, Nikolaus Otto, a German, designed a practical four-stroke engine in 1876 (Rhys 1972). At the same time, an English man, J.R. Dunlop, was patented with the invention of the pneumatic tyre in 1888 and the Marquis de Dion developed a rear suspension system in the same period.

[10]According to Bloomfield (1978), previous gas and oil engines developed about 1 horsepower for every 300 pounds of engine weight at speeds up to 250 revolutions per minute whereas the Daimler engine developed 1 horsepower for every 90 pounds of engine weight at speeds up to 500 revolutions per minute.

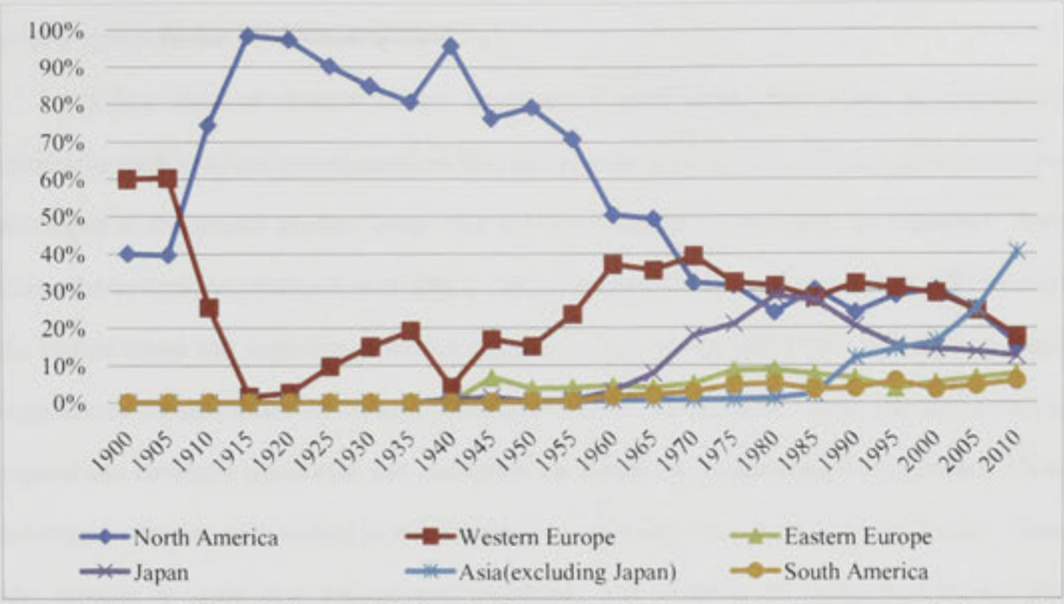
Automobile production in Western Europe was characterised by its craftsmanship. The important factors of craftsman production are customised components, highly skilled workers, low production volume and a wide variety of product (Dicken 2003). Although craftsman production underpinned the automobile industry at the formative stage, the natures of the craftsmanship restrained the further development of Europe's automobile industry. The fundamental drawback of craftsman production was to make it difficult for manufacturers to enjoy benefits from scale economies. As a result, "production costs were high and did not drop with volume, which meant that only the rich could afford cars" and "because each car produced was, in effect, a prototype, consistency and reliability were elusive" (Womack et al 2007, pp 23-24).

Figure 2.2: Production of Automobiles by Regions



Sources: *Nikkan Jidosha Shinbun* and *Nikkan Jidosha Kaigisho* [Automobile Newspaper and Automobile Business Association of Japan] (1999) and International Organisation of Motor Vehicle Manufacturers (OICA): http://www.oica.net/

Figure 2.3: Shares of Regions in World Production



Source: *Nikkan Jidosha Shinbun* and *Nikkan Jidosha Kaigisho* [Automobile Newspaper and Automobile Business Association of Japan] (1999) and International Organisation of Motor Vehicle Manufacturers (OICA): http://www.oica.net/

It was Henry Ford who found a way to overcome the problems inherent in the craftsman production system by introducing mass production that enabled substantial cost reductions by increasing production volume.[11] The symbol of mass production was Ford's Model T that was sold from 1908 to 1927 and reached over 15 million units of total sales during those 19 years. In addition to the low price, the enormous popularity of Model T came from its user-friendliness: almost anyone could drive and fix this automobile without a chauffeur or mechanic (Womack et al 2007). The use of a transmission system with planetary gearing made it easier for drivers to handle the car whereas the dramatic increase in interchangeability of components allowed for the repair and maintenance of the car. As distinct from craft production, the Model T contributed to the

[11] Ford's mass production system was characterised by development of an assembly line process that controlled the pace of production based on scientific management and permitted the production of large volumes of standardised products due to highly standardised components and the simplified attachment of components over highly divided production process. Ford's mass production system was completed in 1913 when the Highland Park plant was built in Detroit with the installation of a moving assembly line. See Womack et al (2007) for further information.

change in the nature of the automobile from being a luxury good for the wealthy to a means of general transportation for the middle class.

Alfred Sloan at General Motors developed a mass production system by introducing innovative marketing and management techniques. To meet a variety of consumer demands, Sloan developed a five-model product range that ran incrementally from cheap to expensive, from Chevrolet to Cadillac (Womack et al 2007). Product diversification was a crucial strategy because the United States had experienced market maturation since the middle 1920s, leading to a larger replacement demand than new demand (Shimokawa 1994). A franchise system was introduced to expand sale networks nationwide and strengthen the cooperative relationships with dealers. Close information sharing with dealers enabled automakers to avoid waste by reducing inventory. Sloan also brought in some new management techniques. For example, to reduce inefficiency and management costs derived from the nature of a highly centralised organisation, the divisional system through the decentralisation of the corporate structure was introduced into General Motors.[12] In addition, experts were allocated into every division to complete the division of professional labour (Womack et al 2007).

The mass production system that incorporated Ford's factory practice and Sloan's marketing and management techniques led the US auto industry to a golden age that lasted nearly a half century. Production volume in North America increased from 1 million units in 1915 to 12 million units in 1965 although it dramatically dropped during World War II (Figure 2.2). Over 70% of world production was consistently concentrated in North America during the period between 1910 and 1955 (Figure 2.3). However, North America's share of global automobile production began to decline in 1915, dropping to 50 % by the 1960s and eventually to around 30% from the 1970s onwards. This declining North American share was partially due to the diffusion of the mass production system to Western European automakers, indicating that the US automobile industry

[12] A number of autonomous divisions were created, ranging from auto manufacturing and component manufacturing to finance and marketing.

was losing its comparative advantage. Daimler-Benz (Mercedes), Wolfsburg (VW), Flins (Renault), and Mirafiori (Fiat) had all made the transition to mass production by the late 1950s (Womack et al 2007). In fact, the two decades following the end of World War II saw a rapid expansion of production in Western Europe, leading to a growing share in world auto production for this region (Figures 2.2 and 2.3). Eventually, Western Europe passed North America in 1970.

The shares of both North America and Western Europe in world production appeared flat or declining from the 1960s onward even though auto production in these regions continued to increase in absolute numbers. This was partly due to the emergence of Japan as a major automobile producing nation. As can be seen in Figures 2.2 and 2.3, the two and half decades from 1960 to 1985 witnessed Japan's growing position with production volume increasing from 0.5 million to 12 million during this period and reaching a peak share in 1980 (29%). In 1977 Japan became the largest exporter of passenger vehicles in the world and, Japan became the largest car producing country in the world in 1980. In 1980, Japan overtook the United States in terms of not only total motor vehicles (commercial vehicles plus passenger vehicles) but also passenger vehicles.[13]

The key to the rise of Japan was not adaptation of the mass production system. Rather, it was a newly invented production system, the so-called *lean production*.[14] Based on a just-in-time inventory and in-station quality, the lean production system enables automakers to dramatically eliminate waste in the production process, leading to a decrease in production costs and improvement of product quality (Liker 2004). A modular component system and multi-skilled worker were also introduced into the lean production system making it possible to flexibly meet the wide variety of fluctuating consumer demands (Dicken 2003). In addition to the diffusion of lean production among Japanese automakers, the two oil shocks that occurred in the 1970s contributed to the competitiveness of Japanese cars. The preference of consumers dramatically shifted to small and medium size motor vehicles with the fuel efficiency Japanese automakers had specialised in a

[13] Japan's overall production was 1.1 million including 0.7 million of passenger vehicles whereas total US production was 0.8 million including 0.6 million passenger vehicles.

[14] I discuss lean production in detail in Section 4.3.

for long time. However, Japan's position in world production started declining in 1985 and its share decreased by 15 percentage points from 1985 to 2005. The decline in domestic production in Japan could be largely attributed to the increase in the overseas production of Japanese automakers encouraged by the rapid appreciation of the Japanese yen caused by the Plaza Accord in 1985 and the voluntary export restraints (VERs) that resulted from trade friction with the United States and Western European countries.[15]

Since 1985, developing Asia (that is Asia excluding Japan, hereafter Asia) has emerged as the new production base. Production in the rest of Asia surpassed that in Japan in 2000, and subsequently, overtook North America and Western Europe in 2005. The share of Asia in world production reached 40% in 2010. Automobile production in South America and Eastern Europe also experienced rapid growth in the early 21st century, leading to a rise in their share of world production. In 2010 the aggregated share of these three regions reached 54% whereas the aggregated share of North America, Western Europe, and Japan dropped to 46%.

The next section examines the characteristics of the unprecedented globalisation process during 2000-2008.

2.3 Global Shift: Production, Market, and Trade

Table 2.1 presents the geographical distribution of production and sales in the automobile industry for 2001/2 and 2007/8.[16] The global automobile industry experienced a shift of production platforms and automobile markets during this period. The combined share of TPCs in total global production declined from 60% to 47%. Among traditional auto-producing countries (TPCs) the United States recorded the sharpest decline. Total US auto production declined by nearly 2 million, leading to a 7% contraction of its share in world production. Other TPCs such as Japan, Germany,

[15] I describe the historical path with a particular focus on Toyota Motors in Section 4.2.
[16] The 2001/2 and 2007/8 stand for two-year averages that level fluctuations between periods

France, and Italy also experienced a decline in their shares of world automobile production although their contractions were not as sharp as in the United States.

On the other hand, developing countries such as those of Asia (excluding Japan), Eastern Europe and South America increased their position in world production. Focusing on NPCs in developing countries, the combined share of NPCs in total global production increased from 21% to 37% between these two years. Among NPCs China, India, Thailand, Brazil and Eastern European countries increased their importance in world production. Growth of automobile production in China was astonishing: it increased by 6 million units, raising China's share of world production by 8 percentage points. By region, both Asia and Eastern Europe expanded auto production, but Asia has been the largest auto-producing region, accounting for 43% of world production in 2007/8.

A global shift can also be observed on the sales side. While TPCs accounted for 64% of the world market for motor vehicles in 2001/2, this figure was down to 50% in 2007/8. All TPCs except Sweden reduced automobile sales. Especially, the decline of the United States was the most substantial with sales contracting by 2.6 million units. As a result, the US share in world sales of motor vehicles dropped from 31% to 24% during the period 2001/2 to 2007/8. In contrast, the share of NPCs rose from 19% to 34%. All NPCs continuously expanded their markets during the same period. China, especially, is emerging as the leading market. Annual sales of motor vehicles in China increased by 5.5 million units during this period and China's share in world car sales rose to 13% in 2007/8.

Table 2.1: World Motor Vehicle Production and Sales in 2001/2 and 2007/8

	Production				Sales[1]			
	Volume (Thousands)		Share (%)		Volume (Thousands)		Share (%)	
	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8
Asia	18,668	30,597	32	43	12,641	19,010	23	30
Japan	10,017	11,585	17	16	5,849	5,210	11	8
South Korea	3,046	3,956	5	6	1,550	1,186	3	2
Taiwan	302	233	1	0	312	227	1	0
Thailand	522	1,340	1	2	353	623	1	1
Malaysia	377	486	1	1	415	517	1	1
Indonesia	289	506	1	1	308	521	1	1
Philippines	47	51	0	0	81	174	0	0
Viet Nam	11	28	0	0	40	95	0	0
China	2,810	9,090	5	13	2,805	8,355	5	13
India	854	2,293	1	3	854	1,985	2	3
Oceania	331	332	1	0	877	1,130	2	2
Australia	331	332	1	0	798	1,031	1	2
North America	16,256	14,199	28	20	19,946	17,481	36	28
USA	11,852	9,737	21	14	17,305	14,716	31	24
Canada	2,581	2,330	4	3	1,664	1,680	3	3
Mexico	1,822	2,131	3	3	976	1,084	2	2
South America	2,052	3,912	4	5	2,035	3,707	4	6
Brazil	1,804	3,096	3	4	1,539	2,351	3	4
Argentina	197	570	0	1	129	550	0	1
Venezuela	12	153	0	0	172	381	0	1
Western Europe	17,386	16,130	30	22	16,752	16,147	30	26
Germany	5,580	6,129	10	9	3,580	3,394	6	5
France	3,615	2,792	6	4	2,678	2,492	5	4
UK	1,754	1,699	3	2	2,829	2,639	5	4
Italy	1,503	1,154	3	2	2,630	2,596	5	4
Netherlands	235	135	0	0	619	601	1	1
Belgium	1,122	779	2	1	544	608	1	1
Spain	2,852	2,715	5	4	1,700	1,519	3	2
Portugal	245	175	0	0	339	275	1	0
Sweden	282	337	0	0	285	329	1	1
Austria	154	189	0	0	319	341	1	1
Eastern Europe	2,976	6,642	5	9	2,611	4,189	5	7
Russia	1,235	1,725	2	2	1,731	2,704	3	4
Czech Rep.	456	942	1	1	172	210	0	0
Romania	74	243	0	0	180	345	0	1
Poland	329	869	1	1	342	386	1	1
Turkey	308	1,123	1	2	184	543	0	1
Africa	488	702	1	1	431	689	1	1
South Africa	405	548	1	1	358	568	1	1
TPCs[2]	34,605	33,436	60	47	35,159	31,379	64	50
NPCs[3]	12,120	26,787	21	37	10,474	21,017	19	34
Total	57,649	71,893	100	100	55,296	62,357	100	100

Notes: [1] Due to data limitation on sales for some countries, the volume is substituted with the closest year as follows: 2007/8 for Philippines is 2006, 2007/8 for Peru is 2004, 2001/2 for Viet Nam is 2004, 2001/2 for Russian Federation is 2004, 2007/8 for Chile is 2006, 2007/8 for Colombia is 2006 and 2007/8 for Egypt is 2005.

[2] TPCs: Traditional auto-producing countries (including Japan, United States, Germany, France, Italy and Sweden).

[3] NPCs: New auto-producing countries (including China, India, Thailand, Indonesia, Malaysia, Philippines, Vietnam, Brazil, Argentina, Mexico, Russia, Poland, Czech Republic and South Africa).

Sources: Compiled from International Organisation of Motor Vehicle Manufacturers (OICA), Automotive information platform and *Nikkan Jidosha Shinbun* and *Nikkan Jidosha Kaigisho* [Automobile Newspaper and Automobile Business Association of Japan] (2008).

Table 2.2: Automobile Trade in 2001/2 and 2007/8

	Exports[1]				Imports[1]			
	Value (Million $US)		Share (%)		Value (Million $US)		Share (%)	
	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8
ASIA	152,891	389,328	21	26	72,720	188,974	10	13
Japan	102,520	190,428	14	13	14,894	28,211	2	2
South Korea	19,497	57,617	3	4	4,076	12,733	1	1
Thailand	4,524	21,657	1	1	4,125	9,422	1	1
Malaysia	1,385	3,467	0	0	3,106	5,840	0	0
Indonesia	1,423	5,276	0	0	2,695	7,406	0	0
Philippines	1,528	3,470	0	0	1,366	2,126	0	0
Vietnam	159	1,644	0	0	887	3,294	0	0
China	8,096	54,444	1	4	9,218	38,589	1	3
India	1,142	6,591	0	0	916	5,764	0	0
Oceania	2,974	5,086	0	0	12,512	30,060	2	2
Australia	2,656	4,678	0	0	9,925	25,369	1	2
North America	188,171	262,741	26	18	285,684	377,884	39	25
United States	86,234	139,487	12	9	202,214	258,625	27	17
Canada	60,978	65,132	8	4	54,153	77,062	7	5
Mexico	40,959	58,121	6	4	29,317	42,197	4	3
South America	9,793	25,612	1	2	14,166	46,845	2	3
Brazil	6,336	16,674	1	1	5,150	15,608	1	1
Argentina	2,112	6,553	0	0	1,913	9,972	0	1
Europe	372,419	801,541	51	54	340,122	777,908	46	52
Western Europe	339,671	660,712	47	44	311,510	621,733	42	42
Germany	126,411	269,162	17	18	62,659	129,007	8	9
France	49,299	80,117	7	5	38,809	83,317	5	6
Italy	25,201	55,008	3	4	32,246	63,997	4	4
England	29,675	54,650	4	4	48,793	85,724	7	6
Spain	31,845	62,075	4	4	30,384	62,139	4	4
Netherlands	9,676	18,136	1	1	15,140	28,675	2	2
Belgium	32,735	56,656	4	4	29,656	58,096	4	4
Sweden	10,640	22,437	1	2	8,768	21,921	1	1
Austria	10,547	24,260	1	2	11,334	22,877	2	2
Eastern Europe	32,748	140,829	4	9	28,612	156,175	4	11
Russia	1,420	4,504	0	0	2,599	42,497	0	3
Czech Rep.	9,053	30,754	1	2	5,377	16,856	1	1
Romania	782	7,364	0	0	1,009	10,731	0	1
Poland	6,327	31,841	1	2	6,215	23,698	1	2
Turkey	3,901	21,399	1	1	3,262	18,079	0	1
Africa	6,041	17,198	1	1	12,171	42,366	2	3
South Africa	2,691	7,459	0	0	2,178	8,630	0	1
TPCs[2]	429,978	811,290	59	54	359,591	585,078	49	39
NPCs[3]	91,837	281,217	13	19	79,334	260,709	11	18
World	729,714	1,495,103	100	100	740,031	1,485,764	100	100

Notes:

[1] Automobile trade includes both completely-built units (CBU) and parts and components (P&C). The complete list of CBU and P&C based on Harmonized System (HS) code are shown in Appendix 3-A and 3-B.

[2] TPCs: Traditional auto-producing countries (including Japan, United States, Germany, France, Italy and Sweden).

[3] NPCs: New auto-producing countries (including China, India, Thailand, Indonesia, Malaysia, Philippines, Vietnam, Brazil, Argentina, Mexico, Russia, Poland, Czech Republic and South Africa).

Sources:

Compiled from UN Comtrade Database.

Table 2.2 presents the geographical distribution of automobile trade. As can be seen, the automobile industry has globally integrated through trade as well. World automobile trade doubled during 2001/2 to 2007/8. It can also be observed that all regions and countries have invariably experienced increasing connection with the global automobile industry through trade. Although the degree of global shift is not as great as observed in automobile production and sales, the importance of TPCs are declining as a result of the rise of NPCs for automobile trade. While TPCs' share of total world automobile exports dropped by 5 percentage points during this period, the NPCs' share rose by 6 percentage points. On the import side, while TPCs share fell by 10 percentage points, the NPCs share rose by 7 percentage points.

Germany was the largest exporter among TPCs, followed by Japan and the United States in both 2001/2 and 2007/8. Among NPCs Mexico was the largest exporter in 2007/8 followed by China, Poland, the Czech Republic, Thailand, Turkey and Brazil. While Mexico's automobile exports exceeded those of Italy, England, and Sweden, the scale of China's automobile exports was almost the same as Italy's and England's in 2007/8. On the import side, among TPCs the United States was the largest importer in 2007/8 although its share had decreased by 10 percentage points since 2001/2. An interesting point is that Japan's share in world automobile imports (2%) is much smaller than those of other TPCs. The limited automobile imports to Japan become more apparent when comparing with the production and market size in Japan. The unique feature of Japan's automobile trade will be investigated further in the next chapter.

2.4 Role of Production Networks

The transformation of the geographical landscape in the world automobile industry has been driven by the leading automobile producers originated in TPCs. They have integrated multiple countries into the global automobile industry by expanding their production and distribution networks. Two factors matters in facilitating the overseas activities of automakers. First is the market. Historically, automobile production has developed within large, affluent consumer markets where high levels of demand have permitted the achievement of economies of scale (Dicken 2003). That production was concentrated in developed countries especially TPCs until the end of the 20th century indicates that the main market for automobiles existed in these regions. However, reflecting the saturation of consumer markets in developed countries (particularly, TPCs) and the fastest-growing markets in developing countries (particularly, NPCs) at the beginning of the 21st century, the leading automobile producers headquartered in TPCs are rapidly increasing their overseas production toward NPCs.

Second, the overseas operations of global automakers are influenced by government policy in host countries such as trade/investment policies and industrial policies. Historically, against the backdrop of the worldwide protectionism in the early 20th century, trade barriers over automobile imports were erected in Europe and elsewhere. Trade barriers encouraged US and European automakers to expand their production networks in Europe (Maxcy 1981).[17] In the post-war period, the establishment of the European Economic Community (EEC) in 1957 and its subsequent enlargement caused an influx of investments by global automakers in Europe (Dicken 2003). The voluntary export restraints (VERs) that result from the trade friction between Japan and the United States (and several Western European countries) encouraged Japanese automakers to increase overseas productions in the United States during the 1980s and 1990s. The local content requirements also matter. Particularly, local content requirements combined with a high tariff on automobile imports were popular among developing countries such as India, Brazil, Argentina, Mexico and Spain during the 1950s and 1960s (Dicken 2003). This import-substitution policy not

[17] It was Daimler, the German automaker that became the first MNE by establishing a wholly-owned subsidiary in Austria in 1902. Three year later, the Italian automaker, Fiat, followed. Against the backdrop of the superiority of their mass production techniques over local competitors, the US automakers expanded global operations toward Europe more actively from 1913 to 1929. Ford founded a subsidiary to assemble the Model T in England in 1911. The second subsidiary in Europe was established in France in 1913 as a response to growing French demand for war purposes. General Motors adopted a strategy of mergers and acquisitions in expanding global operations. In 1925 General Motors purchased an English motor company, Vauxhall Motors that specialised in a relatively high-priced car. Subsequently, General Motors acquired the German company, Adam Opel, in 1929. See Maxcy (1981) for more information.

only stimulates foreign automakers to carry out additional investment for production of engine and key components but also foreign parts suppliers to follow automakers' investment abroad.

Table 2.3 shows the global production of the leading automobile producers headquartered in TPCs in 2002 and 2008.[18] Total overseas production of TPCs increased by 8 million units during this period and this increase was fully attributable to the expansion of overseas production in NPCs (9 million units). Moreover, the expansion of overseas production by auto producers originated from TPCs in NPCs boosted auto production in NPCs by 64% during 2001/2 to 2007/8. Among auto producers from TPCs, the Japanese car maker is the most important player in the globally-integrated automobile industry: nearly one third of global auto production has been dominated by Japanese car makers and its overseas production was much larger than any other producers in 2008 (Table 2.3). The important feature of the Japanese automaker is that it has a production network spread worldwide ranging from TPCs to NPCs.

The globalisation of the automobile industry has been reflected in the rapid growth of intra-firm trade within the global production network (Helleiner 1979, Caves 2007). Production networks facilitate P&C trade among subsidiaries as well as between headquarters and overseas subsidiaries. Table 2.4 shows exports of P&C from Toyota's overseas subsidiaries. As can be seen, subsidiaries all over the world are exporting auto parts to Japan, suggesting the existence of intra-firm trade between headquarter plants and overseas subsidiaries. In addition, overseas subsidiaries are reciprocally exchanging different P&C. For example, Toyota Motors have established a regional division of labour production in Asia where Thailand, Malaysia, Indonesia, the Philippines and Taiwan are mutually swapping different auto parts. It is important to point out that not only intra-firm trade but also inter-firm trade is facilitated by expanding production networks. Since the automobile industry has a large number of parts suppliers, overseas subsidiaries of automobile

[18] The share of the leading automobile producers headquartered in TPCs in global auto production was 88% in 2002 and 82% in 2008.

producers might increase inter-firm trade with parts suppliers at home as well as their overseas plants.

The automobile producers establish overseas plants to sell their products not only to the domestic market but also to other markets in the same region. In addition, overseas subsidiaries of the same parent company assemble different models in individual countries to meet the region-wide demand. Table 2.5 shows exports of completely-built units (CBU) from Toyota's overseas subsidiaries. As can be observed, while the subsidiary in Canada is exporting Corolla, Camry Solara and Matrix to the United States, counterparts in the United States are exporting Tacoma, Avalon, Camry, Sienna, Tundra, and Sequoia to Canada. Also, while the subsidiary in Brazil is exporting Corolla to Argentina, the counterpart in Argentina is exporting Hilux to Brazil. The same phenomenon can be observed between home and host countries: while headquarter plants in the home country exports their core products (e.g. Prius in the case of Toyota Motors), overseas plants exports unique models not produced in the home country (e.g. Avalon in the case of Toyota).

Table 2.3: Global Production of Automobile Producers Headquartered in TPCs in 2002 and 2008

Volume in Thousands	Domestic		Overseas		TPCs[a]		NPCs[b]		Others		Total	
	2002	*2008*	*2002*	*2008*	*2002*	*2008*	*2002*	*2008*	*2002*	*2008*	*2002*	*2008*
Japanese Car Makers	10,256	11,632	**7,652**	**11,606**	3,551	3,967	**2,616**	**5,992**	1,484	1,647	17,908	23,238
Toyota	3,485	4,012	2,258	4,198	1,393	1,571	464	2,090	401	536	5,744	8,210
Honda	1,386	1,264	1,602	2,648	997	1,217	219	1,014	385	416	2,988	3,912
Nissan	1,392	1,293	1,326	2,101	734	931	451	988	141	181	2,718	3,395
US Car Makers	9,493	5,231	**6,462**	**6,958**	850	880	**2,129**	**3,878**	3,482	2,199	15,956	12,190
GM	4,169	2,356	2,704	2,859	-	-	1,253	2,282	1,450	576	6,874	5,215
Ford	3,465	1,602	2,696	3,151	838	855	486	1,258	1,371	1,037	6,162	4,753
Chrysler	1,751	1,106	986	787	-	-	367	279	618	507	2,738	1,893
German Car Makers	4,763	5,232	**4,031**	**5,761**	618	708	**1,634**	**3,781**	1,778	1,271	8,795	10,993
VW	1,210	1,450	2,628	2,899	-	-	1,354	2,440	1,274	458	3,839	4,350
Opel	868	614	430	1,481	35	8	97	1,045	297	427	1,299	2,096
Mercedes-Benz	1,173	1,236	413	491	175	152	126	230	111	107	1,586	1,727
French Car Makers	3,287	2,128	**2,096**	**3,270**	292	171	**341**	**1,312**	1,461	1,787	5,384	5,399
Renault	1,246	700	819	1,294	0.6	26	177	593	640	674	2,065	1,994
Peugeot	1,371	761	576	1,186	253	73	60	389	261	723	1,947	1,947
Citroen	623	587	691	789	38	71	102	329	550	388	1,314	1,377
Italian Car Makers	1,277	883	**1,007**	**1,643**	59	68	**889**	**1,495**	58	78	2,284	2,526
Fiat	893	560	794	1,474	39	38	743	1,413	10	22	1,687	2,035
Swedish Car Makers	276	416	**366**	**522**	23	28	**15**	**51**	327	442	642	938
Volvo	133	325	261	435	-	15	1	29	259	391	395	761
Total	29,650	25,708	**21,617**	**29,763**	5,395	5,823	**7,627**	**16,512**	8,593	7,427	51,267	55,471
Share (%)	58	46	**42**	**54**	11	10	**15**	**30**	17	13	100	100

Notes:

[a] TPCs: Traditional auto-producing countries (including Japan, United States, Germany, France, Italy and Sweden).

[b] NPCs: New auto-producing countries (including China, India, Thailand, Indonesia, Malaysia, Philippines, Vietnam, Brazil, Argentina, Mexico, Russia, Poland, Czech Republic and South Africa).

Source:

Compiled from International Organisation of Motor Vehicle Manufacturers (OICA): http://www.oica.net/

Table 2.4: Exports of Parts and Components (P&C) from Toyota's Overseas Subsidiaries in 2002

Country	*Overseas Subsidiary*	*Parts and Components*	*Destinations*	*Volume (thou)*
Canada	Canadian Autoparts Toyota Inc. (CAPTIN)	Aluminum wheel	Japan	891
United States	Toyota Motor Manufacturing Kentucky Inc (TMMK)	AZ engine	Japan, Canada	51
		MZ engine	Japan, Canada, Australia	45
		Parts for Camry	Australia	7
		Parts for Avalon	Australia	220
	Toyota Motor Manufacturing West Virginia Inc (TMMWV)	Parts for ZZ engine	Canada	157
		MZ engine	Japan	22
	TABC Inc	Catalyst	Japan, Canada	310
		Converter	Japan, Canada	21
	Bodeine Aluminum Inc		Japan	22
Brazil	Toyota do Brazil Ltda. (TDB)	Rear axle assembly	Argentina	11
United Kingdom	Toyota Motor Manufacturing UK Inc (TMUK)	Piston for ZZ engine	Japan, Turkey, Venezuela, Brazil, South Africa	n.a.
		Connecting Rod		
		SZ engine	France	68
South Africa	Toyota South Africa Motors Ltd (TSAM)	Parts for Hiace	Japan	n.a.
		Aluminum wheel	Europe	n.a.
		Catalyst converter	Japan, Europe, Turkey	n.a.
		Manifold	Brazil, Venezuela	n.a.
		Timing chain cover	Brazil, Venezuela	n.a.
China	TTME	Parts for 5A engine	Japan	34
	Tianjin Fengin Auto Parts Co., Ltd. (TFAP)	Constant velocity joint	Japan	92
		Processed parts	Philippines	9
	Tianjin Toyota Forging Co., Ltd. (TTFC)	Forging parts	Japan, Philippines	2,200
Indonesia	P.T. Toyota-Astra Motor (TAM)	Engine block for 5K engine	Japan	6
		7K engine	Japan, Taiwan, Philippines, Malaysia, Vietnam	51
		CKD parts for TUV	Malaysia, Philippines, Vietnam, Taiwan, South Africa	41
Malaysia	T&K	Manual steering gear	Thailand, Philippines, Indonesia, South Africa	20

		Power steering gear	Thailand, Philippines, Indonesia, Taiwan, Viet Nam, South Africa, India, Pakistan	232
		Suspension parts	Thailand, Indonesia, Taiwan, Pakistan	88
	Assembly Services Sdn. Bhd. (ASSB)	Parts for TUV, Corolla and Soluna, rubber parts	Thailand, Indonesia, Philippines, Taiwan, Viet Nam	n.a.
Portugal	Toyota Caetano Portugal, S.A. (SC)	Exhaust pipe	Europe	3
Poland	Toyota Motor Manufacturing Poland SP.zo.o. (TMMP)	Transmission	France, United Kingdom	25
Philippines	Toyota Autoparts Philippines Inc.(TAP)	Transmission	Thailand, Indonesia, Viet Nam, India, Malaysia, Taiwan South Africa	122
		Constant velocity joint	Thailand, Indonesia, Japan, Viet Nam, Pakistan, Malaysia, Taiwan	148
		Aluminum parts Gear parts	Indonesia	54
	Toyota Motor Philippines Corp. (TMP)	Press parts for TUV	Taiwan, Indonesia, Viet Nam, South Africa, Malaysia	336
Taiwan	Kuozui Motors, Ltd.	Press and assembly parts for TUV	Indonesia, Philippines, India, South Africa, Malaysia	n.a.
		Parts for Corolla	Thailand, Viet Nam, Malaysia, Pakistan, Philippines, South Africa, India, Indonesia, South America	n.a.
		Parts for Camry	Thailand, Indonesia, Malaysia, Philippines, Viet Nam, Australia	n.a.
		Parts for NBC	China, Thailand	n.a.
Thailand	Toyota Motor Thailand co., Ltd. (TMT)	Body parts, rubber parts, lamp parts	Philippines, Malaysia, Japan, others	n.a.
	Siam Toyota Manufacturing Co., Ltd (STM)	2L engine, parts for 5L engine	Malaysia, Indonesia, Japan, Philippines, India, South Africa	56
		Parts for 5A, ZZ, AZ engine	Australia, Taiwan, Philippines, Malaysia, Indonesia	
		Cam materials	Japan	91
		Block materials	Japan	45

Source: Compiled from *Toyota no Gaikyo 2002* [Toyota's general condition 2002]

Table 2.5: Exports of Completely-Built Units (CBU) from Toyota's Overseas Subsidiaries in 2002

Country	*Overseas Subsidiary*	*Model*	*Destinations*	*Volume*
Canada	Toyota Motor Manufacturing Canada Inc (TMMC)	Corolla	US, Puerto Rico, Mexico	61,239
		Camry Solara	US, Puerto Rico	31,435
		Matrix	US, Puerto Rico, Mexico	69,435
United States	New United Motor Manufacturing, Inc (NUMMI)	Tacoma	Canada, Puerto Rico	2,700
	Toyota Motor Manufacturing Kentucky Inc (TMMK)	Avalon Camry	Taiwan, Canada, Middle East, Japan, Puerto Rico	8,116
		Sienna	Canada, Puerto Rico, Hawaii	9,695
	Toyota Motor Manufacturing Indiana Inc (TMMI)	Tundra Sequoia	Canada, Oceania, others	7,432
Argentina	Toyota Argentina S.A.(TASA)	Hilux	Brazil, Uruguay	7,568
Brazil	Toyota do Brazil Ltda. (TDB)	Corolla	Argentina	1,096
Colombia	Sociedad de Fabricacion de Automtores S.A. (SOFASA)	Hilux, Prado Land Cruiser	Ecuador, Venezuela	8,159
Venezuela	Toyota de Venezuela Compania Anonima (TDV)	Land Cruiser Corolla	Colombia, Ecuador	431
France	Toyota Motor Manufacturing France S.A.S. (TMMF)	Yaris	Europe	121,000
Portugal	Toyota Caetano Portugal, S.A. (SC)		United Kingdom, Spain, Germany, others	69
Turkey	Toyota Motor Manufacturing Turkey Inc (TMMT)	Corolla	Europe, Middle East	33,400
United Kingdom	Toyota Motor Manufacturing UK Inc (TMUK)	Corolla Avensis	Europe, Middle East, Africa, Latin America	168,331
South Africa	Toyota South Africa Motors Ltd (TSAM)	Corolla, Hiace, Hilux, TUV, Dyna, Large Truck	Zimbabwe, Malawi, Mozambique, Zambia, Nigeria, others	1,971
Indonesia	P.T. Toyota Motor Manufacturing Indonesia Inc (TMMIN)	TUV	Brunei	175
Thailand	Toyota Motor Thailand co., Ltd. (TMT)	Hilux Soluna	Pakistan, Philippines, Brunei, Singapore, Australia	11,801
Australia	Toyota Motor Corporation Australia Ltd.(TMCA)	Camry Avalon	New Zealand, Thailand, Fiji, Papua New Guinea, Brunei, Middle East, South Africa, others	49,323

Source: Compiled from *Toyota no Gaikyo* 2002 [Toyota's general condition 2002]

2.5 Conclusion

Over the past two decades, the global automobile industry has been experiencing a structural shift away from developed countries and towards developing countries at an unprecedented pace over the past decade or so. The purpose of this chapter was to document and analyse this transformation in the globalisation process in the automobile industry by examining data on automobile production, sales and trade during the period 2001/2 to 2007/8. It has been shown that the leading automobile producers that originated from TPCs are the key driving force that caused the global shift at the beginning of the 21st century and that Japanese automakers are playing the most important role in facilitating the global shift among the automakers.[19] It has also been seen that Japan's automobile trade is characterised by a unique feature: the much smaller size of automobile imports comparing with other TPCs.

The limited automobile imports might reflect a unique feature of global production sharing in Japan. It might be that reverse imports of CBU produced in a low-cost country from overseas subsidiaries of Japanese automakers are quite limited unlike US and European automakers.[20] In addition, the limited imports of CBU in Japan also might reflect a competitive market, consumer preference, and strict domestic regulations on fuel efficiency and greenhouse gas emissions. On the other hand, the limited automobile imports might be attributable to the small amount of auto parts imports, reflecting the unique characteristics of the production system and supplier relationships in

[19] Note that even though not mentioned in this chapter, the global shift is partly due to the local automobile companies that have emerged in the latter countries through joint venture and/or technology-sharing arrangements with TPCs auto companies.

[20] Japanese automakers have undertaken reverse imports as a means to expand the variety of products (in particular passenger vehicles) in the Japanese market. The source countries are almost all of the developed countries such as the United States, United Kingdom, Canada and Australia except for Thailand where Nissan and Honda are exporting passenger vehicles, "March" and "Fit Aria", respectively. On the other hand, the developing countries play an important role for the reverse imports of commercial vehicles. For example, Toyota's subsidiary in Indonesia exports minivans and trucks such as "Townace" and "Liteace" to Japan whereas Mitsubishi's subsidiary in Thailand exports the "Triton" pick-up truck to Japan.

Japan (Diehl 2001).[21] In particular, just-in-time systems adopted by Japanese automakers require the geographical proximity of an assembly maker and its specific parts suppliers, leading to a more important role of local procurement rather than global sourcing (Dyer 1996, and Womack et al 2007). In addition, Japanese car makers rely on vertical networks based on *keiretsu* - a long-standing business relationship between an auto maker and its particular parts suppliers through personnel exchange, cross-share holding, and information sharing, making it difficult for foreign company outsides networks to penetrate the automotive market in Japan (Lawrence 1991 and Qiu and Spencer 2002).

The next chapter investigates trends, patterns and determinants of Japan's automobile trade by decomposing it into final goods and P&C. It also undertakes econometric analysis to probe the unique characteristics of global production sharing in Japanese automobile industry.

[21] Refer to Fujimoto (1999), Liker (2004), and Womack et al (2007) for Japanese production system called lean production system. Refer to Asanuma (1988), Aoki (1988), Odaka et al (1988), Nishiguchi (1994), Morita (2001) and Morita and Nakahara (2004) for supplier relationships in Japan.

CHAPTER 3

Global Production Sharing in the Automobile Industry: Is Japan Different?

3.1 Introduction

The objective of this chapter is to examine the hypothesis that the unique characteristics of the production system and supplier relationships in Japan matter in determining the extent and modality of production sharing. Specifically the roles of the 'following-leader' pattern (that is, parts and components suppliers following car producers) of Japanese overseas investment and of interlocking relationships among firms (*keiretsu* networks) in determining the trade in parts and components are analysed.

It is well established that when Japanese automakers build production plants abroad, they attempt to transplant the efficient supplier relationships forged locally into the host country to achieve their competitive advantages such as just-in-time inventory system and quality control. As a result, Japanese parts suppliers follow automakers' investment abroad (Head et al 1995, Banerji and Sambharya 1996, Blonigen et al 2005, Hatch 2005). This unique pattern of Japanese investments seems to substitute auto parts exports from Japan to the extent that exporting and investments are alternative strategies for suppliers. Blonigen (2001) and Head, Ries and Spencer (2004) show empirical evidence that there exists a substitution relationship between auto parts exports from Japan and Japanese suppliers' investment abroad.

Theory predicts that stronger buyer-sellers relationship in a home country would cause lower total auto parts imports in a home country (Rauch 1999, 2001, Greaney 2003). The important implication of this theory is that due to the strong assembler-supplier relationship in the Japanese automobile industry, companies outside the production network would face a cost disadvantage in selling their products to insiders of networks. The existing literature argues that the existence of a unique vertical network called *keiretsu* - a long-standing business relationship between an automaker and its parts suppliers through personnel exchange, cross-share holding, and information sharing - makes it difficult for foreign companies to penetrate the Japanese market (Lawrence 1991 and Qiu and Spencer 2002). Although considerable research has been devoted to examine the disadvantage faced by companies outside the production network in the Japanese market, rather less attention has been paid to the advantage of insiders. Theory also predicts that the strong assembler-supplier relationship in Japan facilitates reverse imports from Japanese affiliates in a host country because it reduces market entry costs for the insiders of production networks (Greaney 2003). Greaney (2005, 2009) and Head, Ries and Spencer (2004) present empirical evidence that the existence of a *keiretsu* network facilitates reverse imports from Japanese firms abroad, suggesting that the network trade plays an important role in determining Japan's imports.

