Global Backward and Forward Multiplier Analysis: The Case Study of Japanese Automotive Industry

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Abstract Thailand is one of the major investment destinations of Japanese automotive industry. In addition to the major automobile companies, Japanese investors have also invested in small and medium enterprises in automobile parts and components in Thailand. Since the 1980s, the automotive industry has been a driving force of the Thai economy. Currently, Thailand is one of the world largest automobile producers. In this study, we analyze the global input-output table. Backward and forward multiplier analysis is used to conduct interindustry linkage analysis of Japanese automotive industry. Unlike a conventional trade statistical analysis, this global input-output table allows for the analysis of interconnection between economic sectors around the world. From our multiplier analysis, Japanese automotive industry has high backward linkages domestically. Internationally, its forward multiplier is among the top five after metal, chemicals and rubber, electrical and optical equipment, and wholesale and retail. In addition, structural path analysis is performed to illustrate the paths of global value chain of Japanese automotive industry. The analysis reveals the interconnection of automotive and other industries in Japan, Thailand, and the rest of the world.

Keywords Automotive industry • Input-output • Structural path analysis

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1 Introduction

The automotive industry consists of a wide range of activities including design, research and development, manufacturing, and marketing. These economic activities have taken place worldwide. In particular, Japanese automotive industry has taken the advantages of global value chain. As we can observe in a car assembling process, a manufacturer uses intermediate inputs from around the world. After the 1985 Plaza Accord, Japanese automotive industry has moved their production bases to many developing countries. These Japanese direct investments in other countries not only benefit the economies of the countries where factories are located but also the economy of Japan. However, increasing global interdependence of automotive producers may cause disruption in production if a producer of intermediate inputs in one country halts its production due to some difficulties from an economic crisis or disaster. In 2011, for example, the global supply chain of automotive industry faced difficulty from the impacts of Tsunami in Japan and flood in Thailand, emphasizing the vulnerability of the global value chain.

Thailand is one of the major investment destinations of Japanese automotive industry. It is the largest automobile producer in Southeast Asia and one of the largest producers in the world. Japan is the largest investor in Thailand in terms of amount of investment and number of projects. In addition to the major automobile companies such as Toyota, Honda, Nissan, Mazda, and Isuzu, Japanese investors have also invested in small and medium enterprises in automobile parts and components in Thailand. The automotive industry is a driving force of the Thai economy. It ranks the fifth largest export industry and accounts for ten percent of the GDP of the country, employs more than 500,000 direct skilled labor jobs, and creates spillover effects to other industries in the economy.

In this study, we analyze the global input-output table, which is publicly available on the World Input-Output Database (WIOD). In addition, we introduce the methodology of extending the WIOD table to cover additional data of Thailand based on sectoral distribution data from Global Trade Analysis Project (GTAP). Backward and forward multiplier analysis is used to conduct interindustry linkage analysis of Japanese automotive industry. Unlike a conventional trade statistical analysis, this global input-output table allows for the analysis of interconnection between economic sectors around the world. From our multiplier analysis, Japanese automotive industry has higher backward linkages domestically. Internationally, its forward multiplier is among the top five after metal, chemicals and rubber, electrical and optical equipment, and wholesale and retail. In addition, structural path analysis is performed to illustrate the influence of global value chain of Japanese automotive industry. The analysis reveals the strong interconnection of automotive industry and other industries in Japan, Thailand, and the rest of the world.

2 Japanese Automotive Industry

The legacy of Japanese automotive industry began in the 1910s. Nissan and Toyota started their business in 1933 after the World War I. But not until the 1950s, the Japanese automotive industry focused on producing their products mainly for commercial. The automotive industry has been one of the leading sectors in Japanese economy since the 1960s (Nakamura 1995). The industry grew rapidly during the 1970s–1990s because of domestic market and export. Japanese cars have become popular around the world since the 1970s due to their reasonable price and reliability. In 1980, Japan became the largest carmaker (OICA 2015). The following year, the USA imposed the voluntary export restriction on Japanese cars to limit the number of Japanese cars to the USA. In response, the Japanese automakers established assembly plants in the USA to locally produce cars in the USA (Feenstra 1984). In addition, as a result of the 1985 Plaza Accord, many Japanese automotive companies increased their investment abroad. The Japanese investment on automotive industry oversea has played an important role in the world economy.

2.1 Japanese Automotive Industry in Thailand

Thailand is currently one of the major car and automotive parts manufacturers in the global production network. Most of major automobile manufacturers, such as Hino, Honda, Mazda, Mitsubishi, Nissan, Suzuki, Toyota, Hyundai, Chevrolet, Ford, Chevrolet, BMW, Mercedes-Benz, MG, and Volvo, are located in Thailand. Among automotive manufacturers, there are approximately 690 Tier 1 automotive suppliers, employing more than 250,000 workers, and 1,700 Tier 2 and 3 companies, employing approximately 175,000 workers. More than half of the world leading automotive manufacturers have factories in Thailand (Thailand Board of Investment 2012). There are approximately 2,400 automotive suppliers in Thailand; more than 700 suppliers are original equipment manufacturers (OEMs) (Kohpaiboon and Athukorala 2010). This makes Thailand one of the strongest automotive suppliers producing all necessary automotive parts, from interior parts to exterior parts and from simple nuts and bolts to sophisticated engines.

The automotive industry began in Thailand in the 1960s (Rasiah 1999). Before that time, all cars in Thailand were imported from aboard. In 1961, Thailand government implemented "1960 Industrial Investment Promotion Act" to provide incentives for the automakers. Anglo-Thai Motor Company started to operate as the first automotive assembly plant in Thailand. The production of cars was 525 units in 1961 and became 10,667 units in 1970 (Thailand Development Research Institute 1993). In 1988, approximately 87,000 vehicles or 0.3 % of world automobile

production was from Thailand (Thailand Development Research Institute 1997). In 2000, Thailand has become a major car producer with 411,721 units accounted for 0.7 % of world production capacity (OICA 2015). The domestic automobile production surpassed one million units in 2005 (Techakanont 2011). In 2010, Thailand produced 1,644,513 units of automobiles or 2.0 % of world production (OICA 2015).

