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TRACING THAILAND'S LINKAGES TO GLOBAL SUPPLY CHAIN: APPLICATIONS OF WORLD INPUT-OUTPUT DATABASE (WIOD) AND STRUCTURAL PATH ANALYSIS

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Abstract: *Trade openness has continuously gained its significance on the structure of Thai economy.The empirical evidence shows that the increasing inflows of intermediate, machinery and Foreign Direct Investment (FDI) have simultaneouslycorrelated with the exports of manufacturing products. This evolution indicates the deeper connection of Thai economy to the global supply chain.Based on this fact, this study introduces the new approach of quantifying and tracing the network of impact transmission between the international supply chain and Thai economy. To construct the global input-output table exhibiting Thailand's international trade linkages, the World Input-Output Database (WIOD) is extended to include Thailand's domestic and international trade statistics. In order toextract the main structure of international production network, the computational techniques of Leontief backward and forward multipliers and the Structural Path Analysis (SPA)are applied to the newly constructed WIOD table. The computational outcome indicatesthat among Thailand's production activities, the electronics manufacturing sector has the highest value of both international backward and forward multipliers. The result obtained from SPA also reveals the international production network of electronics industry linking manufacturing processes across Thailand, Japan, China, Korea, US, EU, Taiwan and rest of the world. The SPA result identifies thesimilar pattern of linkages to the international supply chain of Thailand's manufacturing sector. These findings signify thelinkages between Thai economy and the international production network, and the importanceof the transmission mechanism of impactspropagating through connected supply chains.*

Keywords: *World Input-Output Database, Structural Path Analysis, Global Value Chain.*

JEL Classification: *F140, F410, R150.*

1. INTRODUCTION

Settled on the export-led growth path, the trade openness has gradually deepened its role in Thai economy. As illustrated on Figure 1, the international trade statistics show that both import and export are main components of Thailand's GDP. The

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share of export in GDP has increased from 33% in 1995 to 54% in 2013, and that of import has expanded from 37% to 52% during the same period.