The roles of the 'following-leader' pattern of Japanese investments and of vertical *keiretsu* networks in determining P&C trade in Japan are examined from a comparative perspective. The comparative approach, rather than a sole focus on the Japanese experience, is meaningful because production systems and supplier relationships in the Japanese automotive industry are different from their counterparts in the US and European auto industries (McMillan 1990, Dicken 2003, Womack et al 2007 and Sturgeon et al 2008). I estimate an augmented version of a gravity equation using four-dimensional panel data covering 6 TPCs (Japan, the United States, Germany, France, Italy, and Sweden), 49 auto-producing countries, and 90 auto parts over the 7-year period from 2002 to 2008. The automakers headquartered in TPCs are the key players that spread production networks worldwide therefore the performance of other TPCs becomes a benchmark to examine Japan's unique features. It is important to incorporate multiple countries into an analysis because the leading automobile producers are expanding production networks encompassing not only developed countries but also developing countries especially NPCs as shown in Chapter 2. The period from 2002 to 2008 is chosen due to data availability. The analysis extends to CBU as an additional examination.

Research on Japan's peculiarity has so far focused solely on the bilateral trade with the US and Western European countries (Saxonhouse 1989, Fung 1991, Lawrence 1991). However, there is little research that compares Japanese experiences with those of other countries (Encarnation 1992, Diehl 2001). This study contributes to the latter in two ways. This is the first comparative analysis by an econometric exercise. The existing literature has been limited to descriptive analysis. This study also analyses a newly constructed product-level dataset that makes it possible to control for product-specific characteristics that are difficult to capture but might affect trade flows (Head, Ries and Spencer 2004).

The plan of this chapter is as follows. The next section investigates the trends and patterns of trade in P&C and CBU for TPCs. Through the comparison with other TPCs, the characteristics of Japan's automobile trade are revealed. In Section 3.3, the econometric approach, variable construction and data issue are discussed. Section 3.4 reports the results. In Section 3.5, the analysis is extended to completely-built units (hereafter, CBU). Section 3.6 concludes with the summary and limitations.

3.2 Trends and Patterns of Automobile Trade

This section investigates Japan's trade performance comparing with other TPCs. Splitting automobile trade into P&C and CBU, the trend and pattern are examined.

3.2.1 Data

Bilateral trade data are compiled from the UN Comtrade database, based on the Harmonised Commodity Description and Coding System (HS), which allows for collecting disaggregated data at 6-digit level.[22] This database makes it possible to split the automobile trade into P&C and CBU. However, the classification of P&C related to automobiles has to be paid careful attention. While P&C for motor vehicles is mainly classified into HS code 87, a large number of auto parts come under different headings: tyre and rubber products (40), glass (70), electronic products (84, 85), seats (94), and so on. I classify P&C related to automobiles based on Japan Auto Parts Industries Association (JAPIA), which provides information on the comprehensive coverage of auto parts based on HS code at the 6 digit levels.[23] The code and description of P&C and CBU are shown in Appendix 3-A and Appendix 3-B, respectively. While auto parts are broken down into 90 P&Cs, motor vehicles are classified into 23 CBUs.

There are two limitations of the UN Comtrade database based on HS relating to its use in the present study. First is the short time coverage. The database allows for access to the data from 1988. However, the implementing period of HS varied according to countries. For example, Japan implemented HS in 1988, the United States and Germany in 1991, and France and Italy in 1994. Therefore, the time coverage of my analysis is limited to the period from 1994 to 2008 (the latest year for which data were available at the time of data compilation). Second, it is likely to overstate the trade value of P&C because some 6-digit HS items are not sufficiently disaggregated to accurately identify P&C related specifically to automobiles. For example, the HS code 700711 (i.e. glass) contains not only glass products for motor vehicles but also for aircraft and vessels. The HS code 853910 (i.e. lamps) is also not specific to motor vehicles. However, this is unlikely to bias our comparison of Japan with the other TPCs because the degree of overestimation is unlikely to be specific to Japan.[24]

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[22] See the website of UN Comtrade: (http://comtrade.un.org/) for further information.
[23] Refer to http://www.japia.or.jp/en/index.html for more information.
[24] Chapter 5 and 6 consider this problem, using 9 digit level of HS code.

3.2.2 Trends

The data (nominal US$) on automotive P&C from Japan and the other TPCs are depicted in Figure 3.1. Appreciation of the Japanese yen in the mid-1990s hampered the expansion of P&C exports from Japan. However, the past two decades have seen a tripling of exports, from nearly 23 billion US$ in 1988 to over 70 billion US$ in 2008. The rate of expansion has been particularly rapid since 2001. Over the past decade, the value of Japanese exports has been lower than that of the United States and Germany and higher than that of France, Italy and Sweden.

The value of P&C imports to Japan remained much smaller than exports throughout the period under study, leading to a substantial trade surplus in automobile P&C over time (Figure 3.2). Japan's import value has also been continuously smaller than those of all other TPCs except Sweden. Considering the fact that auto production in Japan is larger than that of any other TPCs, the relatively low dependence on imported P&C is a unique feature of the Japanese automobile industry.

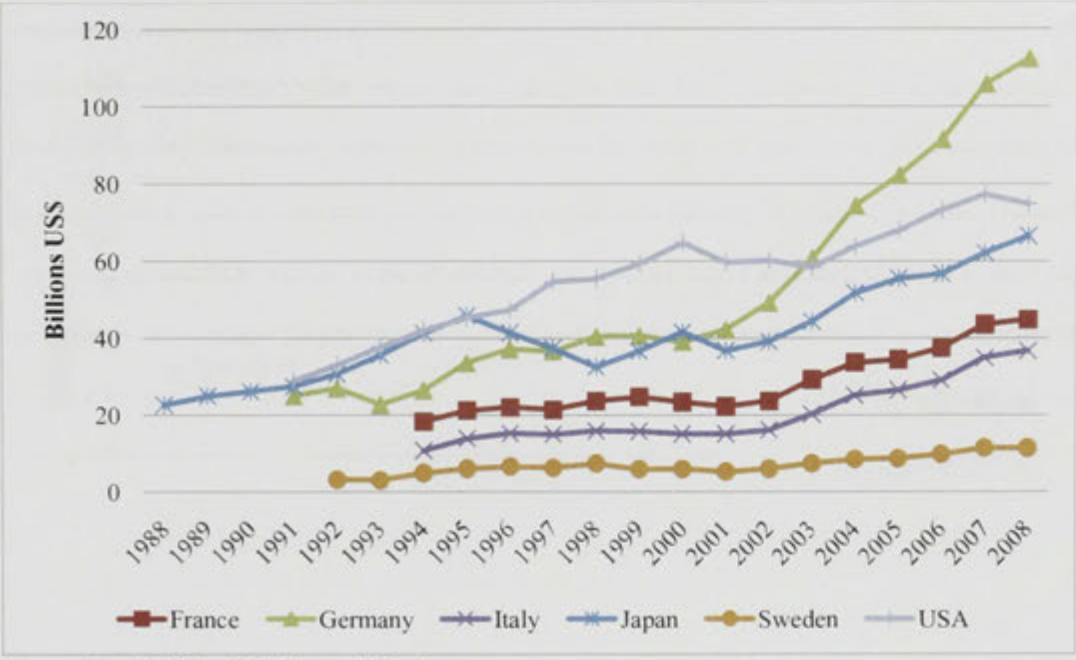
Figure 3.3 shows data of assembled vehicle (completely-built units, CBUs) exports from the six TPCs. As can be observed, Japan's exports remained virtually flat during the 1990s, but began to expand rapidly from about 2001. During the ensuing years CBU exports doubled, from 59 billion US$ in 2001 to 131 billion US$ in 2008. Among the TPCs, Japan has been the second largest exporting country after Germany since 1995.

There are two striking differences in CBU exports from Japan and Germany. First, Japanese automakers are expanding their exports toward Asia, the Middle East, Eastern Europe and Africa (Table 3.2). By contrast, German exports are largely concentrated in Western and Eastern European countries even though the share of Asian and African markets have been growing (from a low base) in recent years. Second, German automakers are generally exporters of high-value vehicles. The ratio of exports value to exports volume in Germany was 10 thousand US$ in 2000 but rose to 22 thousand US$ in 2007. By contrast, the same ratio for Japanese CBU exports remained virtually flat around 9.4 thousand US$ during 2000-2007. This difference reflects the fact that the Japanese automakers have been expanding their exports toward relatively low income countries.

Figure 3.4 shows the trend of aggregated CBU imports. Japan's CBU imports, like its P&C imports, have stayed at quite a low level over time comparing with the other TPCs. While the United States and other European countries have been expanding CBU imports in recent years, Japan's CBU imports have never exceeded 20 billion US$ over the past two decades. Interestingly, the value of Japan's CBU imports has been almost the same as that of Sweden, even though it is the second largest auto market after the United States.

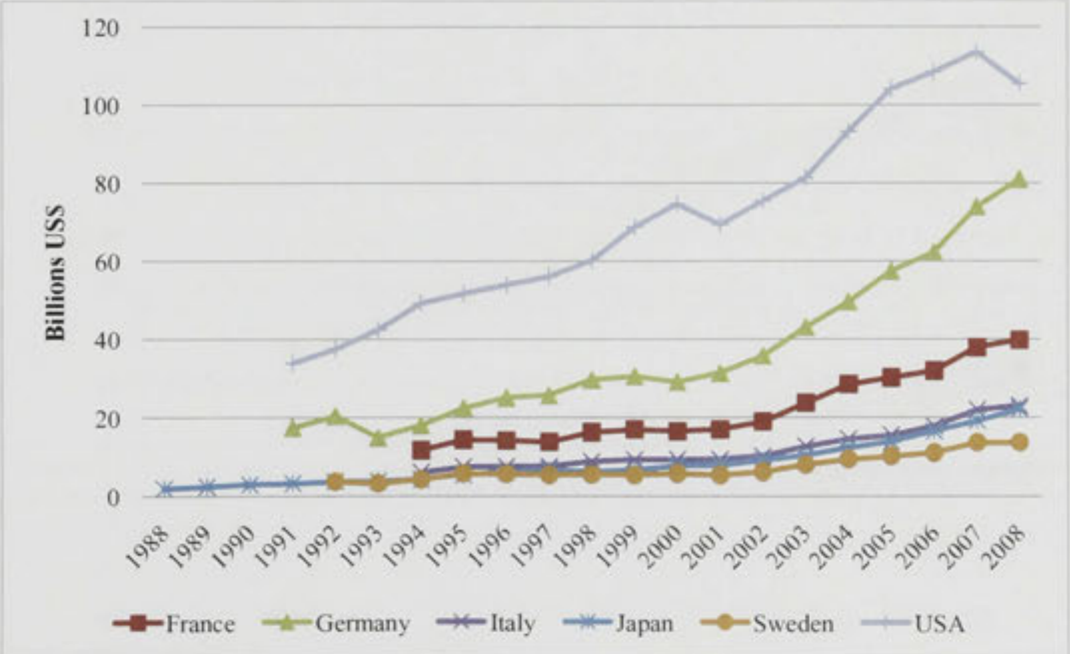
The share of P&C in total trade is commonly used as an indicator of the intensity of global production sharing (Yeats 1998, Kimura and Ando 2005, Athukorala and Yamashita 2006). Figure 3.5 shows the share of P&C in total automobile exports from the six TPCs. Japan's share has stayed between 30% and 40%. Compared to the other TPCs, Japan's share was relatively low. However, on the import side, Japan has experienced a continuing growth in the share of P&C; it rose from 30% in 1990 to 75% in 2008. In 2008, Japan's share was the highest among TPCs (Figure 3.6). This suggests that Japanese automakers are gradually increasing overseas procurement of P&Cs, even though total imports of P&C remain relatively low by the standards of the other TPCs.

Figure 3.1: Exports of Automobile Parts and Components (P&C), 1988-2008



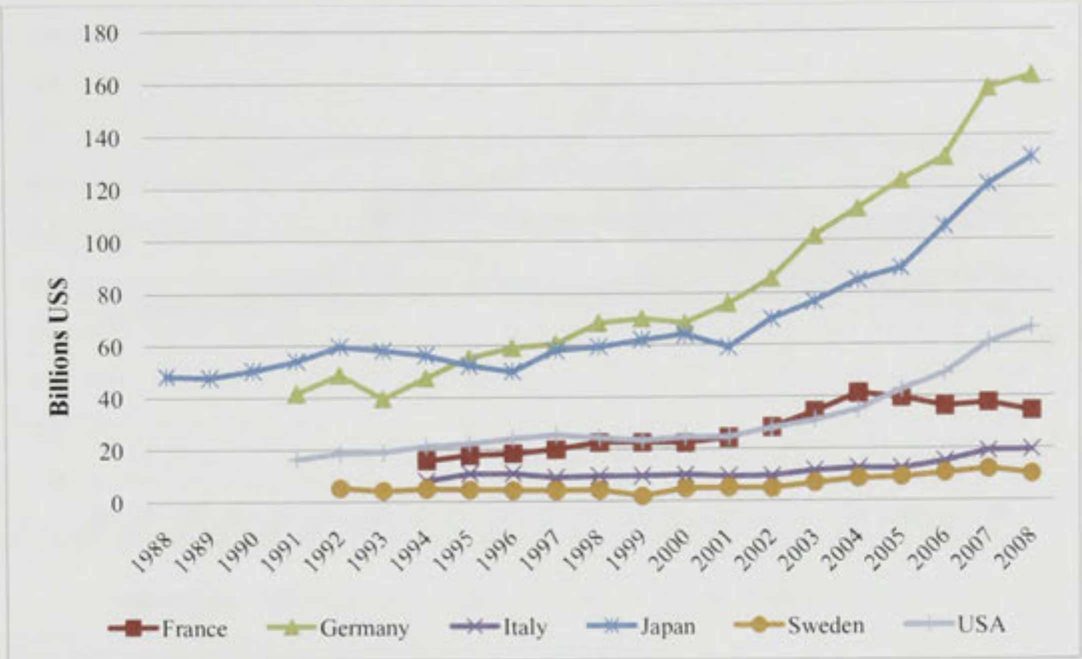
Source: Compiled from UN Comtrade Database

Figure 3.2: Imports of Automobile Parts and Components (P&C), 1988-2008



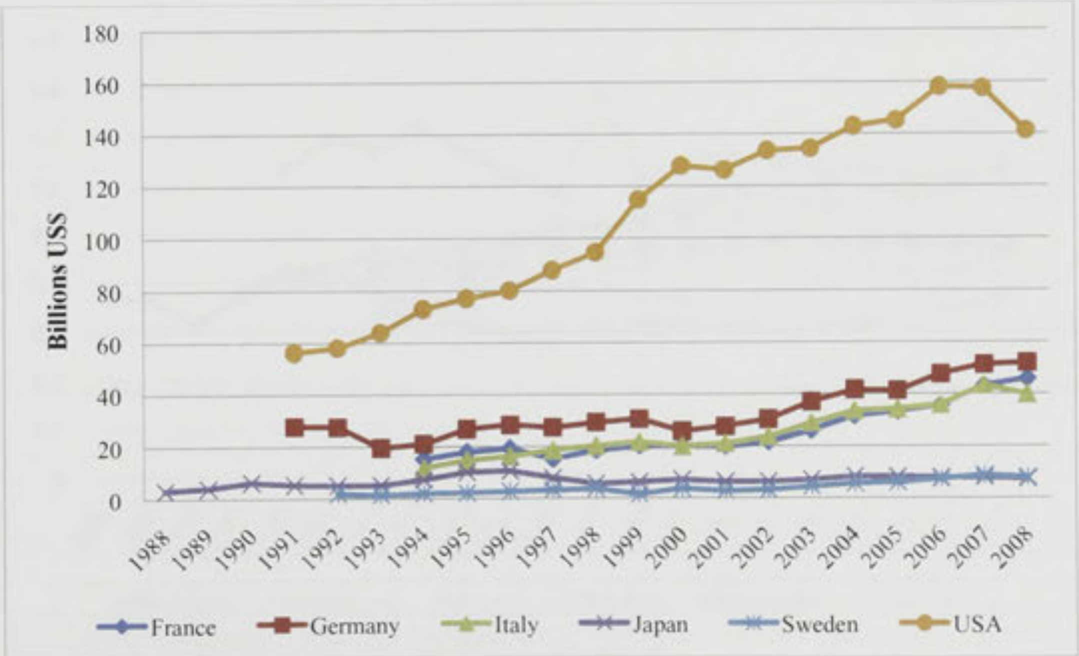
Source: Compiled from UN Comtrade Database

Figure 3.3: Exports of Completely-Built Units (CBU), 1988-2008



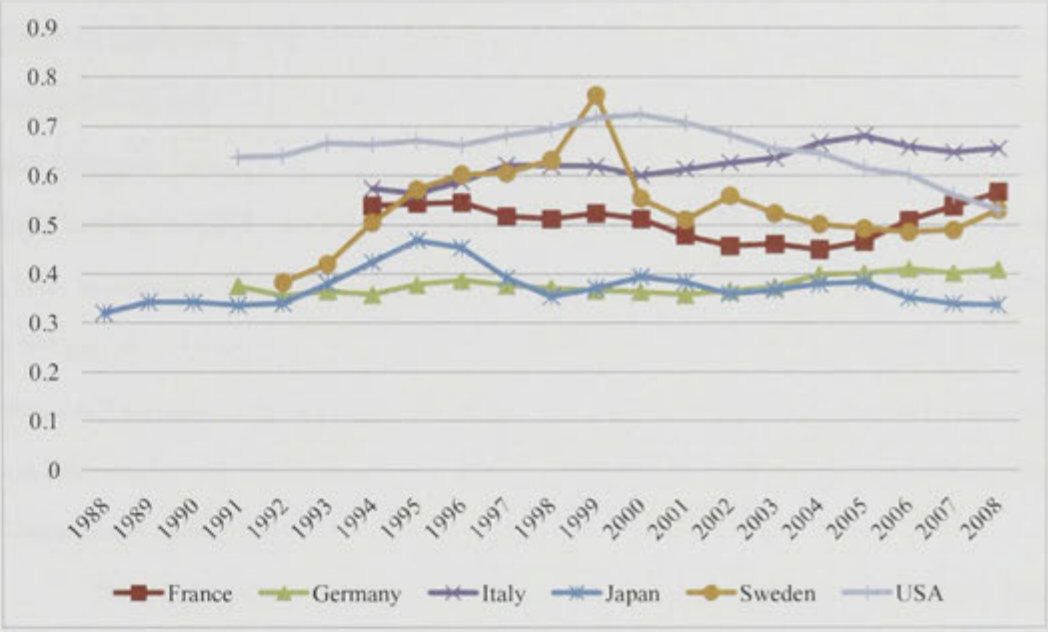
Source: Compiled from UN Comtrade Database

Figure 3.4: Imports of Completely-Built Units (CBU), 1988-2008



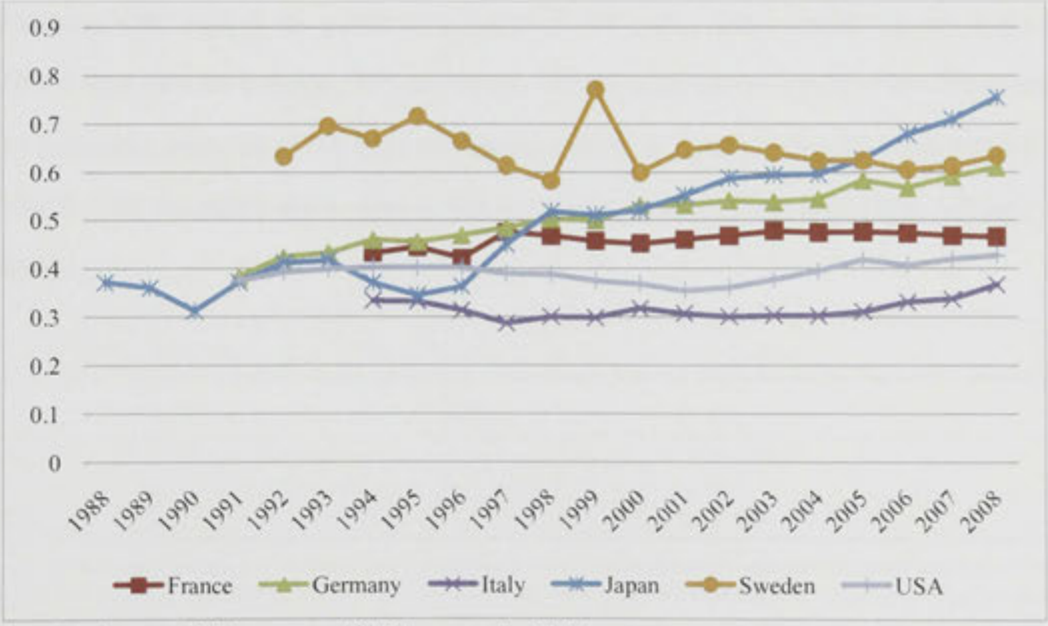
Source: Compiled from UN Comtrade Database

Figure 3.5: Share of Parts and Components (P&C) in Total Automobile Exports, 1988-2008



Note: Total automobile exports are P&C exports plus CBU exports.
Source: Compiled from UN Comtrade Database

Figure 3.6: Share of Parts and Components (P&C) in Total Automobile Imports, 1988-2008



Note: Total automobile imports are P&C imports plus CBU imports.
Source: Compiled from UN Comtrade Database

3.2.3 Patterns

Table 3.1 reports data on the destination of P&C exports from TPCs. It is observed that while the destination of Japan's P&C exports is diversified across regions, exports from the United States and European countries are heavily concentrated in North America and Europe respectively. Japan's main destination of P&C exports in 2007/8 was Asia (40%) followed by North America (31%) and Europe (20%). At the country level, the United States (25%), China (12%) and Thailand (7%) played important roles as destinations. On the other hand, as Table 3.1 shows, the United States and European countries depend on more intra-regional trade: the share of North America in US P&C exports was 68% and every European country exported more than 70% of P&C to other countries in Europe in 2007/8.

The geographical profiles of CBU exports are similar between Japan and United States: exports are diversified across regions (Table 3.2). The main destination for Japan in 2007/8 was North America (39%) followed by Europe (25%) and Asia (21%). The counterparts for the United States were North America (48%), followed by Europe (24%) and Asia (18%). On the other hand, European CBU exports are mostly to countries in the region. Intra-regional exports shares in 2007/8 were 68% for Germany, 87% for France, 83% for Italy, and 74% for Sweden. There was a 10 percentage point rise in the share of Japanese exports to Europe during the period 2001/2 to 2007/8. This was mainly due to rapid growth in consumer markets in Eastern Europe, especially in Russia.

Table 3.1: Geographical Profile of Parts and Components (P&C) Exports, 2001/2 and 2007/8[1] (%)

	Exporters											
	Japan		US		Germany		France		Italy		Sweden	
Destination	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8
ASIA	30	40	9	11	9	13	6	10	9	11	5	6
Japan			4	2	1	1	1	2	1	1	1	1
South Korea	3	3	1	1	1	1	0	1	1	1	0	1
Thailand	4	7	0	0	0	0	0	0	0	0	1	0
Malaysia	2	2	0	0	0	0	0	0	0	0	0	0
Indonesia	4	3	0	0	0	0	0	0	0	0	0	0
Philippines	1	1	0	0	0	0	0	0	0	0	0	0
Vietnam	0	0	0	0	0	0	0	0	0	0	0	0
China	5	12	1	3	3	4	1	2	1	1	1	1
India	1	1	0	0	0	1	0	0	0	1	0	1
Oceania	3	2	2	2	0	0	0	1	1	1	1	1
Australia	3	2	1	2	0	0	0	0	0	1	1	1
North America	44	31	74	68	14	11	7	4	8	6	8	6
United States	40	25			10	9	6	3	7	5	7	5
Canada	3	2	52	47	0	0	0	0	1	0	0	0
Mexico	2	3	22	22	3	2	1	0	0	0	0	1
South America	2	4	3	5	2	2	2	3	3	3	1	3
Brazil	1	2	1	1	1	2	1	1	3	2	1	2
Argentina	0	0	0	0	0	0	1	1	0	1	0	0
Europe	18	20	12	12	72	70	81	79	76	76	83	84
Western Europe	16	16	11	11	55	45	76	66	67	60	80	79
German	3	3	2	3			19	19	21	20	7	7
France	2	2	1	1	10	8			17	13	7	11
England	4	4	3	2	8	7	12	10	8	6	4	4
Spain	1	1	0	0	8	7	24	17	9	9	1	1
Italy	1	1	1	1	5	5	7	6			2	1
Netherlands	2	3	1	1	4	4	3	2	2	2	15	15
Belgium	2	2	1	2	8	4	5	6	3	3	27	24

Sweden	0	0	0	0	4	4	2	2	1	2		
Eastern Europe	1	4	0	1	16	25	5	12	9	16	3	
Russia	0	1	0	0	1	2	0	1	0	1	1	1
Czech Rep.	0	1	0	0	5	5	1	2	1	1	0	0
Romania	0	0	0	0	1	1	0	1	0	1	0	0
Poland	0	1	0	0	3	5	1	2	3	6	2	2
Turkey	0	1	0	0	1	3	2	3	3	3	0	0
Africa	4	5	1	2	5	5	3	3	3	3	1	1
South Africa	2	2	0	0	2	2	0	0	0	0	0	0
TPCs	50	36	11	10	38	34	46	42	54	47	27	29
NPCs	23	37	25	28	20	27	8	14	13	20	6	10
World	100	100	100	100	100	100	100	100	100	100	100	100

Note: [1]Two-year averages

Source: Compiled from UN Comtrade Database

Table 3.2: Geographical Profile of Completely-Built Units (CBU) Exports, 2001/2 and 2007/8[1] (%)

	Exporters											
	Japan		US		Germany		France		Italy		Sweden	
Destinations	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8
ASIA	15	21	10	18	10	12	5	5	4	7	9	5
Japan			2	1	4	2	1	0	2	1	6	1
South Korea	0	1	0	1	0	1	0	0	0	0	0	0
Thailand	0	0	0	0	0	0	0	0	0	0	0	0
Malaysia	1	1	0	0	0	0	0	0	0	0	0	0
Indonesia	0	1	0	0	0	0	0	0	0	0	0	0
Philippines	0	0	0	0	0	0	0	0	0	0	0	0
Vietnam	0	0	0	0	0	0	0	0	0	0	0	0
China	2	3	0	2	1	3	0	0	0	0	0	2
India	0	0	0	0	0	0	0	0	0	0	0	0
Oceania	7	7	2	2	1	1	1	1	1	1	1	1
Australia	5	6	1	2	1	1	0	1	1	1	1	1
North America	57	39	69	48	21	16	0	1	3	5	42	18
United States	52	35			20	14	0	0	3	5	40	17
Canada	4	4	54	40	1	1	0	0	0	0	2	1
Mexico	0	1	15	8	1	0	0	0	0	0	0	0
South America	2	3	1	3	0	1	1	1	0	0	0	0
Brazil	0	0	0	0	0	0	0	0	0	0	0	0
Argentina	0	0	0	0	0	0	0	0	0	0	0	0
Europe	15	25	15	24	66	68	88	87	89	83	46	74
Western Europe	14	14	15	21	60	58	83	78	84	71	43	65
German	3	2	9	13			14	15	22	19	7	10
France	1	1	0	0	8	8			17	15	3	3
England	3	3	2	0	13	13	15	10	13	9	13	10
Spain	1	1	0	0	5	6	17	14	8	8	3	4
Italy	2	1	1	1	10	10	13	13			2	4
Netherlands	1	1	0	1	3	3	5	2	4	2	3	4

Belgium	1	1	1	1	7	4	7	12	5	4	2	3
Sweden	0	0	0	0	2	2	1	1	0	1		
Eastern Europe	1	10	0	3	6	10	5	9	5	13	2	10
Russia	0	8	0	2	2	3	0	2	0	1	2	6
Czech Rep.	0	0	0	0	1	1	1	1	1	2	0	0
Romania	0	0	0	0	0	1	0	1	1	2	0	0
Poland	0	0	0	0	1	2	2	3	1	3	0	1
Turkey	0	0	0	0	0	1	1	2	0	1	0	0
Africa	2	5	2	4	2	3	5	5	2	3	1	1
South Africa	0	1	1	1	1	1	0	0	0	0	0	0
TPCs	58	40	12	17	44	36	28	29	44	40	58	35
NPCs	6	17	17	14	7	12	5	8	3	9	3	11
World	100	100	100	100	100	100	100	100	100	100	100	100

Note: [1]Two-year averages

Source: Compiled from UN Comtrade Database

Table 3.3 reports data on the geographical pattern of P&C imports. Imports to Japan and European countries show a heavy regional concentration, whereas United States imports are highly diversified across source regions. Although Europe and North America are still important sources for Japan's P&C imports, its dependency on Asia has been growing over time: the Asian share in Japan's total P&C imports increased from 50% to 65% between 2001/2 to 2007/8. Over the past decade China has emerged as the premier source country: the share of P&C imports from China increased from 16% to 29% during the same period. The intra-regional concentration of European imports is much higher compared to Japan. On average, European automakers procured 80% of P&C within Europe during the period 2001/2 to 2007/8. A geographical transformation within Europe is taking place: Eastern European countries are emerging as important sources for Western European auto-producing countries, particularly Germany. For example, the share of Germany's P&C imports from Western European countries dropped from 55% to 49% during 2001/2 to 2007/8 while the share from Eastern European countries increased from 30% to 36%. The pattern of the United States is different from Japan and European countries: the P&C imports for the United States are more diversified across regions. The share of North America was 41% followed by Asia (38%) and Europe (17%) in 2007/8.

Japan and European countries have similar patterns of CBU imports (Table 3.4). Europe had been the dominant source for their CBU imports: the shares of Europe were 77% for Japan, 69% for Germany, 87% for France, 89% for Italy and 82% for Sweden. Germany has played a significant role as a CBU exporter. For example, Germany accounted for half of Japan's total CBU imports. On the other hand, the United States shows a different pattern of CBU imports comparing with Japan and European countries: the source of CBU imports are more diversified like its CBU exports. The main source of CBU imports to the US in 2007/8 was the other two countries in North America (Canada and Mexico) (43%) followed by Asia (35%) and Europe (21%) in 2007/8. At a country level, Japan has played the most significant role, accounting for 30% of total CBU imports in the United States.

Table 3.3: Geographical Profile of Parts and Components (P&C) Imports, 2001/2 and 2007/8[1] (%)

	Importers											
	Japan		US		Germany		France		Italy		Sweden	
Source	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8
ASIA	50	65	33	38	8	10	10	10	14	18	6	7
Japan			22	16	3	3	5	4	5	4	3	2
South Korea	5	6	2	4	0	1	0	0	1	1	1	1
Thailand	8	10	1	1	0	0	0	0	0	1	0	0
Malaysia	2	2	0	0	0	0	0	0	0	0	0	0
Indonesia	4	5	0	1	0	0	0	0	0	0	0	0
Philippines	6	6	1	1	0	0	0	0	0	0	0	0
Vietnam	3	5	0	0	0	0	0	0	0	0	0	0
China	16	29	4	11	1	2	2	2	2	5	0	1
India	0	0	0	1	0	1	0	0	0	2	0	1
Oceania	1	0	0	0	0	0	0	0	0	0	0	0
Australia	1	0	0	0	0	0	0	0	0	0	0	0
North America	30	11	48	41	4	3	5	4	5	3	4	3
United States	29	10			3	3	5	3	4	2	4	2
Canada	1	1	24	18	0	0	0	0	0	0	0	0
Mexico	1	1	24	23	1	0	1	0	0	0	0	0
South America	0	0	2	2	1	1	1	1	1	1	1	1
Brazil	0	0	2	2	1	1	0	1	1	1	1	1
Argentina	0	0	0	0	0	0	0	0	0	0	0	0
Europe	19	23	15	17	85	84	83	83	80	77	88	89
Western Europe	18	20	15	16	55	49	77	72	71	60	85	79
German	7	8	6	9			27	26	29	26	33	30
France	2	4	2	2	11	10			18	14	9	8
England	3	2	2	1	9	6	7	6	6	4	10	9
Spain	1	1	1	1	6	6	15	13	6	6	3	3
Italy	2	2	1	2	8	9	13	11			3	4
Netherlands	1	1	0	0	3	2	2	2	3	2	6	5
Belgium	1	1	0	0	3	3	5	5	4	4	7	8

Sweden	1	0	0	0	1	1	2	4	1	1		
Eastern Europe	0	2	1	1	30	36	6	11	9	16	3	9
Russia	0	0	0	0	0	0	0	0	0	0	0	0
Czech Rep.	0	0	0	0	8	10	2	3	1	2	1	2
Romania	0	0	0	0	1	2	0	1	1	1	0	0
Poland	0	1	0	0	6	7	1	3	3	7	2	5
Turkey	0	0	0	0	2	3	2	1	3	3	0	1
Africa	1	0	1	1	3	3	2	2	1	1	0	2
South Africa	0	0	0	0	1	1	0	0	0	0	0	1
TPCs	44	27	35	30	36	31	59	54	63	51	62	56
NPCs	41	59	33	41	22	28	8	13	13	24	5	12
World	100	100	100	100	100	100	100	100	100	100	100	100

Note: [1]Two-year averages

Source: Compiled from UN Comtrade Database

Table 3.4: Geographical Profile of Completely-Built Units (CBU) Imports, 2001/2 and 2007/8[1] (%)

	Importers											
	Japan		US		Germany		France		Italy		Sweden	
Sources	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8	2001/2	2007/8
ASIA	2	3	32	35	10	11	8	12	11	10	11	15
Japan			26	30	8	7	5	4	5	3	7	9
South Korea	0	0	5	5	1	2	1	2	3	2	3	2
Thailand	1	1	0	0	0	0	1	0	0	0	1	1
Malaysia	0	0	0	0	0	0	0	0	0	0	0	0
Indonesia	0	1	0	0	0	0	0	0	0	0	0	0
Philippines	0	0	0	0	0	0	0	0	0	0	0	0
Vietnam	0	0	0	0	0	0	0	0	0	0	0	0
China	0	0	0	0	0	0	0	0	0	0	0	0
India	0	0	0	0	0	0	0	0	0	0	0	0
Oceania	0	0	0	0	0	0	0	0	0	0	0	0
Australia	0	0	0	0	0	0	0	0	0	0	0	0
North America	15	11	48	43	9	18	1	1	0	1	2	2
United States	10	8			8	12	1	1	0	1	2	2
Canada	1	0	31	28	0	0	0	0	0	0	0	0
Mexico	3	3	16	15	1	5	0	0	0	0	0	0
South America	0	0	0	0	0	2	0	0	0	0	0	0
Brazil		0	0	0	0	2	0	0	0	0	0	0
Argentina	0	0	0	0	0	0	0	0	0	0	0	0
Europe	77	77	20	21	80	69	90	87	89	89	87	82
Western Europe	75	75	19	20	66	55	86	73	81	70	84	77
German	52	51	13	13			36	32	37	40	44	40
France	3	2	0	0	15	13			17	11	12	7
England	7	11	3	3	7	7	7	5	6	5	6	11
Spain	2	1	0	0	8	9	27	26	12	10	1	1
Italy	3	4	0	1	7	7	7	7			1	1
Netherlands	1	0	0	0	3	2	1	1	1	1	6	1
Belgium	2	2	1	1	16	7	5	3	6	4	8	14

Sweden	5	2	2	1	1	2	0	1	1	1		
Eastern Europe	2	3	0	1	14	14	4	14	7	18	3	5
Russia	0	0	0	0	0	0	0	0	0	0	0	0
Czech Rep.	0	0	0	0	3	4	1	3	1	3	2	2
Romania	0	0	0	0	0	0	0	1	0	0	0	0
Poland	0	0	0	0	2	2	0	1	3	8	1	0
Turkey	0	0	0	0	1	1	2	5	2	4	0	2
Africa	11	18	0	2	3	1	0	0	0	0	0	2
South Africa	6	9	0	1	1	0	0	0	0	0	0	1
TPCs	73	67	41	44	38	40	50	46	60	56	66	60
NPCs	10	14	17	16	8	16	4	10	7	15	4	7
World	100	100	100	100	100	100	100	100	100	100	100	100

Note: [1]Two-year averages

Source: Compiled from UN Comtrade Database

3.3 Econometric Analysis

This section examines the roles of the 'following-leader' pattern of Japanese overseas investment and vertical *keiretsu* networks in determining the trade in P&C by estimating an augmented version of a gravity model with four-dimensional panel data. I first discuss the model specification followed by a discussion on variable construction and data sources.

3.3.1 The Model

The gravity equation has become the 'work-horse' for modeling bilateral trade flows. The origin of the gravity equation is the "Law of Universal Gravitation" proposed by Newton in 1687, which postulates that the gravitational force between two entities is positively related to their masses and the distance between the two of them. [25] Tinbergen (1962) first applied the gravity equation to empirical analysis of international trade, followed by Pullianinen (1963) and Linneman (1966). Tinbergen (1962) proposed that roughly the same functional form could be applied to the international trade flow between two economies (i and j):

$$T_{ij} = \alpha_1 \frac{M_i^{\alpha_2} M_j^{\alpha_3}}{D_{ij}^{\alpha_4}} \tag{3.1}$$

where T is the trade flow, M is the economic size, and D is the geographical distance, and $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are unknown parameters. Due to its consistent success in explaining trade flows, the gravity equation has been widely used for empirical analysis in international trade.

More recently there have been several attempts to provide a microeconomic foundation to the gravity equation (Deardorff 1998, Anderson and van Wincoop 2003). Broadly speaking, there are two approaches to formulating the gravity equation. The first, such as Bergstrand (1989), applies the Dixit and Stiglitz model of monopolistic competition between heterogeneous firms.

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[25] The attractive force between i and j is given by $F_{ij} = G\frac{M_i M_j}{D_{ij}^2}$ where F stands for the attractive force, M stands for the mass, D stands for distance and G is a gravitational constant.

This approach is based on the assumption that goods are differentiated among firms instead of consumer preference being homogeneous among countries. The second approach, proposed by Anderson (1979), introduces utility functions such as the Cobb-Douglas and constant elasticity of substitution (CES) functions, and assumes goods are homogeneous but the preference of the consumer is allowed to vary across countries. A similar method is taken by Deardorff (1998).

Normally, the gravity equation takes a stochastic form in empirical studies in order to allow for other factors impacting on trade flows. Also, the multiplicative nature of the gravity equation enables taking natural logs to obtain a constant-elasticity relationship between dependent and independent variables as follows;

$$lnT_{ij} = \alpha_1 + \alpha_2 lnM_i + \alpha_3 lnM_j + \alpha_4 lnD_{ij} + \varepsilon_{ij} \tag{3.2}$$

where α_1 is a constant term and ε_{ij} is a stochastic error term assumed to be statistically independent of the regressors. Although the gravity equation explains bilateral trade flows between economies well with just the sizes of the economies and their distances, there is a huge amount of variation in trade this cannot explain. Therefore, the gravity equation is often augmented with variables such as GDP per capita, adjacency, common language and other variables of interest.

For the purpose of this study, the basic gravity model is augmented by adding a number of other variables. Overseas production (*OSP*) allows for the role of production networks in determining trade in P&C for TPCs and its coefficient is expected to be positive, suggesting the existence of an intra-firm trade between headquarters and overseas subsidiaries. Domestic auto production (*DAP*) is included to capture market size and supply capacity of auto parts instead of GDP, which is another essential variable of a gravity equation. Because the dependent variables are specific to trade in auto parts, domestic auto production is a more appropriate variable to capture its market size.[26] Real per capita GDP (*PGDP*) is used to allow for the fact that more developed countries have better ports and communication systems and other trade-related infrastructure as

[26] I thank Theresa M. Greaney for this point.

well as better institutional arrangements for contract enforcement that facilitate trade (Athukorala and Yamashita 2006). Adjacency (*ADJ*) and common language (*LAN*) between countries are included to control for country-specific characteristics that might affect trade flow. The real exchange rate (*RER*) is included to capture the relative competitiveness of traded-goods between economies.

A Japan dummy (*JAP*) is included to see whether Japan's trade pattern of P&C is different from that of other TPCs conditional on the other variables included in the model. The sign of the coefficient is expected to be different between exports and imports. As shown in Figures 3.1 and 3.2, Japan is exporting a large amount of P&C whereas its imports are quite limited. However, the real importance lies in the interpretation of the coefficient. Controlling for overseas productions (*OSP*) that captures an intra-firm trade between headquarters and overseas subsidiaries, a positive coefficient would imply Japan's P&C trade is more related to arm's length comparing with other TPCs. The interaction term ($JAP \times OSP$) is the key variable in the model because it allows for testing the key hypothesis in this study. The coefficient for exports is expected to be negative, suggesting the 'following-leader' pattern of Japanese overseas investment substitutes P&C exports from Japan. The coefficient for imports is expected to be positive, implying that vertical *keiretsu* networks facilitate P&C imports into Japan.