In 2011, there was great flood in the central region of Thailand. One of the hardest hit industries by the flood is an automobile industry, which was already damaged by the East Japan Quake in March 2011. Many factories of automobile makers located in the flooded areas were forced to temporarily shut down. Some factories were under water for weeks and were forced to close for several months after this flood. However, only a year later, in 2012 the automobile industry quickly recovered from these disasters. The exceptionally high growth in both production and sales sectors in Thailand in 2012 pushed the car production to the new record, 2,429,142 units accounted for 7.2 % of world production (OICA 2015). In 2014, Thailand ranked as the largest carmaker in ASEAN and the 12th largest producer in the world (down from ninth in 2013) (OICA 2015).

The automotive industry has become highly export oriented since the mid-1990s, with exports increasing from 14,000 units of automobile in 1996 to 152,835 units in 2000 and 895,855 units in 2010. Vehicle exports have been accounted for more than 50 % of production since 2007. Over the period 2000–2011, exports accounted for 46.5 % of production (Thailand Automotive Institute 2012).

Japanese firms have played an important role in the automotive industry in Thailand since the beginning in the 1960s. In 1962, Nissan and Siam Motor established the first Japanese automobile plant in Thailand. In the following year, Toyota built a plant and began its operation. Isuzu and Hino have operated their businesses since 1963 and 1964, respectively. In 1974, the joint venture of Mazda Motor and local firm was founded. Honda started assembling cars in Thailand in 1984. Suzuki started producing 100,000 cars in Thailand in 2013. The Japanese automakers have assembled more than 85 % of car production in the past two decades (see Table 1). Many Japanese automotive firms have invested in Thailand to create their global and regional hubs of their productions.

2.2 Global Value Chain and World Input-Output Databases

Over the past few decades, the nature of international trade has changed dramatically due to increasing interconnectedness of production processes across many countries, with each country specializes in a particular stage of the production of goods (Hummels et al. 2001). These economic activities create international supply chain, which are the network of producers who produce raw and intermediate products in different regions and countries, and increase the flow of exports and imports among these countries. Hummels et al. (2001) call these dramatic changes in international

Table 1 Production capacity of automobile in Thailand (units)

	1989	1994	1999	2003	2005	2006	2013
Toyota	24,000	100,000	200,000	240,000	350,800	450,000	790,000
Mitsubishi	40,000	126,600	160,000	190,200	170,200	208,000	510,000
Isuzu	27,400	83,200	140,600	189,600	200,000	200,000	400,000
GM	–	–	40,000	40,000	100,000	160,000	250,000
Mazda	7200	8400	135,000	135,000	135,000	155,000	300,000
Ford							150,000
Nissan	23,520	96,500	113,100	124,000	102,000	134,400	370,000
Honda	8,220	39,000	70,000	80,000	120,000	120,000	270,000
Suzuki							100,000
Hino	9600	9600	9600	28,800	28,800	28,800	n.a.
Daimler	2340	4600	14,900	18,100	16,300	16,300	n.a.
YMC	12,000	12,000	12,000	12,000	12,000	12,000	n.a.
Volvo	6000	6000	6000	6000	10,000	10,000	100,000
BMW	–	–	–	–	10,000	10,000	3000
Total	160,280	485,900	901,200	1,063,700	1,255,100	1,576,500	3,243,000
Japanese ratio	87.31 %	95.35 %	91.91 %	92.85 %	88.18 %	86.15 %	84.49 %

Source: Kohpaiboon and Athukorala (2010)

trade "vertical specialization"—the use of imported inputs to produce exported outputs—and find that about 25 % of global trade could be categorized as a part of this vertical trade. A decade later, Escaith et al. (2010) find that the expansion of international supply chains contributed to an increase in trade elasticity, and over 50 % of the value of global trade was in the shipment of raw materials and intermediate inputs for production. Hayakawa (2007) also finds that increasing expenditure on intermediate goods is a contributing factor to rapid growth of trade in machinery parts in East Asia.

This increasing interdependence of different economic sectors across the globe has developed a need for more comprehensive databases that can be used to analyze such phenomenon. Global Trade Analysis Project (GTAP) was founded in the early 1990s as a network for researchers interested in global analysis issues. GTAP serves as a framework for multilateral trade analysis and provides data, models, and resources. Nonetheless, GTAP database is still needed to be adjusted to reflect more accurate trade balance. To analyze value added from international supply chain, Ahmad et al. (2011), Daudin et al. (2009), Johnson and Noguera (2012), and Koopman et al. (2008, 2011) used the GTAP database and found the values of trade balance have to be adjusted to reflect the volume of international shipment of intermediate goods. In Koopman et al. (2011), when adjusted, the US trade deficit to China may decrease about 30–40 %.

The notion of accounting for international supply chain has established a collaboration to create a global input-output database. Based on the data structure concept and applications of Leontief and Strout (1963) and Sanyal and Jones (1982),

the World Input-Output Database (WIOD) was constructed by Dietzenbacher et al. (2013). The WIOD is a result of the compilation of 1995–2011 annual statistics of international trade and production structure of 35 sectors and 40 economies. The development of WIOD tables leads to the widespread application, especially for a deeper and broader insight of global production network. These WIOD tables are also main data sources for Timmer et al. (2013) and Ottaviano et al. (2014) to study impacts of the global production network on European economy. However, there is a limitation on a specific country's application due to the limited number of economies covered in the original data set. Therefore, this study introduces the methodology of extending the WIOD table to cover additional data of a specific economy. The method is described in the following section.