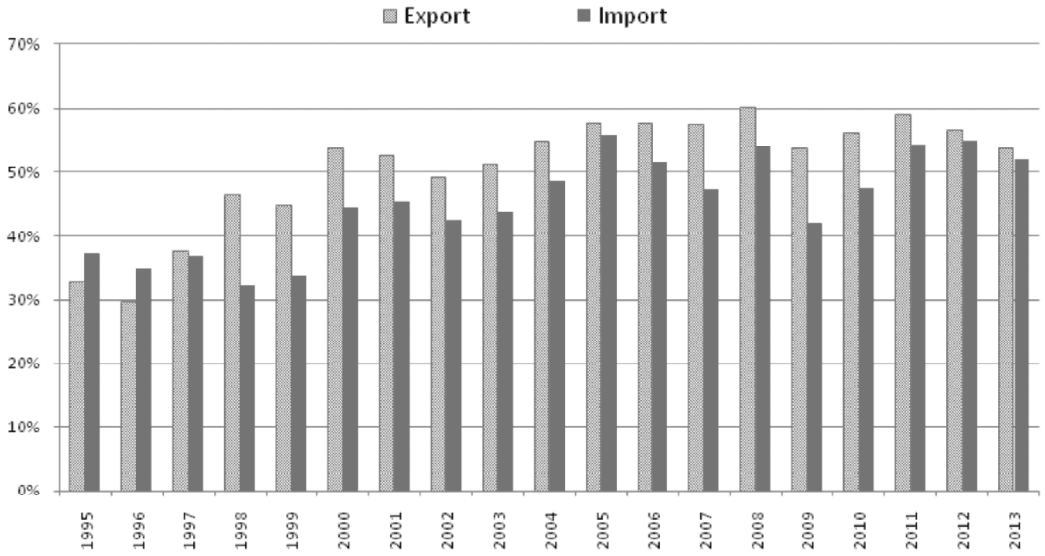

Figure 1: Percentage share as of GDP of export and import

Source: Bank of Thailand and author's calculation

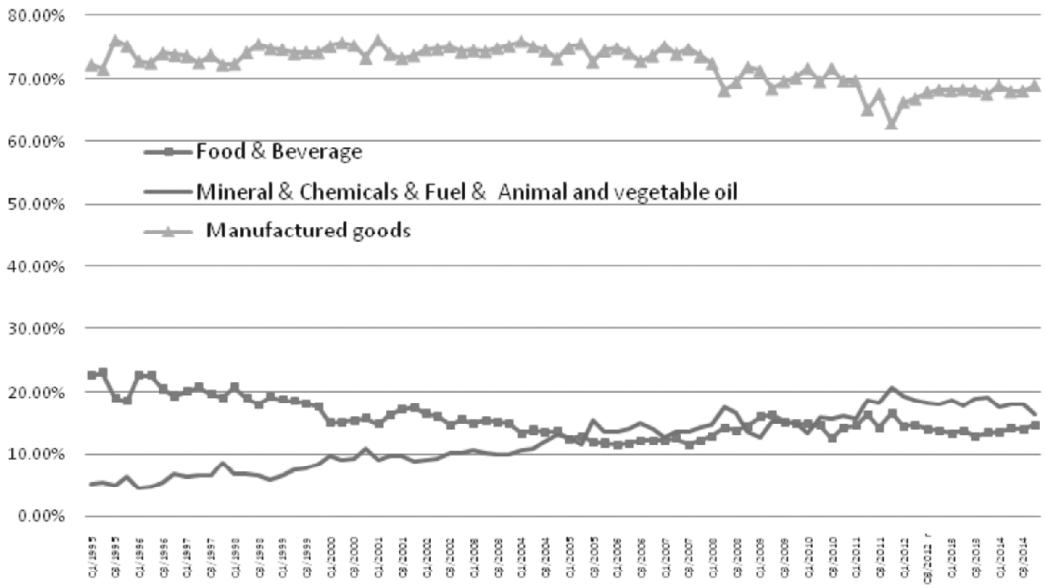

Figure 2: The main structure of exports

Source: Bank of Thailand and author's calculation

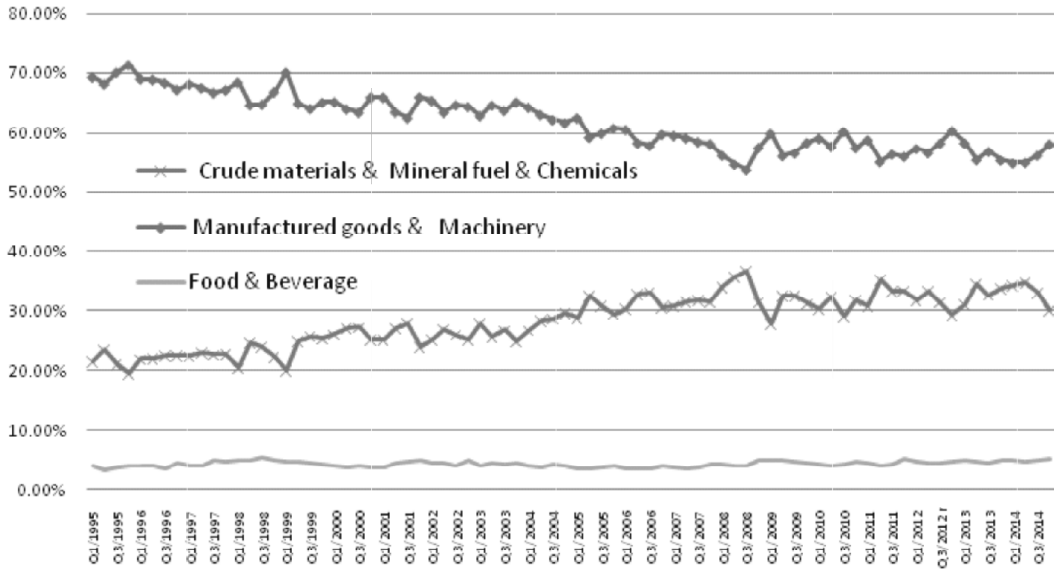

Figure 3: The main structure of imports

Source: Bank of Thailand and author's calculation

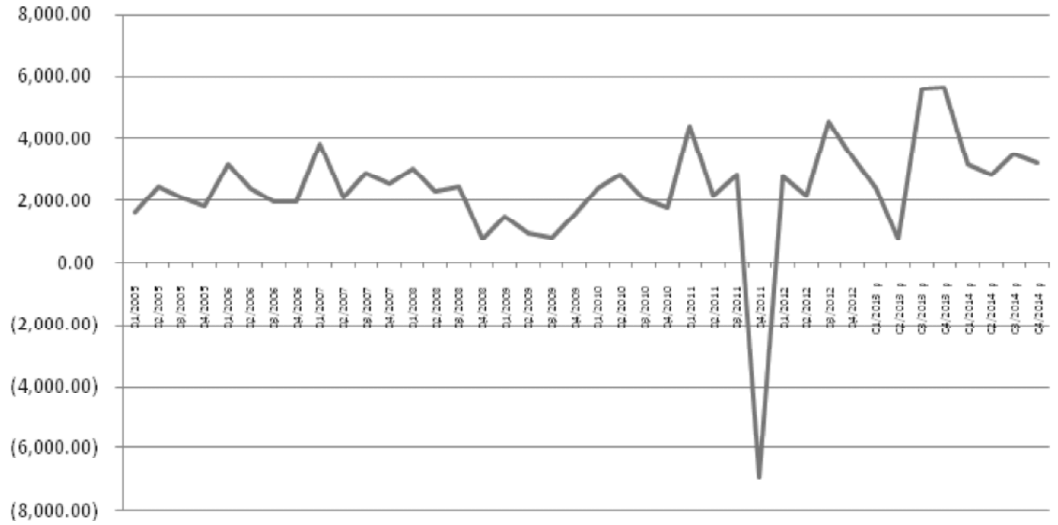

Figure 4: Total Foreign Direct Investment (Unit: millions of US Dollars)

Source: Bank of Thailand

The detailed data, as shown on Figure 2, indicates that the major exported products are manufacturing products, which are mainly electronics and machinery. Also Figure 3 exhibits that the biggest portion of imports is a combination of raw materials and intermediate parts. In addition to the gaining significance of trade volume, the Foreign Direct Investment (FDI) has been the

important part of capital inflows, as shown on Figure 4, and it leads to the expansion of manufacturing activities of foreign companies in Thailand. With this evolution of empirical evidences, the linkage of Thai economy to the global economy has been embedding into the network of global supply chain. Hence, the broader insight on the multifaceted linkage to the world economy is necessary for the country's current and future growth strategy.

This study delivers two contributions toward the deepened comprehension of Thailand's economic structure and her international linkages. Firstthis paper introduces the procedure to develop the new data in the format of global input-output table that represents all connections of Thai economy to the global supply chain. Second it applies quantitative techniques of Leontief backward and forward multipliers and the Structural Path Analysis (SPA) to the newly constructed global input-output table. These computations illustrate and quantify the major paths of international value chains that generate significant contributions to Thai economy.

This paper is structured as follows. The following section reviews related studies on the development of global input-output tables and their applications. The third section introduces the modification of the existing global input-output table in order to incorporate details of Thai economy. Then the outcome of applying computational techniques of the Leontief multiplier and the Structural Path Analysis to this newly constructed global input-output table is discussed in the fourth section. The last section concludes key findings and suggests main issues for future research extension.

2. LITERATURE REVIEW

The expanding globalization has been inducing the higher volume of international trades and the hike of FDI flows. This global development has also incurred the inter-country fragmentation of production or international value chain. Hummels *et al.* (2001) introduces the definition of fragmentation of production, and states that the vertical production is account for 25% of total production. Based on this initiation, Escaith *et al.* (2010 and 2011) and Lantz *et al.* (2009) find that more than 50% of the international trade is the shipment of raw materials and intermediate goods. Almad *et al.* (2011), Daudin *et al.* (2006 and 2009), Johnson and Noguera (2012) and Koopman *et al.* (2008 and 2011) use the GTAP database to study the international trade flow and conclude that the international value chain has played a significant role in the system of world trade, and the value of trade balance has to be adjusted to the volume of international shipment of

intermediate goods. In some cases, this might lead to the magnitude of 30%-40% adjustment of the conventionally reportedvalues of trade balance.

With these findings, the data of global trade statistics organized in the format of input-output table is a necessary fundamental for the analysis of international value chain because it exhibits the detailed structure of production, especially on the imported intermediate, the domestic value-added creation and the cross-country usage of products as intermediates and final consumptions. The fundamental concept of data structure and its application was introduced by Leontief and Strount (1963) and Sanyaland Jones (1982). This framework of data arrangement is then adopted by Dietzenbacher *et al.* (2013) to construct the World Input-Output Database (WIOD) which are the annual tables of 1995-2011 covering the statistics of international trade and production structure of 35 sectors and 40 economies.

This database enables researchers to examine details of international trade and cross-country production network. Studies conducted by Wang *et al.* (2013), Nagengast and Stehrer (2014), Koopman *et al.* (2014), Los *et al.* (2014), Johnson (2014) and Timmer *et al.* (2014) utilize this set of data to investigate the global fragmentation of production and propose the alternative methodologies of estimating cross-country value-added creation. These WIOD tables are also main data sources for Schwörer (2013),Timmer *et al.* (2013) and Ottaviano (2014) to study impacts of the global production network on European economy.

The application of WIOD tables is not only limited to the area of international trade and macroeconomics, but many studies in the field of environmental economics and climate change have extensively used the set of WIOD tables as their main data sources. Studies conducted byArto *et al.* (2013), Zafrilla *et al.* (2014), Arto and Dietzenbacher (2014), Xu and Dietzenbacher (2014) and López *et al.* (2014) introduce the computation of carbon dioxide emission based on quantities of economic activities exhibited on WIOD tables. Also in the field of energy economics, Voigt (2014) uses thetables of WIOD to examine the evolution of energy intensity in 40 major economies during 1995-2011.

The development of WIOD tables leads to the widespread application, especially a deeper and broader insight of global production network. However, there is a limitation on a specific country's application due to the limited number of economies covered in the original data set. Hence, this study introduces the methodology of extending the WIOD table to cover additional data of a specific economy. The following section introduces theprocedure of includingThailand's domestic and international trade statistics into the original WIOD table.

Table 1
A list of country/region and their abbreviations in the new WIOD table

Abbreviation used in WIOD table	*Country/Region*
EU	Members of European Union
USA	United States of America
CHN	China
JPN	Japan
KOR	South Korea
TWN	Taiwan
TH	Thailand
ROW	Rest of the World

3. THE CONSTRUCTION OF WORLD INPUT-OUTPUT DATABASE (WIOD) TABLE WITH THE EXTENSION OF THAILAND'S DATA

There are two main procedures of modifying the WIOD table to explicitly exhibit trade and production statistics of Thailand. The first step is to adjust the dimension of the original WIOD and that of GTAP's global trade data to be compatible. The second step is the consolidation of two sources of data to formulate the new WIOD table. In this study, the data of 2007, which is the latest matching year of both WIOD table and GTAP's data are used.

For the first step, the original WIOD table, which includes the statistics of 40 economies and 35 commodities, has been aggregated into the data of 8 economies and 26 commodities, as listed on Table 1 and 2. The conversion has been conducted by using the author's GAMS code developed based on computational techniquessuggested by Corong (2007a), Corong (2007b), Jensen(2005) and Rutherford(2003). The aggregation of economies is based on the group of countries and regions that have beenthe major trading partners of Thailand, and the aggregate of production sectors and commodities was set to maintain the compatibility with GTAP's data.

The arrangement of GTAP's global trade data has been conducted by using GTAPAgg which is the software of GTAP's package for data aggregation. The classification of economies and commodities onGTAPAggis comprised of8 economies and 26 commodities, as identical to the specification of WIOD table aggregation.After the aggregation process,three important sets of data of Thai economyand her international trade linkages aregenerated, which are the Social Accounting Matrix (SAM) of Thailand, Thailand's imports (represented as GTAP's VIWS variable), and Thailand's exports (the GTAP's VXWD variable).