A set of year dummy variables (*T*) is included to control for time varying effects such as technological changes in automobile industries. The inclusion of a set of regional dummy variables (*R*) is important to control for regional differences such as free trade areas and historical links within region. The importance of regional linkage is reflected in the high intensity of intra-regional trade especially in the case of European countries (Tables 3.1 and 3.3). A set of host country dummy variables (C) is included to control for unobservable country-specific characteristics such as trade and industry polices in the host country.

The augmented version of the gravity equation is:

$$\ln T\_P\&C_{i,j,t} = \alpha + \beta_1 \ln OSP_{i,j,t} + \beta_2 \ln DAP_{i,t} + \beta_3 \ln DAP_{j,t} + \beta_4 \ln DIS_{i,j} + \beta_5 \ln PGDP_{i,t} + \beta_6 \ln PGDP_{j,t} + \beta_7 ADJ_{i,j} + \beta_8 LAN_{i,j} + \beta_9 \ln RER_{i,j,t} + \beta_{10} JAP_i + \beta_{11}(JAP_i \times \ln OSP_{i,j,t}) + \delta T + \omega R + \partial C + u_{i,j,t} \quad (3.3)$$

where subscript i stands for sample countries including Japan, the United States, Germany, France, Italy, and Sweden, j stands for trading partners covering 49 countries worldwide and t stands for the year from 2002 to 2008.[27] The ln attached before variables stands for the natural logarithm. The dependent variable ($T\_P\&C$) has three different forms of real bilateral trade values of parts and components: (1) total trade, (2) exports and (3) imports. The independent variables are listed and defined below with their expected signs of the regression coefficients given in brackets:

OSP	Overseas production in country j by automobile producers headquartered in country i (+)
DAP	Domestic auto production in country i and country j (+)
DIS	Distance between capital cities in country i and country j (-)
PGDP	Real per capita GDP in country i and country j (+)
ADJ	A binary variable assuming the value 1 if country i and country j share a common land border and 0 otherwise (+)
LAN	A binary variable assuming the value 1 if country i and country j share a common official language and 0 otherwise (+)
RER	An index of bilateral real exchange rate which measures the international competitiveness of country i against country j (+or-)
JAP	A binary variable assuming the value 1 if country i is Japan and 0 otherwise (+or-)
T	A set of time dummy variables
R	A set of regional dummy variables
C	A set of host country dummy variables
α	A constant term
u	A stochastic error term

3.3.2 Variable Construction and Data Sources

Data on domestic auto production (*DAP*) are extracted from the website of the International Organisation of Motor Vehicle Manufacturers, which provides information on the volume of motor vehicle production in each country. Real per capita GDP (*PGDP*) measured in $US at constant

[27] Refer to Appendix 3-C for the list of 49 trading partners.

2005 prices is from the World Development Indicators. Distance (*DIS*), adjacency (*ADJ*), and common language (*LAN*) between countries are obtained from the CEPII database. Distance is measured using the geographical coordinates of the capital cities. The adjacency dummy variable indicates whether the two countries are contiguous. The common language is a dummy variable indicating whether countries share a common official language. The real exchange rate (*RER*) is constructed based on the formula,

$$RER_{ij} = NER_{ij} * (P_j^w / P_i^D)$$

where *NER* is the nominal exchange rate index, P^W is the producer price measured by the wholesale price index, and P^D is the domestic price measured by the GDP deflator. These data are obtained from the World Development Indicators.

Data on overseas production (*OSP*) are obtained from the International Organisation of Motor Vehicle Manufacturers, which provides information on production volume by manufacturer and country. Using these data, I calculate overseas production in each trading country by automobile producers headquartered in TPCs including Japan, the United States, Germany, France, Italy and Sweden. The automobile producers classified by the location of their headquarters are listed in Appendix 3-D. While a classification based on ownership would be more appropriate, this study does not employ such a classification for two reasons. First is its difficulty because there are wide varieties of degree of ownership and alliances.[28] In addition, the degree of ownership has changed over time and alliances between automakers have sometimes been dissolved.[29] 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 been headquartered in Germany). Second, the ownership-based calculation might lead to more measurement error, causing a biased and inconsistent estimator. As an example, take the Nissan (Japanese auto maker) and Renault

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

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

(French automobile producer) alliance, in which Nissan has owned a 15% Renault share and Renault has owned a 44% Nissan share. Suppose that Nissan has an overseas plant in Thailand but Renault does not. If Nissan is regarded as a subsidiary of Renault, Nissan's overseas plant in Thailand belongs to Renault. This treatment is able to capture the impact of intra-firm trade between Renault's headquarters in France and the overseas plant in Thailand on trade in P&C between France and Thailand. However, it fails to capture the impact of intra-firm trade between Nissan's headquarters in Japan and the overseas plant in Thailand on bilateral trade between Japan and Thailand. Since the latter has a more significant implication for bilateral trade in P&C, the measurement based on their headquarters' location is more appropriate rather than one based on their ownerships.

A detailed list of variable definitions and data sources is provided in Appendix 3-E. Summary statistics are presented in Table 3.5.

Table 3.5: Summary Statistics

Variables	Units	Mean	Standard Deviation	Min	Max
Log P&C Total Trade	US$	19.52	2.29	7.62	24.78
Log P&C Exports	US$	18.96	2.22	7.62	24.32
Log P&C Imports	US$	17.87	3.37	4.9	23.99
Log Auto Production, Exporter	Volume	14.99	1.24	4.36	16.32
Log Auto Production, Importer	Volume	12.79	2.19	4.36	16.32
Log Auto Sales, Exporter	Volume	14.94	1.15	10.6	16.67
Log Auto Sales, Importer	Volume	13.49	1.27	10.6	16.67
Log Overseas Production	Volume	10.94	2.29	0.69	15.03
Log Per Capita GDP, Exporter	US$	10.23	0.25	9.88	10.61
Log Per Capita GDP, Importer	US$	8.68	1.3	5.91	10.61
Log Distance	km	8.35	1.06	5.16	9.83
Log Real Exchange Rate	Index	4.61	0.14	4.04	5.14
Adjacency Dummy	Binary	0.07	0.25	0	1
Common-Language Dummy	Binary	0.06	0.24	0	1
Japan Dummy	Binary	0.16	0.37	0	1

3.3.3 Estimation Method

The model is estimated by the fixed effect model (FEM) that controls for host country-specific characteristics and time effects by adding dummy variables. The selection of estimation model between the FEM and the random effect model (REM) is based on the underlying assumption: the FEM allows the unobserved host country effects to be correlated with explanatory variables whereas the REM does not (Wooldridge 2002). In this study, it is suspected that unobserved country-specific factors such as trade and industry policy in the host country are strongly correlated with overseas production of the automakers (Head and Ries 2001, Yamashita 2008). Historically, the import-substitution policy in the developing countries and the creation of a free trade area has played an important role in encouraging automakers to set up production plants in the host country (Chapter 2). This leads to superiority of the FEM over the REM.[30]

Estimation is carried out in two steps. The first is to estimate determinants of total trade (exports + imports) in order to see the impact of production networks on total P&C trade as well as Japan's unique features controlling for other relevant variables. The second step is to estimate determinants of exports and imports, separately. This treatment matters because the overseas production of Japanese automakers is expected to have different effects on exports and imports as discussed in Section 3.1. Overseas production of Japanese automakers induces Japanese suppliers' investment to substitute exports of P&C from Japan. On the other hand, the expansion of global production networks might increase reverse imports from insiders of the vertical *keiretsu* networks.

For a robustness check of the result, I will examine the four-dimensional panel data covering 6 TPCs, 49 auto-producing countries, and 90 auto parts over the 7-year time period from 2002 to 2008 at a product-level.[31] The use of the four-dimensional panel data not only enhances the

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[30] I acknowledge that the FEM has disadvantages (Wooldridge 2002). First, the introduction of many variables into the model reduces the degrees of freedom. Second, as the number of independent variables increases, the problem of the multicollinearity is more likely to arise. Third, the FEM makes it difficult to identify the impacts of time-invariant variables such as distance, language and adjacency.

[31] The list of P&C are reported in Appendix 3-A.

efficiency of estimation due to the increase in the number of observations but also allows for controlling for parts-specific characteristics such as asset specificity and engineering costs that are difficult to measure but might affect trade patterns (Head, Ries and Spencer 2004).

3.4 Results

Table 3.6 reports the augmented gravity equation estimated using three-dimensional panel data. With 6 sample countries, 49 trading partners, and 7 years from 2002 to 2008 and allowing for missing observations, the estimates are based on 823 observations for total trade, 800 for exports and 793 for imports.

The first three columns show estimates for total trade. As can be seen in the first column, the coefficient of overseas production (*OSP*), which captures the impact of cross-border production networks on total trade in P&C, is positive and significant as expected. This suggests the existence of a causal relationship between production networks and P&C trade. This result is robust to adding other relevant variables to the estimating equation (Column 2). After controlling for the relevant variables, on average, a 1% expansion of overseas production by automobile producers leads to a 0.23% increase in P&C trade with that trade partner for TPCs. The interpretation is that intra-firm trade between headquarters and overseas subsidiaries plays an important role in determining trade flows. The coefficients of the two central gravity variables have expected signs with significant levels. Auto production for both reporter and partner are positive and a highly significant predictor of bilateral trade in auto parts. Distance is negative and significant at the 1 per cent level, reflecting the importance of proximity for trade. As shown in Tables 3.1 and 3.2, trade in P&C for TPCs tends to be regionally concentrated. For example, while US P&C exports to Canada and Mexico account for nearly 70%, Western European countries' trade in P&C are more heavily intensified within Europe. The positive and significant coefficient of the adjacency dummy supports the importance of geographical clusters in the automobile industry. While the coefficient of partners' per capita GDP is positive and a highly significant predictor of bilateral trade, that of reporters' counterpart is statistically insignificant. This unexpected result is not meaningful because reporters, that are TPCs, are all developed countries with better ports and communications systems and other trade-related infrastructure as well as better institutional arrangements for contract enforcement that facilitate trade. Common language does not seem to be an important determinant of trade in P&C. This is not surprising because a global sourcing that procures auto parts from the most competitive company anywhere in the world has been a common strategy among global automakers and suppliers. The coefficient of the real exchange rate (*RER*) is negative and significant at the 10 percent level. However, the interpretation is not suggestive because the dependent variable includes both exports and imports.

The third column shows results when the Japan dummy (*JAP*) and its interaction term with overseas production (*JAP*×Log (*OSP*)) are added. Both coefficients are not statistically significant, suggesting the pattern of Japan's total P&C trade is not different from that of the other TPCs. However, it still remains unclear about Japan's uniqueness because the focus so far has been on total trade (exports + imports). As shown in Figures 3.1 and 3.2 and Tables 3.1 and 3.3, Japan's P&C exports and imports have had a different trend and pattern. More importantly, as discussed above, the overseas production of Japanese automakers is expected to have different implications for auto parts exports and imports, respectively. It would seem, therefore, that further investigation is needed by estimating determinants of exports and imports separately.

Table 3.6: Regression Results with Three Dimensional Panel Data (Year, Reporter, Partner)

Dependent Variable: Log Total Trade (Exports + Imports), Exports or Imports of Parts and Components (US$)	Total Trade			Exports			Imports		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log Overseas Production (*OSP*)	0.59***	0.23***	0.22***	0.27***	0.26***	0.42***	0.24***	0.14***	0.40***
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)	(0.03)	(0.04)
Log Domestic Production, Reporter (*DAP*)		0.39***	0.38***	0.38***	0.30***	0.24***	0.30***	0.52***	0.42***
		(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.06)	(0.05)	(0.06)
Log Domestic Production, Partner (*DAP*)		0.33***	0.33***	0.25***	0.27***	-0.09	0.69***	0.60***	-0.24
		(0.03)	(0.03)	(0.03)	(0.02)	(0.15)	(0.05)	(0.06)	(0.19)
Log Per Capita GDP, Reporter (*PGDP*)		0.03	-0.17	-0.00	-0.98***	-2.72***	-1.24***	0.73***	-1.06***
		(0.14)	(0.20)	(0.14)	(0.19)	(0.21)	(0.31)	(0.32)	(0.26)
Log Per Capita GDP, Partner (*PGDP*)		0.32***	0.32***	0.41***	0.41***	1.53	0.41***	0.39***	0.60
		(0.04)	(0.04)	(0.03)	(0.03)	(1.03)	(0.07)	(0.07)	(1.44)
Log Distance (*DIS*)		-0.77***	-0.77***	-0.79***	-0.77***		-0.79***	-0.82***	
		(0.05)	(0.05)	(0.05)	(0.04)		(0.10)	(0.10)	
Adjacent Dummy (*ADJ*)		0.51***	0.52***	0.37***	0.37***		0.54***	0.68***	
		(0.13)	(0.13)	(0.11)	(0.12)		(0.25)	(0.21)	
Language Dummy (*LAN*)		-0.04	0.06	-0.20*	0.23		0.73***	-0.01	
		(0.14)	(0.17)	(0.11)	(0.15)		(0.26)	(0.25)	
Log Real Exchange Rate (*RER*)		-0.46*	-0.52*	-0.34	-0.46*	-0.15	-0.99	-1.13*	-0.62
		(0.28)	(0.28)	(0.28)	(0.26)	(0.32)	(0.61)	(0.58)	(0.42)
Japan Dummy (*JPN*)			-0.29		0.85**	3.38**		-6.73***	-1.71*
			(0.40)		(0.39)	(0.58)		(1.21)	(0.90)
*JPN**Log(*OSP*)			0.04		0.01	-0.23***		0.43***	-0.03
			(0.03)		(0.03)	(0.05)		(0.10)	(0.07)
Year: 2002-2008									
Year Dummy	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional Dummy	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Country Dummy (Partner)	No	No	No	No	No	Yes	No	No	Yes
R-Squared	0.47	0.78	0.78	0.77	0.80	0.75	0.67	0.70	0.86
Observations	823	800	800	800	800	718	793	793	718

Notes: Reporter: 6 countries (Japan, United States, Germany, France, Italy, Sweden), and Partner: 49 countries. *** p<0.01, ** p<0.05, * p<0.1

The fourth to sixth columns of Table 3.6 show estimates related to exports. The fourth column, controlling for gravity and other relevant variables, shows a similar result to that for total trade in the second column. The effect of overseas production is positive and significant at the 1 percent level, predicting that a 1% expansion of overseas production leads to an increase in P&C exports to that country by 0.27%. The interpretation is that an intra-firm trade from headquarters to overseas subsidiaries plays an important role in determining P&C exports for TPCs. The fifth column shows results when the Japan dummy (*JAP*) and its interaction term with overseas production (*JAP*×Log (*OSP*)) are added. The coefficient of the Japan dummy is positive and significant at the 5 percent level, suggesting that, after allowing for the other relevant variables, on average, Japan exports more P&C than other TPCs. However, the coefficient of the interaction term is statistically insignificant. The sixth column reports the results when country dummy variables are added to control for time-invariant aspects of industrial policy of individual host countries (partners). [32] This variable addition is justified because the relationship between overseas production and trade flows could well be influenced by country-specific distortions in trade and industry policy. With this specification, the coefficient of the interaction term between Japan dummy and overseas production (*JAP*×Log (*OSP*)) becomes negative and significant at the 1 percent level. The result suggests that the magnitude of the interlink between Japan's P&C exports and overseas production by Japanese car makers is 0.23 percentage points smaller comparing with the magnitude of the average relationship estimated for all TPCs.

Import substitution and local content requirement policies in host countries encourages automakers to build plants in these countries and parts suppliers to follow them. As discussed in section 3.3, the following-leader investment that probably substitutes a direct supply of P&C for exports from home country, is more prevalent among Japanese car makers and their suppliers in comparison with the case of the US and European counterparts.

[32] I exclude regional dummy variables and variables to capture country specific characteristics such as distance, adjacent dummy and language dummy.

The seventh to ninth columns of Table 3.6 show estimates related to imports. Interestingly, the results are very similar to those for exports. The coefficient of overseas production (*OSP*) is positive and significant in all three equations, suggesting that production networks facilitate intra-firm trade between headquarters and overseas subsidiaries. Overall, the gravity variables are statistically significant with the expected signs. However, the signs of the coefficients of the Japan dummy (*JAP*) and its interaction term with overseas production (*JAP*×Log (*OSP*)) are different from those of the exports equations. As can be seen in the eighth column, the coefficient of the Japan dummy is negative and significant at the 1 percent level and that of the interaction term is positive and highly significant. Japan's P&C imports is 6.73% smaller but the interlink between Japan's P&C imports and overseas production by Japanese car makers is 0.43 percentage points larger than is the case for other TPCs.

The ninth column shows the result when country dummies are added as in the case of exports. While the coefficient of the Japan dummy is still negative and significant (10 percent level), that of the interaction term becomes insignificant. However, the result might implicitly reflect Japan's smaller involvement with arms-length transactions comparing with those of other TPCs because the negative coefficient of the Japan dummy controlling for overseas production probably captures the impact of intra-firm trade. That is to say, the result implies that the proportion of P&C imports that Japan is engaging with intra-firm transaction is higher than for the counterparts of other TPCs.

Table 3.7 reports the estimates of the augmented gravity equation with *four*-dimensional panel data covering 90 products, 6 sample countries, and 49 trading partners over 7 years from 2002 to 2008. The disaggregation of dependent variables at product-level allows me to enhance the accuracy of estimation by greatly increasing number of observations. The number of observations for total trade increases to nearly 63,675, while those for exports and imports increase to 60,527 and 48,399 respectively. Also, the disaggregation allows controlling for parts-specific characteristics such as asset specificity and engineering costs that may affect trade patterns. 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 due to the avoidance of a breach of technology and information. On the other hand, 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.

The first three columns show results for total trade. These results are quite similar to those based on the three-dimensional data. All coefficients of overseas production are positive and significant at the one-percent level. The coefficients of gravity variables are statistically significant with the expected signs. It is also found that Japan is not unique (third column). Although the coefficient of the interaction term (*JPN**Log (*OSP)*) is positive and significant at the 5 percent level, the economic significance is not large enough to conclude that Japan's trade in P&C is more strongly linked to its production networks than is the case for other TPCs.

The fourth to sixth columns are estimates relating to exports. The sixth column reports the result when dummy variables are added to control for year-, country- and parts- specific characteristics. The coefficient of the Japan dummy (*JPN*) is positive and significant at the 1 percent level and the coefficient of the interaction term (*JPN**Log (*OSP)*) is negative and significant. The seventh to ninth columns report estimates related to imports. As shown in the eighth and ninth columns, coefficients of the Japan dummy are negative and significant at the 1 percent level. On the other hand, after controlling for the country-specific effects, the sign of the coefficient of the interaction term becomes negative.

Table 3.7: Regression Results with Four Dimensional Panel Data (Year, Reporter, Partner, Auto Part)

Dependent Variable: Log Total Trade (Exports + Imports), Exports or Imports of Parts and Components (US$)	Total Trade				Exports		Imports		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log Overseas Production (*OSP*)	0.52***	0.22***	0.22***	0.22***	0.21***	0.39***	0.18***	0.18***	0.44***
	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Log Domestic Production, Reporter (*DAP*)		0.53***	0.52***	0.62***	0.56***	0.54***	0.43***	0.52***	0.41***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Log Domestic Production, Partner (*DAP*)		0.40***	0.40***	0.31***	0.32***	-0.11**	0.66***	0.67***	-0.07
		(0.01)	(0.01)	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)	(0.08)
Log Per Capita GDP, Reporter (*PGDP*)		-0.32***	-0.54***	-0.66***	-1.48***	-3.37***	-0.05	1.00***	-1.10***
		(0.04)	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.07)	(0.06)
Log Per Capita GDP, Partner (*PGDP*)		0.45***	0.45***	0.47***	0.46***	1.26***	0.29***	0.30***	0.77*
		(0.01)	(0.01)	(0.01)	(0.01)	(0.29)	(0.01)	(0.01)	(0.44)
Log Distance (*DIS*)		-0.80***	-0.80***	-0.80***	-0.79***		-0.89***	-0.90***	
		(0.01)	(0.01)	(0.01)	(0.01)		(0.02)	(0.02)	
Adjacent Dummy (*ADJ*)		0.72***	0.72***	0.65***	0.66***		0.84***	0.82***	
		(0.03)	(0.03)	(0.03)	(0.03)		(0.04)	(0.04)	
Language Dummy (*LAN*)		0.18***	0.28***	0.12***	0.50***		0.26***	-0.22***	
		(0.03)	(0.03)	(0.03)	(0.03)		(0.04)	(0.05)	
Log Real Exchange Rate (*RER*)		-0.42***	-0.46***	-0.14*	-0.27***	-0.05	-0.63***	-0.39***	-0.66***
		(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.11)	(0.11)	(0.12)
Japan Dummy (*JPN*)			0.01		0.42***	3.31***		-1.91***	-0.53**
			(0.11)		(0.11)	(0.14)		(0.20)	(0.24)
*JPN**Log(*OSP*)			0.02**		0.04***	-0.25***		0.06***	-0.12***
			(0.01)		(0.01)	(0.01)		(0.02)	(0.02)
Year Dummy	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional Dummy	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Country Dummy (Partner)	No	No	No	No	No	Yes	No	No	Yes
Parts Dummy	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.16	0.62	0.62	0.61	0.62	0.60	0.46	0.48	0.51
Observations	63,675	62,613	62,613	60,527	60,527	54,736	48,399	48,399	44,331

Notes: Reporter: 6 countries (Japan, United States, Germany, France, Italy, Sweden), Partner: 49 countries, Auto Parts: 90 parts, Year: 2002-2008.

3.5 Extension to Completely-Built Units (CBU)

This section extends the analysis to CBU focusing on the exports side. This is because the exports are quite large whereas imports are quite limited (Figures 3.3 and 3.4). The focus is on the relationship between exports and overseas production, which has been investigated by many researchers (Mundell 1957, Markusen 1984, Caves 2007). A central issue is whether these two variables are complements or substitutes. While the theory predicts both possibilities, empirical research has consistently found complementary relationships between exports and multinationals' activities.[33] In fact, TPCs have experienced simultaneous increases in both overseas production by automakers originated from TPCs and CBU exports from TPCs since 2000 (Table 2.3 and Figure 3.3).

Applying the same estimation method to data compiled from the same sources used to analyse determinants of P&C, CBU exports equations are estimated for TPCs.[34] As before the estimation is carried out in two steps. The first is to estimate the determinant of aggregated CBU exports as a function of overseas production, gravity variables and other relevant variables by examining three-dimensional panel data (year, reporter and partner). The second step is to examine four-dimensional panel data (year, reporter, partner, and commodity) by breaking down the aggregated dependent variable into 23 products. Country and commodity-specific effects are controlled to deal with possible endogeneity problems.

Table 3.8 shows regression results for CBU exports. The first to fifth columns report estimates by examining three-dimensional panel data. As can be seen in the first column, CBU exports and overseas production by car makers seem to be strongly complementary. The second column reports the estimation after adding gravity variables as well as year and regional dummies.

[33] Refer to Navaretti and Venables (2004, pp 220-221) for more information.

[34] On the demand side, I use domestic automobile sales in a partner's country as a proxy of market size of CBU instead of GDP. This is measured by the number of cars sold annually in a host country. On the supply side, domestic automobile production in TPCs is used as a proxy of supply capacity of CBU (Refer to Appendix 3-E for more information).

It suggests that the strong complementary relationship between these two variables is a consequence of failing to correct for gravity model factors. The domestic production in TPCs and domestic sales in host countries are positive and highly significant predictors of CBU exports. An increase in supply capacity in TPCs by 1% leads to a 0.92% expansion of CBU exports from TPCs. An increase in market size in host countries by 1% leads to a 0.7% expansion of CBU exports from TPCs. As the third column shows, as expected the effect of the real exchange rate is positive and significant at the 1 percent level. Holding other variables fixed, a depreciation of the real exchange rate by 1% leads to an increase in exports by 1%. The fourth column, portraying the results when I add the Japan dummy and its interaction term with overseas production, examines Japan's uniqueness. The result shows that Japan exports more CBU comparing with other TPCs holding other variables constant but the degree of complementary relationship between exports and overseas production is not different between Japan and other TPCs.

It could be that a local government's industrial policy, such as import substitution, positively affects the scale of overseas production by car makers but negatively affects exports of CBU from TPCs. The difference in consumer preference and tastes among host countries also matters. Consumers in developed countries tend to be more fuel-efficient and eco-conscious than those in developing countries. A car with fuel efficiency and eco-friendliness are often exported from a home country rather than produced overseas so as to avoid breaches of technology.[35] On the other hand, consumers in developing countries tend to care more about price. This might encourage automobile makers from TPCs to manufacture motor vehicles overseas with cheap labour, leading to less exports of CBU from TPCs to developing countries. In fact, as shown in Table 3.2, the destination of CBU exports from TPCs has been more intensified into developed countries.

The fifth column of Table 3.8 reports the result when dummies are added to control for country-specific characteristics. Interestingly, the coefficient of overseas production becomes

[35] For example, Prius - a full hybrid electric mid-size car developed and manufactured by Toyota Motors- has been produced only in Japan ever since it was created in 1997.

positive and significant at the 1 percent level. Furthermore, the coefficient of the interaction term between the Japan dummy and overseas production becomes negative and significant at the 1 percent level, suggesting Japan's complementary relationship between exports and overseas production is weaker than that of other TPCs. The interpretation is that Japanese car makers tend to be more localised not only to manufacture and develop products based on unique consumer preference in host countries but also to undertake more efficient and quicker deliveries and distribution and after-sale services. Also, the more localisation-oriented behaviour by Japanese car makers might reflect the avoidance of trade frictions with host countries.[36]

It is important to control for product-specific effects because there are a wide range of motor vehicles in terms of purpose (passenger, commercial or special purpose), size, and fuel efficiency. For example, passenger cars have accounted for nearly 90% of Japan's total CBU exports. It seems that while more passenger cars tend to be exported from the home country, overseas demand for commercial vehicles such as trucks, buses and taxis are met from overseas assembly plants. The domestic production of Japanese car makers has also been intensified into a small-medium size car, thus implying a small-medium size of car tends to be exported from a home country whereas a large size of car tends to be produced overseas.[37]

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[36] The growing export of passenger cars from Japan during the 1970s and 1980s caused trade friction with developed countries, especially the United States. As a result, in 1981, the Japanese government was forced to undertake a voluntary export restraint of passenger cars to the US market, setting the limit at 1,680 thousand units per year.

[37] For example, Toyota Motors has produced "Tundra"- a large size pick-up track- in Toyota Motor Manufacturing Texas (TMMTX), instead of exporting it from Japan.

Table 3.8: Regression Results for Completely-Built Units (CBU) Exports

Dependent Variable: Log Exports of Completely-Built Units (US$)		**3 Dimensional Panel Data (Reporter, Partner, Year)**					**4 Dimensional Panel Data (Reporter, Partner, Year, Commodity)**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Log Overseas Production (*OSP*)	0.48***	0.03***	0.02*	0.01	0.30***	0.22***	-0.01	-0.02	-0.01	0.23***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Log Domestic Production, Reporter		0.92***	0.92***	0.82***	0.54***		0.97***	0.96***	0.92***	0.80***
(*DAP*)		(0.02)	(0.02)	(0.02)	(0.02)		(0.04)	(0.04)	(0.04)	(0.05)
Log Domestic Sales, Partner (*DAS*)		0.70***	0.72***	0.78***	0.67***		0.32***	0.34***	0.40***	0.51***
		(0.02)	(0.02)	(0.02)	(0.11)		(0.02)	(0.03)	(0.03)	(0.18)
Log Per Capita GDP, Reporter		0.81***	0.79***	-0.34***	-3.10***		-0.11	-0.08	-1.15***	-3.51***
(*PGDP*)		(0.09)	(0.10)	(0.11)	(0.11)		(0.15)	(0.16)	(0.17)	(0.18)
Log Per Capita GDP, Partner (*PGDP*)		0.58***	0.59***	0.48***	-1.40**		0.44***	0.44***	0.35***	-0.18
		(0.02)	(0.02)	(0.02)	(0.64)		(0.03)	(0.03)	(0.03)	(0.93)
Log Distance (*DIS*)		-1.13***	-1.09***	-1.03***			-0.95***	-0.96***	-0.91***	
		(0.03)	(0.04)	(0.04)			(0.04)	(0.04)	(0.04)	
Adjacent Dummy (*ADJ*)		0.21***	0.23***	0.29***			0.69***	0.67***	0.68***	
		(0.05)	(0.06)	(0.06)			(0.09)	(0.09)	(0.09)	
Language Dummy (*LAN*)		-0.67***	-0.60***	-0.02			-0.40***	-0.36***	0.15	
		(0.07)	(0.08)	(0.09)			(0.10)	(0.10)	(0.11)	
Log Real Exchange Rate (*RER*)			0.99***	0.51***	0.50***			0.58**	0.21	0.14
			(0.19)	(0.19)	(0.17)			(0.26)	(0.26)	(0.30)
Japan Dummy (*JPN*)				1.23***	4.08***				1.87***	3.38***
				(0.28)	(0.29)				(0.44)	(0.53)
*JPN**Log(*OSP*)				0.01	-0.24***				-0.06	-0.22***
				(0.02)	(0.02)				(0.04)	(0.04)
Year: 2002-2008										
Year Dummy	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Regional Dummy	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No
Country Dummy (Partner)	No	No	No	No	Yes	No	No	No	No	Yes
Commodity Dummy	No	No	No	No	No	No	Yes	Yes	Yes	Yes
R-Squared	0.24	0.71	0.73	0.76	0.84	0.02	0.45	0.46	0.47	0.46
Observations	945	839	796	796	801	16,987	15,530	14,854	14,854	14,898

Notes: Reporter: 6 countries (Japan, United States, Germany, France, Italy, Sweden), Partner: 49 countries, Commodity: 23 types. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The sixth to tenth columns report estimates when product-specific dummies are added. The results are quite similar to the previous case. However, an interesting insight lies in the interpretation of coefficients of real exchange rate. As shown in the ninth and tenth columns, the effect of real exchange rate is not statistically significant. This suggests that global car makers are selecting their modes to penetrate overseas markets based on consumer preference and product characteristics as well as market size rather than exchange fluctuations. The failure of the real exchange rate to yield a statistically significant coefficient is also consistent with the view that automakers set prices within a certain range of expected exchange rate and hence exchange rate fluctuations within that range do not affect the exporting behaviour.[38]

3.6 Conclusion

In this chapter I have examined two issues relating to global production sharing by Japanese car makers from a comparative perspective: the roles of (1) the 'following-leader' pattern (that is, parts and components suppliers following car producers) of Japanese overseas investment and of (2) interlocking relationships among firms (*keiretsu* networks), in determining the trade in P&C. The results of the econometric analysis based on a new panel dataset suggest that Japan's P&C exports are less interlinked with the overseas production of Japanese automakers than is the case for other TPCs. This might be attributed to the following-leader investment by parts suppliers that substitute a direct supply of P&C for exports from the home country. On the other hand, I found that the relationship between Japan's P&C imports and overseas production of Japanese automakers is not different from other TPCs.

The key findings of this study are complementary to those of Blonigen (2001) in supporting the existence of a following-leader pattern in overseas investment by Japanese part suppliers. However, the sole focus of Blonigne's analysis is on the experience of overseas operations of Japanese parts and component suppliers. By contrast this study has tested this hypothesis using a newly constructed data set

[38] Moreover, the control for country dummies, which pick up permanent relative price differences and the big lags in moving production might make the exchange rate fluctuation insignificant.

that permits analysing the overseas investment patterns of Japanese automakers and part suppliers in comparison with their counterparts in the other major auto-producing countries.

A major limitation of the analysis in this chapter is that it has overlooked the overseas activities of parts suppliers. It has been assumed that the scale of automaker's overseas production is perfectly correlated with the counterpart of parts suppliers. This could cause a measurement error, leading to a biased estimator. In order to deal with this problem, Chapters 5 and 6 explicitly incorporate parts suppliers into the analysis, examining the case of Toyota and its parts suppliers. Before moving on to the analysis, the next chapter provides background information for the empirical analyses undertaken in Chapters 5 and 6.

Appendices to Chapter 3

Appendix 3-A: List of Parts and Components (P&C)

Serial Number	HS Code	Name
1	392690	Articles of plastics&articles of other materials of headings 39.01 to 39.14, n.e.s. in Ch 39
2	400910	Rubber tube, pipe or hose not reinforced, no fittings
3	400920	Rubber tube, pipe, hose, metal reinforced, no fitting
4	400930	Rubber tube, pipe, hose textile-reinforced no fitting
5	400940	Rubber tube, pipe or hose, reinforced nes, no fitting
6	401110	Pneumatic tyres new of rubber for motor cars
7	401120	New pneumatic tyres, of rubber, of a kind used on buses/lorries
8	401140	Pneumatic tyres new of rubber for motorcycles
9	401199	Pneumatic tyres new of rubber nes
10	401220	Pneumatic tyres used
11	401310	Inner tubes of rubber for motor vehicles
12	401691	Floor coverings, mats of rubber except cellular, hard
13	401699	Articles of vulcanised rubber nes, except hard rubber
14	570242	Carpets of manmade yarn, woven pile, made up,nes
15	570320	Carpets nylon, polyamides, tufted
16	570330	Carpets of other manmade textile materials, tufted
17	570490	Carpets of felt of textile materials, > 0.3 m2
18	700711	Safety glass (tempered) for vehicles, aircraft, etc
19	700721	Safety glass (laminated) for vehicles, aircraft, etc
20	700910	Rear-view mirrors for vehicles
21	732010	Leaf springs/leaves thereof, iron or steel
22	732020	Springs, helical, iron or steel
23	732090	Springs, iron or steel, except helical/leaf
24	830120	Locks of a kind used for motor vehicles of base metal
25	830230	Motor vehicle mountings, fittings, of base metal, nes
26	840729	Marine propulsion spark-ignition engines nes
27	840731	Engines, spark-ignition reciprocating, <50 cc
28	840732	Engines, spark-ignition reciprocating, 50-250 cc
29	840733	Engines, spark-ignition reciprocating, 250-1000 cc
30	840734	Engines, spark-ignition reciprocating, over 1000 cc
31	840790	Engines, spark-ignition type nes
32	840820	Engines, diesel, for motor vehicles
33	840991	Parts for spark-ignition engines except aircraft
34	840999	Parts for diesel and semi-diesel engines
35	841459	Electric fans, motor > 125 watts
36	841490	Parts of vacuum pumps, compressors,fans,blowers,hoods
37	841590	Parts for air conditioners
38	842123	Oil/petrol filters for internal combustion engines
39	842129	Filtering/purifying machinery for liquids nes
40	842131	Intake air filters for internal combustion engines
41	842199	Parts for filter/purifying machines for liquid/gas
42	842542	Hydraulic jacks/hoists except for garages
43	848310	Transmission shafts and cranks, cam and crank shafts
44	848320	Bearing housings etc incorporating ball/roller bearin
45	848330	Bearing housings, shafts, without ball/roller bearing
46	848350	Flywheels & pulleys, incl. pulley blocks
47	848390	Parts of power transmission etc equipment
48	848410	Gaskets & similar joints of metal sheeting combined with other material/of

		2/more layers of metal
49	850211	Generating sets, diesel, output < 75 kVA
50	850710	Lead-acid electric accumulators (vehicle)
51	851110	Sparking plugs
52	851120	Ignition magnetos, magneto-generators and flywheels
53	851130	Distributors and ignition coils
54	851140	Starter motors
55	851150	Generators and alternators
56	851180	Glow plugs & other ignition or starting equipment nes
57	851190	Parts of electrical ignition or starting equipment
58	851220	Lighting/visual signalling equipment nes
59	851230	Sound signalling equipment
60	851240	Windscreen wipers, defrosters & demisters of a kind used for cycles/motor vehicles
61	851290	Parts of cycle & vehicle light, signal, etc equipment
62	852719	Radio-broadcast receivers capable of operating without an external source of power (excl. of 8527.12 & 8527.13)
63	852721	Radio receivers, external power,sound reproduce/recor
64	852729	Radio receivers, external power, not sound reproducer
65	853910	Sealed beam lamp units
66	853921	Filament lamps, tungsten halogen
67	853990	Parts of electric filament or discharge lamps
68	854430	Ignition/other wiring sets for vehicles/aircraft/ship
69	854460	Electric conductors, for over 1,000 volts, nes
70	870710	Bodies for passenger carrying vehicles
71	870790	Bodies for tractors, buses, trucks etc
72	870810	Bumpers & parts thereof of the motor vehicles of 87.01-87.05
73	870821	Safety seat belts for motor vehicles
74	870829	Parts and accessories of bodies nes for motor vehicle
75	870831	Mounted brake linings for motor vehicles
76	870839	Brake system parts except linings for motor vehicles
77	870840	Transmissions for motor vehicles
78	870850	Drive axles with differential for motor vehicles
79	870860	Non-driving axles/parts for motor vehicles
80	870870	Wheels including parts/accessories for motor vehicles
81	870880	Shock absorbers for motor vehicles
82	870891	Radiators for motor vehicles
83	870892	Mufflers and exhaust pipes for motor vehicles
84	870893	Clutches and parts thereof for motor vehicles
85	870894	Steering wheels, columns & boxes for motor vehicles
86	870899	Motor vehicle parts nes
87	871411	Motorcycle saddles
88	871419	Motorcycle parts except saddles
89	910400	Instrument panel clocks etc for vehicles/aircraft etc
90	940120	Seats, motor vehicles

Source: Japan Auto Parts Industries Association (JAPIA)

Appendix 3-B: List of Completely-Built Units (CBU)

Serial Number	HS Code	Name
1	870210	Diesel powered buses
2	870290	Buses except diesel powered
3	870310	Snowmobiles, golf cars, similar vehicles
4	870321	Automobiles, spark ignition engine of <1000 cc
5	870322	Automobiles, spark ignition engine of 1000-1500 cc
6	870323	Automobiles, spark ignition engine of 1500-3000 cc
7	870324	Automobiles, spark ignition engine of >3000 cc
8	870331	Automobiles, diesel engine of <1500 cc
9	870332	Automobiles, diesel engine of 1500-2500 cc
10	870333	Automobiles, diesel engine of >2500 cc
11	870390	Automobiles nes including gas turbine powered
12	870410	Dump trucks designed for off-highway use
13	870421	Diesel powered trucks weighing < 5 tonnes
14	870422	Diesel powered trucks weighing 5-20 tonnes
15	870423	Diesel powered trucks weighing > 20 tonnes
16	870431	Spark ignition engine trucks weighing < 5 tonnes
17	870432	Spark ignition engine trucks weighing > 5 tonnes
18	870490	Trucks nes
19	870510	Mobile cranes
20	870520	Mobile drilling derricks
21	870530	Fire fighting vehicles
22	870540	Mobile concrete mixers
23	870590	Special purpose motor vehicles nes

Source: Compiled from UN Comtrade Database

Appendix 3-C: List of Trading Partners

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	

Appendix 3-D: 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 Organisation of Motor Vehicle Manufacturers (OICA): http://www.oica.net/

Appendix 3-E: List of Definitions and Data Sources of Variables

Variables	Definition	Data Source
E_P&C	Real value of exports of parts and components in US$, deflated by motor vehicle parts manufacturing sub-index of the US producer price index at 2002	UN Comtrade: (http://comtrade.un.org/) US Bureau of Labour Statistics: (http://www.bls.gov/)
I_P&C	Real value of imports of parts and components in US$, deflated by motor vehicle parts manufacturing sub-index of the US producer price index at 2002	UN Comtrade: (http://comtrade.un.org/) US Bureau of Labour Statistics: (http://www.bls.gov/)
E_CBU	Real value of trade in completely-built units in US$, deflated by motor vehicle manufacturing sub-index of the US producer price index at 2002	UN Comtrade: (http://comtrade.un.org/) US Bureau of Labour Statistics: (http://www.bls.gov/)
I_CBU	Real value of trade in completely-built units in US$, deflated by motor vehicle manufacturing sub-index of the US producer price index at 2002	UN Comtrade: (http://comtrade.un.org/) US Bureau of Labour Statistics: (http://www.bls.gov/)
DAP	Volume of domestic auto production	International Organisation of Motor Vehicle Manufacturers: (http://oica.net/category/about-us/)
MRK	Volume of domestic auto sales	Automotive information platform: (http://www.marklines.com/en/index.jsp). *Nikkan Jidosha Shinbun* and *Nikkan Jidosha Kaigisho* [Automobile Newspaper and Automobile Business Association of Japan] (2008).
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/)
PGDP	Real per capita GDP in US$ (at 2002 price)	World Development Indicators: (http://www.worldbank.org/)
RER	Real exchange rate, $RER_{ij} = NER_{ij} * (P_j^w / P_i^D)$ where *NER* is the nominal exchange rate index, P^W is the producer price measured by the wholesale price index, and P^D is the domestic price measured by the GDP deflator	World Development Indicators: (http://www.worldbank.org/)
DIS	Geographical distance between the capital cities in km	CEPII database: (http://www.cepii.fr/anglaisgraph/bdd/fdi.htm)
ADJ	Dummy variable indicating whether the two countries are contiguous	CEPII database: (http://www.cepii.fr/anglaisgraph/bdd/fdi.htm)
LAN	Dummy variable indicating whether the two countries share a common official language	CEPII database: (http://www.cepii.fr/anglaisgraph/bdd/fdi.htm)

CHAPTER 4

Profile of Toyota Motors

4.1 Introduction

This chapter provides the setting for the micro-level analyses in the following two chapters (Chapters 5 and 6) where global production sharing by Toyota Motors is examined from both the export and import sides. The case study of Toyota is interesting for three reasons. First, Toyota Motors is one of the most globalised multinational enterprises in the world, with a world-wide production and distribution network. Second, Toyota has created its own unique 'just-in-time' production system (also called "lean production") and supplier relationships based on "*keiretsu*" in the process of its expansion during the past seven decades. These management systems could influence the form of global production sharing because they require a geographical proximity between the assembler and parts suppliers, presumably leading to a lesser degree of involvement in cross-border trade in P&C compared to the other automakers. Third, Toyota's parts suppliers have also globalised rapidly through following-leader investment. Some global suppliers are now expanding their business relationships toward local automakers in host countries. Also, their cross-border production and distribution networks have been developed not only between their headquarters and overseas subsidiaries but also among overseas subsidiaries.