3 Methodology

3.1 World Input-Output Database Tables

World Input-Output Database (WIOD) serves as an important data system for analyzing the global value chain of Japanese automotive industry in this study. The WIOD contains sectoral transactions of 35 sectors in 40 economies from 1995 to 2011. Table 2 shows the sectors in WIOD, and Table 3 shows a list of countries included in WIOD. WIOD consists of four major components: world table, national table, socioeconomic accounts, and environmental accounts.

Since Thailand is not a country on the list of WIOD table, it is necessary to modify WIOD table so that it explicitly shows the trade and production statistics of Thailand. There are two major steps involved in this modification procedure. First, the dimension of WIOD table must be adjusted so that it is compatible with those of GTAP's global trade data because GTAP data is the main source of Thailand trade and production data. The second step involves consolidating two sources of data from WIOD and GTAP to formulate a modified WIOD table. In this study, 2007 data are used because it is the latest matching year for both WIOD table and GTAP data (Puttanapong 2015).

In the first step, WIOD table has been aggregated into the set of eight economies and 26 commodities. The aggregation is done in the General Algebraic Modeling System (GAMS) platform, and the GAMS code is developed based on computational techniques suggested by Corong (2007a, b), Jensen (2005), and Rutherford (2003). Countries are grouped based on the degree of trading partner with Thailand. The countries in the modified WIOD are (1) European Union (EU) countries, (2) the United States of America (USA), (3) China (CHN), (4) Japan (JPN), (5) South Korea (KOR), (6) Taiwan (TWN), (7) Thailand (TH), and (8) the rest of the world (ROW). The objective of data aggregation is to maintain the maximum number of sectors in WIOD and maintain the computability with GTAP's data. Table 4 shows

Table 2 Sectors in World Input-Output Database (WIOD)

Sector	Description
1	Agriculture, hunting, forestry, and fishing
2	Mining and quarrying
3	Food, beverages, and tobacco
4	Textiles and textile
5	Leather and footwear
6	Wood and products of wood and cork
7	Pulp, paper, printing, and publishing
8	Coke, refined petroleum, and nuclear fuel
9	Chemicals and chemical
10	Rubber and plastics
11	Other nonmetallic minerals
12	Basic metals and fabricated metals
13	Machinery, NEC
14	Electrical and optical equipment
15	Transport equipment
16	Manufacturing NEC; recycling
17	Electricity, gas, and water supply
18	Construction
19	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
20	Wholesale trade and commission trade, except of motor vehicles and motorcycles
21	Retail trade, except of motor vehicles and motorcycles; repair of household goods
22	Hotels and restaurants
23	Other inland transport
24	Other water transport
25	Other air transport
26	Other supporting and auxiliary transport activities, activities of travel agencies
27	Post and telecommunications
28	Financial intermediation
29	Real estate activities
30	Renting of m&eq and other business activities
31	Public admin. and defense, compulsory social security
32	Education
33	Health and social work
34	Other community, social, and personal services
35	Private households with employed persons

the list of 26 sectors in the modified WIOD table in comparison with ISIC Rev. 3.1 code, classification in the original WIOD table, and GTAP sectors.

The GTAP's global trade data is extracted by using GTAPAgg, which is the GTAP software for data aggregation. Like the aggregated WIOD table, GTAP data contains 26 commodities of eight economies. Three major data sets for Thailand from the GTAP's data are the social accounting matrix (SAM), imports, and exports.

Table 3 Countries included in World Input-Output Database (WIOD)

European Union			North America	Latin America	Asia and Pacific
Austria	Germany	Netherlands	Canada	Brazil	China
Belgium	Greece	Poland	USA	Mexico	India
Bulgaria	Hungary	Portugal			Japan
Cyprus	Ireland	Romania			South Korea
Czech Republic	Italy	Slovak Republic			Australia
Denmark	Latvia	Slovenia			Taiwan
Estonia	Lithuania	Spain			Turkey
Finland	Luxembourg	Sweden			Indonesia
France	Malta	UK			Russia

In the second step, using the data from GTAP, the value of Thailand domestic economy and its international trades are disaggregated from the rest of the world in the WIOD table. With this procedure, 27 new rows and columns representing Thailand's production sectors are added to the WIOD table. To fill in the details of Thailand's production, the value of uses of imported intermediates in the WIOD table is extracted proportionally to the value of Thailand SAM from GTAP. All values in the rest of the world are then adjusted by subtracting with the value of Thailand to maintain the identical values of the total sums of each row and each column to the original WIOD table. The consolidation of the WIOD table and GTAP's data yields the global input-output table explicitly with Thai economy. The structure of the new input-output table is shown in Fig. 1.

3.2 Structural Path Analysis

Structural path analysis (SPA) can be employed as an extension of the input-output analysis to identify and measure flows in economy (Defourny and Thorbecke 1984). SPA decomposes the input-output multipliers and identifies a network of paths that are transmitted in the economic system. For more information of SPA, see Defourny and Thorbecke (1984), Azis and Mansury (2003), Lenzen (2007), and Anantsuksomsri and Tontisirin (2014). We calculated the multiplier effects of world input-output tables using the MATLAB code, originally developed by Cornell University Center for Advanced Computing (CAC). The CAC's MATLAB code improves the efficiency of multiplier calculation by implementing code on a modern matrix-oriented platform and can execute approximately 100 times faster than the original Visual Basic-based multiplier effect calculator software, MATS, developed by Berkeley Economic Advising and Research (Cornell University Center for Advanced Computing 2008).