In the second step, three data obtained from GTAPAgghas been usedfor extracting values of Thai domestic economy and her international trades from the "Rest of the World" group of WIOD table. As a result, the newly constructed

Table 2
The concordance between WIOD, GTAP and ISIC rev. 3.1 code

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 Non-Metallic Mineral	26	C11	nmm
10. Basic Metals and Fabricated Metal	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, Retail, 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, Defense, 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

Note: GTAP Sector 57, "DWE"arenot part of ISIC system

Figure 5: The structure of modified WIOD table incorporating Thailand's data

WIOD table includes the new 26 rows and columns representing Thailand's production sectors. To complete details of Thailand'sproduction, the proportion of uses of imported intermediatesis based on those in GTAP's Thai SAM. With this augmentation of WIOD table's dimension, all values of the "Rest of the World" group are adjusted by subtracting with those of Thailand's, leaving the total summation of each row and each columnstill identical to those of original table[1]. The consolidation yields the final outcome of global input-output table that has the structure as shown on Figure 5.

The newly constructed table represents details of trade and production linkages of Thailand to the global economy. With its format of input-output table, the structure of cross-country linkages of trades and productions can be quantitatively extracted by using techniques of the Leontief multiplier and the Structural Path Analysis.Results from applying both computations to the newly constructed WIOD table are discussed in the following section.

4. THE APPLICATIONS ON THAILAND'S DOMESTIC AND INTERNATIONAL TRADE LINKAGES

4.1 The Results from Computation of Leontief Backward and Forward Multipliers

The concept of Input-Output multiplier, introduced byLeontief (1936) and later extended byLeontief (1986), Lahr and Dietzenbacher (2001), Dietzenbacher (2004), Breisinger, Thomas and Thurlow (2009), quantitatively extracts the inter-industry relationship in the Input-Output table and identifies the contribution of each production sector to the whole economyby its multiplier's magnitude. The values of multiplierscan be computed by conducting the row or column summation on the inversed matrix of input ratios (i.e. the "A matrix" in Leontief (1936) and Leontief (1986)). The obtained backward multiplier indicates the degree of impact of a particular sector on its suppliers along the supply chain (i.e. the impacts on its upstream partners). On the other hand, the obtained forward multiplier identifies the impacts of a particular sector on its downstream connected industries.

For the domestic inter-industry connections,Figure 6shows the values of domestic backward and forward multipliers. Also the rankings of both multipliers are exhibited on Table 3. The value of backward multipliers indicates the magnitude of impact transmission originated from a particular sector towards upstream activities. The computational result shows that the Food, Beverages and Tobacco sector has the highest value of backward multiplier, revealing its largest contribution to Thai economy through its supply chain. The major factor of this highest backward impact is its broad and long production network starting from farming activities to food processing industries. The second largest backward multiplier is that of Electricity, Gas and Water Supply sector which demands a variety of input sources with substantial quantity for electricity generation. The third highest value of backward multiplier is that of Inland Transport sector, which is one of the biggesteconomicactivitiesemploying large quantities of fuels and machines. The fourth and the fifth highest backward multipliers are those of Construction and Textiles sectors, respectively. These sectors have high backward impacts due to their usages of various intermediates and equipment.

For the forward multiplier, its order of magnitudes identifies the degree of significance as the upstream producer.For Thai economy, the sector which is the aggregate of WholesaleandRetailand HotelandRestaurant ranks first as the activity having the highestforward multiplier. This indicates its contribution as major supplier to most of domestic productions. The result from calculation reveals that the Coke, Refinery and Natural Gas industry ranks as the second highest

forward multiplier. Also the sector of Electricity, Gas and Water Supply ranksthird. This order of magnitude exhibits the significance of both fossil-based energy and utility service as the second and third important upstream producers to other activities. In addition,the forward multiplier ofthe Financial Intermediate sectorand that of Chemicals and Rubber industryare ranked as the fourthand fifth highest values, respectively. This outcome specifies the high contributions of both financial service and the raw material producer to the downstream productions.

Similar to the methodology and result discussed in Dietzenbacher (2010), the computation of backward and forward multipliers based on data of the newly constructed WIOD table dose not only quantify the domestic relationships of inter-industry networks, but it also yields the magnitudes of trade and production linkages of Thai production sectors and the global supply chains. Figure 7shows the result of this computation and Table 4 exhibits the rankings of both international backward and forward multipliers. Interestingly the Electrical and Optical Equipment ranks first for both values of cross-country backward and forward multipliers. This finding indicates the significance roleof Thailand as an important player in the international value chain ofElectrical and Optical Equipmentindustry. For the ranking of backward multipliers, the Transport