The plan of this chapter is as follows. The next section provides an overview of the history of Toyota Motors during the period 1933 to 2008. Section 4.3 summarises the lean production system and supplier relationships. Section 4.4 examines the expansion and nature of cross-border production networks, with emphasis on following-leader investment by parts suppliers and trends and patterns of P&C trade. Section 4.5 concludes.

4.2 History

Toyota Motors started in 1933 as an automobile department at the Toyoda Automatic Loom in *Koromo* in Aichi prefecture. During the ensuing seven decades it elevated gradually to the top of the global automobile industry, overtaking in 2008 General Motors (GM), which had been number one since 1931. A tiny car company which started with a production capacity of 20 units (in 1935) has grown to become a giant producing 8.2 million units per year (in 2008). Now, Toyota Motors produces 12% of motor vehicles in the world (Table 4.1). This section provides an overview of the development path of Toyota.

4.2.1 Formative Stage (1935-1955)

Kiichiro Toyoda commenced by reverse engineering a 33-year model Chevolet car (*Toyota Jidosha Kogyo* 1958). Through trial and error a first experimental car, Model A1, was produced in 1935. Through refinement of Model A1, Model AA and Model AB were completed in 1936. They were the first Toyota passenger vehicles sold in the domestic market. Kiichiro also launched truck production. By learning the design from a 34-year model Ford truck, the Model G1 was completed in 1935 and sold for a price of 2,900 yen, which was cheaper than that of either Ford or Chevolet at that time (*Toyota Jidosha Kogyo* 1958).

The surge in demand for military trucks during the war period meant Toyota Motors focused on truck production. In order to support capacity expansion of truck production, the Japanese government provided automakers, including Toyota, with various economic incentives based on the Automotive Manufacturing Industries Act (*Jidosha seizo jigyo ho*) enacted in 1936. Table 4.2 shows Toyota's output by type during the war period. Trucks played the dominant role during this period. The heavy reliance on truck production continued even after the war due to the sharp rise in demand from the Korean War occurred in 1950.

Reflecting the limited production of passenger vehicles, Toyota's production volume was much smaller than that of American automakers during this period. While Toyota Motors produced 22 thousand motor vehicles in 1955 (Table 4.1), General Motors, Ford Motors and Chrysler produced 3,639 thousand, 1,980 thousand and 1,206 thousand units respectively in the same year (Shimokawa 1992).

Three factors limited large scale passenger vehicle production. The first was the lack of physical and human capital and raw materials. World War II damaged machines and tools and many engineers and mechanics were killed. Materials such as metal and iron were intensively consumed for military use during the war period and the supply of materials was controlled by the government until 1952 (*Nihon Jidosha Kogyokai* 1988). Second, after World War II, General Headquarters (GHQ) or the Supreme Commander for the Allied Powers (SCAP) initially permitted Japanese car makers to produce only trucks, aiming to expand transportation capacity. Hence, large-scale production of passenger vehicles by Toyota Motors did not resume until 1949 when GHQ lifted all restrictions related to the manufacturing and sales of motor vehicles. Third, the income level of Japanese consumers at that time was not sufficient to underpin the passenger vehicle market, and per capita income did not exceed the pre-war level until 1953.

Table 4.1: Toyota's Performance over 70 Years: Production, Sales, and Exports

Year	Production			Sales			Exports	World Production	Share of Toyota in the World (%)
	Total	Domestic	Overseas	Total	Domestic	Overseas			
1935	20	20	n.a.	n.a.	n.a.	n.a.	n.a	5,134,000	0
1955	22,786	22,786	n.a.	n.a.	n.a.	n.a.	283	13,628,000	0
1960	154,770	154,770	n.a.	n.a.	n.a.	n.a.	6,393	16,488,000	1
1966	587,539	587,539	n.a.	n.a.	n.a.	n.a.	105,145	24,852,000	2
1970	1,609,190	1,609,190	n.a.	n.a.	1,109,322	n.a.	481,892	29,403,000	5
1975	2,336,053	2,336,053	n.a.	n.a.	1,442,275	n.a.	868,352	32,998,000	7
1980	3,293,344	3,293,344	n.a.	n.a.	1,494,350	n.a.	1,785,445	38,514,000	9
1985	3,801,622	3,665,622	136,000	n.a.	1,683,407	n.a.	1,979,955	44,811,000	8
1990	4,890,373	4,212,373	678,000	n.a.	2,504,236	n.a.	1,677,127	48,345,000	10
1995	4,424,600	3,171,277	1,253,323	4,556,300	2,029,022	2,527,278	1,202,420	49,913,000	9
2000	5,180,500	3,429,209	1,751,291	5,154,300	1,763,595	3,390,705	1,706,208	58,374,162	9
2005	7,360,900	3,789,582	3,571,318	7,267,300	1,703,185	5,564,115	2,043,245	66,482,439	11
2008	8,210,500	4,012,388	4,198,112	7,996,100	1,443,335	6,552,765	2,586,338	70,520,493	12

Note: The unit is volume.

Sources:

Compiled from Japan Automobile Manufactures Association (JAMA), International Organisation of Motor Vehicle Manufacturers(OICA), *Toyota Jidosha Kogyo* [Toyota Motors] (1967)

Table 4.2: Toyota Motors' Production During the War Period

	Passenger Vehicle	Truck	Bus	Special purpose	Total
1935	n.a.	20	n.a.	n.a.	20
1936	100	910	132	n.a.	1,142
1937	577	3,023	413	n.a.	4,013
1938	539	3,719	357	n.a.	4,615
1939	107	10,913	961	n.a.	11,981
1940	268	13,574	945	n.a.	14,787
1941	208	14,331	72	n.a.	14,611
1942	41	16,261	n.a.	n.a.	16,302
1943	53	9,739	n.a.	35	9,827
1944	19	12,533	n.a.	168	12,720
1945	n.a.	3,275	n.a.	n.a.	3,275

Note: The unit is volume.
Source: *Toyota Jidosha Kogyo* [Toyota Motors] (1958)

4.2.2 Domestic-Oriented Growth (1955-1970)

Production by Toyota Motors rapidly increased from 22 thousand in 1955 to 1,609 thousand units by 1970 (Table 4.1). Toyota's position in world production rose to 5% in 1970 when production volume exceeded that of Chrysler.[39] The long-term economic boom that started in 1955 and lasted until 1970 boosted consumers' average income levels, leading to the emergence of motorisation, which created a large domestic market for passenger vehicles. The domestic market for motor vehicles expanded from 79 thousand in 1955 to 4,100 thousand units by 1970. It is worth pointing out that the Japanese automobile industry experienced a turning point, where the total sales of passenger vehicles (2,036 thousand units) exceeded that of commercial vehicles including trucks and buses (1,772 thousands units) for the first time in 1969. This suggests that by the early 1970s the Japanese automobile industry had transformed into a passenger vehicle oriented structure.

The national car policy announced by the government in 1955 accelerated the motorisation by stipulating the protocol of passenger cars as the following specification:

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[39] While Toyota's production volume was 1,609 thousand units in 1970, Chrysler's was 1,349 thousand units in the same year.

1. Four-wheel passenger car with a speed of 100 km/hr or over,
2. Fuel efficiency of 30km per liter of gasoline when driving at 60km/hr,
3. An engine capacity of 350-500cc, and
4. A unit production cost of ¥15,000 and unit market price of ¥250,000 at a production rate of 2,000 units per month

The national car policy aimed to subsidise automakers that achieved the above specifications. Although this policy was eventually abandoned because of technical difficulties, it played an important role in providing automakers with goals to be achieved in terms of technology, price and quality (Simokawa 1994). The Provisional Act for the Promotion of the Machinery Industry (*Kikai kogyo shinko rinji sochi ho* or *Kishin ho* for short) that was enacted in 1956 and terminated in 1965, also contributed to the development of supporting industries through rationalisation, export promotion, technological upgrading and materials procurement (Odaka et al 1988). The development of supporting industries helped Toyota Motors reduce production costs and improve product quality.

Toyota Motors had expanded its supply capacity to meet growing demands for passenger vehicles. In addition to the *Koromo* plants established in 1938, Toyota built new plants one after another during this period in *Motomachi* (1959), *Kasuga* (1961), *Kamigo* (1965), *Takaoka* (1966), *Miyoshi* (1968) and *Tsutsumi* (1970) (Table 4.3). However, as Toyota Motors expanded production volume, it experienced more serious safety and emission problems in the late 1960s. The growing number of recalls and serious air pollution were the targets of criticism. The social pressures, coupled with government regulations, forced car makers to develop technologies related to safety and emission controls. The technological improvements led not only to a mitigation of these domestic problems but also to the growing competitiveness in the global market, leading to an increase in exports.

Toyota's exports began in 1947 when a BM type truck was shipped to Okinawa and a SA type passenger car was exported to Egypt (*Toyota Jidosha Kogyo* 1967). The main exporting product during the 1950s was the "Land Cruiser", which accounted for nearly one third of Toyota's export at the time.[40] The increase in Toyota's exports from 283 units in 1955 to 6,393 units in 1960 (Table 4.1) was attributed to favourable consumer perception in developing countries especially South East Asia gained through maintaining quality standards. At the same time, Toyota Motors had attempted to expand exports of passenger cars to developed countries especially the United States, the largest auto market in the world at that time. Toyota Motors established Toyota Motor Sales, U.S.A. (TMS) in California in 1957 and the following year, exported 30 units of the passenger car Crown to the United States for the first time (*Toyota Jidosha Kogyo* 1967). Although quality and technical problems forced Toyota to call off exports to the United States from 1958, Toyota resumed exporting soon after achieving quality and technical improvements. Toyota's exports volume reached 481 thousands units in 1970, accounting for nearly one-fourth of its domestic production (1,609 thousands units) (Table 4.1). The growing exports suggests Toyota's cars had gradually began gaining competitiveness with US and European car makers through productivity and quality improvements. In addition, the increase in passenger car exports reflects technological developments such as emissions control and safety devices, which emerged as new automobile technologies in the late 1960s. In 1969, the cumulative number of motor vehicle exports by Toyota Motors reached one million units.

[40] The export volume of Land Cruiser was 98 in 1955 and 2,403 in 1960 (*Toyota Jidosha Kogyo* 1967).

Table 4.3: Toyota Motors' Domestic Production Plants

Name of Plant	Start of Operation	Number of Employment	Main products	Vehicle Production (1,000units)
Honsha Plant	1938	3,897	Forged parts, hybrid system parts	-
Motomachi Plant	1959	7,681	Crown, Mark X, Estima	80
Kamigo Plant	1965	3,201	Engines	-
Takaoka Plant	1966	4,685	Corolla, Vitz, iQ, ist, Ractis, Scion xD	267
Miyoshi Plant	1973	1,508	Transmission-related parts, cold-forged and sintered parts, engine-related parts	-
Tsutsumi Plant	1970	5,467	Prius, Camry, Premio, Allion, Scion tC	374
Myochi Plant	1973	1,706	Powertrain-related suspension cast parts, powertrain-related suspension machined parts	-
Shimoyama Plant	1975	1,630	Engines, turbochargers, catalytic converters	-
Kinu-ura Plant	1978	3,282	Transmission-related parts	-
Tahara Plant	1979	7,337	LS, GS, IS, GX, RAV4, Wish, Land Cruiser, Vanguard, engines	321
Teiho Plant	1986	1,261	Mechanical equipment, moldings for resin and casting and forging	-
Hirose Plant	1989	1,513	Research and development and production of electronic control devices, ICs	-
Toyota Motor Kyushu, Inc.	1992	6,282	IS, ES, HS, RX, Harrier, Highlander, engines, hybrid system parts	285
Toyota Motor Hokkaido, Inc.	1992	2,345	Automobile parts including automatic transmissions, continuously variable transmissions, transfers, aluminum wheels	-
Toyota Motor Tohoku Co., Ltd.	1998	383	Electronic controlled brakes, suspensions, axles, torque converters	-

Note: As of December 2009, Toyota Motor Kyushu, Inc., Toyota Motor Hokkaido, Inc. and Toyota Motor Tohoku, Inc. are 100%-owned subsidiaries of Toyota Motor Corporation

Source: Toyota Motor Corporation: http://www.toyota-global.com/company/profile/facilities/japanese_production_site.html

4.2.3 Export Expansion (1970-1985)

During the 1970s, Toyota's total production continued to grow from 1,609 thousand in 1970 to 3,293 thousand units by 1980. As a result, the share of Toyota Motors in world auto production grew from 5% to 9% between these two years. In order to expand production capacity further, Toyota Motors established new plants during the 1970s: *Myochi* plant in 1973, *Shimoyama* plant in 1975, *Kinu-ura* plant in 1978 and *Tahara* plant in 1979 (Table 4.3).

The expansion of production volume was obviously attributable to the rapid increase in export rather than domestic sales (Table 4.1). The growth rate of exports was much faster than domestic sales and the volume of exports (1,785 thousand units) eventually exceeded domestic sales (1,494 thousand units) in 1980. Not only Toyota Motors but also other Japanese car makers increased their exports, especially to the United States and European countries. Nearly 60% of cars exported from Japan had been shipped to these developed countries during the 1970s. With continuously growing exports, in 1977 Japan became the largest passenger vehicle exporting country in the world, exporting 2,958 thousand units. In 1980, Japan also became the largest auto-producing country in the world, exceeding the United States.[41]

The rise in competitiveness of Toyota Motors and other Japanese car makers during the 1970s can be attributed to technological improvements in fuel efficiency and productivity improvements by new production systems and production technology. The 1970s saw two oil crises that caused a hike in the oil price and shifted consumer demand toward small and fuel-efficient cars. Toyota Motors and other Japanese auto makers had succeeded in improving fuel efficiency by developing new engine technology and reducing car weight (*Nihon Jidosha Kogyokai* 1988). Japanese automobile manufacturers accelerated investment in new technologies, ranging from electronic control devices and advanced materials for weight reduction, to catalyst

[41] Japan's production volume was 11,040 thousand units and US production volume was 8,010 thousand units in 1980.

technologies for emission reduction, modification of engine design, and exploration of alternative engines. Toyota Motors mobilised roughly half their R&D personnel in Japan for engine technological development in the mid-1970s in order to improve fuel efficiency and emissions control (Fujimoto 1999).

The further motorization and diversification of consumer tastes during the 1970s had facilitated Japanese auto makers to introduce a flexible manufacturing system that enables a high-mix low-volume production with a quick response to market demand (*Nihon Jidosha Kogyokai* 1988). The most important factor that allowed for this flexible manufacturing system was technological innovation such as automation and robotic technologies. These technologies, coupled with electronics and information technologies, had made it possible to produce a wide variety of cars in terms of model, color and size in one production line. Also, computer systems, such as computer-aided design (CAD) and computer-aided manufacturing (CAM), helped reduce the heavy workloads of product development caused by a wide variety of models and frequent model changes. The 1970s was also when the Toyota production system and total quality control continued to spread to suppliers. There was tighter synchronisation of assembler-supplier production through just-in-time delivery, leading to both improvement in productivity and reduction in defects (Fujimoto 1999, Womack et al 2007). These efforts by Toyota Motors and other Japanese car makers bore fruit in the form of growing reputations for better quality and higher fuel efficiency in the US and European markets.

The growing exports of Japanese cars fueled trade frictions between Japan and Western countries, especially the United States, where the automobile industry had plunged into recession caused by the second oil shock in 1979. The Big 3 in the US (Ford, General Motors and Chrysler) were suffering from enormous deficits and closed their factories one after another laying off a large number of workers. Chrysler was in danger of bankruptcy and was eventually bailed out by the government. The high unemployment rate in the US automobile industry reflects the serious situation during the recession: 7.9% in 1979, 20.4% in 1980, 14.7% in 1981 and 20.1% in 1982 (*Nihon Jidosha Kogyokai* 1988). The growing increase in exports from Japan, at the same time as this ongoing crisis in the US automobile industry, determined the trade friction. In 1981, the Japanese government decided on voluntary export restraints (VERs) for passenger cars to the US market, setting the limit at 1,680 thousand units per year. Each Japanese auto maker was allocated a quota in proportion to its exports record (Shimokawa 1994). The VERs continued until 1994.[42]

In addition to voluntary export restraints, the rapid appreciation of the Japanese yen that resulted from the Plaza Accord in 1985, motivated Toyota and other Japanese automakers to change their global strategies by substituting overseas production for exports from Japan. As can be observed in Table 4.1, exports of Toyota's cars from Japan started slowing down between 1980 and 1985 and began declining in 1985. This was accompanied by an increase in Toyota's overseas production from about the mid-1980s.

4.2.4 Internationalisation of Production (1985-)

The expansion of overseas production during 1985 to 1990 led to a rise in Toyota's position in global production. Toyota's total production increased by 1 million units and its share in global production rose from 8% to 10% during the period (Table 4.1). One driving force was the increase in domestic production led by the expansion of domestic markets. The bubble economy that began in 1985 and lasted until the early 1990s boosted domestic consumer demands for motor vehicles. As can be seen in Table 4.1, Toyota's domestic sales grew substantially during this period. Domestic sales were 1,683 thousand in 1985 rising to 2,504 thousand units in 1990. Although exports declined by approximately 300 thousand units in this period, the increase in domestic sales was enough to offset the fall and allow an expansion in the volume of domestic production. Another driving force was that overseas production increased by nearly 500 thousand units during

[42] In addition, the Japanese government agreed to implement VERs on exports to the United Kingdom from 1977 to 1992 and to the European Union in 1986 (Farrell 2008).

this period. The voluntary export restraints that started in 1981 and the appreciation of the Japanese yen caused by the Plaza Accord in 1985 had motivated Toyota Motors to expand its overseas production especially in the United States. The automotive products trade agreement signed in 1988 between the United States and Canada also played an important role in determining overseas operations in North America. As can be seen in Table 4.4, the operations of Toyota Motor Manufacturing Canada (TMMC) and Toyota Motor Manufacturing, Kentucky (TMMK) were started in 1988.

During the period 1990 to 1995 Toyota experienced a contraction in its total production volume by 400 thousand units. This can be attributed to declines in domestic production and exports of nearly 1 million and 400 thousand units, respectively (Table 4.1). The collapse of the bubble economy that occurred in the early 1990s depressed domestic demand. Domestic sales decreased by 500 thousand units from 1990 to 1995 (Table 4.1). The super appreciation of the Japanese yen that hampered exports from Japan accelerated Toyota's overseas production further. Toyota Motors began operation of 6 new plants in the United States, United Kingdom, Turkey, Pakistan, and the Philippines during the period 1990 to 1995 (Table 4.4). In 1995, for the first time the volume of overseas production (1,253 thousand units) exceeded exports from Japan (1,202 thousand units).

Table 4.4: Toyota Motors' Overseas Production Plants

Region / Country	Company Name[1]	Start of Operations	Number of employees	Main Products[2]	Volume[3] (1,000)
North America					
Canada	Canadian Autoparts Toyota Inc. (CAPTIN)	1985	292	Aluminum wheels	–[5]
	Toyota Motor Manufacturing Canada Inc. (TMMC)	1988	5,919	Corolla, Matrix, RX350, RAV4	320
U.S.A.	TABC, Inc.	1971	533	Catalytic converters, steering columns, stamped parts	–
	Toyota Motor Manufacturing, Kentucky, Inc.(TMMK)	1988	7,487	Camry, Camry Hybrid, Avalon, Venza	348
				Engines	–
	Catalytic Component Products, Inc. (CCP)	1991	28	Catalytic converters	–
	Bondine Alumium, Inc	1993	947	Aluminum castings	–
	Toyota Motor Manufacturing, West Virginia, Inc. (TMMWV)	1998	1,124	Engines, transmissions	–
	Toyota Motor Manufacturing, Indiana, Inc. (TMMI)	1999	4,204	Sequoia, Highlander, Sienna	108
	Toyota Motor Manufacturing, Alabama, Inc. (TMMAL)	2003	796	Engines	–
	Toyota Motor Manufacturing, Texas, Inc. (TMMTX)	2006	2,415	Tundra	86
	Subaru of Indiana Automotive, Inc. (SIA)	2007	3,184	Camry	88
Mexico	Toyota Motor Manufacturing de Baja California S .de R.L.de C.V. (TMMBC)	2004	743	Tacoma	42
				Truck beds	–
Latin America					
Argentina	Toyota Argentina S.A. (TASA)	1997	3,105	Hilux, Fortuner (SW4)	62
Brazil	Toyota do Brasil Ltda. (TDB)	1959	3,306	Corolla, Hilux underbody parts	64
Venezuela	Toyota de Venezuela Compania Anonima (TDV)	1981	2,163	Corolla, Fortuner, Hilux	13
Europe					
Czech Republic	Toyota Peugeot Citroën Automobile Czech, s.r.o. (TPCA) *	2005	3,364	Aygo	100
France	Toyota Motor Manufacturing France S.A.S. (TMMF)	2001	3,732	Yaris (Vitz)	208
				Engines	–
Poland	Toyota Motor Manufacturing Poland SP.zo.o. (TMMP)	2002	2,078	Engines, transmissions	–
	Toyota Motor Industries Poland SP.zo.o. (TMIP)	2005	716	Engines	–
Portugal	Toyota Caetano Portugal, S.A.(TCAP)	1968	340	Dyna, Semibon	5[4]
Turkey	Toyota Motor Manufacturing Turkey Inc. (TMMT)	1994	2,894	Corolla Verso, Auris	72

U.K.	Toyota Motor Manufacturing (UK) Ltd. (TMUK)	1992	4,043	Avensis, Auris	127
				Engines	–
Russia	Toyota Motor Manufacturing Russia (TMMR)	2007	774	Camry	6^{1}
Africa					
Kenya	Associated Vehicle Assemblers Ltd. (AVA)	1977	254	Land Cruiser	1
South Africa	Toyota South Africa Motors (Pty) Ltd. (TSAM)	1962	7,343	Corolla, Hiace, Hilux, Fortuner, Dyna	103
				Closed coupled converter, exhaust manifold	–
Asia					
China	Tianjin Jinfeng Auto Parts Co., Ltd. (TJAC)	1997	385	Steering assembly, propeller shafts	–
	Tianjin Fengjin Auto Parts Co., Ltd. (TFAP)	1998	763	Constant velocity joints, axles, differentials	–
	Tianjin FAW Toyota Engine Co., Ltd. (TFTE)	1998	1,898	Engines	–
	Tianjin Toyota Forging Co., Ltd. (TTFC)	1999	235	Forged parts	–
	Tianjin FAW Toyota Motor Co., Ltd. (TFTM)	2002	12,407	Vios, Corolla, Crown, Reiz, RAV4	383
	FAW Toyota (Changchun) Engine Co., Ltd. (FTCE)	2004	783	Engines	–
	Toyota FAW (Tianjin) Dies Co., Ltd. (TFTD)	2004	216	Stamping dies for vehicles	–
	GAC Toyota Engine Co., Ltd. (GTE)	2005	1,300	Engines, engine parts	–
	Sichuan FAW Toyota Motor Co., Ltd. (SFTM)	2000	2,374	Coaster, Land Cruiser, Land Cruiser Prado, Prius	5
	GAC Toyota Motor Co., Ltd. (GTMC)	2006	6,321	Camry, Yaris, Highlander	210
Taiwan	Kuozui Motors,Ltd.	1986	3,361	Camry, Corolla, WISH, Vios, Yaris, Innova, Dyna	91
				Engines, stamped parts	–
India	Toyota Kirloskar Motor Private Ltd.(TKM)	1999	4,433	Corolla, Innova, Fortuner	51
	Toyota Kirloskar Auto Parts Private Ltd.(TKAP)	2002	1,050	Axles, propeller shafts, transmissions	–
Indonesia	PT. Toyota Motor Manufacturing Indonesia (TMMIN)	1970	5,069	Innova, Fortuner, Dyna, Avanza	68
				Engines	–
	P.T. Astra Daihatsu Motor(ADM)	2004	7,790	Avanza	111
Malaysia	Assembly Services Sdn. Bhd. (ASSB)	1968	2,516	Vios, Hilux, Innova, Fortuner, Hiace	50
				Engines	–
	Perodua Manufacturing Sdn. Bhd. (PMSB)	2005	7,183	Avanza	11

Pakistan	Indus Motor Company Ltd.(IMC)	1993	1,879	Corolla, Hilux	38
Philippines	Toyota Motor Philippines Corp. (TMP)	1989	1,421	Innova, Vios	21
	Toyota Autoparts Philippines Inc. (TAP)	1992	1,375	Transmissions, constant velocity joints	–
Thailand	Toyota Motor Thailand Co., Ltd. (TMT)	1964	12,651	Corolla, WISH, Camry, Camry Hybrid, Vios, Yaris, Hilux, Fortuner	435
	Toyota Auto Body Thailand Co., Ltd.(TABT)	1979	n.a.	Stamped parts	–
	Siam Toyota Manufacturing Co., Ltd. (STM)	1989	2,251	Engines, engine parts	–
Vietnam	Toyota Motor Vietnam Co., Ltd.(TMV)	1996	1,408	Camry, Corolla, Vios, Innova, Hiace, Fortuner	28
Oceania					
Australia	Toyota Motor Corporation Australia Ltd. (TMCA)	1963	4,586	Camry, Camry Hybrid	97
				Engines	–
Middle East					
Bangladesh	Aftab Automobiles Ltd.	1982	83	Land Cruiser	0.9

Notes:
[1]The information is as of December 2009.
[2] Some plants do not produce automobiles but instead specialise in engine and components productions.
[3]The automobile production excludes KD and OEM production.
[4]The data come from IRC (2009). Otherwise, the data come from Toyota Motors.
[5]The data related to engine, transmission, engine parts and other auto components are not available.
Sources: Compiled from Toyota Motor Corporation: http://www.toyota-global.com/company/profile/facilities/worldwide_operations.html and Industrial Research Consulting (2009)

Total production volume began to recover after 1995. Due to expansion of both domestic and overseas production, the total production increased by nearly 700 thousand units during the period 1995 to 2000 (Table 4.1). This expansion of domestic production can be attributed to the increasing opportunity for exports due to the depreciation of the Japanese yen and thriving international economies. The scale of exports expansion (500 thousand units) was large enough to offset the decrease in domestic sales (250 thousand units) led by the continuing recession in the Japanese economy. Toyota Motors also accelerated overseas production further based on a "New Global Business Plan" announced in 1995, aimed at raising total production to six million vehicles a year and at increasing Toyota's international market share to 10 percent. Operations of 9 new plants started in the United States, Argentina, China, India and Vietnam (Table 4.4), leading to an increase in overseas production by 500 thousand units during the period 1995 to 2000.

Interestingly the 'substitution relationship' between exports and overseas production observed during the period 1985 to 1995 transformed into a 'complementary relationship' during the ensuing years. This transformation was brought about by Toyota's expansion strategy that aimed to increase its international market share together with the maintenance of domestic production and employment. Given that the domestic market had been shrinking following the bursting of the bubble economy in the early 1990s, combining exporting from Japan and expanding overseas production turned out to be the only viable option for consolidating its position in global markets.

2000 to 2008 was the period when Toyota aimed to become No.1 automaker in the world. One of the important targets of the "Global Vision 2010" plan announced in 2002 was to raise its international market share to 15% by 2010. In order to achieve this goal, Toyota Motors had expanded overseas production by opening 18 new plants worldwide during the period 2000 to 2008. In North America, 4 new factories commenced operations in the United States and Mexico (Table 4.4). The production of "Tundra" in Toyota Motor Manufacturing Texas (TMMTX) indicates a full-scale entry into the US pick-up truck market where US car makers had held an unchallenged position. Also, in 2006 Toyota began producing the "Camry Hybrid" at Toyota Motor Manufacturing, Kentucky (TMMK) to meet the rise in demand for eco-friendly vehicles. Toyota also expanded its overseas production in Eastern Europe where consumer markets are rapidly growing. Four new plants started operations in the Czech Republic, Poland and Russia. Toyota expanded production capacity in Asia especially in China due to a boom in the auto market. Six new plants began operations in China only during this period. Toyota also increased its production capacity in other Asian countries in order to undertake an "Innovative International Multi-Purpose Vehicle (IMV)" project that aims to raise its market share in newly industrialised economies by producing global cars including pick-up trucks, minivans, and sport utility vehicles. The IMV project started in Thailand and has now spread to Indonesia, the Philippines, India, Malaysia, Vietnam, and Pakistan. Thus Toyota's overseas production volume reached more than 4 million units and eventually surpassed its domestic production in 2008 (Table 4.1). Moreover, Toyota's dependency on overseas sales has grown continuously as well. While domestic sales had constantly dropped to 1,443 thousand by 2008, overseas sales rose to 6,552 thousand units (Table 4.1). With the success of overseas production and sales, the share of Toyota Motors in world auto production rose to 12% in 2008 and Toyota eventually climbed all the way to the top of the global automobile industry, overtaking General Motors (GM), which had been number one since 1931.

4.3 Toyota's Management

The source of Toyota's competitive advantage is the efficient production system called "lean production". This management system, which is based on effective supplier relationships, influences Toyota's engagement in global production sharing because it requires geographical proximity between an assembler and parts suppliers, leading to less importance of cross-border trade in P&C. This section examines key features of lean production and supplier relationships.

4.3.1 Production System

"Lean production" is a production practice that considers the use of resources for any goal other than the creation of value-added for the customer to be wasteful. "Lean production is lean because it uses less of everything compared to mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, and half the engineering hours to develop a new product in half the time. It also requires keeping far less than half the needed inventory on site, results in fewer defects, and produces a greater and ever growing variety of products" (Womack et al 2007, p. 11). Development of lean production began in the 1950s when Toyota's chief production engineer, Taiichi Ohno, initiated introducing new approaches to the shop floor in some plants. Over years and, eventually, decades, of practice, he and his colleagues established a new production system called Toyota Production System (TPS) and applied it not only to every factory but also to its close parts suppliers. The lean production based on TPS is regarded as the next major evolution in efficient business processes after the mass production system invented by Henry Ford and it has been documented, analysed, and exported to companies across industries throughout the world (Dicken 2003 and Liker 2004).

Lean production is characterised by three features when comparing with Fordist mass production. First is thorough elimination of waste. Specifically, lean production targets an elimination of 7 types of wastes: (1) overproduction, (2) waiting, (3) unnecessary transport or conveyance, (4) over-processing or incorrect processing, (5) excess inventory, (6) unnecessary movement, and (7) defects.[43] It has been found that shortening time by eliminating waste in each step of the process leads to the best quality and lowest cost, while also improving safety and morale (Liker 2004). Second is flexibility of the production process itself and its organisation within the factory. In order to meet fluctuation of market demand quickly and satisfy diversified consumer preference, lean producers employ teams of multi-skilled workers at all levels of the organisation

[43] Refer to Liker (2004, pp 27-34) for more information.

and use highly flexible, increasingly automated machines to produce volumes of products in enormous variety (Dicken 2003 and Womack et al 2007). Third is a close and long-standing relationship between the automaker and its parts suppliers. They are more interlinked through information sharing, personnel exchange and cross-share holding. Also, parts suppliers not only play an important role as a source of auto parts procurement for auto makers but also undertake co-design and co-development of parts and components with auto producers.

Lean production is based on two concepts: *Jidoka* (built-in quality) and the just-in-time system. *Jidoka* aims to prevent a defect from passing into the next stage by undertaking quality control at all stages of the production process. When a problem occurs but is not solved at the same stage, the production line stops until the problem is solved.[44] Unlike mass production, *Jidoka* aims to build in quality from the beginning rather than inspect faults at the end, leading to the elimination of wasteful handling time and effort caused by repair or rework, scrap, replacement production and inspection (Dicken 2003).

The just-in-time system aims to deliver the right items at the right time in the right amounts.[45] Unlike the *just-in-case* system of Fordism where the mass producer adds many buffers to assure smooth production, under the just-in-time system individual items are replenished as each item begins to run low, making it possible to eliminate waste caused by overproduction and excess inventory.

A car consists of around 30,000 parts and components and Toyota outsources 70% of these parts. How has Toyota Motors established just-in-time delivery of such a large number of auto parts with different firms? The key weapon is "*kanban*"- the instruction card that contains

[44] The idea of *Jidoka* originated from the invention by Sakichi Toyoda, who is the father of Kiichiro Toyoda, the founder of Toyota Motors. Sakichi invented a mistake-proof loom with a special mechanism to automatically stop a loom whenever a thread broke. See *Toyota Jidosha Kogyo* [Toyota Motors] (1967) for more information.

[45] The idea of the just-in-time system was Kiichiro Toyoda's contribution. His idea was influenced by a study trip to Ford's plants in Michigan in the 1950s to see the automobile industry as well as seeing the US supermarket system of replacing products on the shelves just in time as customers purchased them (Liker 2004).

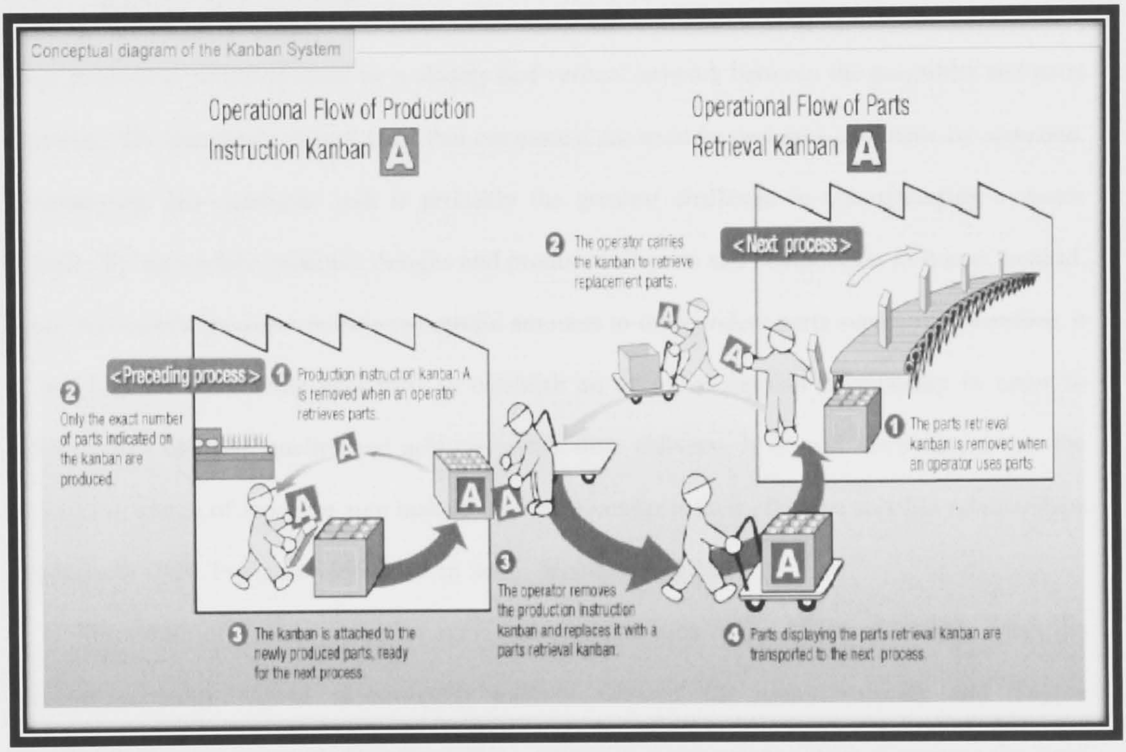
information on the product name, description, code, storage and other relevant information (Figure 4.1). The *kanban* was first introduced in 1954 and had spread to every Toyota factory by 1963. In addition, the *kanban* began bringing in first tier suppliers in the 1960s and the just-in-time system was completed in the late 1970s after the oil shocks (Fujimoto 1999).

Figure 4.1: Example of *Kanban*

Source: Retrieved from http://www.resourcesystemsconsulting.com/blog/archives/58

Figure 4.2 illustrates how *kanban* plays an important role in the just-in-time system. When assembly line workers begin to use parts from containers (hinges, door handles, windshield wipers), they take out a *kanban* and put it in a box. The operators carry empty containers and withdrawal *kanban* to the station where the assembly plant keeps a small store of parts and components. In this station, the new parts container is replaced by a withdrawal *kanban* and carried to the production line. The material handler will come on a timed route, pick the empty containers and withdrawal *kanban* and go back to a store of parts suppliers to replenish what is used on the assembly line. The parts supplier also keeps a small supply of finished parts in the store. When parts are withdrawn from the parts store shelves, they must be replenished by sending a *kanban* and an empty container back to the production cell where new parts are produced and then sent to refill the parts store shelves. The material handler picks up the refilled container and *kanban* and transports them to the station at the next process (assembly plants). Again, the operator at the assembly plant comes to the station to replenish the empty parts box in exchange for withdrawal *kanban*, signaling to parts suppliers to produce what is used. And so on.

Figure 4.2: *Kanban* System



Source: Toyota Motors:
http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/just-in-time.html

It is impressive to observe how the just-in-time system based on *kanban* works in reality. In an assembly plant there are thousands of parts moving about. Alongside the assembly line, there are small containers of parts that are being moved from neatly organised stores. For example, in the case of the Tsutsumi plant, 81,500 containers and 10,200 parts are transported into the plant in a day. In addition, 3,600 deliveries are undertaken in a day.[46] The innovation of *kanban* is that a simple instruction board enables organic orchestration of thousands of parts produced by a large number of parts suppliers into a just-in-time production system. It would be difficult even for a computer system to do such a good job of orchestrating such a complex movement of parts (Liker 2004).

4.3.2 Supplier Relationships

Lean production is underpinned by a closely tied vertical network between the assembler and parts suppliers. The thousands of auto parts that compose a car must be designed and made by someone. Coordinating this enormous task is probably the greatest challenge in manufacturing a motor vehicle. No automobile producer designs and produces all parts and components in-house. Instead, every automobile producer outsources certain amounts to independent parts suppliers. Therefore, it is essential for automobile producers to establish an effective supplier relationship in order to reduce costs, improve quality and achieve just-in-time delivery. It is well documented that the underlying source of Japanese auto makers' competitiveness is their effective supplier relationships (Nishiguchi 1994, Fujimoto 1999, Dicken 2003, Womack et al 2007).

The origin of Toyota's supplier relationships dates back to the 1930s and 1940s when the wartime economy caused skyrocketing military demand for motor vehicles and Toyota subcontracted some auto parts to independent suppliers as a convenient means of meeting the rapid surges in demand (Nishiguchi 1994).[47] The plan for production capacity expansion announced in 1938, ordered Toyota to produce military trucks in the next three years: 20,000 units in 1939,

[46] The information is as at 9th January 2004, as obtained when the author visited the Tsutsumi plant in January 2009.