Table 4 A Comparison of Sector Classification in the Modified WIOD Table, ISIC Rev. 3.1 Code, Original WIOD Table, and GTAP

New sector classification for consolidated WIOD table		ISIC Rev. 3.1 code	Original WIOD's sector classification	GTAP sector
1	Agriculture, hunting, forestry, and fishing	01–05	C1	prd, wht, gro, v_f, osd, c_b,
				pfb, ocr, prc, ctl, oap, rmk, wol, fsh, frs
2	Mining and quarrying	10–14	C2	coa, oil, gas, omn
3	Food, beverages, and tobacco	15–16	C3	cmt, omt, mil, sgr, ofd, vol,
				b_t
4	Textiles and textile products	17–19	C4–C5	tex, wap, lea
5	Wood and products of wood and cork	20	C6	lum
6	Pulp, paper, paper, printing, and publishing	21–22	C7	ppp
7	Coke, refined petroleum, and nuclear fuel	23	C8	p_c
8	Chemicals and rubber	24–25	C9–C10	crp
9	Other nonmetallic mineral	26	C11	nmm
10	Basic metals and fabricated metals	27–28	C12	i_s, nfm, fmp
11	Machinery	29	C13	otn
12	Electrical and optical equipment	30–33	C14	ele, ome
13	Transport equipment	34–35	C15	mvh
14	Manufacturing	36–37	C16	omf
15	Electricity, gas, and water supply	40–41	C17	ely, gdt, wtr
16	Construction	45	C18	cns
17	Wholesale and retail and hotels and restaurants	50–55	C19–C22	trd
18	Inland transport	60, 63	C23, C26	otp
19	Water transport	61	C24	wtp
20	Air transport and others	62	C25	atp
21	Post and telecommunications	64	C27	cmn
22	Financial intermediation	65–66	C28	ofi, isr
23	Real estate activities and renting	70–74	C29–C30	obs
24	Public admin and defense and health and education	75, 80, 85	C31–C33	osg
25	Other community, social, and personal services	90–95	C34–C35	ros
26	Private households with employed persons	–	–	dwe

Source: Puttanapong (2015)

	EU Industry	USA Industry	CHN Industry	JPN Industry	KOR Industry	TWN Industry	TH Industry	ROW Industry	
EU Industry	EU's intermediate use of domestic output	Intermediate use by USA (imported from EU)	Intermediate use by CHN (imported from EU)	Intermediate use by JPN (imported from EU)	Intermediate use by KOR (imported from EU)	Intermediate use by TWN (imported from EU)	Intermediate use by TH (imported from EU)	Intermediate use by ROW (imported from EU)	Final Demand of EU
USA Industry	Intermediate use by EU (imported from USA)	USA's intermediate use of domestic output	Intermediate use by CHN (imported from USA)	Intermediate use by JPN (imported from USA)	Intermediate use by KOR (imported from USA)	Intermediate use by TWN (imported from USA)	Intermediate use by TH (imported from USA)	Intermediate use by ROW (imported from USA)	Final Demand of USA
CHN Industry	Intermediate use by EU (imported from CHN)	Intermediate use by USA (imported from CHN)	CHN's intermediate use of domestic output	Intermediate use by JPN (imported from CHN)	Intermediate use by KOR (imported from CHN)	Intermediate use by TWN (imported from CHN)	Intermediate use by TH (imported from EU)	Intermediate use by ROW (imported from EU)	Final Demand of CHN
JPN Industry	Intermediate use by EU (imported from JPN)	Intermediate use by USA (imported from JPN)	Intermediate use by CHN (imported from JPN)	JPN's intermediate use of domestic output	Intermediate use by KOR (imported from JPN)	Intermediate use by TWN (imported from JPN)	Intermediate use by TH (imported from JPN)	Intermediate use by ROW (imported from JPN)	Final Demand of JPN
KOR Industry	Intermediate use by EU (imported from KOR)	Intermediate use by USA (imported from KOR)	Intermediate use by CHN (imported from KOR)	Intermediate use by JPN (imported from KOR)	KOR's intermediate use of domestic output	Intermediate use by TWN (imported from KOR)	Intermediate use by TH (imported from KOR)	Intermediate use by ROW (imported from KOR)	Final Demand of KOR
USA Industry	Intermediate use by EU (imported from TWN)	Intermediate use by USA (imported from TWN)	Intermediate use by CHN (imported from TWN)	Intermediate use by JPN (imported from TWN)	Intermediate use by KOR (imported from TWN)	TWN's intermediate use of domestic output	Intermediate use by TH (imported from TWN)	Intermediate use by ROW (imported from TWN)	Final Demand of TWN
TH Industry	Intermediate use by EU (imported from TH)	Intermediate use by USA (imported from TH)	Intermediate use by CHN (imported from TH)	Intermediate use by JPN (imported from TH)	Intermediate use by KOR (imported from TH)	Intermediate use by TWN (imported from TH)	TH's intermediate use of domestic output	Intermediate use by ROW (imported from TH)	Final Demand of TH
ROW Industry	Intermediate use by EU (imported from ROW)	Intermediate use by USA (imported from ROW)	Intermediate use by CHN (imported from ROW)	Intermediate use by JPN (imported from ROW)	Intermediate use by KOR (imported from ROW)	Intermediate use by TWN (imported from ROW)	Intermediate use by TH (imported from ROW)	ROW's Intermediate use of domestic output	Final Demand of ROW
	Value-Added of EU	Value-Added of USA	Value-Added of CHN	Value-Added of JPN	Value-Added of KOR	Value-Added of TWN	Value-Added of TH	Value-Added of ROW	

Fig. 1 The structure of modified WIOD table

4 Results

4.1 Japan Backward and Forward Multipliers

Backward and forward multipliers of Japanese sectors are calculated to show the linkages to both domestic and international industries. Figure 2 shows domestic backward and forward linkages of production sectors in Japan. Transport equipment sector is used as a proxy to the automotive industry. Among the 26 sectors, the automotive industry has the highest domestic backward multiplier, suggesting a strong interconnection of the automotive industry and its local suppliers. As expected, wholesale, retail, hotel, and restaurant sector has the highest forward multiplier. Although the forward multiplier of the automotive industry is not the highest domestically, it is among the top ten industries that have strong domestic linkages.