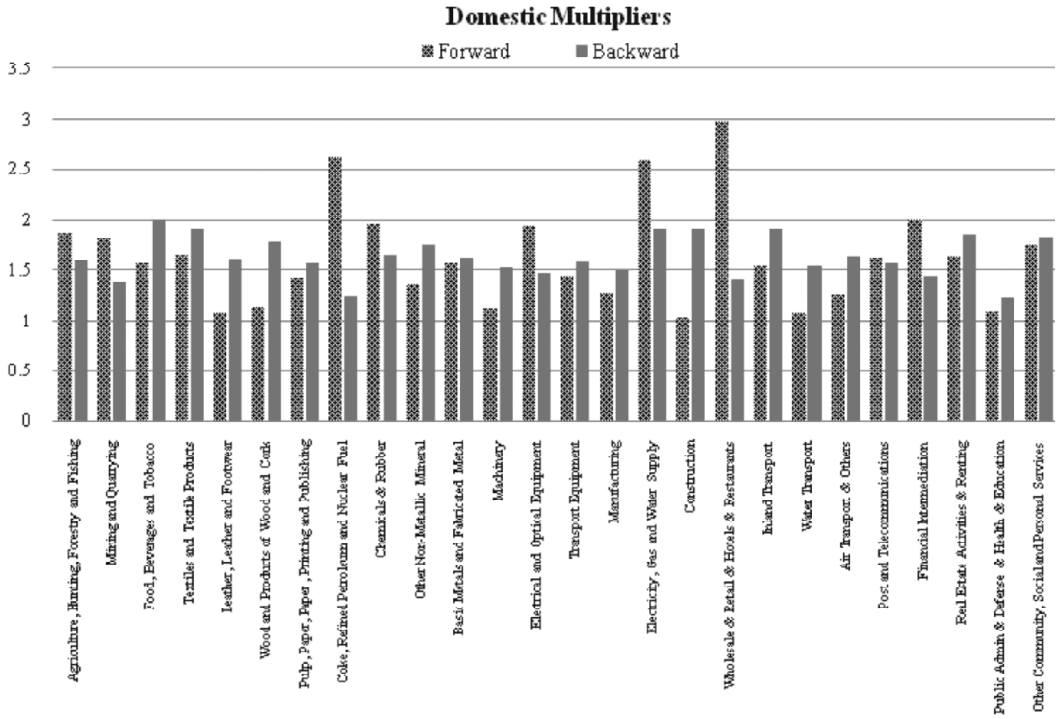

Figure 6: Domestic backward and forward multipliers of Thailand

Table 3
Rankings of domestic backward and forward multipliers of Thailand

Rank	*Sector*	*Backward Multiplier*	*Rank*	*Sector*	*Forward Multiplier*
1.	Food, Beverages and Tobacco	2.0020	1.	Wholesale and Retail and Hotels and Restaurants	2.9778
2.	Electricity, Gas and Water Supply	1.9236	2.	Coke, Refined Petroleum and Nuclear Fuel	2.6194
3.	Inland Transport	1.9191	3.	Electricity, Gas and Water Supply	2.5951
4.	Construction	1.9171	4.	Financial Intermediation	1.9984
5.	Textiles and Textile Products	1.9133	5.	Chemicals and Rubber	1.9610
6.	Real Estate Activities and Renting	1.8656	6.	Electrical and Optical Equipment	1.9539
7.	Other Community, Social and Personal Services	1.8276	7.	Agriculture, Hunting, Forestry and Fishing	1.8845
8.	Wood and Products of Wood and Cork	1.7723	8.	Mining and Quarrying	1.8294
9.	Other Non-Metallic Mineral	1.7484	9.	Other Community, Social and Personal Services	1.7527
10.	Chemicals and Rubber	1.6542	10.	Textiles and Textile Products	1.6521
11.	Air Transport and Others	1.6355	11.	Real Estate Activities and Renting	1.6486
12.	Basic Metals and Fabricated Metal	1.6172	12.	Post and Telecommunica-tions	1.6231
13.	Leather, Leather and Footwear	1.6108	13.	Food, Beverages and Tobacco	1.5702
14.	Agriculture, Hunting, Forestry and Fishing	1.5926	14.	Basic Metals and Fabricated Metal	1.5700
15.	Transport Equipment	1.5822	15.	Inland Transport	1.5494
16.	Pulp, Paper, Paper, Printing and Publishing	1.5720	16.	Transport Equipment	1.4523
17.	Post and Telecommuni-cations	1.5715	17.	Pulp, Paper, Paper, Printing and Publishing	1.4344
18.	Water Transport	1.5354	18.	Other Non-Metallic Mineral	1.3657
19.	Machinery	1.5221	19.	Manufacturing	1.2782
20.	Manufacturing	1.4918	20.	Air Transport and Others	1.2650
21.	Electrical and Optical Equipment	1.4765	21.	Wood and Products of Wood and Cork	1.1418
22.	Financial Intermediation	1.4391	22.	Machinery	1.1252
23.	Wholesale and Retail and Hotels and Restaurants	1.4132	23.	Public Admin and Defense and Health and Education	1.0958
24.	Mining and Quarrying	1.3872	24.	Leather, Leather and Footwear	1.0835
25.	Coke, Refined Petroleum and Nuclear Fuel	1.2476	25.	Water Transport	1.0808
26.	Public Admin and Defense and Health and Education	1.2359	26.	Construction	1.0455

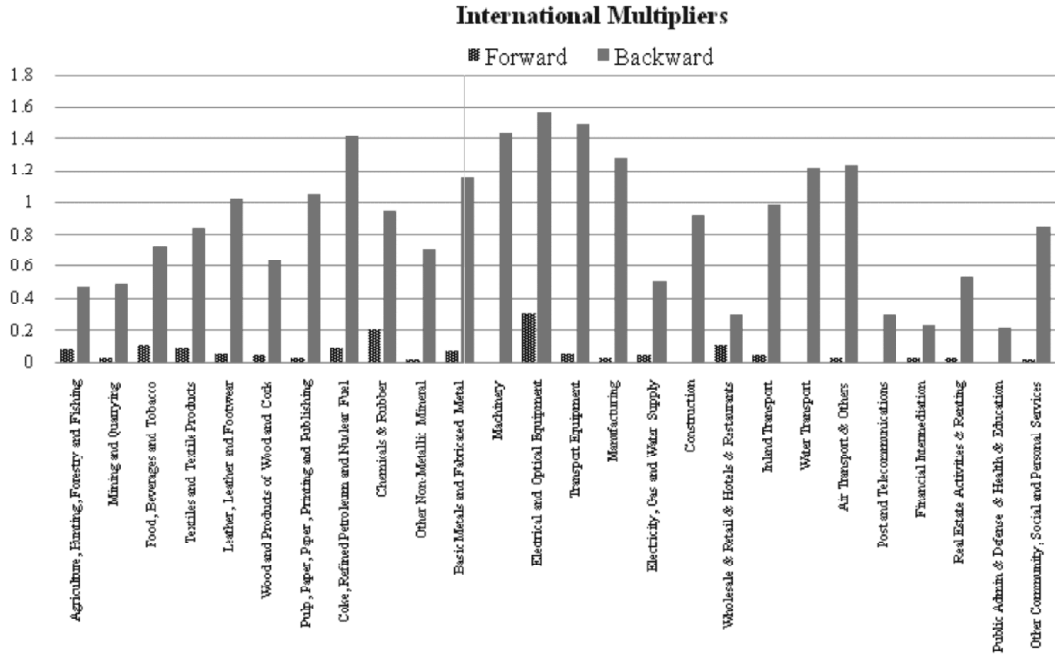

Figure 7: International backward and forward multipliers of Thailand

Equipmentsector and the Machinery industry have the second and third highest values, respectively. This result identifies the large demand for imported intermediates of both sectors. The Coke, Refined Petroleum and Nuclear Fuel sector also ranks fourth for this category, reflecting the substantial dependence of Thai energy supplies on imports. TheManufacturing sector ranks fifth for its value of international backward multiplier. Following the import statistics shown on Figure 3, this calculation resultsignifies the dependence of Thai manufacturing sector on imported inputs.

For international forward multipliers, the Chemicals and Rubber sector has the second high value. This magnitude affirms the significance of Thai exports of plastic and rubber products which are among global and regional main players. The third highest international forward multiplier is that of Wholesale and Retail and Hotel and Restaurant sector, indicating its contribution as the major service providers facilitating international trade activities. The Food, Beverages and Tobacco sector has the fourth biggest value of international forward multiplier, and this outcome is consistent with its position as one of the world's major food exporters. The fifth highest cross-country forward multiplier is that of Textile industry. This computational result confirms the fact that although some activities of the textile industry have been reallocated to other countries, there are still many upstream productions operating in Thailand.

Table 4
Rankings ofinternational backward and forward multipliers of Thailand

Rank	*Sector*	*Backward Multiplier*	*Rank*	*Sector*	*Forward Multiplier*
1.	Electrical and Optical Equipment	1.5623	1.	Electrical and Optical Equipment	0.2998
2.	Transport Equipment	1.4933	2.	Chemicals and Rubber	0.2020
3.	Machinery	1.4262	3.	Wholesale and Retail and Hotel and Restaurant	0.1048
4.	Coke, Refined Petroleum and Nuclear Fuel	1.4131	4.	Food, Beverages and Tobacco	0.1033
5.	Manufacturing	1.2783	5.	Textiles and Textile Products	0.0912
6.	Air Transport and Others	1.2380	6.	Coke, Refined Petroleum and Nuclear Fuel	0.0836
7.	Water Transport	1.2206	7.	Agriculture, Hunting, Forestry and Fishing	0.0740
8.	Basic Metals and Fabricated Metal	1.1472	8.	Basic Metals and Fabricated Metal	0.0699
9.	Pulp, Paper, Paper, Printing and Publishing	1.0499	9.	Leather, Leather and Footwear	0.0512
10.	Leather, Leather and Footwear	1.0126	10.	Transport Equipment	0.0496
11.	Inland Transport	0.9796	11.	Electricity, Gas and Water Supply	0.0417
12.	Chemicals and Rubber	0.9459	12.	Inland Transport	0.0415
13.	Construction	0.9203	13.	Wood and Products of Wood and Cork	0.0411
14.	Other Community, Social and Personal Services	0.8511	14.	Mining and Quarrying	0.0295
15.	Textiles and Textile Products	0.8376	15.	Real Estate Activities and Renting	0.0290
16.	Food, Beverages and Tobacco	0.7198	16.	Financial Intermediation	0.0285
17.	Other Non-Metallic Mineral	0.7037	17.	Manufacturing	0.0281
18.	Wood and Products of Wood and Cork	0.6321	18.	Pulp, Paper, Paper, Printing and Publishing	0.0276
19.	Real Estate Activities and Renting	0.5266	19.	Air Transport and Others	0.0269
20.	Electricity, Gas and Water Supply	0.5072	20.	Other Community, Social and Personal Services	0.0173
21.	Mining and Quarrying	0.4818	21.	Other Non-Metallic Mineral	0.0137
22.	Agriculture, Hunting, Forestry and Fishing	0.4700	22.	Post and Telecommunications	0.0118
23.	Post and Telecommunications	0.2947	23.	Water Transport	0.0117
24.	Wholesale and Retail and Hotels and Restaurant	0.2901	24.	Machinery	0.0057
25.	Financial Intermediation	0.2251	25.	Public Admin and Defense and Health and Education	0.0047
26.	Public Admin and Defense and Health and Education	0.2146	26.	Construction	0.0027

The relationships among domestic and international multipliers are summarized as illustrated on Figure 8. Interestingly, there are seven sectors that have the highest values across categories, implying their multiple roles in both Thai economy and the international market. The sector of Coke, Refined Petroleum and Nuclear Fuel has high multipliers of both cases of domestic forward and international backward. These indicate its operation as the high import-content producerand also the main supplier to domestic production activities. The Electricity, Gas and Water Supply sector has double roles to the domestic economy. With high values of backward and forward multipliers, these utility services have substantial influences on both upstream and downstream connected sectors. For the cross-country production chain,Thailand's Electrical and Optical Equipment sector has a unique combination of having high values of both international backward and forward multipliers. This combination indicates its operation as the high import-content exporter. In addition, other two major exporting sectors, which are

1. the Food, Beverages and Tobacco and
2. the Textiles, have the mixture of high domestic backward and high international forward multipliers.