[47] The technological development in machine tools enabled this subcontracting. Even small parts suppliers with a family operation were equipped with prime movers, lathes and drilling machines and were capable of manufacturing products. The development in infrastructures such as national transportation and communication systems reinforced this production sharing process, alleviating geographical distance between assembly makers and parts suppliers. Also, the government policy intervention did matter. In 1940, the Ministry of Commerce and Industry issued the Rationalization Outline of the Machinery and Iron and Steel Industries, which was aimed at structuring for the existing anarchic state of subcontracting in the Japanese manufacturing industry (Nishiguchi 1994).

25,000 units in 1940 and 40,000 units in 1941, respectively (*Toyota Jidosha Kogyo* 1958). However, this increasing demand overrode the production capacity of Toyota Motors. To alleviate the insufficient capacity, Toyota found it necessary to externalise part of their production activities, leading to increasing reliance on purchasing from parts suppliers: the share of purchased parts of the manufacturing cost per vehicle was 51% in 1936 but rose to 66% by 1939 (Nishiguchi 1994).

The Toyota suppliers relationship has been strengthened by the first tier suppliers' cooperative association called *Kyoho-kai* that promotes intimate information sharing and two-way communication with Toyota Motors and between its parts suppliers through meetings and an education program. The origin of *Kyoho-kai* dates back to 1939 when the first roundtable conference of Toyota's subcontractors named *Kyoryoku-kai* (officially renamed *Kyoho-kai* in 1943) took place, aiming to promote mutual friendship between Toyota and twenty key parts suppliers. After the 1950s, the purpose of *Kyoho-kai* shifted to a more functional one including cost reduction, technological improvements and information sharing (Nishiguchi 1994). In order to achieve these, supplier relationships have been reinforced by personnel exchange and cross-share holding. The *Kyoho-kai* established by twenty parts suppliers, has grown to a large organisation with 218 members in 2008.

Toyota's supplier relationship is characterised by three features.[48] First, the relationship is long-standing and stable (Asanuma 1988). Normally, the contract period between an auto maker and its parts supplier is 4 years based on model change. Termination of the contract during this period rarely occurs. In addition, the contract tends to be renewed most of the time. Appendix 4-A shows a list of members of *Kyoho-kai* during the period 1958 to 2008. The length of membership in *Kyoho-kai* can be a proxy for the continuity and stability of the business relationships with Toyota Motors (Asanuma 1988). As can be seen, a large number of suppliers have established long-standing relationships with Toyota Motors. Taking the year 2008 as an example where the

[48] Although there are a number of features that characterise Toyota's supplier relationships, I focus on the three features which are directly related to production sharing. See Fujimoto (1999) for details.

number of members was 218, 61% of suppliers (134) had been a member since 1958 and 16% (35) had been a member since 1988. These long-standing and stable supplier relationships help reduce transaction costs between firms by preventing opportunistic behaviour and facilitating information-sharing (Helper 1990, Nishiguchi 1994).

The second feature is closeness. Parts suppliers participate in automobile product development known as "design-in", "black box parts system" and "drawings approved" (Asanuma 1988, Fujimoto 1999). In other words, Toyota Motors has outsourced not only parts production but also their parts development. This higher dependence on parts suppliers began in the 1960s when, due to the advent of motorisation, the domestic auto market grew rapidly. In order to meet the growing demand for passenger cars, Toyota Motors moved into offering a full line of products by increasing the number of basic platforms from two in 1960 to three in 1965 and to eight by 1970. This product proliferation meant that workloads increased rapidly, not only in production but also in product development (Fujimoto 1999). Toyota expanded the range of outsourcing to parts suppliers in order to reduce such workload pressures.

The third feature is the hierarchical structure of division of labour. Toyota procures auto parts from tier-1 suppliers, who assemble sub-parts procured from specific tier-2 suppliers. This hierarchical division of labour is underpinned by well-built vertical networks between an auto producer and its parts suppliers and sub-networks between a tier-1 supplier and its tier-2 suppliers. Toyota Motors has a cooperative association (*Kyoho-kai*) organised mainly by tier-1 part suppliers (Appendix 4.A.). Likewise, key tier-1 suppliers have formed their own cooperative associations organised mainly by tier-2 parts suppliers. *Denso* and *Aishin Seiki* have formed their own cooperative associations called *Hisho-kai* comprised of 81 second tier suppliers and *Aishin Kyoryoku-kai* made of 84 second tier suppliers, respectively (IRC 2008).[49]

[49] Other key suppliers have organised their own cooperative associations as follows: Kyosan Electric is made of 31 tier-2 suppliers, Tokai Rika is made of 52, Toyoda Gosei is made of 72, Toyota Industries is made of 65, and Toyota Iron Works is made of 44, and Toyota Boshoku is made of 53 (IRC 2008). Note that some tier-1 suppliers belong to cooperative associations and there are overlaps of members between associations.

4.4 Expansion of Production Networks

The lean production system and supplier relationship developed by Toyota have been a significant source of competitive advantage. While the long-term business relationship with specific suppliers creates opportunity costs by neglecting price signals, this system often yields net gains through greatly reduced transaction costs (McMillan 1990, Hatch 2005). Toyota would attempt to transfer these locally forged systems into host countries by asking intimate suppliers to follow the investment abroad when it builds new production plants. On the other hand, the expansion of production networks creates intra/inter firms trade between headquarter and overseas subsidiaries as well as among overseas subsidiaries. This section investigates the pattern of following-leader investment by Toyota's suppliers and then the trend and pattern of P&C trade between Toyota and its suppliers.

4.4.1 Following-Leader Investment

Table 4.5 shows the trend of the number of overseas production plants owned by Toyota Motors and *keiretsu* suppliers during the period 1988, 1999 and 2008.[50] The *keiretsu* supplier is defined as a member of *Kyoho-kai* (Appendix 4-A). The total number of overseas plants of suppliers increased by nearly 1,000 over the past two decades as Toyota expanded its overseas operations, suggesting the existence of the following-leader investments by *keiretsu* suppliers. It is clearly observed that suppliers have located at every country with Toyota's plants and the numbers of suppliers are positively correlated with the counterparts of Toyota. For example, Toyota and its suppliers had 8 and 131 plants in Thailand in 2008, respectively, whereas counterparts had 4 and 55 plants in Indonesia. Overseas production by Toyota and suppliers is concentrated in Asia, North America and Europe.

[50] Original Equipment Manufacturer (OEM) is included.

Table 4.5: Number of Overseas Subsidiaries of Toyota and *Keiretsu* Suppliers

	1988		1999		2008	
	Toyota	Supplier[1]	Toyota	Supplier	Toyota	Supplier
Asia	11	101	19	329	36	659
South Korea		9		27		41
Taiwan	2	23	1	33	1	40
Malaysia	1	8	2	15	4	18
Indonesia	3	14	1	39	4	55
Singapore		10		16		23
Philippines		6	2	18	2	28
Thailand	3	24	4	78	8	131
Vietnam			1	7	1	18
China			5	58	12	258
India	1	4	1	28	2	35
Others	1	3	2	10	2	12
North America	5	72	9	173	12	290
Canada	2	8	2	11	2	20
United States	3	60	7	146	9	241
Mexico		4		16	1	29
South America	6	14	6	20	4	25
Brazil	1	12	1	14	1	21
Argentine			1	3	1	4
Others	5	2	4	3	2	0
Europe	1	31	2	113	6	186
United Kingdom		8	1	39	1	36
Spain		4		12		13
Germany		10		20		30
France		2		15	1	20
Netherland		3		6		4
Italy		0		6		7
Portugal	1	1	1	3	1	6
Belgium		1		3		13
Hungary				2		7
Czech Republic					1	21
Poland				1	1	12
Romania				1		6
Others		2		5	1	11
Rest of World	7	10	5	24	4	43
Australia	1	6	1	17	1	17
Turkey		1	1	2	1	11
South Africa	1		1	1	1	8
Others	5	3	2	4	1	7
Total	30	228	41	659	62	1203

Notes:
[1]Supplier represents "*keiretsu* supplier" is defined as the member of *Kyoho-kai* – a cooperative association organised by suppliers, who have business relationships with Toyota. Note that although many *keiretsu* suppliers also sell their products to other car makers, there is a tendency that their main customers are Toyota.
Sources: Compiled from Industrial Research Consulting and *Nihon Jidosha Buhin Kogyo Kai* [Japan Auto Parts Industries Associations (JAPIA)], various issues.

Especially, the high intensity in Asia suggests the more important role of the following-leader investments due to the relatively underdeveloped supporting industries in these countries and low labour costs.

Table 4.6 shows the number of Japanese suppliers for Toyota's overseas plants by location.[51] The first column shows the locations of Toyota's overseas plants with the number of plants in the parenthesis and the first row shows the locations of suppliers. The numbers in the table show the total number of Japanese suppliers who sell their products to Toyota's overseas subsidiaries located in each country and the number in the parenthesis shows the number of Japanese *keiretsu* suppliers belonging to *Kyoho-kai*. The last two columns show the total number of Japanese suppliers with the total number of *keiretsu* suppliers in the parenthesis and the share of *keiretsu* suppliers in the total of Japanese suppliers, respectively. As can be seen, the shares of *keiretsu* suppliers are very high even though there are large variations in the number of suppliers among countries, ranging from 226 in China and 203 in the United States to 3 in Portugal and 1 in Venezuela. This suggests Toyota is transplanting locally forged vertical networks with *keiretsu* suppliers abroad. In Southeast Asian countries especially, overseas affiliates of *keiretsu* suppliers play a dominant role, supplying a wide variety of P&C from wire harnesses to seat upholstery and from alternators to brake systems (Hatch 2005).

Automobile production tends to be organised, with the production of bulky, heavy, and model-specific parts located close to final assembly plants to ensure timely delivery, and the production of lighter and more generic parts taking place where scale economies and low labour costs exist (Sturgeon et al 2008). Indeed, Toyota's overseas plants and suppliers' overseas affiliates tend to be geographically concentrated. As Table 4.6 shows, many Japanese (*keiretsu*) suppliers are located in the same country or region as their customers. In the case of the United States, while 183

[51] Note that Table 4.6 is limited to only Japanese suppliers including *keiretsu* suppliers. Toyota's overseas parts plants and local suppliers are not included. Venezuela and Portugal are excluded from the location of Toyota's plants due to the space limitations. Countries located out of North America, Europe and Asia such as Brazil, Australia and South Africa is included in others.

Japanese suppliers are at the same location as Toyota's plants, only 5 and 11 Japanese suppliers are located in Canada and Mexico, respectively. The number of Japanese suppliers outside of North America is negligible. However, the interesting phenomenon lies in the different patterns among the regions.

As can be observed, while the United States occupies the central position in Toyota's production networks in North America, their production networks in Europe are spreading out more horizontally. Asia is between them. This disparity can be attributed to the increasing returns to scale. Reflecting market size, Toyota's production volumes in the United States and China are so large that suppliers are able to gain benefits from economies of scale. On the other hand, Toyota's production volumes in Europe and Asian countries other than China are relatively small. So suppliers are located in a few countries and they ship P&Cs to multiple countries within a region to obtain the benefit from economies of scale.

Table 4.6: Number of Japanese Suppliers by Locations for Toyota's Overseas Subsidiaries

Locations of Toyota's Plants[1]	North America[2]			Europe							Asia									Total[6]	Share (%)[7]
	USA	CAN	MEX	GBR	FRA	CZE	POL	PRT	RUS	TUR	CHN	TAW	THA	IDN	MYS	PHL	VNM	IND	Others		
United States (9)	183[3] (156)[4,5]	5 (3)	11 (9)										1 (1)	2 (1)		1 (1)				**203 (171)**	**84**
Canada (2)	86 (75)	16 (13)	6 (6)																1 (1)	**109 (95)**	**87**
Mexico (1)	21 (20)	1 (0)	3 (3)																	**25 (23)**	**92**
United Kingdom (1)				20 (18)	4 (3)	9 (7)	2 (2)	3 (3)		3 (3)									12 (10)	**53 (46)**	**87**
France (1)				11 (10)	7 (7)	8 (7)	4 (4)	1 (1)		2 (2)									14 (13)	**47 (44)**	**94**
Czech Republic (1)				1 (1)	1 (1)	15 (12)	2 (2)						1 (1)						7 (6)	**27 (23)**	**85**
Poland (2)				1 (1)	2 (2)	2 (2)	3 (3)	1 (1)		1 (1)									2 (2)	**12 (12)**	**100**
Russia (1)							1 (1)		2 (2)										1 (1)	**4 (4)**	**100**
Turkey (1)				4 (4)	1 (1)	5 (5)				9 (9)									3 (3)	**22 (22)**	**100**
China (10)											225 (191)		1 (1)							**226 (192)**	**85**
Taiwan (1)											2 (2)	27 (25)	1 (1)							**30 (28)**	**93**
Thailand (3)											2 (2)	1 (1)	138 (94)	2 (2)		1 (1)	1 (1)			**145 (101)**	**70**
Indonesia (2)											1 (1)	3 (3)	7 (5)	50 (40)		1 (1)	1 (1)			**63 (51)**	**81**
Malaysia (2)													1 (0)		13 (12)	1 (1)	1 (1)			**16 (14)**	**88**
Philippines (2)												1 (1)	1 (1)			22 (13)	1 (1)			**25 (16)**	**64**
Vietnam (1)																	10 (10)			**10 (10)**	**100**

India (2)																		39 (37)		**39 (37)**	**95**
Brazil (1)																			15 (14)	**15 (14)**	**93**
Argentina (1)																			5 (4)	**5 (4)**	**80**
Australia (1)																			8 (8)	**8 (8)**	**100**
South Africa (1)												1 (1)							8 (8)	**8 (8)**	**100**

Notes:
[1]The first column demonstrates the country where Toyota has founded plants and the number of Toyota's plants shown in parentheses.
[2]The first and second rows demonstrate the region and country (abbreviated due to the space limitation) of Japanese suppliers' subsidiaries.
[3]The numbers in the table (the above) show the number of Japanese parts suppliers, who sell their products to Toyota's overseas plants in each country. The number includes both *keiretsu* and non-*keiretsu* suppliers.
[4]The number in parentheses (the below) show the number of only *keiretsu* suppliers – a member of *Kyoho-kai*.
[5]The box with grey color means that Toyota and suppliers' subsidiaries locate in the same country. The area marked by bold line suggests that Toyota's overseas plants and suppliers' subsidiaries locate in the same region.
[6]The last second column shows the total number of Japanese suppliers (the above) and *keiretsu* suppliers (the below in parentheses) in each country.
[7]The last column shows the share of *keiretsu* suppliers out of total Japanese suppliers in each country. Take Thailand as an example. As can be seen, 138 Japanese suppliers located in Thailand sell their products to Toyota's plants (3 plants) in Thailand and 94 out of 138 are *keiretsu* suppliers. The table also shows that Japanese suppliers located in China, Taiwan, Indonesia, Philippines and Vietnam ships their products to Toyota's plants in Thailand. The total number of Japanese suppliers who sell their products to Toyota located in Thailand is 145 and the number of *keiretsu* suppliers is 101 out of 145. Thus, the share of *keiretsu* suppliers turns out to be 70% (= (101/145)*100).

Source: Compiled from Industrial Research Consulting (2009)

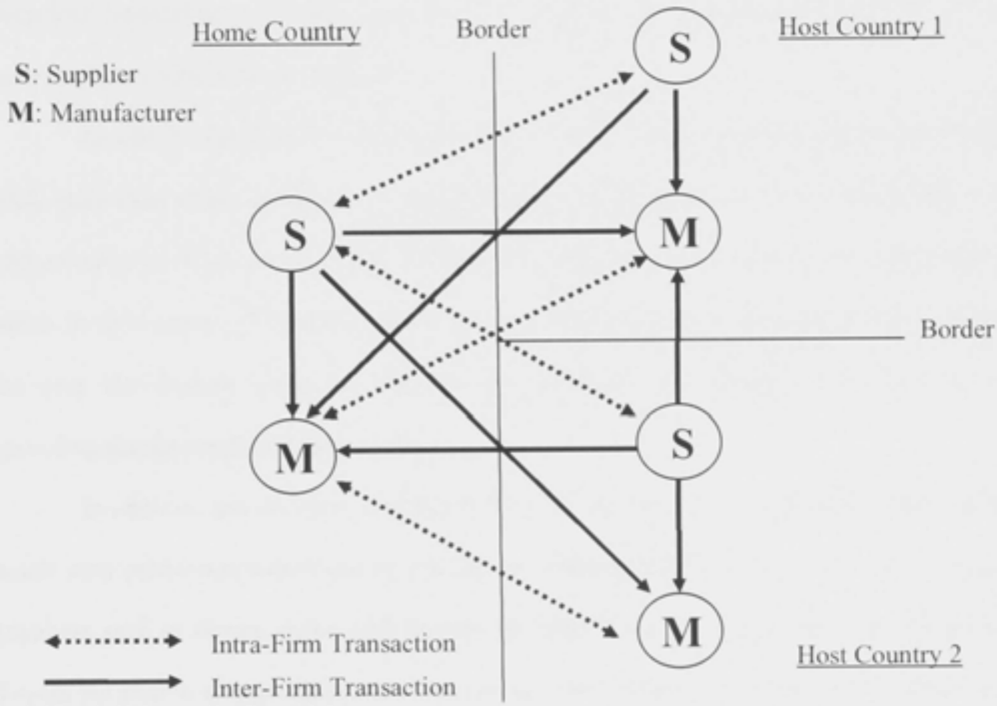
4.4.2 *Trend and Pattern of Parts and Components Trade*

In the previous section we saw that Toyota's production network accompanied by *keiretsu* suppliers is spreading worldwide and the procurement of Toyota's overseas subsidiaries tend to become more domestic- or region-oriented. The global spread of production networks also leads to an increase in transactions between headquarters plants and their overseas subsidiaries. Determinants of products traded and their directions and volumes depend on various factors such as trade costs, factor endowments, product attributes, and government policy. Bulky parts such as chassis and body parts tend not to be transacted across borders due to high trade costs. High-value and technology-intensive products such as engine and engine parts tend more to be exported from headquarters' plants to overseas subsidiaries. The strict local content requirements in a host country lead to less cross-border transactions of P&C.

The cross-border trade in P&C between home and host countries takes four forms: (Figure 4.3). First is an intra-firm transaction between Toyota's headquarters' plants in Japan and its overseas plants. Second is an inter-firm transaction between headquarters' plants of *keiretsu* suppliers in Japan and Toyota's overseas plants. Third is an intra-firm transaction between headquarters' plants of *keiretsu* suppliers in Japan and their overseas plants. This is the case where a headquarter plant of a *keiretsu* supplier (e.g. Denso) in Japan ships sub-components and materials to its overseas affiliate and the affiliate assembles them into the final product and supplies to Toyota in a given country. Fourth is an inter-firm transaction between Toyota's headquarters' plants in Japan and overseas plants of *keiretsu* suppliers. This is the case where an overseas affiliate of a *keiretsu* supplier directly ships its products to Toyota plants in Japan.

Although the transaction can be separable conceptually, data are not available to measure the four types separately. The available alternative is to use data extracted from the records of ports in the Aichi prefecture, the transport hub of the Toyota-centred auto cluster in Japan.[52] The 12 main plants of Toyota Motors and 173 *keiretsu* suppliers of the total 218 are located in the Aichi prefecture. More importantly, all key *keiretsu* suppliers of Toyota are located in this area.[53] Thus, using port-level trade data I can capture the big picture of cross-border transactions related to Toyota and its *keiretsu* suppliers.

Figure 4.3: Global Production Sharing in Automobile Industry



[52] There are 9 main custom ports in Japan: Tokyo, Yokohama, Kobe, Osaka, Nagoya, Moji, Nagasaki, Hakodate, and Okinawa. Nagoya customs cover ports in the Aichi prefecture. Calculating by "Google map", the distances between the headquarter of Toyota Motors (address: 1 Toyota-cho, Toyota city, Aichi prefecture) and each custom are: Nagoya custom is 25.91 km, Hakodate is 813.49 km, Tokyo is 247.17 km, Yokohama is 228.56 km, Kobe is 183.36 km, Osaka is 162.78 km, Moji is 580.98, Nagasaki is 715.92 km, and Okinawa is 1,333.2 km.

[53] Here, key suppliers are synonymous with members of the Toyota group including Toyota Industries Corporation, Aichi Steel Corporation, JTEKT Corporation, Toyota Auto Body Co.,Ltd, Toyota Tsusho Corporation, Aisin Seiki Co.,Ltd., Denso Corporation, Toyota Boshoku Corporation and Toyoda Gosei Co.,Ltd. For more information, see Toyota Motors website: http://www2.toyota.co.jp/en/facilities/manufacturing/index.html.

Using port-level data, I will examine the trend and pattern of P&C by country and products during the period 1988 and 2008. Table 4.7 lists the top 30 countries and Table 4.8 lists the top 40 products according to the value of P&C exports and its share, respectively.[54] A country colored with gray represents a country where Toyota had overseas plants at that time. Total exports value increased by five times during the period 1988 to 2008. On the demand side, the expansion of overseas production by Toyota and *keiretsu* suppliers might lead to the increase in cross-border intra-firm transactions of Toyota and *keiretsu* suppliers and cross-border inter-firm transaction between Toyota and *keiretsu* suppliers.

As can be observed in Table 4.7, countries with Toyota's overseas plants tends to import P&C more than others countries: 21 countries with Toyota plants are ranked in the top 30 out of 180 countries in 2008 and the scale of exports is positively correlated with the scale of Toyota's plants in each country.[55] That every auto part had experienced increases in its exports value over the past two decades seems to suggest that intra/inter cross-border transactions are widely spreading among suppliers (Table 4.8).

In addition, the increase in demand for P&C can be partly attributable to the increase in world auto production which can be a proxy of world demand for auto parts.[56] In fact, *Keiretsu* suppliers such as Denso, Aisin, and Toyoda Boshoku are now selling their products not only to Toyota but also to foreign auto makers as well as other Japanese car makers (IRC 2009). Another demand factor is 'aftermarket' effects. As shown in Table 4.1, Toyota's overseas sales have continuously increased since the middle 1990s. The demand for auto parts for repair and maintenance is growing as Toyota cars become popular worldwide.

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[54] See Appendix 4-B for the concordance of each product category with HS code.

[55] I simply regress log (export value) on log (number of employees of Toyota's plants) with cross section data in 2008 and the coefficient is 0.96.

[56] World auto production increased from 48 million in 1988 to 70 million units in 2008.

Table 4.7: Exports of Parts and Components (P&C) in Aichi Prefecture by Country

	1988			2008		
	Destination[1]	Value (Million Yen)[2]	Share (%)[3]	Destination	Value (Million Yen)	Share (%)[3]
1	United States	217,148	44.6	United States	512,691	22.6
2	South Africa	32,920	6.8	China	313,879	13.9
3	Australia	32,700	6.7	Thailand	188,631	8.3
4	Indonesia	23,633	4.9	Germany	121,357	5.4
5	Thailand	17,012	3.5	Netherlands	102,641	4.5
6	Taiwan	16,075	3.3	South Africa	87,414	3.9
7	Saudi Arabia	12,693	2.6	United Kingdom	87,010	3.8
8	Netherlands	10,570	2.2	South Korea	75,861	3.3
9	Germany	10,479	2.2	Mexico	72,017	3.2
10	China	9,697	2.0	Canada	66,198	2.9
11	South Korea	9,621	2.0	Brazil	60,694	2.7
12	Sweden	8,714	1.8	Belgium	55,633	2.5
13	Canada	6,729	1.4	Australia	54,218	2.4
14	Belgium	5,519	1.1	Indonesia	39,072	1.7
15	United Kingdom	5,247	1.1	France	36,811	1.6
16	Iraq	4,890	1.0	Saudi Arabia	33,514	1.5
17	Malaysia	4,136	0.9	UAE	29,423	1.3
18	Hong Kong	3,307	0.7	Taiwan	29,168	1.3
19	Oman	3,184	0.7	Oman	24,937	1.1
20	UAE	2,897	0.6	Turkey	24,593	1.1
21	France	2,738	0.6	Malaysia	21,253	0.9
22	India	2,563	0.5	Poland	19,674	0.9
23	Singapore	2,507	0.5	Argentina	18,823	0.8
24	Portugal	2,330	0.5	Italy	18,195	0.8
25	Finland	2,083	0.4	India	14,518	0.6
26	Norway	2,000	0.4	Pakistan	11,518	0.5
27	Switzerland	1,988	0.4	Singapore	10,152	0.4
28	Greece	1,895	0.4	Philippines	10,109	0.4
29	Denmark	1,674	0.3	Russia	9,788	0.4
30	Mexico	1,598	0.3	Czech Republic	9,343	0.4
	Total	486,364	100	Total	2,265,232	100
	Total Destination	167		Total Destination	180	

Notes:
[1] The countries are ordered according to value or share. A country with gray represents a country where Toyota has overseas plants.
[2]The monetary unit is Japanese yen in million.
[3] The share of top 30 countries is 94% in 1988 and 95% in 2008.

Source: Trade Statistics of Japan: http://www.customs.go.jp/toukei/srch/index.htm

Table 4.8: Exports of Parts and Components (P&C) in Aichi Prefecture by Product

	1988			2008		
	Product[1]	Value (Million Yen)[2]	Share (%)	Product	Value (Million Yen)	Share (%)
1	Other auto parts	80,353	16.5	Engines	214,158	9.5
2	Body and parts	53,766	11.1	Other auto parts	190,075	8.4
3	Air conditioning and parts	45,458	9.3	Engine parts	185,476	8.2
4	Tyres	41,393	8.5	Body and parts	161,814	7.1
5	Engines	34,474	7.1	Tyres	112,742	5.0
6	Engine parts	32,585	6.7	Air conditioning and parts	75,791	3.3
7	Starter Motors	19,732	4.1	Brakes and parts	72,308	3.2
8	Pressure regulator	16,799	3.5	Suspension and parts	51,656	2.3
9	Flasher units	9,234	1.9	Steering and parts	45,767	2.0
10	Audio	9,006	1.9	Spark/Glow plug	37,963	1.7
11	Bumpers	8,593	1.8	Alternators	32,243	1.4
12	Cam/Crankshafts	7,221	1.5	Clutches and parts	26,667	1.2
13	Suspension and parts	7,105	1.5	Starter Motors	25,842	1.1
14	Igniter	5,969	1.2	Pressure regulator	25,222	1.1
15	Wheels	5,581	1.1	Igniter	25,096	1.1
16	Clutches and parts	5,517	1.1	Cam/Crankshafts	21,651	1.0
17	Windowshiled wipers and parts	4,578	0.9	Mufflers, exhaust pipe and parts	21,492	0.9
18	Mufflers, exhaust pipe and parts	4,505	0.9	Flasher units	21,466	0.9
19	Gaskets	3,437	0.7	Bumpers	19,928	0.9
20	Glasses	3,212	0.7	Wheels	16,189	0.7
21	Steering and parts	2,580	0.5	Windowshiled wipers and parts	15,185	0.7
22	Flywheels and Pulleys	2,303	0.5	Flywheels and Pulleys	14,313	0.6
23	Oil/Fuel filters	2,268	0.5	Radiator	14,212	0.6
24	Ignition coils	2,177	0.4	Gaskets	13,584	0.6
25	Mirrors	2,029	0.4	Oil/Fuel filters	11,649	0.5
26	Wire harness	1,667	0.3	Airbags	11,310	0.5
27	Radiator	1,450	0.3	Wire harness	9,626	0.4

28	Seat belts	1,036	0.2	Glasses	5,753	0.3
29	Air cleaner	965	0.2	Ignition coils	5,540	0.2
30	Alternators	724	0.1	Mirrors	4,202	0.2
31	Seats	463	0.1	Batteries	3,921	0.2
32	Meters	288	0.1	Audio	3,309	0.1
33	Horns	277	0.1	Seat belts	1,909	0.1
34	Lamp and parts	142	0	Seats	1,757	0.1
35	Batteries	51	0	Horns	1,385	0.1
36	Airbags	-	-	Air cleaner	1,017	0
37	Floor carpet	-	-	Lamp and parts	719	0
38	Brakes and parts	-	-	Meters	492	0
39	Locks	-	-	Engine oil seal	375	0
40	Ring gear and drive plate	-	-	Floor carpet	-	0
	Total	486,364	100	Total	2,265,232	100

Notes:
[1]See Appendix 4-B for the concordance of each product category with HS code.
[2]The monetary unit is Japanese yen in million.

Source: Trade Statistics of Japan: http://www.customs.go.jp/toukei/srch/index.htm

The distribution of P&C exports has become geographically more diversified over the past two decades. While the United States occupies a dominant position as an export destination in 1988, European and Asian countries are emerging as important new destinations in 2008. Exports to China and Thailand especially are growing more rapidly than for any other countries. As a result, the share of the United States dropped to 22.6% in 2008 while China and Thailand rose to 13.9 and 8.3, respectively. This is consistent with the internationalisation process in which Toyota began its full-scale overseas operation in the United States after 1985 due to appreciation of the Japanese yen and trade friction with the United States and, subsequently, Toyota has expanded its production and distribution systems toward Europe and Asian countries (Section 4.2).

Table 4.9: Imports of Parts and Components (P&C) in Aichi Prefecture by Country

	1988			2008		
	Source[1]	Value (Million Yen)[2]	Share (%)[3]	Source	Value (Million Yen)	Share (%)[3]
1	United States	12,901	43.8	China	159,320	31.5
2	Austria	3,625	12.3	Thailand	57,211	11.3
3	Germany	3,559	12.1	Viet Nam	51,650	10.2
4	Canada	2,142	7.3	Germany	43,023	8.5
5	Australia	1,701	5.8	Indonesia	39,115	7.7
6	Taiwan	1,655	5.6	United States	26,780	5.3
7	South Korea	1,142	3.9	Philippines	25,947	5.1
8	Italy	948	3.2	South Korea	20,969	4.1
9	Spain	441	1.5	Taiwan	13,205	2.6
10	France	314	1.1	France	11,202	2.2
11	Indonesia	284	1.0	Italy	10,580	2.1
12	United Kingdom	211	0.7	Poland	6,551	1.3
13	Sweden	185	0.6	United Kingdom	5,894	1.2
14	Malaysia	70	0.2	Belgium	5,686	1.1
15	Switzerland	53	0.2	Canada	4,140	0.8
16	Thailand	52	0.2	Netherlands	3,474	0.7
17	China	51	0.2	Malaysia	2,708	0.5
18	Hong Kong	45	0.2	Mexico	2,587	0.5
19	Netherlands	23	0.1	Slovakia	1,919	0.4
20	Sri Lanka	22	0.1	India	1,915	0.4
21	Brazil	15	0.1	Hungary	1,778	0.4
22	Singapore	10	0	Czech Republic	1,469	0.3
23	Belgium	10	0	Spain	1,358	0.3
24	Greenland	8	0	Austria	1,265	0.2
25	South Africa	4	0	Malta	1,185	0.2
26	Saudi Arabia	2	0	Turkey	1,093	0.2
27	India	1	0	Romania	758	0.1
28	Finland	1	0	Sri Lanka	618	0.1
29	Portugal	1	0	South Africa	554	0.1
30	Denmark	1	0	Sweden	533	0.1
	Total	29,476	100	Total	506,497	100
	Total Source	34		Total Source	73	

Notes:

[1] The countries are ordered according to value or share. A country with gray represents a country where Toyota has overseas plants.

[2] The monetary unit is Japanese yen in million.

[3] The share of top 30 countries is 100% in 1988 and 99% in 2008.

Source: Trade Statistics of Japan: http://www.customs.go.jp/toukei/srch/index.htm

Table 4.10: Imports of Parts and Components (P&C) in Aichi Prefecture by Product

	1988			2008		
	Product	Value (Million Yen)	Share (%)	Product	Value (Million Yen)	Share (%)
1	Tyres	16,016	54.8	Wire harness	124,737	25.7
2	Glasses	3,786	13.0	Engines	63,431	13.1
3	Wheels	3,676	12.6	Wheels	46,691	9.6
4	Other auto parts	1,265	4.3	Engine parts	31,057	6.4
5	Engine parts	715	2.4	Airbags	22,854	4.7
6	Batteries	449	1.5	Other auto parts	19,418	4.0
7	Air conditioning and parts	373	1.3	Tyres	18,230	3.8
8	Lamp and parts	359	1.2	Body and parts	18,761	3.9
9	Horns	339	1.2	Audio	17,306	3.6
10	Audio	279	1.0	Floor carpet	15,162	3.1
11	Flasher units	232	0.8	Steering and parts	11,297	2.3
12	Engines	217	0.7	Flasher units	8,024	1.7
13	Floor carpet	189	0.6	Clutches and parts	6,493	1.3
14	Steering and parts	182	0.6	Brakes and parts	8,826	1.8
15	Bumpers	142	0.5	Pressure regulator	4,191	0.9
16	Seats	112	0.4	Flywheels and Pulleys	8,103	1.7
17	Turbo chargers	110	0.4	Batteries	6,237	1.3
18	Air cleaner	103	0.4	Cam/Crankshafts	5,876	1.2
19	Cam/Crankshafts	79	0.3	Mirrors	3,496	0.7
20	Suspension and parts	67	0.2	Glasses	4,975	1.0
21	Mufflers, exhaust pipe and parts	56	0.2	Windowshiled wipers and parts	4,383	0.9
22	Seat belts	56	0.2	Locks	3,331	0.7
23	Windowshiled wipers and parts	48	0.2	Seat belts	1,848	0.4
24	Wire harness	45	0.2	Mufflers, exhaust pipe and parts	2,956	0.6

25	Ignition coils	45	0.2	Oil/Fuel filters	3,551	0.7
26	Pressure regulator	37	0.1	Air conditioning and parts	3,518	0.7
27	Body and parts	33	0.1	Suspension and parts	3,094	0.6
28	Igniter	31	0.1	Ring gear and drive plate	3,304	0.7
29	Flywheels and Pulleys	29	0.1	Igniter	2,889	0.6
30	Mirrors	22	0.1	Radiator	2,472	0.5
31	Radiator	19	0.1	Bumpers	2,042	0.4
32	Meters	15	0.1	Horns	1,290	0.3
33	Ring gear and drive plate	15	0.1	Starter Motors	869	0.2
34	Starter Motors	15	0.1	Ignition coils	1,018	0.2
35	Spark/Glow plug	12	0	Seats	929	0.2
36	Oil/Fuel filters	12	0	Gaskets	765	0.2
37	Locks	10	0	Air cleaner	451	0.1
38	Alternators	10	0	Alternators	552	0.1
39	Clutches and parts	2	0	Lamp and parts	549	0.1
40	Gaskets	1	0	Turbo chargers	221	0
	Total	29,476	100	Total	506,497	100

Notes:
[1]See Appendix 4-B for the concordance of each product category with HS code.
[2]The monetary unit is Japanese yen in million.

Source: Trade Statistics of Japan: http://www.customs.go.jp/toukei/srch/index.htm

Tables 4.9 and 4.10 list the top 30 countries and top 40 products according to the value of P&C imports and its share. It is evident that the value of P&C imports is much smaller than that of exports, reflecting a production system based on just-in-time delivery and a supplier relationship with *keiretsu* suppliers. Nevertheless, the value of P&C imports and the number of source countries have increased from 29 billion to 506 billion, and 34 to 73, respectively, between 1988 and 2008.

On the demand side, this rapid increase might partially reflect a global sourcing strategy undertaken by Toyota and *keiretsu* suppliers since the middle of the 1990s. As far as parts suppliers satisfy the standard conditions of quality, price, speed, and delivery, Toyota and *keiretsu* suppliers will procure parts from any supplier anywhere in the world. In order to increase overseas procurement, Toyota has established windows for local suppliers in each country to supply their products to Toyota's factories in Japan. As shown in Table 4.10, all products had experienced increases in their import values. This seems to suggest that global sourcing strategy is spreading among Toyota and *keiretsu* suppliers.

On the supply side, the growing ability of local firms in exporting countries might be a reason for the rapid growth of auto parts imports to Japan. In the last two decades, global automakers expanded overseas production and many new auto makers were established especially in newly industrialised economies, resulting in growing automotive industries in each country. In addition, the globalisation of Toyota and its *keiretsu* suppliers might also play an important role for the rapid growth of P&C imports through cross-border intra-/inter-firm transactions. As can be seen in Table 4.9, the fact that 20 countries out of the top 40 have Toyota overseas plants in 2008 probably implies the existence of reverse imports from overseas affiliates of Toyota and *keiretsu* suppliers. Furthermore, the large share of Asian countries such as China, Thailand, Vietnam, Indonesia, and the Philippines suggests that Toyota and *keiretsu* suppliers undertake labour-intensive production process in these countries to be used in final assembly in Japan. The dramatic increase in import value of wire harness, which is a labour-intensive product, supports this inference (Table 4.10).

4.5 Conclusion

This chapter has provided background information for empirical analyses in the ensuing chapters. In the development process, Toyota has globalised its production and distribution systems especially since the late 1980s when the Japanese yen appreciated and trade friction with the United States became serious. One of the characteristics of Toyota's internationalisation is the following-leader investments by *keiretsu* suppliers, aiming to transplant locally forged supplier relationships to host countries in order to achieve a just-in-time system and to fulfill the local content requirements imposed by host governments. The expansion of production networks of Toyota and its *keiretsu* suppliers could have led to the increase in trade in P&C through cross-border intra-/inter-firm transactions.

The next two chapters address two research questions by undertaking micro-level empirical analyses using newly-constructed three-dimensional panel data sets covering 44 auto parts and 32 countries for four years (1999, 2002, 2005 and 2008). Chapter 5 attempts to answer whether following-leader investment substitutes or complements export. Chapter 6 explores whether *keiretsu* decreases or increases imports of automotive parts and components to Japan.

Appendices to Chapter 4

Appendix 4-A: List of Members of *Kyoho-Kai* during the Period 1958 to 2008

	Company Name[1,2,4]	1958	1988	1990	1993	1996	1999	2002	2005	2008
1	Advics Co., Ltd.							■	■	■
2	Ahresty Corp.									■
3	Aichi Hikaku Industry Co., Ltd.	■	■	■	■	■	■	■	■	■
4	Aichi Steel Corp.	■	■	■	■	■	■	■	■	■
5	Aisan Industry Co., Ltd.	■	■	■	■	■	■	■	■	■
6	Aisin AI Co., Ltd.				■	■	■	■	■	■
7	Aisin AW Co., Ltd.		■	■	■	■	■	■	■	■
8	Aisin Chemical Co., Ltd.		■	■	■	■	■	■	■	■
9	Aisin Keikinzoku Co., Ltd.		■	■	■	■	■	■	■	■
10	Aisin Seiki Co., Ltd.	■	■	■	■	■	■	■	■	■
11	Aisin Takaoka Co., Ltd.		■	■	■	■	■	■	■	■
12	Akebono Brake Industry Co., Ltd.	■	■	■	■	■	■	■	■	■
13	Aoyama Seisakusho Co., Ltd.	■	■	■	■	■	■	■	■	■
14	Arai Seisakusho Co., Ltd.		■	■	■	■	■	■	■	■
15	Art Metal Mfg. Co., Ltd.	■	■	■	■	■	■	■	■	■
16	Asahi Glass Co., Ltd.	■	■	■	■	■	■	■	■	■
17	Asahi Tekko Co., Ltd.	■	■	■	■	■	■	■	■	■
18	Asmo Co., Ltd.	■	■	■	■	■	■	■	■	■
19	Autoliv Inc.						■	■	■	■
20	Bando Chemical Industries, Ltd.	■	■		■	■	■	■	■	■
21	Bosch Corp.						■	■	■	■
22	Bridgestone Corp.	■	■	■	■	■	■	■	■	■
23	Cable industry Co.Ltd.	■	■	■	■	■	■	■	■	■
24	Cataler Corporation.		■	■	■	■	■	■	■	■
25	Cemedine Corp.	■	■	■	■	■	■	■		
26	Central Motor Co., Ltd.	■	■	■	■	■	■	■	■	■
27	Central Motor Wheel Co., Ltd.	■	■	■	■	■	■	■	■	■
28	Chugai Co., Ltd.	■	■	■	■	■	■	■	■	■
29	Chuo Malleable Co., Ltd.	■	■	■	■	■	■	■	■	■
30	Chuo Spring Co., Ltd.	■	■	■	■	■	■	■	■	■
31	Chuyo Spring Co. Ltd.	■	■	■	■	■	■	■	■	■
32	CMK Corporation.	■	■				■	■	■	■
33	Daicel Chemical Industries, Ltd.	■	■		■	■	■	■	■	■
34	Daido Metal Co., Ltd.	■	■	■	■	■	■	■	■	■
35	Daido Steel Co., Ltd.	■	■				■	■		■
36	Daihatsu Motor Co., Ltd.	■	■			■	■	■	■	■
37	Daiwa Paint Trading Co., Ltd.	■	■	■	■	■	■	■	■	■

38	Denso Corp.									
39	Diamond Electric Mfg. Co., Ltd.									
40	Dunlop Corp.									
41	DuPont Shinto Automotive Systems Co., Ltd.									
42	Dynax Corp.									
43	Eguchi Iwao Co.Ltd.									
44	EXEDY Corp.									
45	Exxon Mobil Corporation.									
46	Fine Sinter Co., Ltd.									
47	Firbest.									
48	FTS Co., Ltd.[5]									
49	Fuji Bellows Co., Ltd.									
50	Fuji Oozx Inc.									
51	Fuji Valve Co., Ltd.									
52	Fujikakou kenkyuzyo.									
53	Fujitsu Ten Ltd.									
54	Furukawa AS Co., Ltd.									
55	Furukawa Automotive System Inc.									
56	Furukawa Battery Co., Ltd.									
57	Furukawa Electric Co., Ltd.									
58	Futaba Industrial Co., Ltd.									
59	Gates Unitta Asia Company.									
60	General Motors Japan Limited.									
61	Gifu Auto Body Co., Ltd.									
62	Gipuro Corporation.									
63	Goodyear Japan.									
64	GS Yuasa Corporation.[6]									
65	Hagiwara Electric Co., Ltd.									
66	Hamanakodenso Co., Ltd.									
67	Harada Industry Co., Ltd.									
68	Hayashi Telempu Co., Ltd.									
69	Hikari Seiko Co., Ltd.									
70	Hi-Lex Corporation.[7]									
71	Hino Motors, Ltd.									
72	Hitachi Cable, Ltd.									
73	Hitachi, Ltd.[8]									
74	Hosei Brake Industry Co., Ltd.									
75	Howa Textile Industry Co., Ltd.									
76	Ibiden Co., Ltd.									