Internationally, Japanese automotive industry is among the highest forward multipliers industries. As shown in Fig. 3, the forward multiplier of Japanese automotive industry is the fifth highest, following metal, chemical and rubber,

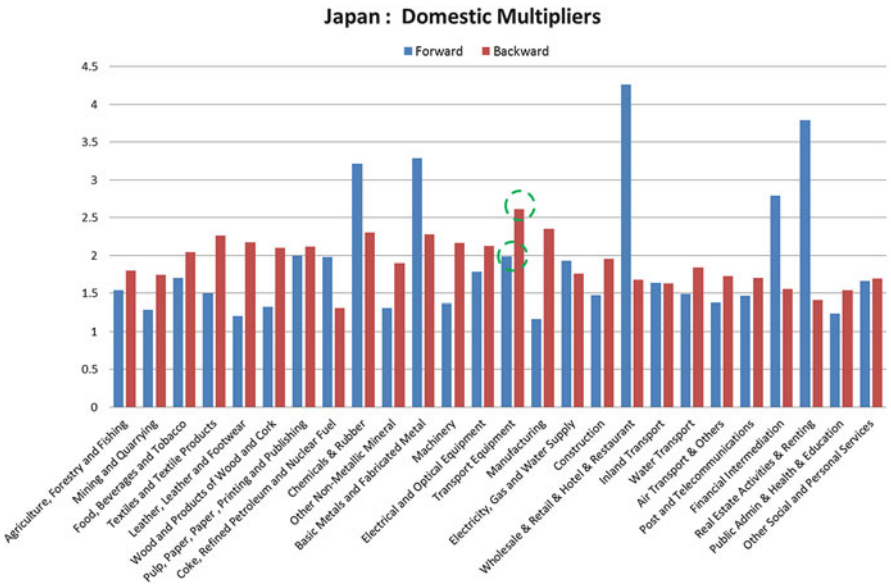

Fig. 2 Japan domestic backward and forward multipliers

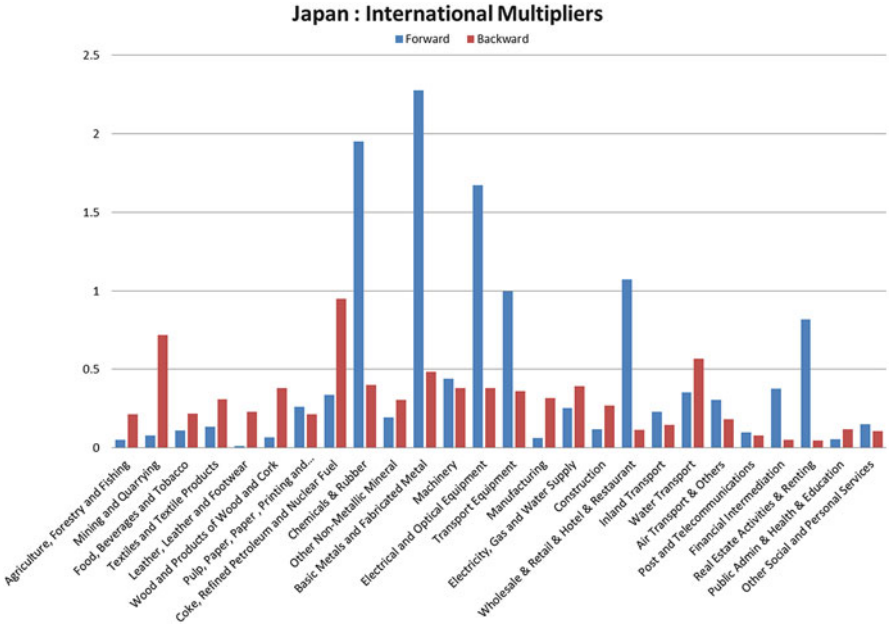

Fig. 3 Japan international backward and forward multipliers

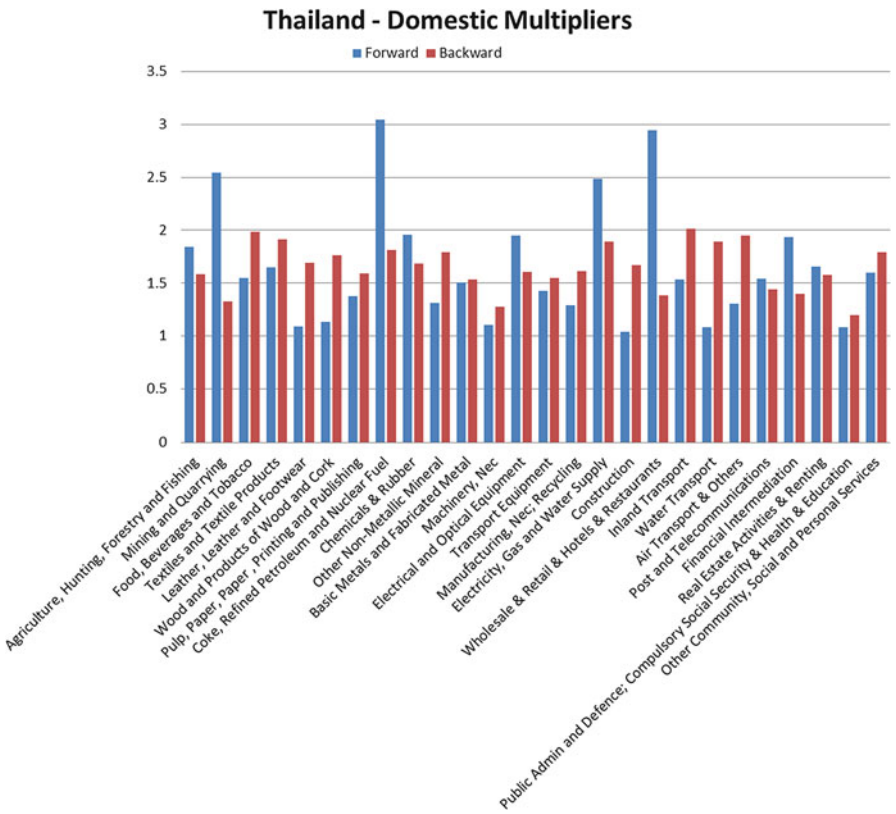

Fig. 4 Thailand domestic backward and forward multipliers

electrical and optical equipment, and wholesale, retail, hotel, and restaurant sectors, respectively. The high forward multiplier of automotive industry suggests the strong interconnection of Japanese automotive industry to its customers around the world.