These reflect their production processes as the high local-content exporters. The last group of combination is the case of high values of both domestic and international forwards multipliers. This group, which is comprised of

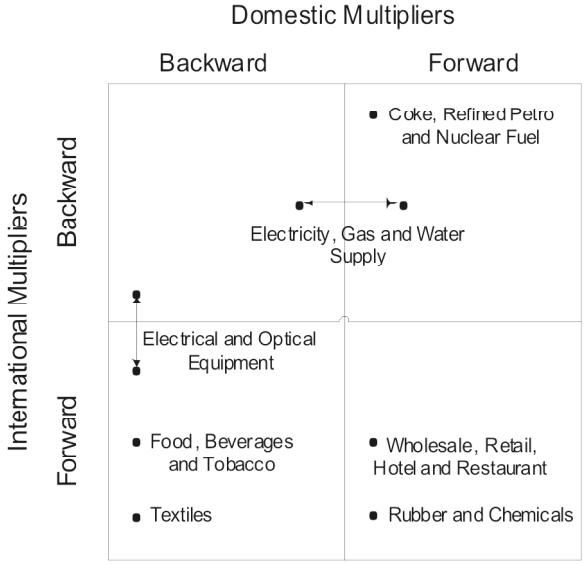

Figure 8: The relationships among top values ofdomestic and international multipliers

1. Wholesale and Retail and Hotel and Restaurant and
2. Chemicals and Rubber, plays a significant role as the main upstream producers that supply both domestic and exporting activities.

4.2 THE RESULTS FROM STRUCTURAL PATH ANALYSIS (SPA)

As introduced by Defourny and Thorbecke(1984) and Kahn and Thorbecke(1989), the Structural Path Analysis (SPA) is the mathematical technique that decomposes the detail of Leontief multiplier. Specifically, this methodology reveals the network relationship of economy-wide impact transmission. Technically the SPA is based onthe concept developed by Lantner (1974), which generates the values of all direct and indirect influences transmitted from the point of origin to the sector of destination. In this study, the SPA is applied to the newly constructed WIOD table, which incorporates the explicit data of Thailand. This computation decomposes Leontief multipliers and reveals details of direct and indirect paths of each multiplier.

Due to the limitation of space, the decomposition results of the five highest backward multipliers are discussed. These selected results obtained from the SPA are shown in on Table 5-9[2]. Table 5 and Figure 9-11 exhibit the decomposition result of the international backward multiplier of Thailand's Electrical and Optical Equipment sector, which has the highest value of this category. The SPA results identify that there are 3 main paths[3] of backward connections behind this multiplier.All paths starts from Thailand's Electrical and Optical Equipment sector but have different destination points which are the Electrical and Optical Equipment sectors located in Rest of the World, Japan and China. The results from SPA also unveil the indirect linksthat represent the production network of this industry connecting manufacturing based in Thailand, Japan, China, Korea, Taiwan, US, EU and Rest of the World.

For the Transport Equipment sector whose backward multiplier ranks second, the result from SPA, as shown on Table 6 and Figure 12, indicates that there is the only main path which is the linkages of production between Thailand and Japan, with two indirect influences showing the intermediate processes located in EU and the Rest of the World. This result of multiplier decomposition is similar the case of Thailand's Machinery sector, whose backward multiplier ranks as the third highest value. The SPA result, exhibited on Table 7 and Figure 13,indicates that there is the onlymain production linkage between the Machinery

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[1] The full details of results obtained from SPA are also available upon request.

[2] The path is classified as the main one if the value of its influence is higher than 0.1.

Table 5
SPA's result of main backward paths of Thailand's Electrical and Optical Equipment sector

Country and Sector of Origin	*Country and Sector of Destination (order 1)*	*Country and Sector of Destination (order 2)*	*Country and Sector of Destination (order 3)*	*Global Influence (GI)*	*Direct Influence*	*Path Multiplier*	*Total Influence (TI)*	*TI/GI (%)*	*Cumulative (%)*
Main path 1									
TH Electrical and Optical Equipment	ROW Electrical and Optical Equipment			0.1494	0.1008	1.2930	0.1303	87.2408	87.2408
TH Electrical and Optical Equipment	CHN Electrical and Optical Equipment	ROW Electrical and Optical Equipment			0.0033	1.7763	0.0059	3.9365	91.1772
TH Electrical and Optical Equipment	EU Electrical and Optical Equipment	ROW Electrical and Optical Equipment			0.0016	1.4884	0.0025	1.6431	92.8203
TH Electrical and Optical Equipment	JPN Electrical and Optical Equipment	ROW Electrical and Optical Equipment			0.0003	1.6318	0.0005	0.3644	93.1847
TH Electrical and Optical Equipment	KOR Electrical and Optical Equipment	ROW Electrical and Optical Equipment			0.0006	1.7769	0.0011	0.7057	93.8903
TH Electrical and Optical Equipment	TWN Electrical and Optical Equipment	ROW Electrical and Optical Equipment			0.0027	1.3223	0.0036	2.3784	96.2688
TH Electrical and Optical Equipment	USA Electrical and Optical Equipment	ROW Electrical and Optical Equipment			0.0010	1.3776	0.0013	0.8788	97.1475
TH Electrical and Optical Equipment	CHN Electrical and Optical Equipment	TWN Electrical and Optical Equipment	ROW Electrical and Optical Equipment		0.0002	1.8099	0.0004	0.2821	97.4296
Main path 2									
TH Electrical and Optical Equipment	JPN Electrical and Optical Equipment			0.1515	0.0959	1.4628	0.1403	92.6257	92.6257
TH Electrical and Optical Equipment	CHN Electrical and Optical Equipment	JPN Electrical and Optical Equipment			0.0013	2.0199	0.0025	1.6705	94.2961
TH Electrical and Optical Equipment	EU Electrical and Optical Equipment	JPN Electrical and Optical Equipment			0.0002	1.6885	0.0004	0.2479	94.5440
TH Electrical and Optical Equipment	JPN Basic Metals and Fabricated Metal	JPN Electrical and Optical Equipment			0.0002	2.3624	0.0004	0.2572	94.8012
TH Electrical and	KOR Electrical and	JPN Electrical and			0.0004	2.0124	0.0007	0.4800	95.2812

Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	TWN Electrical and	JPN Electrical and			0.0012	1.4993	0.0018	1.2199	96.5010
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	USA Electrical and	JPN Electrical and			0.0001	1.5616	0.0002	0.1470	96.6480
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	ROW Electrical and	JPN Electrical and			0.0011	1.6318	0.0017	1.1330	97.7810
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	CHN Electrical and	TWN Electrical and	JPN Electrical and		0.0001	2.0618	0.0002	0.1453	97.9263
Optical Equipment	Optical Equipment	Optical Equipment	Optical Equipment						
TH Electrical and	ROW Electrical and	CHN Electrical and	JPN Electrical and		0.0001	2.2401	0.0002	0.1650	98.0913
Optical Equipment	Optical Equipment	Optical Equipment	Optical Equipment						
Main path 3									
TH Electrical and	CHN Electrical and								
Optical Equipment	Optical Equipment			0.1257	0.0623	1.6015	0.0997	79.3327	79.3327
TH Electrical and	EU Electrical and	CHN Electrical and			0.0012	1.8474	0.0023	1.8038	81.1365
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	JPN Electrical and	CHN Electrical and			0.0014	2.0199	0.0028	2.2565	83.3930
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	KOR Electrical and	CHN Electrical and			0.0008	2.1986	0.0017	1.3186	84.7117
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	TWN Electrical and	CHN Electrical and			0.0016	1.6358	0.0026	2.0418	86.7535
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	USA Electrical and	CHN Electrical and			0.0009	1.7083	0.0015	1.1641	87.9176
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	ROW Electrical and	CHN Electrical and			0.0055	1.7763	0.0099	7.8357	95.7533
Optical Equipment	Optical Equipment	Optical Equipment							
TH Electrical and	TWN Electrical and	ROW Electrical and	CHN Electrical and		0.0001	1.8099	0.0003	0.2128	95.9662
Optical Equipment	Optical Equipment	Optical Equipment	Optical Equipment						
TH Electrical and	ROW Electrical and	EU Electrical and	CHN Electrical and		0.0001	2.0438	0.0003	0.2118	96.1780
Optical Equipment	Optical Equipment	Optical Equipment	Optical Equipment						
TH Electrical and	ROW Electrical and	TWN Electrical and	CHN Electrical and		0.0001	1.8099	0.0002	0.1611	96.3391
Optical Equipment	Optical Equipment	Optical Equipment	Optical Equipment						
TH Electrical and	ROW Electrical and	USA Electrical and	CHN Electrical and		0.0001	1.8912	0.0002	0.1824	96.5215
Optical Equipment	Optical Equipment	Optical Equipment	Optical Equipment						

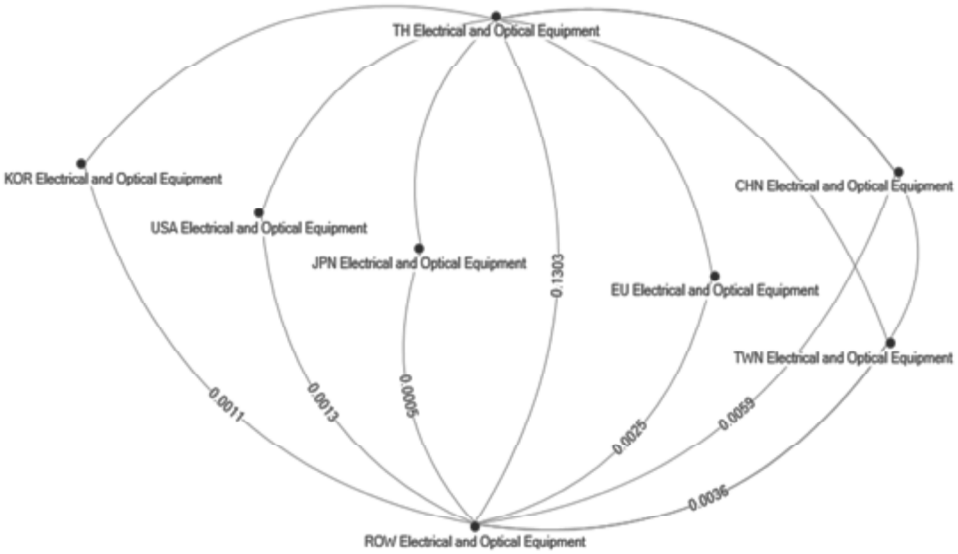

Figure 9: Main backward path 1 of Thailand's Electrical and Optical Equipment sector
Note: The value shown on each path is its Total Influence (TI)

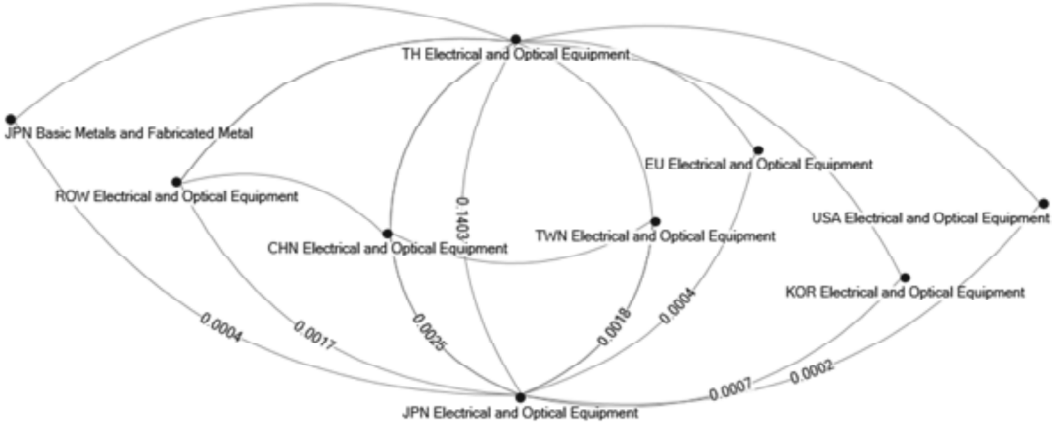

Figure 10: Main backward path 2 of Thailand's Electrical and Optical Equipment sector
Note: The value shown on each path is its Total Influence (TI)

sector in Thailand and that of EU. In addition to the direct link, the SPA result shows that there are three indirect influences that represent the network connecting productions located in Thailand, US and EU.

The fourth highest multiplier is that of Coke, Refined Petroleum and Nuclear Fuel sector. As Thailand's fossil-based energy mainly depends onimports, the decomposition result,shown on Table 8 and Figure 14, signifies the important

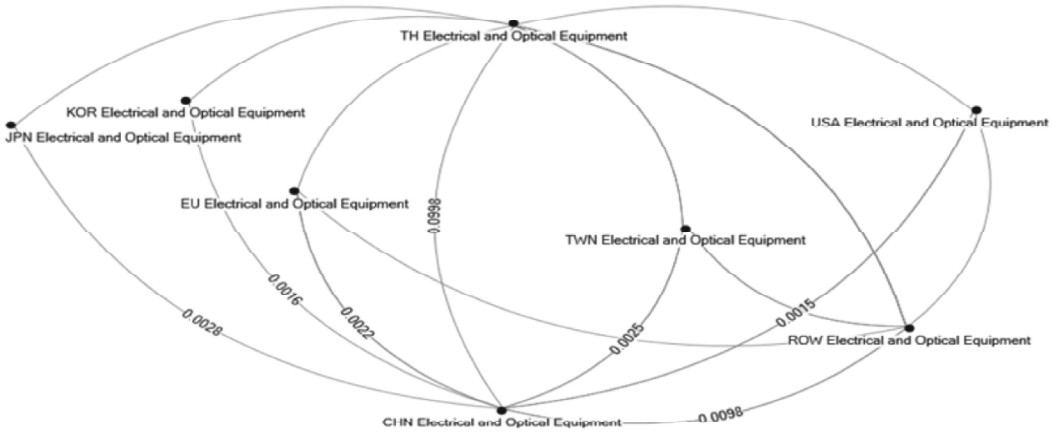

Figure 11: Main backward path 3 of Thailand's Electrical and Optical Equipment sector

Note: The value shown on each path is its Total Influence (TI)

Table 6
SPA's result of main backward paths of Thailand'sTransport Equipment sector

Country and Sector of Origin	*Country and Sector of Destination (order 1)*	*Country and Sector of Destination (order 2)*	*Global Influence (GI)*	*Direct Influence*	*Path Multiplier*	*Total Influence (TI)*	*TI/GI (%)*	*Cumulative (%)*
TH Transport Equipment	JPN Transport Equipment		0.2060	0.1100	1.8435	0.2027	98.4033	98.4033
TH Transport Equipment	EU Transport Equipment	JPN Transport Equipment		0.0001	2.2423	0.0003	0.1331	98.5364
TH Transport Equipment	ROW Transport Equipment	JPN Transport Equipment		0.0004	2.1880	0.0008	0.3923	98.9287