77	Ichikoh Industries, Ltd.									
78	IHI Corp.									
79	Iida Industry Co., Ltd.									
80	Iida Name Co., Ltd.									
81	Inoac Corporation.[9]									
82	Ishikawa Iron Works Co., Ltd.									
83	Itokin Corp.									
84	J.S.T. Mfg. Co.,Ltd									
85	Japan Chemical Industries.									
86	Japan Michelin Co., Ltd.									
87	Jeco Co., Ltd.									
88	JFE Steel Corporation.[10]									
89	Jidosha Kiki Hanbai Corporation.									
90	JTEKT Corp.[11]									
91	Kanamachi Lubber Co., Ltd.									
92	Kansai Paint Co., Ltd.									
93	Kanto Auto Works, Ltd.									
94	Kanto Kasei Co., Ltd.									
95	Kawasaki Industrial Co., Ltd									
96	Kawashima Selkon Textiles Co., Ltd.									
97	Kobe Steel, Ltd.									
98	Koito Mfg Co., Ltd.									
99	Kojima Press Industry Co., Ltd.									
100	Kosei Aluminum Co., Ltd.									
101	Kuze Corp.									
102	KYB Co., Ltd.[12]									
103	Kyoho Machine Works, Ltd.									
104	Kyokuto Kaihatsu Kogyo Co.,Ltd									
105	Kyokuyo Corp.									
106	Kyosan Denki Co., Ltd.									
107	Kyowa Leather Cloth Co., Ltd.									
108	Kyowa Sangyo Corp.									
109	Lonseal Corporation.									
110	Mannoh Indutrial Co., Ltd.									
111	Marui Industries Corp.									
112	Maruko Keihoki Co., Ltd.									
113	Maruman Sangyo Corporation.									
114	Marutaka Co., Ltd.									
115	Maruyasu Industries Co., Ltd.									
116	Meidoh Co., Ltd.[13]									

117	Meiwa Industry Co., Ltd									
118	Mitsubishi Electric Corp.									
119	Mitsubishi Steel Mfg. Co., Ltd.									
120	Mitsuboshi Belting Ltd.									
121	Mitsui High-tec, Inc.									
122	Mitsui Mining and Smelting Co., Ltd.									
123	Mitsuiya Industry Co,.Ltd.									
124	Mizuno Tekkosho Co., Ltd.									
125	Murakami Corp.									
126	Muro Corporation.									
127	Muro Metal Corp.									
128	Nachi-Fujikoshi Corp.									
129	Nagoya Industrial Felt Corporation.									
130	NEC Electronics Corp.									
131	NGK Insulators, Ltd.									
132	NGK Spark Plug Co., Ltd.									
133	NHK Spring Co.,Ltd									
134	Nichias Corp.									
135	NIFCO Inc.									
136	Nihon Delphi Automotive LLP.									
137	Nihon Timken Company.									
138	Nihon Tokushu Toryo, Co., Ltd.									
139	Nikki Co., Ltd.[14]									
140	Nippon AMP Co., Ltd									
141	Nippon Electric Company, Ltd.									
142	Nippon Gasket Co., Ltd.									
143	Nippon Hunmatsu Gokin Co., Ltd.									
144	Nippon Light Metal Co., Ltd.									
145	Nippon Oil Corporation.									
146	Nippon Paint Co., Ltd.									
147	Nippon Pillar Packing Co., Ltd.									
148	Nippon Piston Ring Co., Ltd.									
149	Nippon Sekiso Co., Ltd.									
150	Nippon Sheet Glass Co., Ltd.									
151	Nippon Steel Corp.									
152	Nippon Valqua Industries, Ltd.									
153	Nishikawa Rubber Co., Ltd.									
154	Nisshin Steel Co., Ltd.									
155	Nisshinbo Brake Sales Co., Ltd.									
156	Nisshinbo Industries, Inc.									

157	Nissin Kogyo Co., Ltd.									
158	Nittan Valve Co., Ltd.									
159	Nitto Denko Corp.									
160	NOK Corp.									
161	NSK Ltd.									
162	NTN Corp.									
163	Ohashi Iron Works Co., Ltd.									
164	Ohashi Technica Inc.									
165	Ohtsu Tyre & Rubber Co., Ltd.									
166	Omi Corp.									
167	OTICS Corporation.[15]									
168	Owari Precise Products Co., Ltd.									
169	Pacific Industrial Co., Ltd.									
170	Panasonic Corporation.									
171	Panasonic Energy Co., Ltd.									
172	Panasonic EV Energy Co., Ltd.									
173	Panasonic Mobile Communications Co., Ltd.									
174	Pioneer Corp.									
175	PP Japan Co., Ltd.									
176	Renesas Technology Corp.									
177	Riken Corp.									
178	Ryobi Ltd.									
179	Ryoden Trading Co., Ltd.									
180	Sango Co., Ltd.									
181	Sanoh Industrial Co., Ltd.									
182	Sansho Co., Ltd.									
183	Seiren Co., Ltd.									
184	Sekiso Corp.									
185	Shin-Kobe Electronic Machinery Co., Ltd.									
186	Shinto Paint Co., Ltd.									
187	Shiroki Corp.[16]									
188	SNB Corporation.									
189	Somic Ishikawa Inc.									
190	SSC Co., Ltd.									
191	Stanley Electric Co., Ltd.									
192	Suminoe Textile Co., Ltd.									
193	Sumitomo Electric Industries, Ltd.									
194	Sumitomo Light Metal Industries, Ltd.									

195	Sumitomo Metal Industries, Ltd.									
196	Sumitomo Rubber Industries, Ltd.									
197	Sumitomo Wiring Systems, Ltd.									
198	Suncall Corp.[17]									
199	T. RAD Co., Ltd.[18]									
200	Tachi-S Co., Ltd.									
201	Taiho Kogyo Co., Ltd.									
202	Takagi Mfg Co., Ltd.									
203	Takata Corp.									
204	Takehiro Co., Ltd.									
205	Tamagawa Seiki Co,.Ltd.									
206	Tamura Plastic Mfg Co., Ltd.									
207	Tatsumura Textile AI Co., Ltd.									
208	Tatsuta Chemical Corp.									
209	TDF Corporation.[19]									
210	Technol Eight Corporation.									
211	Teikoku Piston Ring Co., Ltd.									
212	Togo Seisakusho Corp.									
213	Tokai Gasket Co., Ltd.									
214	Tokai Kasei Co.Ltd.									
215	Tokai Kogyo Co., Ltd.									
216	Tokai Rika Co., Ltd.									
217	Tokai Rubber Industries, Ltd.									
218	Tokai TRW.									
219	Tokuhatsu Co., Ltd.									
220	Tokyo Roka Kogyosyo Co., Ltd									
221	Tokyo Shouketsu kinzoku Co., Ltd.									
222	Topre Corportion									
223	Topura Co., Ltd.									
224	Topy Industries Co., Ltd.									
225	Toshiba Corp.									
226	Toyo Gomaku Kagaku Co., Ltd.									
227	Toyo Quality One Corporation.									
228	Toyo Tyre & Rubber Co., Ltd.									
229	Toyoda Gosei Co., Ltd.									
230	Toyota Auto Body Co., Ltd.									
231	Toyota Boshoku Corp.[20]									
232	Toyota Industries Corp.									
233	Toyota Iron Works Co., Ltd.									
234	Toyota Kako Co., Ltd.									

235	Toyota Tsusho Corporation.	■	■	■	■	■	■	■	■	■
236	Toyotomi Kiko Co., Ltd.	■	■	■	■	■	■	■	■	■
237	Trinity Industrial Corp.	■	■	■	■	■	■	■	■	■
238	TRW Automotive Japan Co., Ltd.	■	■				■	■	■	■
239	TRWSI			■	■	■				
240	Tsubakimoto Chain Co.	■	■	■	■	■	■	■	■	■
241	Tsuchiya Co., Ltd.	■	■	■	■	■	■	■	■	■
242	Tsuda Industries Co., Ltd.	■	■	■	■	■	■	■	■	■
243	Tyco Electronics Japan G.K.	■	■				■	■	■	■
244	Uchiyama Manufacturing Corp.	■	■	■	■	■	■	■	■	■
245	Unitta Corp.					■	■			
246	Usui Kokusai Sangyo Kaisha, Ltd.		■	■	■	■	■	■	■	■
247	Viscodrive Japan Ltd.	■	■				■	■	■	■
248	Yahagi Industry Co.Ltd.						■	■	■	■
249	Yamaha Motor Co., Ltd.		■	■	■	■	■	■	■	■
250	Yazaki Corporation.	■	■	■	■	■	■	■	■	■
251	Yazaki Kako Corporation.		■	■	■	■	■	■	■	■
252	Yokohama Rubber Co., Ltd.	■	■	■	■	■	■	■	■	■
253	Yokowo Co., Ltd.									■
254	Yutaka Seimitsu Kogyo, Ltd.		■	■	■	■	■	■	■	■
255	Zexcel Corp.	■	■			■	■	■		
	Total[3]	**169**	**174**	**171**	**178**	**185**	**213**	**210**	**207**	**218**

Notes:

[1]Suppliers are alphabetically ordered.

[2]While the gray color shows the member of *Kyohokai*, the white does not.

[3]The last row shows the total number of members of *Kyoho-kai* in each year.

[4]Some suppliers are not reported for (1) change in company name and (2) merger and acquisition.

[5]Horie Kinzoku Industries Co., Ltd changed to FTS Co., Ltd in 2008.

[6]Nippon Batteries Co., Ltd was incorporated into GS Yuasa Corporation in 2006.

[7] Nippon Cable System Co., Ltd changed to Hi-Lex Corporation in 2008.

[8]Tokiko Corp changed was merged by Hitachi, Ltd in 2004.

[9] Inoue MTB Co., Ltd changed to Inoac Corp. in 1990.

[10]Tokyo Shiya Ring Co., Ltd changed to JFE Steel Corporation.

[11]Toyota Koki and Koyo Seiko were merged and estabished JTECT in 2005.

[12]Kayaba Co. Ltd changed to KYB Co., Ltd in 2005.

[13] Meidoh Tekko Co., Ltd changed to Meidoh Co., Ltd in 1991.

[14] Nippon Kikaki Co., Ltd changed to Nikki Co., Ltd in 2001.

[15] ODAI Corp changed to OTICS Corp in 1992.

[16] Shiroki Metal Industry Corp changed to Shiroki Corp in 1988.

[17] Sanko Senzai Industry Co., Ltd changed to Suncall Corp in 1991.

[18] Toyo Radiator Co., Ltd changed to T. RAD Co., Ltd in 2005.

[19] Tokyo Tankozyo Co., Ltd changed to TDF Corporation 1990.

[20] Arakawa Auto Body Co., Ltd changed to Arako Co., Ltd in 1988 and Arako was incoporated into Toyota Boshoku in 2004. Also, Takashimaya Nippatsu Corp was merged by Toyota Boshoku in 2004.

Sources: Compiled from *Toyota Jidosha Kogyo* [Toyota Motors] (1958) and *Jidosha Buhin Kogyo Kai* [Japan Auto Parts Industries Associations (JAPIA)], various issues.

Appendix 4-B: Concordance of Auto Parts

	Products	Harmonized System (HS) Code
1	Air cleaner	842131000
2	Airbags	870895000
3	Alternators	851150000
4	Batteries	850710010
5	Brake Linings	870830010
6	Brakes and parts	870830090
7	Bumpers	870810000
8	Cam/Crankshafts	848310010
9	Clutches and parts	870893000
10	Engine oil seal	848420000
11	Flasher units	851220000
12	Flywheels and Pulleys	848350010
13	Gaskets	848410000
14	Horns	851230000
15	Ignition coils	851130000
16	Locks	830120000
17	Meters	910400000
18	Mirrors	700910000
19	Motor for hybrid car	850211000
20	Mufflers, exhaust pipe and parts	870892000
21	Oil/Fuel filters	842123010
22	Other auto parts	870899090
23	Pressure regulator	871419000
24	Radiator	870891000
25	Ring gear and drive plate	848390010
26	Seat belts	870821000
27	Seats	940120000
28	Spark/Glow plug	851110010
29	Starter Motors	851140000
30	Steering and parts	870894000
31	Suspension and parts	870880000

32	Turbo chargers	841459010
33	Wheels	870870090
34	Wire harness	854430010 854460010
35	Air conditioning and parts	841520000 841590010
36	Engine parts	840991010 840999010
37	Glasses	700711010 700721010
38	Igniter	851190010 851190090
39	Windowshiled wipers and parts	851240000 851290000
40	Audio	852719000 852721000 852729000
41	Body and parts	870710000 870790000 870829000
42	Lamp and parts	853910010 853921000 853990010
43	Engines	840731000 840732000 840733000 840734000 840790000 840820000
44	Floor carpet	401691010 401699010 570242100 570320100 570330100 570490100
45	Tyres	401110010 401110090 401120000 401140010 401140090 401161010 401162010 401169010 401192010 401193010 401199010 401220000 401290010

Sources: Compiled by author based on *Nihon Jidosha Buhin Kogyo Kai* [Japan Auto Parts Industries Associations (JAPIA)] and Trade Statistics of Japan, Ministry of Finance (http://www.customs.go.jp/toukei/info/index_e.htm)

CHAPTER 5

Relationship between FDI and Exports: New Evidence from Product-Level Data

5.1 Introduction

The difficulty in finding the substitution relationship between foreign direct investment (FDI) and exports has been a puzzle that remains unsettled in empirical research. Since the seminal work by Mundell (1957), the nexus between FDI and exports has been theoretically and empirically explored by a large number of economists. One stylized fact is that although the theoretical literature postulates the possibility of both substitution and complementarity between FDI and exports from the home country, depending on assumptions, empirical research has consistently found a complementary relationship at firm-, industry-, and country-levels across countries (Blomstrom et al 1988, Yamawaki 1991, Chedor et al 2002).

Previous research has addressed two statistical concerns. One has been possible endogeneity bias resulting from omitted variables that simultaneously determine FDI and exports. Previous studies attempt to reduce omitted variable bias by controlling for observable variables at the country-, industry- and firm-levels and by employing an estimation technique such as instrumental variable estimation. The other concern has been aggregation bias emanating from the nature of multiproduct firms.[57] In order to address this issue, Blonigen (2001) analyses a product-level data and finds overseas operations by Japanese automakers are positively correlated with auto

[57] The multiproduct nature is a common feature of contemporary multinational enterprises. For example, automakers produce a wide variety of products from commercial cars (truck and bass) to passenger cars whereas they also produce intermediate products such as engine, engine parts, transmission and so on. In addition, it is common that auto parts suppliers involve several type s of products.

parts exports from Japan but negatively associated with overseas operations by Japanese parts suppliers. Head et al (2004) find the similar evidence in the case of the US.

The objective of this study is to contribute to the literature by analysing a broader and more up-to-date product-level data on auto parts exports from Japan covering 79 products and 36 countries over the period 1993 to 2008. The advantage of this dataset allows both endogeneity and aggregation bias to be addressed simultaneously. The key focus of this study is to search for the substitution effects of overseas operations by Japanese parts suppliers on auto parts exports from Japan, controlling for the complementary effects emanating from overseas operations by Japanese automakers (vertical networks).

The findings of my empirical analysis are broadly consistent with those of Blonigen (2001). However, there are two notable differences. First, the degree of substitution between overseas operations by Japanese suppliers and auto parts exports from Japan is found to be much weaker. This is consistent with the view that Japanese suppliers predominantly sell their products to Japanese automakers at the initial stage but expand their business with non-Japanese firms in host countries over time. Second, the disaggregated analysis in this study points to the relevance of 'value to weight' ratio (bulkiness) in deterring the nature of procurement practices of Japanese overseas automakers. There is a tendency for domestic procurement of bulky components (such as engine, chassis, body and seats) while procuring high value-to-weight components from Japan. This implies that Japanese parts suppliers' overseas operations are largely confined to the production of the former types of components.

The relationship between FDI and exports has been an issue of policy interest for home countries of multinational enterprises (MNEs). It is widely held in policy circles in Japan and other home countries that the growing overseas activity of MNEs could replace exports from a home country thereby depriving the locals of job opportunities (Navaretti and Falzoni 2004). However, the empirical evidence of this study casts doubt on this pessimistic view. The expansion of overseas operations of MNEs could in fact strengthen trade relations between home and host countries.

While existing studies have addressed either endogeneity or aggregation bias, to the best of my knowledge, this study is the first attempt to address them simultaneously. The novelty of this study is that this has been done not only by constructing broader product-level panel datasets but also in some original ways. In order to minimise aggregation bias, this study examines the case of Toyota and its parts suppliers, enabling the matching of the level of data aggregation by identifying specific suppliers for *each* auto part. For the same purpose, this study undertakes product-by-product analyses following aggregated analyses.

The rest of this paper is structured as follows. Section 5.2 discusses endogeneity and aggregation bias relating to the empirical analyses of the relationship between FDI and exports in more detail. Section 5.3 presents the empirical model, data and measurement of variables and discusses the estimation methods. Section 5.4 reports the estimation results. Section 5.5 discusses the key results obtained in Section 5.4. Section 5.6 concludes.

5.2 Relationship between FDI and Exports: Empirical Issues

One stylized fact is that although the theoretical literature postulates the possibility of both substitution and complementarity between FDI and exports from the home country, empirical research has consistently found a complementary relationship between these two variables (Table 5.1).[58] A positive relationship can be explained by at least two factors (Head and Ries 2004). First, the expansion of a firm's product in a given foreign market could lead to an increase in demand for the firm's other products. This is called "statistical complementarity". Second, investment abroad by a downstream firm (e.g. automaker) could create demand for parts and components, leading to an increase in export demand for upstream firms (e.g. parts suppliers) in a home country. This is called "economic complementarity".

[58] See Mundell (1957), Bergsten, Horst, and Moran (1978), Markusen (1995) for theoretical studies.

The difficulty in finding the substitution relationship between FDI and exports has been an empirical issue yet to be settled over the past decades. In order to address this issue, previous research has explored two statistical concerns. One has been possible endogeneity bias resulting from omitted variables that simultaneously determine FDI and exports. It might be argued that unobservable variables related to policy in a host country could be a cause of the complementarity between FDI and exports. For example, liberalisation policy favourable to trade and FDI in a host country might encourage home country's MNEs to increase both exports from the home country and the activities of their overseas affiliates in the same host country. The other concern is that firm- and industry-heterogeneity might cause the upward bias. Helpman et al (2004) suggest that firm-heterogeneity in terms of productivity and size matters as determinants of firms' exports and FDI: the more productive the firm, the more the firm exports and invests overseas.

Previous research attempts to reduce the omitted variable bias in two ways. The first is to control for observable variables at the country-, industry- and firm-levels. Many previous studies employ a gravity equation as an analytical framework (Table 5.1). This is because the gravity equation could capture observable country-specific factors such as trade costs, market size and income level. Within the gravity model, Lipsey and Weiss (1981) and Kim (2000) additionally put a dummy variable for membership in the EEC (European Economic Community) into the equation to control for the downward bias derived from a free-trade area. Yamawaki (1991) employs industry-level data and attempts to control for observable industry-specific variables such as the size of industry, and the industry's capital-intensity. Lipsey and Weiss (1984) employ firm-level data and control for the size of the parent firm. Chedor et al (2002) and Head and Ries (2001) attempt to control for a wider variety of time-varying firm characteristics such as size, capital intensity, productivity, and expenditure on R&D.

The second way to enable an escape from the endogeneity problem is to employ an estimation method such as instrumental variable (IV) estimation (Blomstrom et al 1988, Grubert and Mutti 1991, Clausing 2000). However, Head and Ries (2001) claim that IV approaches are not appropriate because of the difficulties in finding an instrument that is correlated with MNEs overseas activity, does not determine exports from the home country, and is excludable from the equation. The alternative method is to use a least squares dummy variables (LSDV) model, allowing controls for time-invariant unobservable factors among countries, industries and firms. However, previous studies have not found a substitution relationship between FDI and exports overall notwithstanding the efforts to reduce possible endogeneity bias.

The other statistical concern is aggregation bias emanating from the nature of the conventional data such as firm-, industry- and country-level trade data. Given that firm-level data, for example, does not provide information on trade by products, it is difficult to identify a substitution effect to the extent that the firm is multiproduct. For example, if a firm produces two products (A and B) and only product A is produced abroad, it would be possible that overseas production of product A increases demand for product B due to statistical complementarity. To the extent that the statistical complementarity for product B offsets the substitution effects arising from the decrease in exports of product A, the relationship between FDI and exports would be complementary. Another example is an economic complementarity. If a firm produces both an intermediate and a final good, it would be possible that overseas production of a final product is associated with exports of intermediate goods from the home country. To the extent that the economic complementarity for the intermediate products offsets the substitution effects arising from the decrease in final products, the relationship between FDI and exports would be complementary.

Product-level data enables addressing the aggregation biases emanating from the nature of a multiproduct firm by separating the substitute effects from the complementary effects, especially when vertical networks between upstream and downstream firms play an important role (Blonigen 2001). Suppose that an intermediate product is produced by two upstream firms (A and B) and is sold to a downstream firm. Only firm A produces abroad to supply its product to the downstream firm directly in the host country. Controlling for the economic complementarity for exports from firm B at home, it would be possible to identify the substitution effects emanating from the replacement of exports with overseas production by firm A.

Despite the potential importance of product-level data, the empirical evidence is still limited. Constructing a time-series data for 10 products over 1978 to 1991 between Japan and the US, Blonigen (2001) undertakes product-by-product analyses. The analyses find auto parts exports from Japan are positively correlated with overseas production by Japanese automakers but negatively correlated with overseas production by Japanese suppliers. Constructing a three-dimensional panel data covering 53 products and 26 countries over 1989-1994, Head et al (2004) examine the case of the US and find similar results.

This study relates closely to Blonigen (2001) extending it in several ways.[59] First, I analyse a broader product-level data covering 79 auto parts and 36 countries over the period 1993 to 2008 in the case of exports from Japan. The superiority of using a wider coverage of data is the opportunity to address endogeneity and aggregation bias simultaneously. The endonegeity issue is addressed by controlling for unobserved country-, product- and year-effects whereas the aggregation bias is tackled in various ways. The latter is discussed in detail in the next section. The estimation efficiency is also enhanced due to the increased number of observations. In addition to these econometric reasons, an extension of data coverage is prompted by the rapid expansion of global production networks by Japanese automakers and parts suppliers over the past two decades: Asia, and particularly China, is emerging as a centre of global production networks whereas the

[59] It is important to note that the differences between this study and Blonigen (2001) are not only the dataset used but also model specification. This study examines determinants of auto parts exports from Japan by estimating a gravity equation whereas Blonigen (2001) estimates a demand function of auto parts exports derived originally. To the extent that both specifications include overseas operations by Japanese automakers and parts suppliers, however, this difference would not be an issue.

importance of North America, and particularly the US, is declining.[60] In line with this compositional change in overseas operations, the destination of auto parts exports from Japan has shifted toward Asia: in 2008 the share of Asia was 40%, followed by North America (31%) and Europe (20%). Thus, the extension of country coverage is more informative. Second, this study undertakes not only product-by-product analyses (as done by Blonigen) but also three-dimensional panel data analyses by combining 79 products into the same dataset following Head et al (2004). The panel data analyses are extended to an in-depth case study of Toyota and its parts suppliers. The details of these analyses are discussed in the next section.

[60] Regarding overseas production (in volume) by Japanese automakers, the share of North America dropped from 42% in 1988 to 31% in 2008 whereas the share of Asia rose from 26% to 42% during the same period. In particular, the sharp contrast between these two regions reflects in the rise of China and the fall of the US. Regarding overseas operations by Japanese parts suppliers, their overseas subsidiaries are most concentrated in Asia: Out of 1,203 subsidiaries in 2008, 659 were located in Asia, followed by North America (290), and Europe (186).

Table 5.1: Summary of Previous Research[1]

Author[2]	*Period*[3]	*Dependent Variable*[4]	*Measurement of MNEs' Overseas Activities*[5]	*Results*[6]	*Data*[7]	*Control Variables*[8]	*Method*[9]
Lipsey and Weiss (1981)	1970	US Exports, industry-level	Net sales of US affiliates including manufacturing and non-manufacturing	Complement	Cross-section (44 destinations)	GDP, Distance, Dummy for membership in EEC	OLS
Lipsey and Weiss (1984)	1970	Exports of US Parent Firms	Sales of manufacturing affiliates minus their imports from the US	Complement	Cross-section (1090 firms, 5 areas)	Scale of parent's firm, GDP, Sales by non-manufacturing affiliates	OLS
Blomstrom, Lipsey and Kulchycky (1988)	1982	US Exports, industry-level	Net sales of US affiliates in industry	Mixed	Cross-section (countries)	GDP, Per capita GDP	OLS, 2SLS
Blomstrom, Lipsey and Kulchycky (1988)	1978	Swedish Exports, industry-level	Net local sales	Complement	Cross-section (countries)	GDP, Per capita GDP	OLS, 2SLS
Chedor, Mucchielli and Soubaya (2002)	1993	Intra-Firm Exports of French Firms	Number of employees at French overseas affiliates	Complement	Cross-section (firm, 21 destinations)	Firm's characteristics (size, capital intensity, R&D), GDP and Distance	OLS
Kim (2000)	1994	South Korea's Exports, industry-level	Value of outward FDI	Complement	Cross-section (9 industries and 57 countries)	GDP, PGDP, Dummy for membership in EEC	OLS
Yamawaki (1991)	1986	Total Japanese Exports to US markets, industry-level	Total employment of Japanese distribution affiliates in US	Complement	Cross-section (44 industries)	Total industry employment in US, Total industry employment in Japan, etc	OLS
Lipsey, Ramstetter and Blomstrom (2000)	1986-1992	Exports of Japanese parent firms	Number of employees in parent's affiliates	Complement	Cross-section (firms, regions)	GDP, Per capita GDP, Distance, Total sales of parent	OLS
Lipsey and Ramstetter (2003)	1986-1995	Japan's Exports, industry-level	Number of employment in Japanese affiliates	Complement	Cross-section (96-98 countries)	GDP, Per capita GDP, Distance	OLS

Head and Ries (2001)	1966-1991	Japanese automaker's exports to world	Number of new manufacturing investment by automakers	Substitute	Panel data (932 firms, 25 years)	Time-varying firm characteristics (Size, Capital Intensity, Labour Productivity, Wage)	OLS
		Japanese supplier's exports to world	Number of new manufacturing investment by suppliers/by automakers	Complement/ Complement	Panel data (932 firms, 25 years)	Time-varying firm characteristics (Size, Capital Intensity, Labour Productivity, Wage)	OLS
Blonigen (2001)	1978-1991	Japan's auto parts exports to US, product-level	Number of employees of Japanese suppliers' plants in US/ Number of vehicles produced by Japanese automakers in US	Substitute/ Complement	Time series (14 years)	Price, capital, US automobile production	OLS, SUR
Head, Ries and Spencer (2004)	1989-1994	US auto parts exports, product-level	Number of employees of US affiliates related to automobile industry/ Number of vehicles produced by Big 3	Substitute/ Complement	Panel data (53 products, 26 countries, 5 years)	Distance, Per capita GDP, Dummy for Mexico and Canada, Dummy for language, and communist	OLS

Notes:

[1] A large number of studies relevant to the relationship between FDI and exports from home country are not listed here due to the space limitation. Since this study examines the case of Japanese automobile industry, I focus only on literature related to developed countries including the United States, France, Sweden, Japan and South Korea. Also, this study has been interested in the analysis at disaggregated level therefore I focus only on industry-, firm- and product-level analyses.

[2] The author(s) of the paper with published year.

[3] The period of analysis.

[4] The dependent variables relating to exports from home country measured by various definitions according to the authors.

[5] The key variables related to MNE's overseas activities.

[6] The relationships between FDI and exports from home country derived from the regression analysis.

[7] The datasets employed in each study.

[8] The control variables. EEC represents European Economic Community.

[9] The estimation methods. SUR represents seemingly unrelated regression.2SLS represents of two stage least squares.

5.3 Estimation Strategy and Data

This study examines a broader product-level data covering 79 auto parts and 36 countries over the period 1993 to 2008 and undertakes not only product-by-product analyses but also three-dimensional panel data analyses. This section discusses the estimation model followed by a discussion on variable construction and estimation method.

5.3.1 The Model

Following the previous studies, I estimate an augmented version of the gravity equation,

$$\ln EX_{i,j,t} = \alpha + \beta_1 \ln FDI\_M_{j,t} + \beta_2 \ln FDI\_S_{j,t} + \beta_3 \ln GDP_{j,t}$$
$$+ \beta_4 \ln PGDP_{j,t} + \beta_5 \ln DIS_j + \beta_6 \ln NER_{j,t} + \gamma C + \delta P + \omega T + u_{i,j,t} \qquad (5.1)$$

where subscripts i stands for i th auto parts: i =1,…,79, j stands for the j th country: j =1,….,36 and t stands for the year: t = 1993,1996,1999, 2002,2005 and 2008. The auto parts and countries are listed in Appendix 5-A and 5-B, respectively. The variables are listed and defined below with expected sign of the coefficient for independent variables in parentheses:

EX	Export value of auto parts i from Japan to country j in Japanese yen
FDI_M	Scale of overseas operations by Japanese automakers in country j (+)
FDI_S	Scale of overseas operations by Japanese suppliers in country j (+or-)
GDP	Real gross domestic product (GDP) in country j (+)
PGDP	Real GDP per capita in country j (+)
DIS	Distance between Japan and a capital of country j (-)
NER	Nominal exchange rate index in country j (+)
C	A set of country dummy variables
P	A set of part dummy variables
T	A set of time dummy variables
α	A constant term
u	An error term

The scale of overseas operation by Japanese automakers (*FDI_M*) is a measure of outward FDI by Japanese automakers into the host country. It is expected that FDI by automakers increases auto parts exports from Japan because of economic complementarities (Head and Ries 2004). The scale of overseas operation by Japanese parts suppliers (*FDI_S*) is used as a measure of outward FDI by Japanese suppliers into the host country. The sign of the coefficient is of primary interest in this study.

The destination GDP (*GDP*) and distance (*DIS*) are included as measures of market size and trade costs, respectively. The GDP per capita (*PGDP*) is added as a measure of the development level of the destination country. Controlling for the development level matters because richer countries tend to have better ports, infrastructure, and communication systems that facilitate trade and FDI. In addition, more advanced countries tend to have more developed supporting industries that induce FDI but replace exports from home with local procurement. In addition to these gravity variables, the control for the exchange rate (*NER*) matters because changes in exchange rate cause the changes in the relative price between home and host country, affecting firms' decisions on exporting and FDI. Finally, I control for unobservable factors to eliminate the possibility of endogeneity bias by including country-, part-, and time-dummy variables.[61]

5.3.2 Variable Construction and Data Source

Japan's disaggregated trade data classified according to the harmonised system (HS) are from the Trade Statistics of Japan compiled by the Ministry of Finance. These data enable identification of auto parts at the 9 digit-level. However, careful attention has to be paid to the classification of auto parts. While parts and components for motor vehicles are mainly classified into HS code 87, a large number of auto parts come under a different heading: tyres and rubber products (40), glass (70),

[61] I have already discussed the country dummy variables (*C*). The part dummy variables (*P*) are included to control for part-specific characteristics such as bulkiness, engineering and designing costs, and asset specificity that could influence FDI and exports, simultaneously (Head, Ries and Spencer 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 due to the avoidance of a breach of technology and information. On the other hand, 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. The time dummy variables (*T*) are included to control for time-varying factors relating to auto parts such as technological change, and price changes.

electronic products (84, 85), seats (94), and so on. I classify auto parts based on the Japan Auto Parts Industries Association (JAPIA), which provides information on the comprehensive coverage of auto parts based on the HS code at the 9 digit level.[62] The monetary unit of export value is measured in Japanese yen. A complete list of 79 auto parts with HS code and product name is presented at Appendix 5-A.

The scale of overseas operations by Japanese suppliers (*FDI_S*) is measured by the number of employees at Japanese suppliers' overseas affiliates. The data are extracted from *Nihon no jidoshabuhin kogyo* [Japanese Automotive Parts Industry] compiled by the Japan Auto Parts Industries Association (JAPIA) for various issues. This data source provides information on the overseas activities of Japanese auto parts suppliers in terms of location, establishment year, products, number of employees at overseas affiliates, and other relevant information. Using these data, I calculate the total number of employees at Japanese suppliers' overseas affiliates in each destination country. The scale of overseas operations by Japanese automakers (*FDI_M*) is measured by the number of employees at the overseas affiliates of Japanese automakers. The data are from *Kaigai kigyo shinshutsu soran* [List of Japanese overseas affiliates] complied by Toyo Keizai for various issues. Employing these data, I calculate the total number of employees at Japanese automakers' overseas affiliates in each destination country, excluding non-manufacturing affiliates such as those involved in R&D, distribution, insurance and other non-manufacturing services.

The number of employees is a better measure of overseas operations by firms among possible alternatives for three reasons. First, the number of employees at overseas affiliates is closely correlated with the scale of production. Data on the number of affiliates are also available for Japanese automakers and suppliers but this measure could underestimate the variations of overseas operations among countries. Second, data on the number of employees at overseas

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[62] Refer to http://www.japia.or.jp/en/index.html for more information.

subsidiaries are available for both automakers and suppliers. Although the production volume is the better measure, the data are available for only auto production by automakers. Third, data on the number of employees at overseas subsidiaries are available for a longer period. The disaggregated data on overseas operations by Japanese automakers are accessible only from 1998.

The potential disadvantage of this measure is that the variable of overseas operations by Japanese suppliers is not calculated by product (but only by country) although the dependent variable (i.e. exports of auto parts from Japan) is classified by product.[63] The failure of capturing the variation of overseas operations by suppliers among auto parts might lead to a spurious regression problem. To deal with the problem, I undertake an in-depth analysis of the case of Toyota and its suppliers, enabling identification of specific suppliers for each auto part and calculation of the total number of employees of suppliers' overseas affiliates for each auto part, which can be a proxy of overseas operations of suppliers by product (and by country).

Real gross domestic product (*GDP*) measured in $US at constant 2000 price and real per capita GDP (*PGDP*) measured in $US at constant 2005 prices are from the World Development Indicators. Distance (*DIS*) is obtained from the CEPII database. Distance is measured using the geographical coordinates of the capital cities. Nominal exchange rate index (*NER*) is constructed based on the formula,

$$NER_{jt} = \frac{Japaneses\ Yen\ per\ \$US_t}{Local\ Currency\ per\ \$US_{jt}} = \frac{Japanese\ Yen_t}{Local\ currency_{jt}}$$

where j and t represent destination country and year, respectively. An increase in the index indicates the depreciation of Japanese yen, which should lead to an expansion of auto parts from Japan.[64]The information for constructing the official exchange rate is obtained from the World Development Indicators. I report the summary statistics for variables and correlation matrix in Tables 5.2 and 5.3, respectively.

[63] Blonigen (2001) measures this variable by product.
[64] Although real exchange rate is a more accurate measure, the limited availability of price data does not allow me to construct it for the period 1993 to 2008.

Table 5.2: Summary Statistics

Variables	Obs.	Mean	Standard Deviation	Min	Max
Log Auto Parts Exports, Japanese Yen	18,495	10.73	2.82	5.30	19.72
Log Overseas Operations by Suppliers	13,525	7.96	2.42	0	12.62
Log Overseas Operations by Automakers	8,913	8.08	1.65	1.61	11.36
Log GDP, $US	18,497	25.87	1.50	19.09	30.09
Log GDP Per Capita, $US	18,497	8.67	1.42	5.55	10.65
Log Distance, km	18,100	8.96	0.58	7.05	9.83
Log Nominal Exchange Rate Index	17,774	2.78	2.65	-5.06	9.22

Table 5.3: Correlation Matrix

	FDI_S	*FDI_M*	*GDP*	*PGDP*	*DIS*	*NER*
Log Overseas Operations by Suppliers (*FDI_S*)	1					
Log Overseas Operations by Automakers (*FDI_M*)	0.60	1				
Log GDP (*GDP*)	0.44	0.36	1			
Log GDP Per Capita (*PGDP*)	-0.03	0.16	0.57	1		
Log Distance (*DIS*)	-0.34	-0.13	0.26	0.60	1	
Log Nominal Exchange Rate Index (*NER*)	-0.09	0.01	0.53	0.74	0.43	1

The model is estimated not only by ordinary least squares (OLS) but also by poisson pseudo-maximum-likelihood (PPML) technique to allow a robustness check of the OLS estimates. It is claimed that estimating the constant-elasticity model (i.e. the log-log model) by OLS might result in inconsistency estimates for two reasons (Silva and Tenreyro 2006). First is the strong assumption that the expected value of the error term is independent from any values of explanatory variables. The violation of this assumption leads to inconsistency of the OLS estimator. Second, the parameters estimated by OLS might be biased under heterosckedasticity. Silva and Tenreyro (2006) demonstrate that the OLS estimates of gravity variables such as distance and GDP are overestimated: the estimate of distance is biased downward whereas the estimates of GDP are biased upward. In order to tackle these problems, Silva and Tenreyro (2006) propose a PPML technique as an alternative, using a multiplicative form of the constant-elasticity model and demonstrate that PPML estimates are less susceptible to a bias. One of the useful properties of the PPML estimator is a wide range of applicability including panel data analysis (Woodridge 1999).

The empirical analyses are carried out in three steps. First, a panel dataset covering 36 countries over the period 1993 to 2008 is examined. Subsequently, I analyse three-dimensional panel data by disaggregating the dependent variable (i.e. auto parts exports from Japan) into 79 products following Head et al (2004). This treatment not only enhances the efficiency of estimation due to the increase in the number of observations but also allows for controlling for parts-specific characteristics as already discussed.

Next I apply the previous panel data analyses to the in-depth analysis of Toyota and its suppliers for two reasons. First, matching the level of data aggregation is important to reduce the possibility of aggregation bias (Blonigen 2001). The variable of overseas operations by Japanese suppliers in the previous analyses is not calculated by product (but only by country). On the other hand, this case study enables identification of specific suppliers for *each* auto part and calculation of the total number of employees of suppliers' overseas affiliates by product (and by country). Second, Toyota's supplier relationship is the most intimate among Japanese automakers, leading to the higher degree of the following-leader investments by its suppliers. Therefore, it is more likely that a substitute relationship between overseas operations by Toyota's suppliers and auto parts exports will be found.

