Heterogeneity of impact on national income from participating in the global value chain

---- An empirical study based on worldwide value-added trade

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Abstract

This research focuses on analysing how participation in global value chain(GVC) affects a country's national income per capita. I start with an introduction of the methods to decompose trade in value added from Inter-country input-output Tables, and the definition of indicators to measure GVC integration. Then I use these indicators calculated from EORA Global MARIO database to fit in fixed-effect models and analyse the effect of GVC on national income per capita. The results show that GVC-related contents embedded in gross trade have positive effects while traditional trade contents have no significant effects. Also the result indicates that higher GVC participation and GVC position have heterogeneous influences on the national income per capita of countries across different income-levels. Lastly I will compare specific countries' performance in GVC, using the sector-level decomposed data and explain the reasons.

Key words: Global value chain; Input-output Table; International trade

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1. Introduction

The modern division of labor in international industries continues to evolve from the division of labor among products to the division of labor within products, so that GVC trade has become more and more popular. It is said in Zheng(2020) that along with the growth of trade in final products, trade in intermediate products has grown rapidly, making both the expansion and intensive margins of global value chains continue to increase. Theoretically, developed countries can benefit from on a wealth of diversified technologies and intermediate products to continuously reconfigure production among countries, taking advantage of the comparative advantages of each country to obtain the dividend of technological diversification. The economic development of developing countries relies on abundant cheap labor resources, undeveloped land, environment and other natural endowments to attract the transfer of intermediate products and technologies from developed countries. So questions naturally arise: whether a country's national income will get increased by participating in GVC and does different countries get the same influence? However, there are few empirical researches about solving these questions. In section 2, I give a literature review of former researches about GVC, decomposition and the benefit of participation in GVC.

An important influence of the development of GVC trade is that it makes the calculation of export value based on traditional perspective unreliable. Traditional trade mainly focuses on the international exchange of final products, or the products which are directly absorbed in that imported country. If the circulation process of intermediate products becomes more lengthy and the direction becomes more complicated (back and forth), the measurement of export value based

on traditional trade will be much larger than the actual added value, so-called double counting. In order to calculate the "real" exports accurately, researchers have developed and improved a set of decomposition methods based on the international input-output table. Using these decomposition methods, export value in value-added of each country and industry can be calculated and used for solving the questions above.

In section 3, I summarize a brief introduction to the decomposition methods and the calculation of GVC-related indicators.

In the rest parts of this paper, firstly the data source are provided, and then I describe the regression equations for analyzing the relationship between national income per capita and GVC-related indicators. Finally, the results and conclusions are given.

2. Literature Review

Researches about GVC by using input-output tables dates back back to Hummels et al.(2001), in which the definition of vertical specialization was firstly given (see Figure1). The production process of country2 can be described as: country2 imports intermediate products from country1 (A) and uses other domestic intermediate products (B), labor and capital (C) to create gross output, which is divided into two parts: domestically absorbed (D) and exports (E). The vertical specialization measure(VS) is defined as A/(D+E)*E, A/(D+E) represents the intermediate contents imported which are input for output per unit, so the whole product equals to the whole imported contents embedded in gross exports (i.e foreign value added share). Also, this paper provided a the VS1 concept which means "domestic value added contents embedded in the

re-export of the imported country ”. Hummels’s decomposition method (HIY) is considered as an early version of the later Koopman(2014) and Wang et al.(2013), while the shortage of HIY is that it didn’t provide the calculation of VS1 (i.e indirect domestic value added share). Koopman and Wang(2010) improved HIY by using the value added share matrix which allows to calculate both the domestic value added, VS and VS1.

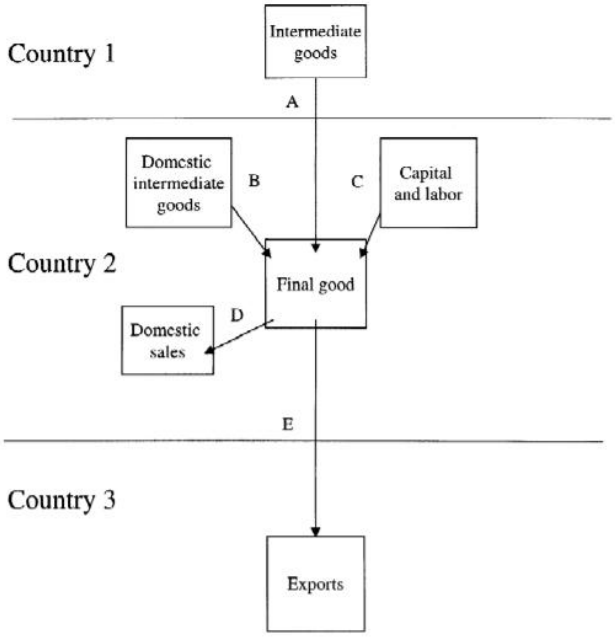


Figure 1: Vertical Specialization

(Source:Hummels(2001))

The researches of Koopman et al.(2010, 2012, 2014) provide a more detailed decomposition of exports into 9 terms (KPWW method), the method calculates value added components by sourcing countries/sectors, absorbed destinations, and product categories, for example, value added embedded in the exports of final products or intermediate products which are used to produce final products). This method also considers the double counting contents, when back and forth trade happens and intermediate goods travel across countries over twice.