4.2 Thailand Backward and Forward Multipliers

Thailand domestic backward and forward multipliers are shown in Fig. 4. The sectors in Thailand with the highest domestic backward multiplier are (1) inland transport; (2) food, beverage, and tobacco; (3) air transport; (4) textiles; and (5) water transport, respectively. Unlike Japan, the automotive industry in Thailand does not have a strong backward linkage locally. On the other hand, the sectors in

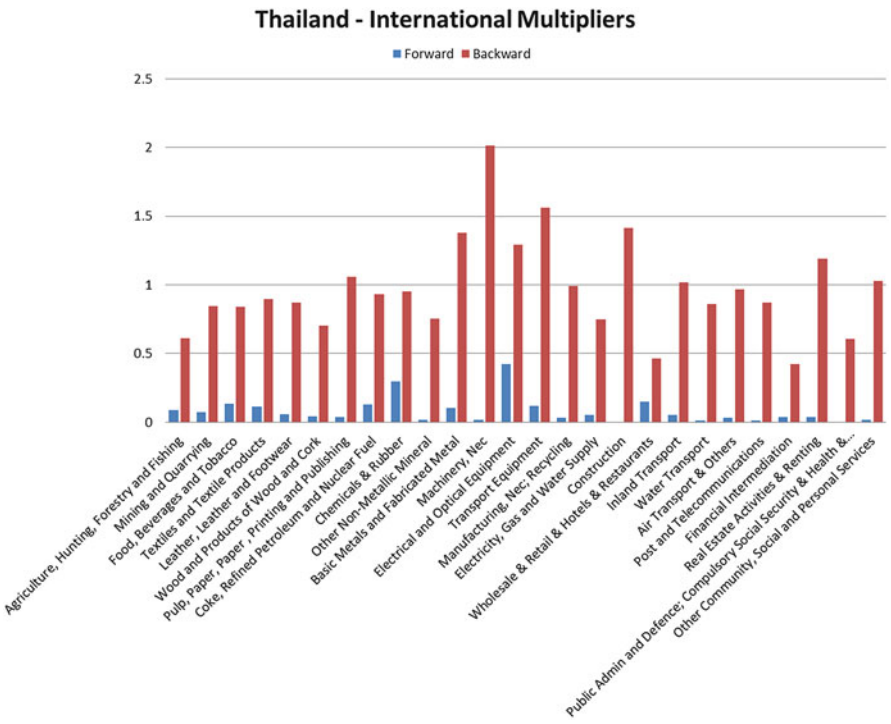

Fig. 5 Thailand international backward and forward multipliers

Thailand with the highest domestic forward multiplier illustrate the manufacturing-based nature of Thai economy. These sectors with the highest domestic forward multiplier are (1) coke, refined petroleum, and nuclear fuel; (2) wholesale, retail, hotel, and restaurant; (3) mining; (4) electricity, gas, and water supply; and (5) chemical and rubber, most of which are intermediate inputs for production. Overall, automotive industry in Thailand has a moderate forward and backward linkage locally.

Thailand international multipliers, however, are different from its domestic multipliers. Figure 5 shows international backward and forward multipliers of Thailand sectors. Internationally, backward multipliers of sectors in Thailand are significantly higher than forward multipliers. These high backward multipliers suggest that Thailand industries are strongly linked to the global supply chain through their international suppliers. The sectors with the highest backward multipliers are (1) machinery, (2) automotive industry (transport equipment), (3) construction, (4) metal, and (5) electrical and optical equipment, respectively. The multipliers also show that Thailand industries rely on their international suppliers much more than Japan industries.

4.3 Structural Path Analysis

The parameter settings for SPA are for the minimum threshold of path influence and the maximum number of arcs. In this analysis, the threshold of path influence and the number of arcs are set to 0.0001 and 4, respectively. As such, a path with the influence lower than 0.0001 or with the number of arc more than 4 will be excluded from the result. After all paths have been calculated, they are ranked according to their total influence values. Only top 100 and 200 are reported in the following section.

4.3.1 The Top 100 Highest Influence Values

To analyze the global influence of Japan industries, multipliers of all sectors from eight economies are decomposed and ranked. Table 5 shows the top 100 highest influences by sectors of origin. Out of the 100 highest influence paths, 77 paths originated in Japan, while the remainder is from other seven economies. The sum of total influence from Japan is 0.78, which accounted for 90 % of the sum of total influences of these highest 100 paths. The results suggest the dominance of Japan industries and its interconnectedness to the global economies.

4.3.2 The Top 200 Highest Influence Values

Table 6 shows the 200 highest influence paths. Out of the top 200, 145 paths have originated in Japan, while the other 55 originated elsewhere. Japanese sectors are among the top that is the source of most of the highest influences to the global economy. In comparison to 145 paths from Japan, 11 paths are from China, 9 from European economies, and 11 from the USA. Out of these 145 paths, basic metals and fabricated metals are the sector with the highest value of influences with 33 paths; followed by 24 paths from chemical and rubber sector; 18 paths from wholesale, retail, hotel, and restaurant; and 18 paths from electrical and optical equipment. Automotive industry is ranked the ninth in Japan and has originated six paths with the influence value of 0.021. As for Thailand, there are two sectors that have high influence from Thailand: transport equipment and electrical and optical equipment sectors.