Third step is go one step further by undertaking product-by-product analyses. I estimate the model (1) for 79 products and 37 product groups. This analysis is motivated by two reasons. First is to address the possible aggregation bias that makes it difficult to identify the substitution effects (Blonigen 2001). Second is to compare the estimation result with previous studies, particularly Blonigen (2001), which undertakes product-by-product analyses for 10 auto parts in the case of auto parts exports from Japan.

5.4 Results

Panel Data Analysis

Table 5.4 reports estimates of model (1) with panel data. The first three columns show OLS estimates whereas the last three columns present PPML estimates. The overall goodness-of-fit of both OLS and PPML regressions are sufficient to conduct an econometric analysis. Some gravity variables such as distance and GDP per capita perform in accordance with expectations whereas other variables such as GDP and nominal exchange rate do not.

Table 5.4: Regression Results, Panel Data

Estimator:	OLS[2]			PPML[2]		
Dependent Variable: Auto Parts Exports from Japan	$\ln(EX_{jt})$[1]			EX_{jt}		
Log Overseas Operations by Japanese Automakers (FDI_M_{jt})	0.21*** (0.04)[3]		0.16*** (0.04)	0.11** (0.05)		0.09** (0.05)
Log Overseas Operations by Japanese Suppliers (FDI_S_{jt})		0.21*** (0.07)	0.07 (0.05)		0.09*** (0.03)	0.04* (0.03)
Log Distance from Japan (DIS_j)	-4.77*** (1.8)	-2.7*** (0.98)	-2.47*** (0.94)	-21.3*** (5.7)	-7.71*** (2.13)	-27.04*** (4.75)
Log GDP in the Host Country (GDP_{jt})	-3.34* (1.78)	-2.33** (1.1)	-1.29 (0.97)	-1.67** (0.7)	-1.88*** (0.65)	-2.42*** (0.62)
Log GDP Per Capita in the Host Country ($PGDP_{jt}$)	4.8*** (1.81)	4.05*** (1.32)	3.06*** (1.12)	3.79*** (0.77)	3.85*** (0.67)	4.35*** (0.79)
Log Nominal Exchange Rate (NER_{jt})	-0.22*** (0.08)	-0.23* (0.13)	-0.27*** (0.08)	-0.21*** (0.06)	-0.18** (0.09)	-0.17* (0.09)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared/Pseudo R-Squared	0.96	0.96	0.97	0.99	0.98	0.99
Observation	141	227	126	141	227	126

Notes:
[1] j represents the destination including 59 countries and t represents the year covering 1993, 1996, 1999, 2002, 2005, and 2008.
[2] OLS is ordinary least squares and PPML is poisson pseudo-maximum-likelihood.
[3] The number shown in the parenthesis is heteroscedasticity-consistent standard errors.
***p-value < 0.01, ** p-value < 0.05, * p-value < 0.1.

The first column shows the specification where only overseas operations by automakers is added. The coefficient of overseas operations by automakers (*FDI_M*) is positive and statistically significant at the 1% level, predicting that, overall, a 1% expansion of overseas production by Japanese automakers leads to a 0.21% increase in auto parts exports from Japan. Likewise, the second column reveals the existence of a complementary relationship between overseas operations by suppliers and exports from Japan. When overseas production by both automakers and suppliers are added to the model (third column), the coefficient of overseas production by automakers is still positive and significant whereas the counterpart of overseas production by suppliers is positive but no longer statistically significant. The results of the PPML estimation are given in the fourth to sixth columns in Table 5.4. They are generally consistent with the results obtained by OLS.

Table 5.5: Regression Results, Product-Level Data

Estimator:	OLS[2]			PPML[2]		
Dependent Variable: Auto Parts Exports from Japan	$\ln(EX_{ijt})$[1]			EX_{ijt}		
Log Overseas Operations by Japanese Automakers (FDI_M_{jt})	0.11*** (0.03)[3]		0.08** (0.04)	0.12*** (0.05)		0.08** (0.04)
Log Overseas Operations by Japanese Suppliers (FDI_S_{jt})		0.1*** (0.02)	0.03 (0.04)		0.08** (0.03)	0.03 (0.04)
Log Distance from Japan (DIS_j)	-3.85*** (0.76)	-2.35*** (0.5)	-2.78*** (0.71)	-3.26*** (1.16)	-7.24*** (2.39)	-2.78*** (1.4)
Log GDP in the Host Country (GDP_{jt})	-1.75** (0.7)	-0.53 (0.5)	-1.27 (0.79)	-2.48 (1.02)	-1.94*** (0.74)	-2.1 (0.82)
Log GDP Per Capita in the Host Country ($PGDP_{jt}$)	3.65*** (0.72)	1.98*** (0.6)	3.47*** (0.83)	3.71*** (1.05)	3.9*** (0.78)	4.85*** (0.9)
Log Nominal Exchange Rate (NER_{jt})	-0.28*** (0.05)	-0.37*** (0.06)	-0.44*** (0.06)	-2.64*** (0.06)	-0.17** (0.07)	-0.23** (0.08)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Country Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Part Dummy	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared/Pseudo R-Squared	0.66	0.64	0.66	0.87	0.86	0.89
Observation	8,489	12,893	7,722	8,489	12,893	7,722

Notes:

[1] *i* represents auto parts including 79 products, *j* represents the destinations including 59 countries and *t* represents the year covering 1993, 1996, 1999, 2002, 2005 and 2008. The dependent variable is disaggregated at the product-level but not the independent variables.

[2] OLS is ordinary least squares and PPML is poisson pseudo-maximum-likelihood.

[3] The number shown in the parenthesis is heteroscedasticity-consistent standard errors.

*** p-value<0.01, ** p-value<0.05, * p-value<0.1.

Table 5.6 reports estimates with three-dimensional panel data that disaggregates the dependent variable (i.e. auto parts exports from Japan) into 79 products and combines them into the same dataset. The data disaggregation increases the numbers of observations dramatically, leading to the improvement in the efficiency of estimation. The overall goodness-of-fit of both OLS and PPML regressions are still reasonably high to conduct an econometric analysis. As shown in Table 5.6, the result with three-dimensional data is quite similar to that with panel data presented in Table

4. To sum up, there is no evidence that overseas operations by Japanese suppliers and auto part exports from Japan are substitutes. On the other hand, there is strong evidence that auto parts exports is positively associated with overseas operations by automakers.

The Case of Toyota and its Suppliers

Following the previous analyses, I estimate an augmented version of the gravity equation:

$$\ln EX_{i,j,t} = \alpha + \beta_1 \ln FDI\_T_{j,t} + \beta_2 \ln FDI\_S_{i,j,t} + \beta_3 \ln GDP_{j,t} + \beta_4 \ln PGDP_{j,t} + \beta_5 \ln DIS_j + \beta_6 \ln NER_{j,t} + \gamma C + \delta P + \omega T + u_{i,j,t} \quad (5.2)$$

where subscripts i stands for the i th auto part: $i = 1,\ldots,44$, j stands for the j th country: $j = 1,\ldots,32$ and t stands for the year: $t = 1993, 1996, 1999, 2002, 2005$, and 2008. Since the firm-level data is not available, the dependent variable is extracted from the records of ports in the Aichi prefecture, the transport hub of the Toyota-centred auto cluster in Japan.[65] The 12 main plants of Toyota Motors and 173 of its *keiretsu* suppliers, out of the total 218, are located in the Aichi prefecture. More importantly, all key *keiretsu* suppliers of Toyota are located in this area.[66] The scale of overseas operations by Toyota Motors (*FDI_T*) is a measure of outward FDI by Toyota Motors into the host country. The scale of overseas operations by Toyota's suppliers (*FDI_S*) is used as a measure of investment by Toyota's suppliers into the host country. The other variables are identical to those used in the previous section.

Table 5.6 reports the estimation result at the aggregate level. The key finding is that, on average, overseas operations by Toyota Motors is positively correlated with auto parts exports,

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[65] There are 9 main custom ports in Japan: Tokyo, Yokohama, Kobe, Osaka, Nagoya, Moji, Nagasaki, Hakodate, and Okinawa. Nagoya customs cover ports in the Aichi prefecture. Calculating by "Google map", the distances between the headquarter of Toyota Motors (address: 1 Toyota-cho, Toyota city, Aichi prefecture) and each custom are: Nagoya custom is 25.91 km, Hakodate is 813.49 km, Tokyo is 247.17 km, Yokohama is 228.56 km, Kobe is 183.36 km, Osaka is 162.78 km, Moji is 580.98, Nagasaki is 715.92 km, and Okinawa is 1,333.2 km.

[66] Here, key suppliers are synonymous with members of the Toyota group including Toyota Industries Corporation, Aichi Steel Corporation, JTEKT Corporation, Toyota Auto Body Co.,Ltd, Toyota Tsusho Corporation, Aisin Seiki Co.,Ltd., Denso Corporation, Toyota Boshoku Corporation and Toyoda Gosei Co.,Ltd.

predicting that 1% increases in overseas operations by Toyota leads to 0.3% increases in auto parts exports from ports in Aichi (Third column). Another finding is that there is no evidence that overseas operations by suppliers substitutes auto parts exports. As can be seen, both OLS and PPML estimations show positive coefficients even though the significance levels vary. These results are consistent with those presented in the previous analysis (Table 5.4).

Table 5.6: Regression Results for Toyota Motors, Panel Data

Estimator: Dependent Variable: Auto Parts Exports from Ports in Aichi (EX_{jt})	OLS[2] Log (EX_{jt})[1]			PPML[2] EX_{jt}		
Log Overseas Operations by Toyota Motors (FDI_T_{jt})	0.29*** (0.09)[3]		0.30*** (0.08)	0.16** (0.1)		0.16** (0.1)
Log Overseas Operations by Suppliers (FDI_S_{jt})		0.14 (0.09)	0.09 (0.07)		0.14** (0.07)	0.12** (0.06)
Log Distance from Japan (DIS_j)	-8.55*** (2.78)	-5.85** (2.29)	-7.22*** (1.96)	-23.91*** (4.69)	-23.17*** (4.70)	-24.89*** (4.68)
Log GDP in the Host Country (GDP_{jt})	-4.61* (2.37)	-4.20* (2.47)	-6.14*** (2.12)	-5.86*** (1.51)	-5.79*** (1.56)	-6.38*** (1.52)
Log GDP Per Capita in the Host Country ($PGDP_{jt}$)	7.67*** (2.54)	7.64*** (2.70)	9.41*** (2.40)	8.46*** (1.53)	8.19*** (1.51)	8.78*** (1.53)
Log Nominal Exchange Rate (NER_{jt})	-0.59*** (0.11)	-0.62*** (0.11)	-0.63*** (0.12)	-0.41*** (0.11)	-0.41*** (0.11)	-0.45*** (0.11)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Country dummy	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared/Pseudo R-Squared	0.92	0.92	0.93	0.98	0.98	0.98
Observations	106	102	102	106	102	102

Notes:
[1] j represents the destination including 32 countries and t represents the year covering 1993, 1996, 1999, 2002, 2005, and 2008.
[2]OLS is ordinary least squares and PPML is poisson pseudo-maximum-likelihood.
[3]The number shown in the parenthesis is heteroscedasticity-consistent standard errors.
***p-value < 0.01, ** p-value < 0.05, * p-value < 0.1.

Table 5.7 shows the results obtained by re-estimating the model after disaggregating auto parts exports and overseas operations by suppliers at the product level. The results are mixed. The OLS estimates show quite similar results whereas the PPML estimates imply that overseas operations by both Toyota and suppliers are insignificant predictors in explaining the flow of auto parts exports. To sum up, the in-depth analyses of Toyota and its parts suppliers indicate that a complementary relationship between overseas operations by Toyota Motors and auto parts exports seems to exist. On the other hand, the relationship between overseas operations by suppliers and auto parts exports is ambiguous. However, there is no evidence that overseas operations by suppliers substitutes auto parts exports.

Table 5.7: Regression Results for Toyota Motors, Product-Level Data

Estimator:	OLS[2]			PPML[2]		
Dependent Variable: Auto Parts Exports from Ports in Aichi (EX_{ijt})	Log (EX_{ijt})[1]			EX_{ijt}		
Log Overseas Operations by Toyota Motors (FDI_T_{jt})	0.21**		0.46**	0.03		0.03
	(0.09)		(0.21)	(0.09)		(0.17)
Log Overseas Operations by Suppliers (FDI_S_{ijt})		0.08***	-0.03		0.14***	-0.01
		(0.03)	(0.10)		(0.04)	(0.07)
Log Distance from Japan (DIS_j)	-4.66*	-0.48	-10.34**	17.74***	-1.98**	18.33***
	(2.61)	(0.82)	(4.53)	(3.45)	(0.79)	(5.03)
Log GDP in the Host Country (GDP_{jt})	-1.46	-7.11***	-9.18*	-6.82***	-6.74***	-4.87
	(2.52)	(1.34)	(5.05)	(2.58)	(1.84)	(3.99)
Log GDP Per Capita in the Host Country ($PGDP_{jt}$)	3.77	8.79***	13.65**	9.61***	8.47***	8.89**
	(2.57)	(1.39)	* (5.05)	(2.48)	(1.85)	(3.82)
Log Nominal Exchange Rate (NER_{jt})	-0.28**	-0.56***	-1.33***	-0.20	-0.40***	0.14
	(0.12)	(0.08)	(0.24)	(0.18)	(0.11)	(0.25)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Part dummy	Yes	Yes	Yes	Yes	Yes	Yes
Country dummy	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared/Pseudo R-Squared	0.66	0.63	0.83	0.92	0.87	0.96
Observations	863	2,779	202	1,059	3402	230

Notes:

[1] *i* represents auto parts including 44 products, *j* represents the destinations including 32 countries and *t* represents the year covering 1993, 1996, 1999, 2002, 2005 and 2008.

[2] OLS is ordinary least squares and PPML is poisson pseudo-maximum-likelihood.

Product-by-Product Analyses

I estimate the model (1) by 79 products *separately* and calculate the numbers of coefficients of overseas operations by both automakers and suppliers according to its sign and significance level. Table 5.8 presents the summary of the result. As can be seen, 53 OLS estimates of overseas operations by Japanese automakers are positive and significant with at least a 10% significance level whereas the counterpart of PPML is 46. More importantly, the export value of 53 products (in the case of OLS regression) has accounted for nearly 80% of the total value of auto parts exports from Japan during the period 1993 to 2008. This indicates that the complementary effect of overseas operations by Japanese automakers is quite prevailing across products.

On the other hand, as expected the complementary effect of overseas operations by suppliers seems to be more limited comparing with that by automakers. There are only 22 OLS coefficients and 31 PPML coefficients, which are positive and statistically significant with at least a 10% significance level. However, the important finding is that there are some products that have the substitutability between overseas operations by suppliers and auto parts exports although the number of products is quite limited: with 2 OLS estimates and 7 PPML estimates, respectively.

Table 5.8: Number of Coefficients of 79 Products According to Sign and Significance Level[1]

Dependent Variable: Auto Parts Exports from Japan Year: 1993-2008	Overseas Operations by Automakers (*FDI_M*)[3]		Overseas Operations by Suppliers (*FDI_S*)[4]	
	OLS[2]	PPML[2]	OLS	PPML
(a) Positive Coefficients	71	67	56	51
Significant	53	46	22	31
p-value < 0.01	36	30	8	24
0.01 < p-value < 0.05	13	11	7	5
0.05 < p-value < 0.1	4	5	7	2
Insignificant	18	21	34	20
(b) Negative Coefficients	8	12	23	28
Significant	3	6	2	7
p-value < 0.01	0	5	1	2
0.01 < p-value < 0.05	2	0	0	4
0.05 < p-value < 0.1	1	1	1	1
Insignificant	5	6	21	21
Total ((a)+(b))	79	79	79	79

Notes:
[1] I estimate the model (1) by running the regression for 79 products.
[2] OLS is ordinary least squares and PPML is poisson pseudo-maximum-likelihood.
[3] The first and second columns show the numbers of OLS and PPML coefficients relating to overseas operations by automakers (*FDI_M*).
[4] Third and fourth columns show the numbers of OLS and PPML coefficients relating to overseas operations by suppliers (*FDI_S*).

In order to compare the estimation results with those in Blonigen (2001) in a more comparable manner, I classify 79 products into 37 groups and estimate the model (1) for *each* product group.[67] As expected, a wide range of product groups presents complementarities: 21 product groups show positive and significant coefficients of overseas operations by automakers for both OLS and PPML estimations (Table 5.9). However, the interesting finding lies in the product group that does not present the significant coefficient of overseas operations by automakers. In particular, the insignificant coefficients of engine, chassis and body and seat are consistent with the idea that bulky components tend to be produced locally rather than get exported from Japan due to high transportation costs.

The number of positive and significant coefficients of suppliers' overseas operations is more limited: only 10 product groups have positive coefficients which are significant at least at the 10% level. The interesting finding is the positive coefficients for product groups that are likely to have sub-components of auto parts including engine parts, components of electric engine parts, components of lighting/signaling equipment, parts of body, and other parts of motor vehicles. This might suggest the vertical linkage between suppliers (e.g. first and second tier suppliers) also facilitates auto parts exports from the home country. On the other hand, there is no product that shows a substitute relationship between overseas operations by suppliers and auto parts exports from Japan in OLS estimation whereas PPML shows two products (Air conditioners and Bumpers) with the substitution relationship (Table 5.9).

[67] This is because according to the classification of HS code, some products are classified into several HS codes (e.g. tyre and engine. See Appendix 1 for more the details). For example, Tyre has 7 product categories based on HS code (i.e. 401110000, 401120000, 401140000, 401211000, 401212000, 401220000 and 401310000). For simplicity, I group these products into one product group (i.e. Tyres in this case).

Table 5.9: Regression Results by Product Groups[1]

Dependent Variable: Auto Parts Exports from Japan Year: 1993-2008	Overseas Operations by Automakers (*FDI_M*)[2]		Overseas Operations by Suppliers (*FDI_S*)[3]	
	OLS	PPML	OLS	PPML
1 Tyre	0.250**	0.169	0.046	0.161*
2 Glass	0.482***	0.604***	-0.143	-0.166
3 Leaf springs	0.449*	0.567	0.278	0.526
4 Mountings	0.607***	0.587***	0.243	0.474***
5 Engine	0.041	-0.257	-0.058	-0.474
6 Engine parts	0.414***	0.318***	0.246**	0.461***
7 Air Conditioners	0.240	0.175***	0.032	-0.453***
8 Filters	0.510***	0.497***	-0.008	0.019
9 Jacks/hoists	0.405***	0.039	0.110	0.791***
10 Shafts and cranks	0.276***	0.252***	0.184*	0.532***
11 Gaskets	0.292***	0.330***	0.097	0.329***
12 Electric engine parts	0.207**	-0.043	-0.014	0.411
13 Component of electric engine parts	0.138	0.019	0.470***	0.948***
14 Lighting and signaling equipment	0.519***	0.609***	0.032	-0.053
15 Component of lighting/signaling equipment	0.378***	0.252**	0.282**	0.502***
16 Speakers	0.426	0.845***	-0.048	-0.077
17 Car audio and radio	0.169	0.173	0.299	0.515
18 Lamps	1.114**	0.735**	-0.481	0.092
19 Wire harness	0.365***	0.190	0.140*	0.324***
20 Chassis and body	-0.055	-0.241	0.385	0.337**
21 Bumpers	0.496***	0.517***	-0.139	-0.219**
22 Seat belts	0.503**	0.898***	0.262*	0.420***
23 Parts of bodies	0.475***	0.532***	0.179*	0.170*
24 Brake system	0.797**	0.825***	-0.190	0.322**
25 Transmission	0.475***	0.629***	0.261**	0.140
26 Axles	0.736***	0.784***	0.183	0.393***
27 Wheels	0.265***	0.188**	0.208*	0.325***
28 Shock absorbers	0.498***	0.165	-0.013	0.383***
29 Radiators	0.361***	0.386**	0.091	0.099
30 Mufflers and exhaust pipes	0.263**	0.300***	0.028	0.083
31 Clutches	0.534***	0.441***	0.156	0.378***
32 Steering wheels	0.456***	0.248**	0.092	0.067
33 Airbags	-0.241	-0.365***	0.937***	1.139***
34 Other parts of motor vehicle	0.424***	0.399***	0.286***	0.484***
35 Motorcycle parts	0.066	0.477*	0.034	-0.140
36 Clocks	0.193	0.602	0.055	0.647**
37 Seats	0.052	-0.152	0.351**	-0.386

Notes:

[1] I estimate the model (1) by running the regression for 37 product groups. Country dummy variables are not controlled because of the small number of observations. Due to the space limitation, standard errors are not reported.

[2] Second and third columns show the coefficients of overseas operations by Japanese automakers measured by the number of employees at automakers` overseas affiliates.

[3] Fourth and fifth columns show the coefficients of overseas operations by Japanese suppliers measured by the number of employees at suppliers` overseas affiliates.

*** p-value<0.01, ** p-value<0.05 and * p-value<0.1.

5.5 Discussions

Through product-by-product analyses, Blonigen (2001) finds that auto parts exports from Japan are positively correlated with overseas operations by Japanese automakers but negatively correlated with overseas operations by Japanese suppliers. The empirical analyses in this study support these findings (Tables 5.8 and 5.9), although the evidence on the latter is much weaker. The panel data analyses, rather, suggest that there is no statistical association concerning the latter but strongly support the former. The interesting questions here are: Why have the empirical analyses in this study found much weaker evidence on the relationship between overseas operations by Japanese suppliers and auto parts exports from Japan? Why is the complementary relationship between overseas operations by Japanese automakers and auto parts exports from Japan robust even after controlling for Japanese suppliers' overseas operations? This section explores these two questions.

Why Is the Substitution Relationship between Overseas Operations by Suppliers and Exports Weak?

The substitution relationship between overseas operations by auto parts suppliers and auto parts exports is consistent with the 'following-leader' pattern of overseas investments by Japanese suppliers – parts suppliers' investment following their customers' (automakers') investments abroad (Head et al 1995, 1999, Banerji and Sambharya 1996, Blonigen et al 2005). When Japanese automakers build production plants abroad, they attempt to transplant the efficient supplier relationships forged locally to the host country to achieve competitive advantages such as a just-in-time inventory system and quality control. The recent development of modularity has also encouraged parts suppliers to follow their customers' overseas investments. The modularity results in large modules (e.g. Cockpit Module, Chassis Module, Axle Module, Front/Rear End Module, Door Module), 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). Thus, the following-leader pattern of overseas investment by auto parts suppliers seems to reduce auto parts exports from Japan.

Nevertheless, the empirical analyses in this study have found only limited evidence of substitution between overseas operations by suppliers and exports of components from Japan. How does this result compare with the finding of Blonigen (2001)? I argue that it is the result of the growing market penetration of Japanese parts suppliers in host counties over time, leading to an increase in total demand for the firms' products (statistical complementarity). In the beginning Japanese suppliers follow the overseas investments of Japanese automakers, predominantly selling their products to automakers. Their customers are limited because they are not yet recognised in the host country market. At this stage, it is expected that the substitution effects of overseas operations by Japanese suppliers on auto parts exports from Japan is strong as found in Blonigen (2001). The time period covered by the empirical analyses of Blonigen (2001) is 1978-1991 suggesting that these were the formative period of overseas operations by Japanese auto parts suppliers. In recent years, Japanese auto parts suppliers such as Denso have been expanding their overseas operations to meet expanding demand from both Japanese and non-Japanese automakers (IRC 2009).[68] This growing market penetration of Japanese parts suppliers tends to increase demand for some parts and components produced in Japan. The time period covered in this study (1993-2008) is representative of these new developments.

Another explanation could be that Japanese MNEs have followed a mixed strategy of combining exports and overseas production over time, leading to weakening substitution effects. Japanese suppliers have attempted to establish production networks in order to position themselves in face better perpetual external shocks such as a rapid appreciation of Japanese yen, economic fluctuations in host country and unforeseen events such as natural disasters, political riot and strike.

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[68] As of 2009, Denso is selling products to GM, Ford and Chrysler in North America, VW, Volvo, Jaguar, Daimler, Audi, Land Rover, Fiat, Iveco, Maserati, Porche, Ford, SEAT, Renault, Alfa Romeo, Ferrari, Lamborghini, Lancia, PSA, and BMW in Europe, GM, BMW, Hyundai, and Tata in Asia (IRC 2009).

Why Are Overseas Operations of Automakers and Exports Complementary?

Japanese automakers have gradually expanded local procurements in host countries. In the case of Toyota local procurements in North America and Europe had reached 80% to 90% by 2009 (IRC 2009). The increasing overseas operations of Japanese parts suppliers and the existence of competitive suppliers enables such a high local procurement in these regions. On the other hand, the local procurement in developing countries is still limited. For example, in China, the local procurement for Land Cruiser is still less than 40% while in India, the local procurements for Innova and Altis are 55% and 35%, respectively (IRC 2009). This low local procurement is mainly due to the absence of competitive suppliers in these countries although components suppliers have begun to follow the automakers in setting up plants there. Thus, many components are imported from Japan. One of the underlying factors that could cause complementary effects of overseas operations by Japanese automakers on auto parts exports from Japan is that over the past two decades developing countries in East Asia, in particular Thailand, Indonesia, China and India, have been emerging as a centre of global production networks for Japanese automakers.

The strong vertical linkages between Japanese automakers and their suppliers can be another factor contributing to the complementary relationship between overseas operations by Japanese automakers and auto parts exports from Japan. The vertical linkages within production networks between Japanese automakers and their suppliers is characterised by a long-standing and stable hierarchical structure of division of labour (Nishiguchi 1994). It is well documented that the nature of the strong vertical network limits the degree of substitutability between local procurement within host countries and auto parts exports from Japan (Swenson 1997, Hackett and Srinivasan 1998). At the same time, the strong vertical network could reduce the complementarity by facilitating the following-leader investment of suppliers that could substitute for local procurement of auto parts exports from Japan. In fact, the estimation results show that the magnitudes of the positive coefficients of overseas operations by Japanese automakers on Japan's auto parts exports are smaller when overseas operations by suppliers are included in the model (Tables 5.4 and 5.5). However, the positive coefficient of overseas operations by Japanese automakers remains statistically significant indicating that the export-creating effect of the vertical linkage is large enough to offset the export-reducing effects. In addition, the coefficients of overseas operations by Toyota are mostly larger than those of overseas operations by Japanese automakers (Compare Table 5.6 with Table 5.4), affirming the role of *keiretsu* in creating the complementary relationship between overseas operations and exports.

5.6 Conclusion

This study has analysed a broader product-level data that enables endogeneity and aggregation bias to be addressed simultaneously. The empirical analyses confirm that auto parts exports from Japan is positively associated with overseas operations by Japanese automakers but negatively correlated with overseas operations by Japanese suppliers. However, the evidence on the latter is rather weaker than that of previous studies, probably involving the existence of statistical complementarity. The robust evidence on the former suggests the existence of economic complementarity. This study concludes that, despite the discovery of substitution effects highlighting the role of aggregation bias, the empirical results suggest that overall the relationship between FDI and exports seems to be more complementary than substitution.

It should be noted that a product-level data employed in this study allows for separation of economic complementarity emanating from vertical networks between upstream and downstream firms but not that of statistical complementarity emanating from the increase in total demand for the firms' products. As discussed in the previous section, the statistical complementarity could be an important factor that makes it difficult to find the substitution relationship between FDI and exports. Thus, the search for substitution effects by separating statistical complementarity would be a future work.

Appendices to Chapter 5

Appendix 5-A: List of Products

	HS Code	*Name of Products*
1	401110000	New pneumatic tyres, of rubber, of a kind used on motor cars (incl. station wagons & racing cars)
2	401120000	New pneumatic tyres, of rubber, of a kind used on buses/lorries
3	401140000	New pneumatic tyres, of rubber, of a kind used on motorcycles
4	401211000	Retreaded pneumatic tyres of rubber, of a kind used on motor cars (incl. station wagons & racing cars)
5	401212000	Retreaded pneumatic tyres of rubber, of a kind used on buses/lorries
6	401220000	Used pneumatic tyres of rubber
7	401310000	Inner tubes, of rubber, of a kind used on motor cars (incl. station wagons & racing cars), buses/lorries
8	700711000	Safety glass (tempered) for vehicles, aircraft, etc
9	700721000	Safety glass (laminated) for vehicles, aircraft, etc
10	700910000	Rear-view mirrors for vehicles
11	732010100	Leaf springs/leaves thereof, iron or steel for motor vehicles
12	830230000	Motor vehicle mountings, fittings, of base metal, nes
13	840731000	Engines, spark-ignition reciprocating, <50 cc
14	840732100	Engines, spark-ignition reciprocating for motorcycle, 50-250 cc
15	840732900	Engines, spark-ignition reciprocating for others, 50-250 cc
16	840733100	Engines, spark-ignition reciprocating for motorcycle, 250-1000 cc
17	840733900	Engines, spark-ignition reciprocating for others, 250-1000 cc
18	840734100	Engines, spark-ignition reciprocating for motorcycle , over 1000 cc
19	840734900	Engines, spark-ignition reciprocating for others, over 1000 cc
20	840820000	Engines, diesel, for motor vehicles
21	840991100	Parts for spark-ignition engines for motor vehicle
22	840999100	Parts for diesel and semi-diesel engines for motor vehicle
23	841430100	Compressors for refrigerating equipment for motor vehicle
24	841520000	Air cond used in vehicle
25	842123000	Oil/petrol filters for internal combustion engines
26	842131000	Intake air filters for internal combustion engines
27	842542000	Hydraulic jacks/hoists except for garages
28	848310000	Transmission shafts and cranks, cam and crank shafts

29	848340100	Gearing, ball screws, speed changers, torque converter
30	848350000	Flywheels and pulleys including pulley blocks
31	848410000	Gaskets of metal sheeting, including sandwich type
32	848420000	Mechanical seals
33	850211000	Generating sets, diesel, output < 75 kVA
34	850212000	Generating sets, diesel, output 75-375 kVA
35	850710000	Lead-acid electric accumulators (vehicle)
36	851110000	Spark plugs
37	851120000	Ignition magnetos, magneto-generators and flywheels
38	851130100	Distributors and ignition coils for motor vehicle
39	851140100	Starter motors for motor vehicle
40	851150000	Generators and alternators
41	851180100	Glow plugs & other ignition or starting equipment nes for motor vehicle
42	851190100	Parts of electrical ignition or starting equipment for motor vehicle
43	851220000	Lighting/visual signalling equipment nes
44	851230000	Sound signalling equipment
45	851240000	Windscreen wipers/defrosters/demisters
46	851290000	Parts of cycle & vehicle light, signal, etc equipment
47	851821100	Single loudspeakers, mounted in enclosure for motor vehicle
48	851829100	Loudspeakers, nes for motor vehicle
49	851840200	Audio-frequency electric amplifiers for motor vehicle
50	852719990	Radio receivers, portable, non-recording for motor vehicle
51	852721000	Radio receivers, external power, sound reproduce/record
52	852729000	Radio receivers, external power, not sound reproducer
53	853910000	Sealed beam lamp units
54	853921000	Filament lamps, tungsten halogen
55	853929100	Filament lamps, except ultraviolet or infra-red, nes for motor vehicle
56	854430000	Ignition/other wiring sets for vehicles/aircraft/ship
57	870600100	Motor vehicle chassis fitted with engine for buses
58	870600200	Motor vehicle chassis fitted with engine for trucks
59	870600900	Motor vehicle chassis fitted with engine for others

60	870710000	Bodies for passenger carrying vehicles
61	870790000	Bodies for tractors, buses, trucks etc
62	870810000	Bumpers and parts thereof for motor vehicles
63	870821000	Safety seat belts for motor vehicles
64	870829000	Parts and accessories of bodies nes for motor vehicles
65	870830000	Brake system and its parts
66	870840000	Transmissions for motor vehicles
67	870850000	Drive axles with differential for motor vehicles
68	870870000	Wheels including parts/accessories for motor vehicles
69	870880000	Shock absorbers for motor vehicles
70	870891000	Radiators for motor vehicles
71	870892000	Mufflers and exhaust pipes for motor vehicles
72	870893000	Clutches and parts thereof for motor vehicles
73	870894000	Steering wheels, columns & boxes for motor vehicles
74	870895000	Airbags and its parts
75	870899900	Motor vehicle parts nes for others
76	871411000	Motorcycle saddles
77	871419000	Motorcycle parts except saddles
78	910400000	Instrument panel clocks etc for vehicles/aircraft etc
79	940120000	Seats, motor vehicles

Source: *Nihon Jidosha Buhin Kogyo Kai* [Japan Auto Parts Industries Associations (JAPIA)].

Appendix 5-B: List of Countries

1	Argentina	21	Malaysia	41	Serbia
2	Australia	22	Mexico	42	Singapore
3	Austria	23	Morocco	43	Slovakia
4	Belgium	24	Netherlands	44	South Africa
5	Brazil	25	New Zealand	45	Spain
6	Bulgaria	26	Nicaragua	46	Sri lanka
7	Canada	27	Nigeria	47	Sweden
8	Columbia	28	Norway	48	Switzerland
9	Czech Republic	29	Pakistan	49	Taiwan
10	Ecuador	30	Panama	50	Tanzania
11	Finland	31	China	51	Thailand
12	France	32	Peru	52	Tunisia
13	Germany	33	Philippines	53	Turkey
14	Hong Kong	34	Poland	54	UAE
15	Hungary	35	Portugal	55	Ukraine
16	India	36	Republic of Korea	56	United Kingdom
17	Indonesia	37	Romania	57	United States of America
18	Iran	38	Russia	58	Venezuela
19	Ireland	39	Samoa	59	Viet Nam
20	Italy	40	Saudi Arabia		

CHAPTER 6

The Role of *Keiretsu* in Global Production Sharing: The Case of Toyota Motors

6.1 Introduction

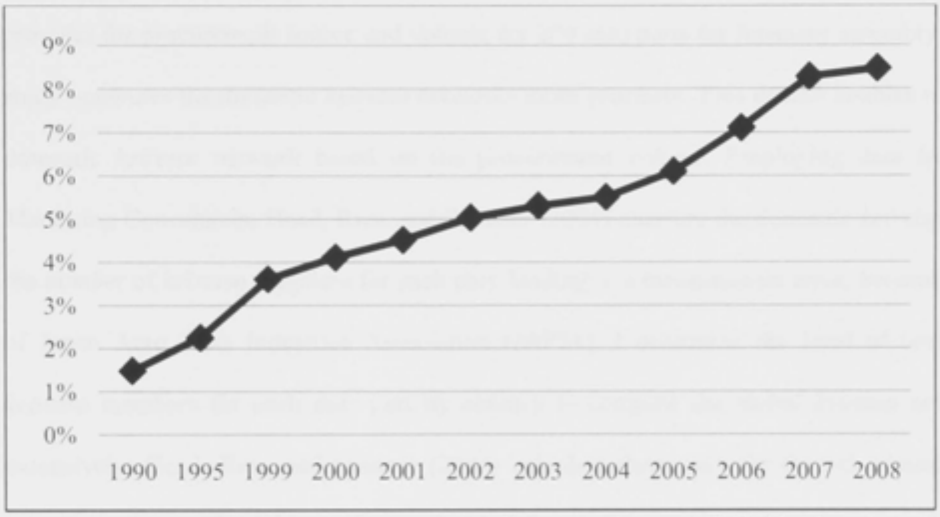
The consensus view based on studies conducted in the 1980s and 1990s is that foreign auto parts suppliers have difficulty in penetrating the Japanese market due to the existence of *keiretsu* networks.[69] The *keiretsu* in the automobile industry is based on a close and long-standing business relationship between an assembly maker and particular parts suppliers through personnel exchange, share cross-holding, and information sharing. Lawrence (1991, 1993) and Fung (1991) argued in the context of the US-Japan trade friction during the 1980s and 90s that the domestic *keiretsu* networks reduced auto parts imports in Japan because the preferential business relationship imposes market entry costs on non-*keiretsu* members.

Despite the dominant role of domestic *keiretsu* networks in auto parts procurements by Japanese automakers, Japan has experienced a notable increase in auto parts imports, albeit from a very low base, in recent years (Figure 6.1). The share of auto parts in domestic vehicle production in Japan amounted to only 1% in 1990 but had risen to 8% in 2008. Then, an interesting question arises: who exports to Japan? Greaney (2003) and Head, Ries, and Spencer (2004) discuss the role

[69] The *keiretsu* is of two forms: horizontal *keiretsu* and vertical *keiretsu*. Horizontal *keiretsu* refers to business groups, loosely connected through a common "main bank" affiliation, dispersed interlocking shareholdings, director ties, supplier-purchaser ties, a common corporate name, and president clubs. Some have antecedents in the four major pre-war zaibatsu (Mitsubishi, Mitsui, Sumitomo and Fuji). The vertical *keiretsu* includes manufacturing or supply chain groups: suppliers, subcontractors, and distributors organised in a vertical division of labour around a large industrial firm such as Hitachi, Toyota, or Matsushita. This study focuses on the vertical *keiretsu*. For more details on *keiretsu* in the auto industry, refer to Odaka et al (1988), Asanuma (1988), and Miwa (1996).

of the global *keiretsu* networks that could possibly have an import-creating effect with lower costs of market entry in Japan: the global production networks established by Japanese automakers and their parts suppliers might result in exchange of auto parts across borders within the *keiretsu* networks.

Figure 6.1: Share of Auto Parts Imports of Domestic Vehicle Production in Japan



Note: The share is calculated by the import value of auto parts in Japan divided by the value of domestic auto production in Japan.
Sources: Compiled from Ministry of Finance in Japan and Ministry of Economy, Trade and Industry

By examining the case of Toyota Motors, this study explores the role of *keiretsu* for auto parts imports in Japan. Two hypotheses will be tested based on previous studies: (1) the domestic *keiretsu* network has trade-reducing effects and (2) the global *keiretsu* network has trade-creating effects. The inclusion of both domestic and global *keiretsu* is statistically significant in explaining Japanese parts and components imports. To the extent that both *keiretsu* effects work differently, the inclusion of both variables allows for capturing the *net* effects of the two forms of *keiretsu* networks. This study examines a parts-level data set covering 44 auto parts and 32 countries for the years 1988, 1999, and 2008. Multiple countries including both developed and developing countries are included because the trade pattern of P&C have been diversified reflecting the expansion of global production sharing (Table 4.5). The consideration of auto parts enables control for products-specific characteristics that might affect investment and exports simultaneously.[70] The years included in the study are due to data availability. The Poisson pseudo-maximum likelihood (PPML) estimator is employed as an appropriate estimation method.

The innovation of this study is the use of more accurate and extensive measurements of variables. First, employing information from Industry Research and Consulting (IRC), which provides the procurement source and volume for 200 auto parts for Japanese assembly makers, this study computes the domestic *keiretsu* networks more precisely. This dataset enables measuring the domestic *keiretsu* network based on the procurement *volume*. Employing data from Dodwell Marketing Consultants, Head, Ries, and Spencer (2004) measure the domestic *keiretsu* network by the *number* of *keiretsu* suppliers for each part, leading to a measurement error. Second, making use of Japan Auto Parts Industries Association (JAPIA), I determine the level of employment by *keiretsu* members for each auto part by country to compute the global *keiretsu* networks more extensively: Head, Ries, and Spencer (2004) calculate them only for the US whereas this study calculates for multiple countries worldwide. The wide coverage of countries leads to a more generalised result.

This chapter is organised as follows. The next section summarises the previous literature. Section 6.3 discusses an estimation strategy, data and measurement of variables. Section 6.4 reports and discusses the results. Section 6.5 concludes.

6.2 *Keiretsu* and Trade: What is New?

Table 6.1 provides a summary of the relevant empirical works for the effect of *keiretsu* on trade.[71] This study is most closely related to Head, Ries, and Spencer (2004) and makes two contributions.

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[70] For example, bulky auto parts tend to be produced near the assemblers rather than exporting from home however it is difficult to measure the bulkiness of each auto part.

[71] For the literature on the impact of *keiretsu* on foreign direct investment (FDI), see Smith and Florida (1994), Head, Ries and Swenson (1995) and Blonigen, Ellis and Fausten (2005).

First, this study analyses the role of *keiretsu* with wider scope. While all previous works focused on bilateral trade between the US and Japan, this study involves many countries in the context of global production sharing. Second, using data sources, which provide information on *keiretsu* members in more detail, this study is able to examine the role of *keiretsu* more accurately and extensively than previous studies (Section 6.3.3 for more details).