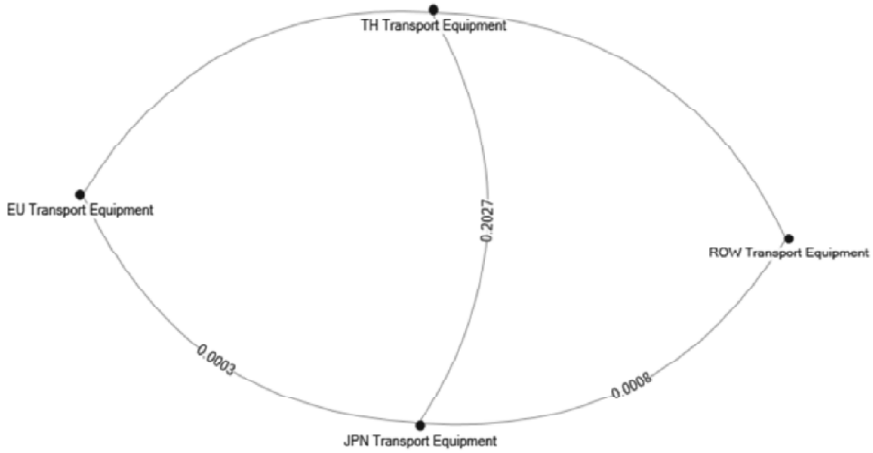

Figure 12: Main international backward paths of Thailand'sTransport Equipment sector

Note: The value shown on each path is its Total Influence (TI)

Table 7
SPA's result of main backward paths of Thailand'sMachinery sector

Country and Sector of Origin	*Country and Sector of Destination (order 1)*	*Country and Sector of Destination (order 2)*	*Global Influence (GI)*	*Direct Influence*	*Path Multiplier*	*Total Influence (TI)*	*TI/GI (%)*	*Cumulative (%)*
TH Machinery	EU Machinery		0.1348	0.1108	1.1708	0.1297	96.2508	96.2508
TH Machinery	USA Machinery	EU Machinery		0.0008	1.2435	0.0009	0.6944	96.9452
TH Machinery	ROW Basic Metals and Fabricated Metal	EU Machinery		0.0001	1.4543	0.0002	0.1208	97.0660
TH Machinery	ROW Machinery	EU Machinery		0.0012	1.2802	0.0016	1.1813	98.2472

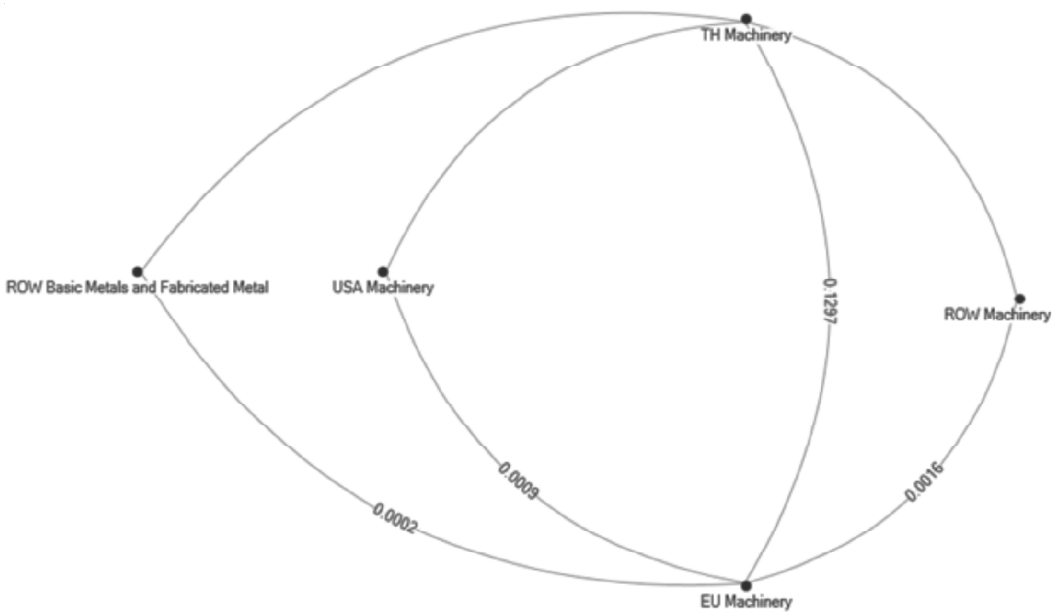

Figure 13: Main international backward paths of Thailand's Machinery sector
Note: The value shown on each path is its Total Influence (TI

ofimport inputs from the Rest of the World's Mining and Quarrying sector. The last selected SPA result is the decomposition of the backward multiplier of Machinery sector, which is composed of two main paths. As exhibited on Table 9 and Figure 15, the first path is the international production network that links Thailand's Machinery sector and Rest of the World's Basic Metals and Fabricated Metal sector. The decomposition shows that in addition to the direct linkage,there are also indirect paths connecting production processes located in Japan, Korea, China, Taiwan, EU, US and the Rest of the World. Interestingly, the decomposition

Table 8
SPA's result of main backward paths of Thailand's Coke, Refined Petroleum and Nuclear Fuel sector

Country and Sector of Origin	*Country and Sector of Destination (order 1)*	*Country and Sector of Destination (order 2)*	*Global Influence (GI)*	*Direct Influence*	*Path Multiplier*	*Total Influence (TI)*	*TI/GI (%)*	*Cumulative (%)*
TH Coke, Refined Petroleum and Nuclear Fuel	ROW Mining and Quarrying		0.9373	0.7048	1.3124	0.9250	98.6920	98.6920
TH Coke, Refined Petroleum and Nuclear Fuel	CHN Coke, Refined Petroleum and Nuclear Fuel	ROW Mining and Quarrying		0.0002	1.3846	0.0003	0.0281	98.7200
TH Coke, Refined Petroleum and Nuclear Fuel	EU Coke, Refined Petroleum and Nuclear Fuel	ROW Mining and Quarrying		0.0001	1.4320	0.0002	0.0168	98.7369
TH Coke, Refined Petroleum and Nuclear Fuel	JPN Mining and Quarrying	ROW Mining and Quarrying		0.0002	1.3830	0.0003	0.0305	98.7674
TH Coke, Refined Petroleum and Nuclear Fuel	JPN Coke, Refined Petroleum and Nuclear Fuel	ROW Mining and Quarrying		0.0005	1.3730	0.0007	0.0780	98.8454
TH Coke, Refined Petroleum and Nuclear Fuel	USA Coke, Refined Petroleum and Nuclear Fuel	ROW Mining and Quarrying		0.0002	1.4039	0.0003	0.0324	98.8778
TH Coke, Refined Petroleum and Nuclear Fuel	ROW Coke, Refined Petroleum and Nuclear Fuel	ROW Mining and Quarrying		0.0053	1.3651	0.0072	0.7666	99.6444

reveals the complex connections which are domestic linkages across industries and also intra-industry network across countries. For the second main path, as illustrated on Figure 16, the SPA result identifies that the international network connecting Thailand's Machinery sector and Japan's Basic Metals and Fabricated Metal sector. Similar to the first path, the decomposition reveals the multifaceted linkages of both inter-industry and cross-country connections.