5 Conclusions

The change of production process has made economies throughout the world increasingly interconnected. A country specializes in a particular stage of the production of goods and becomes a part of international supply chain. International

Table 5 The top 100 of highest influence values

Sector of Origin	Count of total influence	Sum of total influence
CHN	7	0.0260124
Transport equipment	2	0.0108522
Electrical and optical equipment	2	0.0084255
Basic metals and fabricated metals	1	0.0027729
Chemicals and rubber	1	0.0027661
Machinery	1	0.0011957
EU	2	0.0097641
Transport equipment	1	0.0073893
Basic metals and fabricated metals	1	0.0023748
JPN	77	0.7800027
Basic metals and fabricated metals	21	0.2494465
Chemicals and rubber	12	0.1321461
Wholesale and retail and hotel and restaurant	6	0.1080716
Electrical and optical equipment	6	0.0782295
Real estate activities and renting	4	0.0532993
Machinery	6	0.0365426
Electricity, gas, and water supply	5	0.0249906
Financial intermediation	2	0.0224786
Inland transport	1	0.0161991
Other nonmetallic minerals	2	0.0141421
Coke, refined petroleum, and nuclear fuel	2	0.0070947
Other social and personal services	1	0.0060180
Pulp, paper, paper, printing, and publishing	1	0.0058972
Air transport and others	1	0.0049450
Water transport	1	0.0042140
Textiles and textile products	1	0.0038116
Post and telecommunications	1	0.0030144
Construction	1	0.0027825
Manufacturing, NEC; recycling	1	0.0026699
Public admin and health and education	1	0.0020973
Wood and products of wood and cork	1	0.0019121
KOR	3	0.0066681
Basic metals and fabricated metals	1	0.0026078
Transport equipment	1	0.0024287
Electrical and optical equipment	1	0.0016316
ROW	5	0.0205289
Basic metals and fabricated metals	2	0.0104851
Transport equipment	2	0.0097348
Chemicals and rubber	1	0.0014225
TH	2	0.0044635
Transport equipment	1	0.0026346
Electrical and optical equipment	1	0.0018290
TWN	1	0.0012002
Transport equipment	1	0.0012002
USA	3	0.0146985
Transport equipment	3	0.0146985
Grand total	100	0.8644520

Table 6 The top 200 of highest influence values

Sector of Origin	Count of total influence	Sum of total influence
CHN	11	0.0289671
Transport equipment	5	0.0130333
Electrical and optical equipment	3	0.0091991
Basic metals and fabricated metals	1	0.0027729
Chemicals and rubber	1	0.0027661
Machinery	1	0.0011957
EU	9	0.0145859
Transport equipment	5	0.0101359
Basic metals and fabricated metals	1	0.0023748
Chemicals and rubber	1	0.0007841
Electrical and optical equipment	1	0.0007450
Machinery	1	0.0005462
JPN	145	0.8307073
Basic metals and fabricated metals	33	0.2576390
Chemicals and rubber	24	0.1402734
Wholesale and retail and hotel and restaurant	18	0.1188294
Electrical and optical equipment	18	0.0869346
Real estate activities and renting	5	0.0543370
Machinery	6	0.0365426
Electricity, gas, and water supply	7	0.0267327
Financial intermediation	3	0.0230969
Inland transport	6	0.0207596
Other nonmetallic mineral	8	0.0178727
Coke, refined petroleum, and nuclear fuel	2	0.0070947
Pulp, paper, paper, printing, and publishing	3	0.0070906
Other social and personal services	1	0.0060180
Air transport and others	2	0.0055540
Water transport	1	0.0042140
Textiles and textile products	1	0.0038116
Construction	2	0.0032932
Post and telecommunications	1	0.0030144
Manufacturing, NEC; recycling	1	0.0026699
Public admin and health and education	1	0.0020973
Wood and products of wood and cork	1	0.0019121
Food, beverages, and tobacco	1	0.0009197
KOR	5	0.0080060
Basic metals and fabricated metals	1	0.0026078
Transport equipment	1	0.0024287
Electrical and optical equipment	1	0.0016316
Water transport	1	0.0007225
Chemicals and rubber	1	0.0006154
ROW	14	0.0254855

(continued)

Table 6 (continued)

Sector of Origin	Count of total influence	Sum of total influence
Basic metals and fabricated metals	3	0.0121755
Transport equipment	4	0.0115934
Chemicals and rubber	1	0.0020948
Machinery	1	0.001057
Mining and quarrying	1	0.0006217
Wholesale and retail and hotel and restaurant	1	0.0005797
TH	2	0.0044635
Transport equipment	1	0.0026346
Electrical and optical equipment	1	0.0018290
TWN	3	0.0025011
Transport equipment	1	0.0012002
Electrical and optical equipment	1	0.0006682
Basic metals and fabricated metals	1	0.0006326
USA	11	0.0202938
Transport equipment	6	0.0164888
Electrical and optical equipment	1	0.0010284
Basic metals and fabricated metals	1	0.0008413
Chemicals and rubber	1	0.0007502
Machinery	1	0.0006736
Real estate activities and renting	1	0.0005115
Grand total	200	0.9376470

trade is no longer for raw materials or final goods but for intermediate inputs for a production of goods. As a result, economies throughout the world become highly interlinked through this network of international supply chain.

Japanese automotive industry is among the industries that take advantage of this global value chain since the automotive industry involves many production processes, from design, manufacturing, to marketing. A car, for example, may be designed in Japan, while the car assembling process may take place in a plant in Thailand using the intermediate inputs from around the world.

This study examines the global backward and forward multiplier of industries in Japan and Thailand, focusing on the automotive industry, as well as global influences of production sectors from eight economies. It employs input-output multiplier analysis and structural path analysis as an analytical framework. The analysis utilizes the World Input-Output Database (WIOD) table as a data system with some modifications to incorporate Thailand data in the table. Inland transport sector is used as a proxy for automotive industry.

The results of input-output multiplier analysis show that domestically Japanese automotive industry has a very strong backward linkage to other local industries. Internationally, Japanese automotive industry is among the top sectors with high forward influence. Thailand automotive industry does not have as strong domestic linkage as Japan. However, Thailand automotive industry is the second highest

backward linkage to international economies. The results of the structural path analysis reveal that Japan is the leader in generating economic impacts both locally and globally. Japan industries contribute to 77 out of 100 highest influence paths and 145 out of 200 highest influence paths in the world. Japanese automotive industry originates one dominant impact in the top 100 and six paths in the top 200.