Table 6.1: Summary of Empirical Literature on *Keiretsu* Effect on Trade

Author	Variable Explained	Measurement/ Data Source	Data/ Technique	*Keiretsu* 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 US exports 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	Dummy: if a firm belongs to *keiretsu*, it equals 1 otherwise 0 / Nikkei (1993)	Cross section/ Tobit	Domestic network (+)
Head, Ries, and Spencer (2004)	US 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 (+)

Notes: Signs in parentheses show the predicted impact of network effects on trade. OLS represents ordinary least squares estimator.

Both the theoretical and empirical early 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, 1993, Fung 1991, Spencer and Qiu 2000, Qiu and Spencer 2002). This view was prominent in the policy debate on the US-Japan trade friction during the 1980s and 90s. In recent years, there has been some research on the impact of the "global *keiretsu* network", which has trade-creating effects arising from the cost advantage of members within *keiretsu* networks in market penetration.

The works of Spencer and Qiu (2000) and 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.[72] Hence, the 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.[73]

More recent work by Baldwin and Ottaviano (2001) and Greaney (2003) has emphasised that the global *keiretsu* network promotes international trade by providing *keiretsu* members with a cost advantage in market access. 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

[72] There are several forms of RSI such as physical asset specificity (e.g. customised 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).

[73] Saxonhouse (1989) takes an opposite position, arguing that Japan's trade pattern can be explained by factor endowment as with 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.

and buyer belong to the *keiretsu*, the costs could be much lower compared to non-*keiretsu* members because they already have mutual trust based on a close and long-standing business relationship. This theoretical prediction is supported by Head, Ries and Spencer (2004) and Greaney (2005, 2009). Head, Ries and Spencer (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 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 displayed 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 important role in determining Japan's trade.

6.3 Empirical Analysis

This section discusses the econometric modeling, estimation methods and data. This study examines the effects of domestic and global *keiretsu* networks on auto parts imports in Japan. The hypotheses to be tested are (1) the domestic *keiretsu* network reduces auto parts trade and (2) the global *keiretsu* network increases trade.

6.3.1 The Model

Head, Ries and Spencer (2004) formulated their model based on the incomplete contract theory. An assembly maker procures each auto part from either insiders or outsiders. Insiders are members of a vertical network that make relation-specific investments (RSI) creating rents to reduce assembly costs for an assembler. The higher rent created by RSI implies that insiders have more advantages to sell their products to the assembler than outsiders. Outsiders sell their products at a competitive market price equal to their marginal costs. The model predicts that the production scale of an assembly maker and the cost advantage for outsiders plays a crucial role for the determinant of the boundary between insiders and outsiders.

Taking into account the locations of insiders and outsiders, Head, Ries, and Spencer (2004) extend this vertical networks model to trade. Assuming that vertical networks are transplanted in other countries, the transplant procures auto parts from insiders in the same country as the assembly makers because auto parts with high asset specificity such as engine parts require geographical proximity between an assembly maker and its parts suppliers. This is mainly because these kind of parts need the close communication and information-sharing due to the complexity of the engine requiring the higher level of RSI. However, the vertical networks mitigate the necessity of this geographical proximity, leading to the possibility that insiders in the US exports to transplants of the assembly makers in other countries. Correspondingly, the members of Toyota *keiretsu* located in the U.S could be an insider when exporting to customs ports in the Aichi prefecture.

The vertical networks model predicts that the US auto parts exports depend on an average scale of assembly makers (y_j), the efficacy of the RSI (ρ_{ij}), and the probability that a transplant in other countries imports auto parts from insiders located in the US conditional on not purchasing the part from a local insider (Υ_{ij}): $EX_{ij} = f(y_j, \rho_{ij}, \Upsilon_{ij})$ where subscripts i stands for parts and j denotes an exporting country to the US. The model envisages that the larger average scale of assembly makers (y_j) has negative impacts on US auto parts exports because it expands the local procurement from insiders by a transplant in country j instead of imports. The higher efficacy of the RSI (ρ_{ij}) for each part in other countries is also expected to decrease the imports due to the fact that auto parts with a higher level of RSI require geographical proximity between insiders, leading to the decreasing role of imports. However, as discussed above the vertical networks across countries probably facilitate the US exports.

Based on the theoretical prediction, Head, Ries and Spencer (2004) formulate the specification model for regression analysis extending the gravity equation. With a particular focus on US auto parts exports to Japan, the domestic and global *keiretsu* networks established by the Japanese automotive industry are incorporated into the model in order to examine the role of *keiretsu*. While the domestic *keiretsu* network is one of the important factors that enhances the efficacy of the RSI, the global *keiretsu* network is expected to increase the probability of reverse imports through the vertical networks. Modifying the model specification by Head, Ries, and Spencer (2004) to an appropriate form for auto parts imports of Toyota *keiretsu* from multiple countries[74], I formulate the model

$$\ln(IM_{kjt}/CAR_t) = \beta_1 \ln DIS_j + \beta_2 \ln GDP_{jt} + \beta_3 \ln PGDP_{jt} + \beta_4 DKN_{kt} + \beta_5 \ln GKN_{kjt} + \alpha_0 + \sum_{i=2}^{44} \alpha_k \, Dpart_k + \delta_0 + \sum_{j=2}^{3} \delta_t \, Dyear_t + u_{kjt} \quad (6.1)$$

where subscripts k stands for auto parts: k =1, ... , 44, j for the j th country, from which Toyota *keiretsu* imports. t stands for the year: 1988, 1999, and 2008. Since this study focuses only on imports of Toyota *keiretsu*, there is no particular advantage in normalising all observations of the dependent variable by the GDP of Japan. Therefore it is omitted from the equation. Note that *DKN*, a domestic *keiretsu* network has a level form because it is calculated as the share. The variables are

[74] There are mainly three differences in model specification from Head, Ries and Spencer (2004). First, I exclude variables related to trade costs for the U.S because this study focuses on auto parts imports of Toyota *keiretsu* located in Japan. I leave only distance and GDP per capita. Second, I also omit other variables that probably affect US auto parts exports because they are not relevant to the imports of Toyota *keiretsu* or just negligible. For example, according to the model by Head, Ries and Spencer (2004), the production share of foreign car makers in the Aichi prefecture affects auto parts imports of Toyota *keiretsu*. However, there are no assembly plants owned by foreign assembly makers in the Aichi prefecture therefore it is negligible. Correspondingly, the direct investments in the Aichi prefecture by foreign parts suppliers substitute for the supplier exports from abroad, leading to a negative impact on auto parts import of Toyota *keiretsu*. However, there are only 15 foreign subsidiaries located in the Aichi prefecture in 2008, dealing with the automobile sector (Foreign Affiliated Companies in Japan compiled by Toyo Keizai 2008). Third, this study does not account for the impact of relation specific investment (RSI) assumed to increase the procurement volume within the *keiretsu* network because of data limitation. This study integrates in-house production by Toyota Motors into the *keiretsu* network as already explained.

listed and defined below, with the postulated sign of the estimated coefficient for the explanatory variables in brackets.

IM	Imports value of auto parts *k* from country *j* through ports in Aichi prefecture at time *t*
CAR	Number of domestic production of Toyota Motors in Japan at time *t*
DIS	Distance in kilometres from Japan to country *j* (-)
GDP	GDP calculated by PPP at country *j* at time *t* (+)
PGDP	GDP per capita calculated by PPP at country *j* at time *t* (+)
DKN	Domestic *keiretsu* network measured by the share of auto parts *k* procured within Toyota *keiretsu* at time *t* in terms of volume in Japan (-)
GKN	Global *keiretsu* network measured by the number of employees of plants of Toyota *keiretsu* for auto parts *k* in country *j* at time *t* (+)
Dpart	Parts specific effect dummy variables
Dyear	Year specific effect dummy variables
u	Unobserved error terms associated with the dependent variable

As firm-level trade data are not available, auto parts imported through custom ports in the Aichi prefecture are used as a proxy for imports of Toyota *keiretsu*. Distance is included as a proxy for shipping costs and other costs associated with time lags such as Internet charges, and spoilage as well as costs associated with physical distance such as ignorance of foreign customs and tastes. Geographical 'distance' is still a key factor in determining international transport costs, in particular shipping costs (Hummels, 1999). The use of GDP as an explanatory variable of bilateral trade flows is normally justified by the modern theory of trade under imperfect competition; one will choose to trade more with a large country than with a small country because it has more variety to offer and customers like variety. The size of GDP can also be treated as a proxy for market thickness, which is the important determinant of transaction costs. A thicker market increases the ease with which an auto maker and parts suppliers can match with local firms in foreign countries (Spencer 2005). Therefore, greater GDP is expected to have a positive impact on trade. The GDP per capita is a proxy to measure the effect of the quality of logistics. More developed countries have better ports and communication systems that facilitate trade by reducing the cost of maintaining the 'service links' involved in global production sharing (Jones and

Kierzkowski 1990).

The domestic *keiretsu* network is included as the measurement of potential import-reducing effects. This effect has been studied against the backdrop of the US-Japan trade friction during the 1980s and 1990s. As Lawrence (1991, 1993), Fung (1991), and Head, Ries, and Spencer (2004) found, it is predicted that higher domestic *keiretsu* involvement for auto parts reduces imports because of the preferential choice of domestic procurement within the *keiretsu* network rather than overseas procurement. It is also reasonable to regard auto parts with higher *keiretsu* involvement as more specialised parts, requiring physical closeness between auto makers and suppliers. Therefore, a higher degree of domestic *keiretsu* network might lead to less imports. The global *keiretsu* network is contained as the measurement of possible trade-creating effect, which is the main interest of this study. The members within *keiretsu* have an advantage in accessing the Japanese market due to lower transaction costs within the global *keiretsu* network. The Denso in Thailand, for example, is more easily able to sell their products to Toyota Motors in Japan because of the lower transaction costs based on the long-standing business history than local firms located in Thailand. Therefore, a higher presence of Toyota *keiretsu* in a country is expected to increase auto parts exports to Toyota *keiretsu*.

The endogeneity problem is always a concern for econometric analysis. The more likely source of the endogeneity in this study is the omitted variables. I discuss this problem in connection with the domestic and global *keiretsu* networks. One possible omitted variable is the number of non-*keiretsu* parts suppliers importing auto parts through the customs ports in the Aichi prefecture. Due to data availability, I estimate the model by excluding this variable. However, regarding the domestic *keiretsu* network, the domestic procurement choice by Toyota Motors is highly likely to be independent from the omitted variable because it has been based on business history, making the domestic *keiretsu* network uncorrelated with this omitted variable.

On the other hand, the global *keiretsu* network measured by the number of employees of

Toyota *keiretsu* in each country for each part seems to be correlated with this omitted variable. This is because the *keiretsu* members do not always trade within the *keiretsu* network. For example, Denso, one of the *keiretsu* suppliers of Toyota Motors, in Thailand might sell products to non-*keiretsu* parts suppliers located in the Aichi prefecture. Hence, as the scale of Toyota *keiretsu* becomes larger in a foreign country, the imports of non-*keiretsu* parts suppliers is expected to grow. This positive correlation between them results in an upward-biased estimate of the global *keiretsu* network. The seriousness of this bias depends on the degrees of both the possible coefficient of this omitted variable and the correlation between the global *keiretsu* network and this omitted variable. However, I insist that this bias can be negligible for two reasons. First, the former is likely to be positive but quite small because Toyota *keiretsu* includes almost all of the large firms including Toyota Motors, tier1 and tier2 suppliers located in the Aichi prefecture: the sizes of non-*keiretsu* firms are expected to be quite small since they are mainly tier3 and tier4 suppliers less involved with trade activity. Therefore the variations caused by the omitted variable hardly affect the dependent variable. Second, the latter also appears to be very low. As Greaney (2003) shows, the cost benefit for the market penetration is only realised when the buyer and seller belong to the *keiretsu*. In this case, the buyer is not a *keiretsu* member therefore the sellers have to compete with other foreign parts suppliers on the same condition, leading to less influence from the global *keiretsu* networks. In addition, it is difficult to think that the members of Toyota *keiretsu* sell their products to tier3 and tier4 non-*keiretsu* suppliers.

Another problem needs to be considered. No matter how serious the bias of the global *keiretsu* network, the estimate of the domestic *keiretsu* network must be biased. The degree of this bias depends on the level of the correlation between them. Fortunately, the degree of correlation is quite low: 0.05 thus the affect on the estimate of the domestic *keiretsu* network is irrelevant.[75] In

[75] I acknowledge that this bias affects other independent variables including distance, GDP, and GDP per capita since the global *keiretsu* network and they are correlated. The domestic and global *keiretsu* networks, however, are variables of interest in this study therefore I assume their correlations are zero for simplicity.

short, to the extent that other dependent variables are not correlated with domestic and global *keiretsu* networks, the estimates of domestic and global *keiretsu* networks are susceptible to upward biasness, but this is likely to be negligible.

6.3.2 Estimation Method

The long-standing practice in estimating the constant-elasticity model is to use the OLS estimator. However, this is susceptible to an inconsistency of OLS estimator for two reasons (Silva and Tenreyro, 2006). First, the validity of estimating equation (1) is critically dependent on an assumption that the expected value of the error term is independent from any values of explanatory variables. If these assumptions are violated, OLS estimation of the constant elasticity model provides inconsistent estimates. Second, the existence of observations with zeroes creates two problems: a log (0) cannot be defined and trade with negative value might occur. Normally, a large amount of studies drop the zero observations or replace log (0) with log (1). However, these procedures generally cause the inconsistency of the OLS estimator. In addition, a simulation study demonstrates that estimation results by OLS are badly biased under heteroskedasticity.

In place of OLS, Santos Silva and Tenreyro (2006) propose a Poisson pseudo-maximum likelihood (PPML) estimator as an alternative method, using a multiplicative form of the constant-elasticity model. They demonstrate that this alternative is less susceptible to a bias of estimates. One of the useful properties of the PPML estimator is a wide range of applicability including panel data analysis (Woodridge 1999). Extending the PPML estimator to this study, equation (1) can be rewritten as the multiplicative form of the constant-elasticity model with the conditional expectation

$$E(IM_{kjt}/CAR_t | DIS_j, GDP_{jt}, PGDP_{jt}, DKN_{kt}, GKN_{kjt}, Dpart_k, Dyear_t)$$
$$= exp\left(\beta_1 \ln DIS_j + \beta_2 \ln GDP_{jt} + \beta_3 \ln PGDP_{jt} + \beta_4 DKN_{kt} + \beta_5 \ln GKN_{kjt} + \alpha_0 + \sum_{i=2}^{44} \alpha_k \, Dpart_k + \delta_0 + \sum_{j=2}^{3} \delta_t \, Dyear_t\right) \quad (6.2)$$

This solution not only offers a feasible alternative to the OLS estimator but also removes the issue of observations with zero since the dependent variable is no longer transformed into the log form.

It is reported that the OLS and PPML cause different estimation results. In the connection with variables relevant to this study, Santos Silva and Tenreyro (2006), covering a cross section of 136 countries in 1990 demonstrate that the OLS overestimates exporter's income and distance elasticity comparing with the PPML estimator. Employing panel data for 22 OECD countries during 1988 to 1990, Siliverstovs and Schumacher (2007) show that while the distance is overestimated by the OLS, the exporter's income elasticity is almost same. Following these studies, this chapter also reports both estimation results of the OLS and PPML.

6.3.3 Data

Disaggregated Japan trade data classified according to the harmonised system (HS) are from the Trade Statistics of Japan published by the Ministry of Finance. This source provides trade data not only by commodity and country but also by customs ports. Using this data source, I classify auto parts into 44 types at the 9 digit-level. Import through the custom ports in the Aichi prefecture is taken as a proxy for the global sourcing of Toyota *keiretsu*. Although efforts to reduce measurement errors of this variable have been made as already explained in Section 4.4.2, I acknowledge that the trade through customs in the Aichi prefecture still captures trade by other companies, which are not members of the Toyota *keiretsu*. To the extent that this error in measurement is uncorrelated with independent variables, however, the estimates are not biased (Wooldridge 2002).[76] The data on distance are from Jon Havenman's International Trade Data and GDP and GDP per capita data from the World Development Indicators.

One of the contributions of this study is to measure the domestic *keiretsu* network more accurately and the global *keiretsu* network more extensively. In order to demonstrate how accurate the measurements of the domestic *keiretsu* network employed are, I compare it with Head, Ries, and Spencer (2004), which uses Dodwell Marketing Consultants (1990) as the data source. Table 6.2 demonstrates the calculation method employed by Head, Ries, and Spencer (2004) using the case of aluminum wheels. The first section shows the "number" of each procurement source by the assembly makers. The second and third sections represent fractions of In-House production and procurement from *keiretsu* suppliers, respectively. The last section shows the weights of each assembly maker based on the share of their domestic production. While Toyota Motors produce aluminum wheels in house and procure from two *keiretsu* suppliers, Nissan sources these from one *keiretsu* supplier and three non-*keiretsu* suppliers. Then Toyota's fractions are 1/3 for In-House production and 2/3 for outsourcing to the *keiretsu* suppliers. Now Toyota's domestic *keiretsu* network is calculated as $0.27(= 2/3 \times 0.4)$. The same calculation is applied to other assembly makers and it then turns out that the domestic *keiretsu* network of the aluminum wheel in Japan is 0.49.

The main problem with this measure is that it is calculated by the "number" of *keiretsu* suppliers. This is mainly because the "number" fails to capture the relative importance of each procurement source. In other words, the calculation using the "number" is based on the assumption that the procurement volumes from each parts supplier are homogeneous. As a consequence, this measurement is highly likely to cause a misleading estimation result.

To address this problem, I measure the domestic *keiretsu* network based on the "volume" in place of the "number" using a different data source from previous studies. This information is

[76] In other words, it is assumed that the measurement error is just a random reporting that is independent of the explanatory variables.

taken from "Automotive parts sourcing in Japan: Japanese OEM procurement from domestic suppliers for 200 products lines" compiled by Industry Research and Consulting (IRC). This source provides data on procurement sources including in-house, *keiretsu* suppliers, and non-*keiretsu* suppliers and a procurement volume of 200 auto parts for 12 Japanese car makers located in Japan, such as Toyota, Honda, Nissan, Mitsubishi and other main auto makers. Since the IRC has published this report every three years since 1984, it enables an exploration of the change in domestic procurement activities of Japanese assembly makers. This report is only published in Japanese.

Table 6.2: Measurement of Domestic *Keiretsu* Network by Head, Ries, and Spencer (2004)

Procurement source	Toyota	Nissan	Honda	Mitsubishi
In-House	1	0	1	0
Keiretsu supplier	2	1	2	2
Non-*Keiretsu* suppliers	0	3	1	3
Fraction In-House	1/3	0	1/4	0
Fraction *Keiretsu*	2/3	1/4	2/4	2/5
Weight	40%	25%	25%	10%

Source: Author's calculation based on Head, Ries, and Spencer (2004)

Table 6.3 shows Toyota's procurement activity of aluminium wheels using IRC (2008). The first column represents the procurement sources, the second column is the procurement volume (in thousands) from each source and the third column shows the share of each source. The share of In-House production is 0.19 (=159.5/860.5) and the counterpart of keiretsu suppliers is 0.63(=543/860.5). The domestic *keiretsu* network of Toyota *keiretsu* for the aluminium wheel is calculated as 0.82 (= 0.19 + 0.63). For the concordance with trade data, the domestic *keiretsu* networks of 44 auto parts classified are calculated in the same manner.

Table 6.3: Measurement of Domestic *Keiretsu* Network by this Study

Procurement source	Procurement volume	Share
In-House	159.5	0.19
Keiretsu supplier	543	0.63
Non-*keiretsu* suppliers	158	0.18
Total	860.5	1

Note: The unit of procurement volume is thousand.
Source: "Automotive parts sourcing in Japan: Japanese OEM procurement from domestic suppliers for 200 products lines 2008, compiled by IRC.

I now turn to the explanation of the measure of the global *keiretsu* network employed in this study. Using Dodwell Marketing Consultants (1997), Head, Ries, and Spencer (2004) calculate the global *keiretsu* network as the "share" of employment level of Japanese parts producers out of the total employment across Japanese firms for each auto part in the US. In contrast, this study measures it by the "number" of employees of overseas plants owned by members within the Toyota *keiretsu* for each auto part. Justification might be asked for the use of not the "share" like the domestic *keiretsu* networks but the "number instead. The validation lies in the context of this study: while Head, Ries, and Spencer (2004) is in the context of the US-Japan trade friction, this study is in the context of global production sharing, leading to the measurement of the global *keiretsu* network for multiple countries. The "number" of employees enables capture of the variations of the global *keiretsu* networks for each auto part between countries. The "share" fails to capture these variations.

The data source for the number of employees is the "Japanese Automotive Parts Industry" compiled by the Japan Auto Parts Industries Association (JAPIA). This annual publication (in Japanese) provides information on overseas plants of Japanese auto parts makers including the establishment year and the number of employees by country. However, JAPIA does not give information on the employment level of Japanese assembly makers in foreign countries. To complement this, I employ "Actual condition on Toyota group" compiled by the IRC, providing the data on the number of employees in each plant owned by Toyota Motors worldwide.

Table 6.4 demonstrates the example of aluminum wheels in the case of Toyota. Suppose Toyota Motors domestically not only produces aluminum wheels in-house but also procures them from *keiretsu* suppliers and non-*keiretsu* suppliers, which have overseas plants in China, Germany and Samoa. Toyota Motors have factories with 20,000 employees in China but 0 in Germany and Samoa. *Keiretsu* suppliers have overseas plants with 60,000 employees in China, 6,000 in Germany and 0 in Samoa. From these, the global *keiretsu* network of Toyota *keiretsu* is calculated as 80,000 (= 20,000 + 60,000) in China, 6,000 (= 0 + 6,000) in Germany and 0 (= 0 + 0) in Samoa. The global *keiretsu* network is calculated in the same way by 44 auto parts.

Table 6.4: Measurement of Global *Keiretsu* Network

Procurement source	China	Germany	Samoa
In-House	20,000	0	0
Keiretsu supplier	60,000	6,000	0
Non-*keiretsu* suppliers	3,500	1,300	400
Total	83,500	7,300	400

Sources: "Automotive parts sourcing in Japan: Japanese OEM procurement from domestic suppliers for 200 products lines 2008, compiled by IRC.

6.4 Results

Table 6.5 presents OLS and PPML estimates. Columns 1-3 report OLS estimates of the model in (6.1). The first column shows a preliminary specification that omits part- and year-specific effects. As expected, the coefficient of distance is negative and statistically significant, suggesting the importance of proximity for trade. The coefficient of GDP is positive and significant at the 1% level, suggesting that market thickness matters. The coefficient predicts that 1% larger GDP leads to an increase in exports to Japan by 0.5%. However the coefficient of the GDP per capita is positive but not significant. This might reflect the shift in the source country of auto parts toward Asian countries over the past two decades: in 1988 only Taiwan and South Korea were in the top ten while in 2008 there were 7 Asian countries such as China, Thailand and Vietnam in the top ten

(Table 4.9). This suggests the existence of production sharing with Asia, aiming to reduce production costs. Controlling for distance, GDP, and GDP per capita, the amount of auto parts imports by the Toyota *keiretsu* depends on the global *keiretsu* network at a significant level but not on the domestic *keiretsu* network. The elasticity of the global *keiretsu* network on imports per vehicle is 0.29, predicting that an increase in the global *keiretsu* network by 1% enhances imports per vehicle by 0.29%.

Column 2 reports the result that controls for both part and year specific effects. Compared to 19% in the previous specification, the goodness-of-fit substantially improves: the independent variables together explain about 34% of the variation in auto parts imports per vehicle. Signs and significance levels are broadly similar. The impact of distance is nearly the same, the effect of market thickness is larger, but the impact of the global *keiretsu* network is smaller. However, the effect of the global *keiretsu* network is still significant not only statistically but also economically, supporting the evidence that *keiretsu* has a trade-creating effect. The 1% increase of the global *keiretsu* network boosts imports per vehicle by 0.17%. Following Head, Ries, and Spencer (2004), column 3 reports the results with the separation of the domestic *keiretsu* network into the In-House network and *keiretsu* supplier network. As can be seen, the results are almost same as column 2.

The estimation results derived from the PPML estimator in the same manner as OLS are reported using columns 4-6 in Table 6.5. Comparing with the OLS estimates, there are three differences. First, as Santos Silva and Tenreyro (2006) find, the effects of distance and economic size are overestimated using the OLS estimator. Controlling for parts and year specific effects, the poisson estimates of distance and GDP reported in column 5 are -0.68 and 0.29 whereas counterparts of OLS shown in column 2 are -1.06 and 0.69. Secondly, as can be seen in columns 4-6, the PPML estimator makes exporter GDP per capita turn out to be statistically significant with a negative sign. This result is unexpected and quite different from the OLS estimates shown in columns 1-3. This might reflect the fact that Toyota *keiretsu* has expanded from developed countries to developing countries especially East Asian countries with lower levels of GDP per capita. Thirdly, the OLS estimator underestimates the impact of the global *keiretsu* network: controlling for parts and year specific effects, the poisson estimate is 0.25 but the OLS estimate is 0.17. Now, the elasticity of the global *keiretsu* network is almost the same size as counterparts of GDP. On the contrary, the PPML estimates demonstrate that the domestic *keiretsu* network does not reduce imports at a significant level. As can be seen in column 6, even if the domestic *keiretsu* network is broken into the In-House and domestic supplier networks, the result remains unchanged. These results are consistent with the OLS estimation results. Based on these estimation results I conclude that in the case of Toyota, the domestic *keiretsu* network does not reduce auto parts imports while the global *keiretsu* network increases auto parts imports.

Table 6.5: Estimation Results of Auto Parts Imports per Vehicle

Estimator:	OLS			PPML		
Dependent Variable:	log(*IM/CAR)*			*IM/CAR* > 0		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Log Distance	-1.03***	-1.06***	-1.07***	-0.6***	-0.68***	-0.68***
	(0.11)	(0.1)	(0.1)	(0.12)	(0.09)	(0.09)
Log Exporter's GDP	0.53***	0.69***	0.68***	0.13	0.29*	0.28*
	(0.06)	(0.06)	(0.06)	(0.14)	(0.12)	(0.11)
Log Exporter's GDP per	0.15	0.14	0.14	-0.29**	-0.21*	-0.21*
capita	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Domestic *Keiretsu*	-0.29	-0.72		1.94	-1.77	
Network	(0.66)	(0.97)		(1.93)	(1.84)	
In-House Network			-0.29			-6.46
			(1.93)			(5.3)
Keiretsu Supplier Network			-0.67			-4.05
			(1.72)			(4.2)
Log Global *Keiretsu*	0.29***	0.17***	0.17***	0.52***	0.25*	0.26*
Network	(0.03)	(0.04)	(0.04)	(0.15)	(0.11)	(0.1)
Parts Specific Effects	No	Yes	Yes	No	Yes	Yes
Year Specific Effects R-	No	Yes	Yes	No	Yes	Yes
Squared	0.19	0.34	0.34			
Pseudo R-Squared				0.19	0.4	0.4
Observations	1,176	1,176	1,171	1,176	1,176	1,171
Years: 1988, 1999,2008						

Notes: * Significant at 5%, ** Significant at 1% and *** Significant at 0.1%

The robust standard errors are shown in parentheses below estimates. The coefficients of part-specific and year-specific are not reported for space limitations.

6.5 Conclusion

The purpose of this chapter was to answer the question: who exports auto parts to Japan? I have examined the role of *keiretsu* for Japan's auto parts imports by testing two hypotheses: (1) the domestic *keiretsu* network reduces auto parts imports and (2) the global *keiretsu* network increases imports. The empirical analyses of Toyota *keiretsu* found that the first hypothesis is not supported but the second hypothesis holds. The former is a new finding, which runs counter to the established view supported by a large number of studies. That the effect of domestic *keiretsu* networks on Japanese imports is not statistically insignificant might suggest the underlying change in the nature of procurement activity. As Stepffensen (1998) points out, the development of information technology and its prevalence are facilitating a shift in the assembler-supplier relationships in Japan from the closed form with stability to the open form with flexibility. For example, the CAD/CAM (computer-aided design and computer-aided manufacturing) and Japanese automotive Network eXchange (JNX) would reduce the communication and transaction costs when overseas suppliers do business with Japanese automakers.[77] Therefore, the increase in Japan's auto parts imports over the past decades might be attributed to the growth in overseas procurement by Japanese automakers.

The results suggest that the overseas subsidiaries of the *keiretsu* members play an important role in facilitating imports. That the main source of auto parts imports in Japan has been Asia implies the existence of global production sharing: Japanese automakers and suppliers would re-import auto components assembled with cheap labour from their overseas subsidiaries.

Does the unprecedentedly large scale of recalls by Toyota Motors in 2010 have any implication for the role of *keiretsu*? I would argue that this recall problem might cause Japanese auto makers to strengthen the global *keiretsu* network in future. Take the accelerator pedal problem that caused nearly eight millions recalls worldwide by Toyota Motors as an example. The

[77] On the contrary, Morita and Nakahara (2004) shows that the information-technology revolution can strengthen several aspects of vertical networks.

outsourcing of accelerator pedals and pedal assembly to CTS Corp, the maker of the throttle-pedal assemblies that Toyota identified as one of the causes of "unintended acceleration", started when Toyota's vehicle assembly in the US outstripped the capacity of the part's original Japanese manufacturer, Denso Corp (Financial Post 26th Jan 2010). This traumatic experience may result in Toyota`s procurements from pure local suppliers (such as CTS Corp in US) to global sourcing from companies within the *keiretsu* network (such as Denso Corp in Japan). Thus there is the possibility that that the role of global *keiretsu* network will become even more important in years to come. The sourcing within the global *keiretsu* network might cost more than non-*keiretsu* suppliers due to transportation costs, exchange rate fluctuation, time lags, and other factors. However, this recent trouble has made Toyota recognise that damage to reliability and corporate image are more expensive than procurement costs.

CHAPTER 7

Conclusion

7.1 Summary

The purpose of this thesis has been to contribute to the empirical literature on global production sharing by examining the case of the Japanese automobile industry in the global context. The key hypothesis is that the unique characteristics of the production system and supplier relationships in Japan matter in determining the extent and modality of production sharing. The analysis focuses specifically on the implications of the 'following-leader' pattern (that is, parts and components suppliers following car producers) of Japanese overseas investment and of interlocking relationships among firms (*keiretsu* networks).

The analysis was conducted at both macro and micro levels. The macro-level analysis has examined whether the following-leader investment and *keiretsu* network serve to differentiate the patterns of Japan's parts and components and final trade from that of the other five major auto-producing countries in the world (the United States, Germany, France, Italy, and Sweden). The methodology involved estimating an augmented gravity model using a newly-constructed three-dimensional (country-partner-product) panel dataset. The micro-level analysis was carried out for the export and import sides, separately. The export-side analysis looked at whether the following-leader investments by Japanese suppliers substitute or complement auto parts exports from Japan. The import-side analysis examined the role of *keiretsu* networks through an in-depth case study of the supplier network of Toyota Motors, focusing specifically on the role of domestic and overseas parts suppliers in determining Toyota's global procurement patterns of parts and components. The analysis made use of a unique product-level dataset.

The thesis begins with a descriptive analysis of the globalisation process of the automobile industry, focusing on the comparative performance of Japanese automakers in the global automobile industry. Chapter 3 undertakes a comparative analysis at the macro-level to investigate the uniqueness of Japan's global production sharing. Chapter 4 to 6 reports the results of micro-level analyses. Chapter 4 provides a profile of the Japanese automobile industry with a particular focus on Toyota including history, management method and production networks for empirical analyses in subsequent chapters. Chapter 5 explores the effect of the following-leader investment by Japanese suppliers on auto parts exports from Japan. Chapter 6 deals with how domestic and global *keiretsu* networks impact on auto parts imports through an in-depth case study of the supplier network of Toyota Motors. Chapter 7 summarises the key findings and policy implications.

7.2 Findings and Contributions

A number of interesting results emerge from the analyses. Econometric analysis in Chapter 3 has shown that overseas operations of automakers from TPCs and P&C exports are complements however Japan's P&C exports is less interlinked with the overseas operations of Japanese automakers than is the case for other TPCs. The weak complementary effect of production networks on exports can be partly attributed to the following-leader type of Japanese investments that substitutes exports from home. In terms of imports, it has been shown that overseas operations facilities P&C imports for TPCs however the hypothesis that Japan's P&C imports are more interlinked to overseas operations of Japanese auto makers than is the case for other TPCs, failed to be supported.

There are two contributions from Chapter 3. First, this is the first comparative analysis of the trade performance of Japanese automotive industry. Previous studies on Japan's peculiarity in auto trade have focused on the bilateral trade with the US and Western European countries (Saxonhouse 1989, Fung 1991, Lawrence 1991). The comparative perspective is meaningful because production systems and supplier relationships in the Japanese auto industry are different from counterparts in the US and European auto industries (McMillan 1990, Dicken 2003, Womack et al 2007, Sturgeon et al 2008). Moreover, the existing literature on the comparative analysis of Japan's uniqueness has been limited to the descriptive (Encarnation 1992, Diehl 2001). Second is the extensiveness of the dataset. The newly-constructed three-dimensional (country-partner-product) panel dataset over the period from 2001 to 2008 was analysed in this study. The most important feature of this dataset is that the data are disaggregated to the product-level, enabling me to control for product-specific characteristics that are difficult to capture but might affect trade flows (Head, Ries and Spencer 2004).

Chapter 5 has demonstrated that in contrast to previous research, there is a complementary relationship between overseas operations by Japanese suppliers and auto parts exports from Japan, rather than a substitute relationship. However, the trade-creating effect of overseas operations by suppliers is not statistically significant. Rather, the increase in auto part export from Japan is explained by growing overseas operations by Japanese automakers, suggesting the important role of vertical networks in facilitating trade in P&C. It has also been found that product attributes affects the relationship between these two variables. For example, that the body and chassis does not show the complementary relationship between FDI and exports suggest bulky components tend to be procured locally rather than imported from home due to high transportation costs.

There are two novelties in the analysis in Chapter 5. The first is to go one step further by carefully examining not only the relationship between FDI and exports itself but also its magnitude and attributes of each product. The product-level analysis allows me to find the coexistence of products with a complementary relationship and products with a substitute relationship although the former are more dominant. Another novelty is the use of a more up-to-date and comprehensive product-level dataset than previous studies such as Blonigen (2001) and Head, Ries, and Spencer (2004), allowing me to reduce the possibility of selection bias and to generalise the findings.

According to the analysis in Chapter 6, there is no evidence to support the hypothesis that the domestic *keiretsu* network constrains auto parts imports to Japan, suggesting the underlying change in the nature of procurement activity of Japanese automakers. This is in contrast to the inferences of previous studies such as Lawrence (1991, 1993) and Fung (1991). One possibility is that the development of information technology and its prevalence would reduce communication and transaction costs dramatically, leading to growth in global sourcing by Japanese automakers. It has been also found that the global *keiretsu* network increases P&C imports in Japan, suggesting that the overseas subsidiaries of the *keiretsu* members play an important role in facilitating imports. That the main source of auto parts imports in Japan has been Asia implies the existence of the global production sharing: Japanese automakers and suppliers would re-import auto components assembled with cheap labour from their overseas subsidiaries.

The innovation of Chapter 6 is the use of more accurate and extensive measurements of variables. First, employing information from Industry Research and Consulting (IRC), which provides procurement source and volume for 200 auto parts for Japanese assembly makers, this study computes the domestic *keiretsu* networks more precisely. This dataset enables measurement of the domestic *keiretsu* network based on the procurement *volume*; employing data from Dodwell Marketing Consultants, Head, Ries, and Spencer (2004) measure the domestic *keiretsu* network by the *number* of *keiretsu* suppliers for each part, probably leading to measurement error. Second, making use of Japan Auto Parts Industries Association (JAPIA), I determine the level of employment by *keiretsu* members for each auto part by country to capture the global *keiretsu* networks more extensively: Head, Ries, and Spencer (2004) calculate them only for the US whereas this study uses multiple countries worldwide. The wide coverage of countries included in the study leads to a more generalised result.

7.3 Policy Implications

Policy-makers are always interested in the automobile industry because it has a significant influence on domestic economies.[78] The automobile industry comprises a wide range of supporting industries including assembly, auto parts, glass, rubber, iron, metal, fiber, plastic, electronics and information technology. In addition, the automobile industry is closely related to service sectors such as finance, insurance, transportation, parking, lease, distribution and maintenance. The strong backward and forward linkages of the automobile industry not only create employment but also have a great ripple effect on a whole economy.

Industrialisation through the automobile industry has been regarded as an important development strategy among policy-makers in developing countries. Import substitution within a protected market, frequently combined with a national car policy, was part of the industrialisation policy in many developing countries. Western European countries, the United States, Japan and South Korea succeeded in developing the automobile industry by protecting their manufactures against competition from imports following the Industrial Revolution, sometimes for extended periods.[79] On the other hand, developing economies in Asia and South America failed to develop their own industrial capacity due to a lack of entrepreneurs as well as a limited domestic market and immature supporting industries, leading to high costs, poor quality and slow productivity improvement.

In recent years market-oriented policy has attracted more attention from policy-makers due to the remarkable success of some developing countries such as Thailand that has emerged as a

[78] The automobile industry also relates to environmental issues such as CO2 emissions, air pollution and noise pollution as well as safety issues. However, I focus on the economic aspect in line with the purpose of this study.

[79] Ford and GM dominated the Japanese market between 1926 and 1935. For example, 91% of total domestic supply was occupied by Ford and GM in 1934. In order to eradicate the dominance by American automakers and establish an autarkic automobile industry, the Japanese government launched a protectionist policy called the Automotive Manufacturing Industries Act in 1936. In addition, the government brought Ford and GM to a head further, raising import tariff on CBU, engines, and other auto parts: 70% on CBU and 60% on engines respectively. Three years later, after the enactment of the Automobile Act, the government eventually succeeded in kicking the US auto makers out of Japan (*Nihon Jidosha Kogyokai* 1988).

major hub of automotive production for the regional and global markets (Athukorala and Kohpaiboon 2009). Thailand has succeeded in its capacity building not by its own national automaker but multinational automakers that invested into Thailand. In other words, Thailand has been able to take advantage of opportunities to join the global production networks established by multinational automakers.

The findings of this study, in line with the policy debate on industrialisation, have three policy implications for developing economies, especially for Asian countries where Japanese automakers and suppliers have played a dominant role. One result that stands out from Chapter 3 is that global production sharing takes many forms, reflecting different production systems and supplier relationships among automakers. This casts a caution on the relevance of the standard trade flow analysis in understanding global production sharing in the automotive industry. The finding shows that the domestic-oriented procurement activity by Japanese automakers tends to reduce cross-border sourcing of P&C, leading to a lower degree of global production sharing. However, this does not mean that the production sharing itself diminishes. It seems that in the automotive industry, production sharing within national boundaries of host countries, which is not captured in trade data, plays a much more significant role than cross-border production sharing. I claim that policy-makers could be misled without explicitly taking into account heterogeneous firm behaviours and industry-specific characteristics.

The result in Chapter 5 suggests the weak backward linkage between Japanese firms and local suppliers in developing countries. The backward linkage is crucial for industrialisation in developing countries through technological spillover, productivity gains, and job creation. This finding has implications for designing policies by developing host countries to facilitate development of backward linkages between MNE affiliates involved in the auto industry and local auto part suppliers. First is that it is crucial for the government to know what multinationals want. For example, Japanese car makers and parts suppliers pay more attention to just-in-time delivery ability and capacity building over time as well as costs and quality. Second, the local government needs to take initiatives to bridge the "information gap" between buyer and seller because some multinationals in the host counties are not aware of the local firms that satisfy the requirements imposed by buyers (UNCTAD 2001). Finally, incentives such as tax breaks that facilitate transaction with local firms might be helpful to strengthen the backward linkage in developing countries.

The result in Chapter 6 suggests that the global *keiretsu* network could have a trade-creating effect operating through trade among overseas subsidiaries of parts and component suppliers. In other words, the global *keiretsu* network could provide the host country with more opportunities to participate in global production networks. A relevant question for policy-makers in developing countries is how to attract Japanese automakers and suppliers. Two factors matter. First is the policy environment. As shown in the case of Thailand, a market-conforming policy is an important factor to attract inward investments. Strict local content requirement, high tariff rate, and ownership restriction could estrange investors. Second is supporting industries. As already mentioned, the automobile industry comprises a wide range of supporting industries. Since automakers and suppliers attempt to increase their local procurements in order to avoid costs associated with transportation and exchange rate as well as establish a just-in-time delivery, the developed supporting industries in a host country could favour them.

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