Figure 14: Main international backward paths of Thailand's Coke, Refined Petroleum and Nuclear Fuel sector

Note: The value shown on each path is its Total Influence (TI)

Table 9
SPA's result of main backward paths of Thailand'sManufacturing sector

Country and Sector of Origin	*Country and Sector of Destination (order 1)*	*Country and Sector of Destination (order 2)*	*Country and Sector of Destination (order 3)*	*Global Influence (GI)*	*Direct Influence*	*Path Multiplier*	*Total Influence (TI)*	*TI/GI (%)*	*Cumula-tive (%)*
Main path 1									
TH Manufacturing	ROW Basic Metals and Fabricated Metal			0.1103	0.0656	1.3335	0.0875	79.2981	79.2981
TH Manufacturing	CHN Basic Metals and Fabricated Metal	ROW Basic Metals and Fabricated Metal			0.0004	2.1256	0.0008	0.7369	80.0350
TH Manufacturing	EU Basic Metals and Fabricated Metal	ROW Basic Metals and Fabricated Metal			0.0014	1.7603	0.0024	2.1862	82.2213
TH Manufacturing	EU Manufacturing	ROW Basic Metals and Fabricated Metal			0.0008	1.3926	0.0012	1.0594	83.2806
TH Manufacturing	JPN Basic Metals and Fabricated Metal	ROW Basic Metals and Fabricated Metal			0.0016	2.1572	0.0034	3.1185	86.3992
TH Manufacturing	KOR Basic Metals and Fabricated Metal	ROW Basic Metals and Fabricated Metal			0.0007	2.3781	0.0017	1.5280	87.9272
TH Manufacturing	TWN Basic Metals and Fabricated Metal	ROW Basic Metals and Fabricated Metal			0.0005	1.9605	0.0011	0.9749	88.9021
TH Manufacturing	USA Basic Metals and Fabricated Metal	ROW Basic Metals and Fabricated Metal			0.0003	1.7700	0.0006	0.5030	89.4051
TH Manufacturing	USA Manufacturing	ROW Basic Metals and Fabricated Metal			0.0002	1.3636	0.0003	0.2438	89.6489
TH Manufacturing	TH Basic Metals and Fabricated Metal	ROW Basic Metals and Fabricated Metal			0.0004	1.6522	0.0007	0.6623	90.3112

TH Manufacturing	TH Electrical and Optical Equipment	ROW Basic Metals and Fabricated Metal			0.0002	1.5454	0.0003	0.2579	90.5690
TH Manufacturing	TH Transport Equipment	ROW Basic Metals and Fabricated Metal			0.0001	1.4526	0.0002	0.1414	90.7105
TH Manufacturing	ROW Chemicals and Rubber	ROW Basic Metals and Fabricated Metal			0.0001	1.5512	0.0002	0.1475	90.8580
TH Manufacturing	ROW Manufacturing	ROW Basic Metals and Fabricated Metal			0.0024	1.3854	0.0033	2.9870	93.8450
TH Manufacturing	EU Manufacturing	EU Basic Metals and Fabricated Metal	ROW Basic Metals and Fabricated Metal		0.0002	1.8326	0.0004	0.3564	94.2013
Main path 2									
TH Manufacturing	JPN Basic Metals and Fabricated Metal			0.1010	0.0521	1.7371	0.0904	89.5137	89.5137
TH Manufacturing	CHN Basic Metals and Fabricated Metal	JPN Basic Metals and Fabricated Metal			0.0001	2.7696	0.0004	0.3630	89.8768
TH Manufacturing	JPN Manufacturing	JPN Basic Metals and Fabricated Metal			0.0006	1.8404	0.0012	1.1485	91.0252
TH Manufacturing	KOR Basic Metals and Fabricated Metal	JPN Basic Metals and Fabricated Metal			0.0005	3.0980	0.0014	1.4228	92.4480
TH Manufacturing	TWN Basic Metals and Fabricated Metal	JPN Basic Metals and Fabricated Metal			0.0003	2.5545	0.0008	0.8142	93.2622
TH Manufacturing	TH Basic Metals and Fabricated Metal	JPN Basic Metals and Fabricated Metal			0.0004	2.1520	0.0008	0.7476	94.0098
TH Manufacturing	TH Electrical and Optical Equipment	JPN Basic Metals and Fabricated Metal			0.0001	2.0130	0.0003	0.2911	94.3008
TH Manufacturing	ROW Basic Metals and Fabricated Metal	JPN Basic Metals and Fabricated Metal			0.0006	2.1572	0.0012	1.1933	95.4942

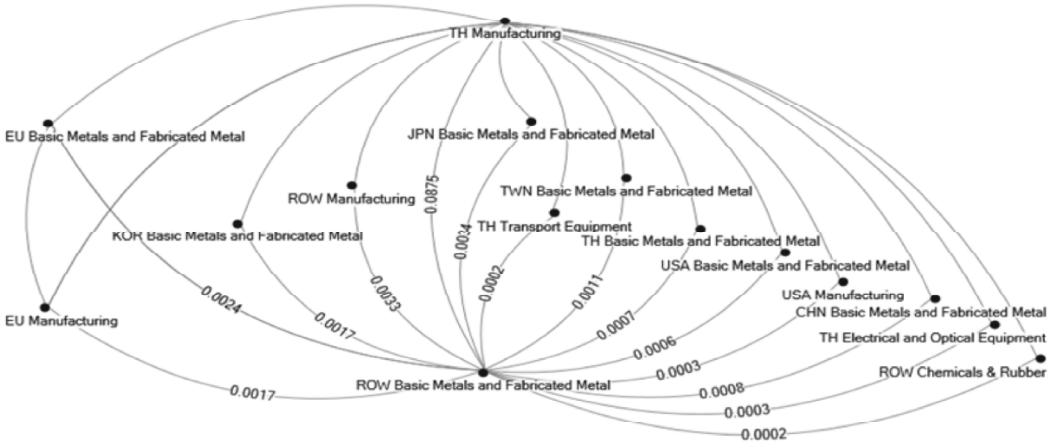

Figure 15: Main backward path 1 of Thailand's Manufacturing sector

Note: The value shown on each path is its Total Influence (TI)

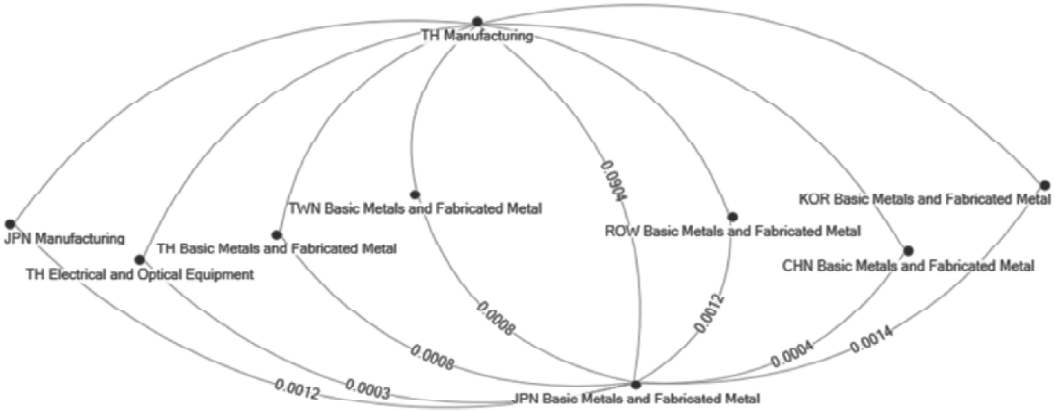

Figure 16: Main backward path 2 of Thailand's Manufacturing sector

Note: The value shown on each path is its Total Influence (TI)

5. CONCLUSION

This paper delivers two contributions on the study of Thailand's linkages to the international supply chain. First the procedure of extending the original WIOD table to explicitly exhibit Thailand's domestic and international trade data is introduced. Second the quantitative techniques of Leontief multiplier and the Structural Path Analysis (SPA) are applied to the modified WIOD table. The calculation of multipliers indicates that electronics manufacturing has the highest value of both international backward and forward multipliers. This finding signifies its contribution to both upstream and downstream connected productions located across countries. The result generated by Structural Path Analysis (SPA)

also illustrates the global production network of electronics manufacturing across Thailand, Japan, China Korea, Taiwan, US, EU and rest of the world. The SPA result of Thailand's manufacturing sector also reveals the similar pattern. These findings affirm the importance of connections between Thai economy and the international supply chain, and these computational results also identify the increasing contribution of global volatilities propagating through the linkages of global production network.

For the future extension and development, the modification of WIOD table should be expanded to include data of other economies. Similarly the modification of WIOD tables should be extended to cover the broader time periods in order to capture the rapidly changing structure of global production network. In addition to theproposed issues of data improvement, the modified WIOD table should be applied to the multi-region Computable General Equilibrium model or other price-endogenous techniques. These proposed applications would provide more insights on the global transmission mechanism of trade and production.

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