The extensions of this analysis include disaggregating automotive industry from inland transport sector and building a global CGE model to examine the interconnection of the automotive industry to other economies in the world.

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References

Ahmad N, Escaith H, Miroudot S, Webb C, Yamamo N (2011) Trade in value-added: concepts, methodologies, and challenges. Joint OECD/WTO Note. Retrieved from http://www.oecd.org/sti/ind/49894138.pdf

Anantsuksomsri S, Tontisirin N (2014) Distributional impact of university-led revitalization on the neighborhood economy: a computable general equilibrium model of a small urban area. Int J Build Urban Inter Landsc Technol 4:5–22

Azis IJ, Mansury Y (2003) Measuring economy-wide impacts of a financial shock. J Southeast Asian Econ 20(2):112–127

Cornell University Center for Advanced Computing (2008) Modeling Cornell's economic impact on New York. Retrieved from https://www.cac.cornell.edu/about/studies/Azis.pdf

Corong E (2007a) Input_Output_2.gms: the accompanying GAMS code for the note— aggregating input-output table in GAMS: accounting for changes in sectoral aggregation. Poverty and Economic Policy (PEP) Research Network. Available at www.pep-net.org

Corong E (2007b) Aggregating input-output table in GAMS. Poverty and Economic Policy (PEP) Research Network. Available at www.pep-net.org

Daudin G, Rifflart C, Schweisguth D (2009) Who produces for whom in the world economy? Can J Econ 44(4):1403–1437

Defourny J, Thorbecke E (1984) Structural path analysis and multiplier decomposition within a social accounting matrix framework. Econ J 94(373):111–136

Dietzenbacher E, Los B, Stehrer R, Timmer M, de Vries G (2013) The construction of world input-output table in the WIOD project. Econ Syst Res 25(1):71–98

Escaith H, Lindenberg N, Miroudot S (2010) International supply chains and trade elasticity in times of global crisis. World Trade Organization Economic Research and Statistics Division. Staff Working Paper ERSD-2010-08. Retrieved from https://www.wto.org/english/res_e/reser_e/ersd201008_e.pdf

Feenstra RC (1984) Voluntary export restraint in U.S. Autos, 1980–81: quality, employment, and welfare effects. In: National Bureau of Economic Research Chapters (ed) The structure and evolution of recent U.S. Trade Policy, Inc., University of Chicago Press, Chicago, pp 35–66

Hayakawa K (2007) Growth of intermediate goods trade in East Asia. Pac Econ Rev 12(4):511–523

Hummels D, Ishii J, Yi K (2001) The nature and growth of vertical specialization in world trade. J Int Econ 54(1):75–96

International Organization of Motor Vehicle Manufacturers (OICA) (2015) World motor vehicle production by Country and Type. Retrieved from http://www.oica.net/category/production-statistics/

Jensen J (2005) Lecture on: aggregating input-output tables using GDX. Introduction to CGE modeling using GAMS and MPS/GE. Essen, Germany. Jesper Jensen's website: www.tecatraining.dk

Johnson RC, Noguera G (2012) Accounting for intermediates: production sharing and trade in value added. J Int Econ 86(2):224–236

Kohpaiboon A, Athukorala P (2010) Detroit of the East: Thailand in global automobile networks. Paper submitted to Study for the International Trade Centre, Geneva

Koopman R, Wang Z, Wei S J (2008) How much Chinese exports is really made in China – assessing foreign and domestic value-added in gross exports. NBER Working Paper No. 14109

Koopman R, Powers W, Wang Z, Wei S J (2011) Give credit to where credit is due: tracing value added in global production chains. NBER Working Papers No. 16426

Lenzen M (2007) Structural path analysis of ecosystem networks. Ecol Model 200(3–4):334–342

Leontief W, Strout A (1963) Multiregional input-output analysis. In: Barna T (ed) Structural interdependence and economic development. St-Martin's Press, New York, pp 119–150

Nakamura T (1995) The postwar Japanese economy: its development and structure, 1937–1994, 2nd edn. University of Tokyo Press, Tokyo

Ottaviano G, Pessoa JP, Sampson T, van Reenen J (2014) The costs and benefits of leaving the EU, No 472, CFS Working Paper Series, Center for Financial Studies (CFS). http://EconPapers.repec.org/RePEc:zbw:cfswop:472

Puttanapong N (2015) Tracing and quantifying Thailand's linkages to international supply chains: the modification of world input-output database and the application of multiplier and structural path analysis. Proceedings, Singapore Economic Review Conference 2015

Rasiah R (1999) Liberalization and the car industry in South East Asia. Occasional Paper No. 99, Department of Intercultural Communication and Management, Copenhagen Business School

Rutherford T (2003) A GAMS program which maps social accounting data into labeled submatrices. University of Colorado, Boulder. Available at www.mpsge.org

Sanyal K, Jones R (1982) The theory of trade in middle products. Am Econ Rev 72(1):16–31

Techakanont K (2011) Thailand automotive parts industry. In: Kagami M (ed) Intermediate goods trade in east Asia: economic deepening through FTAs/EPAs. BRC research report no. 5. Bangkok Research Center, IDE-JETRO, Bangkok, pp 192–229

Thailand Automotive Institute (2012) Master plan for automotive industry 2012–2016. Ministry of Industry, Bangkok

Thailand Board of Investment (2012) Opportunities in Thailand's automotive industry. Retrieved from http://www.boi.go.th/index.php?page=opp_automotive

Thailand Development Research Institute (1993) TNC involvement in the Thai auto industry. TDRI Quarterly Review (in Thai)

Thailand Development Research Institute (1997) Master plan for industrial development (in Thai)

Timmer M, Los B, Stehrer R, de Vries G (2013) Fragmentation, incomes, and jobs: an analysis of European competitiveness. Econ Policy 11(4):613–661