Wang et al.(2013) update KPWW to a 16-term decomposition which can fully decompose gross exports into 1.Domestic value added (DVA) absorbed as final products, intermediate products

used to produce domestic final demand. 2.DVA in intermediate products which is produced by the importer into re-exported final products to the third countries (including re-exported back to the origin country (RDV)). 3.Foreign value added absorbed as final products, intermediate products by different FVA sourcing countries: sourcing from the direct importer or sourcing from other countries. 4.Pure double counting contents.

Besides these, there are also introduction files in some value added trade database which interpreting decomposition methods.

There are many papers focusing on comparing changes in countries' GVC participation or GVC positions, few of them analyze the relationship between GVC participation and national income. Kummritz(2015) uses WIOD and OECD ICIO database of year 1995, 2000, 2005, and 2008, and gets a conclusion that higher GVC participation benefits one country's domestic value added (GDP), he also finds that *i2e* and *e2r* indicators have robust and significant effects on mid and high income countries, but not significant on low income countries. Another working paper is Anna Ignatenko et al.(2019) , showing a similar relationship between national income per capita using Eora Multi Regional Input-Output (MARIO) database. They also conclude that these positive effects are only related to GVC trade but not to conventional trade.

One issue in Kummritz's research is that he treats countries' income level as a time-invariant character, but as countries' GNI per capita changes, income level is non-fixed (See appendix of Cristina Constantinescu et al(2017). Hence, there is a need to reconsider the relationship between GVC participation and income per capita across countries at different income levels . In addition, whether different GVC positions have an effect on GDP per capita also needs to be studied.

3. Methodology and data

3-1. KPWW

For simplicity, consider a 3-country 2-sector IO Table (See Table 2). Each cell of intermediate demand block represents a 2 by 2 matrix, each cell of final demand and gross output blocks represents a 2 by 1 matrix, and each cell of value added and gross input blocks represents a 1 by 2 matrix. Let A be the intermediate input coefficient matrix (6 by 6), $A_{ij}^{mn} = I_{ij}^{mn} / X_j^n$,it gives the direct input across sectors needed to produce each unit of gross output. Let v be the value added coefficient matrix (6 by 6) ,where diagonal element gives value added share of gross output, $v_i^m = V_i^m / X_i^m$. $i,j \in (1,2)$, $mn \in (R,S,T)$.

Table 1 : 3-country 2-sector non-competitive International IO Table

		Intermediate demand			Final demand			Gross output
		Country R	Country S	Country T	Country R	Country S	Country T	
Intermediate input	Country R	I^{RR}	I^{RS}	I^{RT}	F^{RR}	F^{RS}	F^{RT}	X^R
	Country S	I^{SR}	I^{SS}	I^{ST}	F^{SR}	F^{SS}	F^{ST}	X^S
	Country T	I^{TR}	I^{TS}	I^{TT}	F^{TR}	F^{TS}	F^{TT}	X^T
Value added		V^R	V^S	V^T				
Gross input		X^R	X^S	X^T				

It is easily to get: $(I-A)^{-1} F = X$ by using the relationship: AX+F=X, where F is a 6 by 1 matrix, each element is the sum of the elements in final demand block by row, it represents all countries' final demand for each country's each sector, for instance, final demand for country m's sector i is

$F_i^m = \sum_n F_i^{mn}$. Multiplying v and (I-A)$^{-1}$ - which is known as Leontief inverse- gives the value added multiplier. contents of the gross output induced by each country's final demand. For example, as for country S's final demand column F_i^{mS}, we can compute:

$$\begin{pmatrix} v_1^R & & & \dots & & 0 \\ 0 & v_2^R & & & & \\ & & v_1^S & & & \\ \dots & & & v_2^S & & \dots \\ & & & & v_1^T & \\ 0 & & & \dots & & v_2^T \end{pmatrix} \begin{pmatrix} B_{11}^{RR} & B_{12}^{RR} & B_{11}^{RS} & B_{12}^{RS} & B_{11}^{RT} & B_{12}^{RT} \\ B_{21}^{RR} & B_{22}^{RR} & B_{21}^{RS} & B_{22}^{RS} & B_{12}^{RT} & B_{22}^{RT} \\ B_{11}^{SR} & B_{12}^{SR} & B_{11}^{SS} & B_{12}^{SS} & B_{11}^{ST} & B_{12}^{ST} \\ B_{21}^{SR} & B_{12}^{SR} & B_{21}^{SS} & B_{22}^{SS} & B_{21}^{ST} & B_{22}^{ST} \\ B_{11}^{TR} & B_{12}^{TR} & B_{11}^{TS} & B_{12}^{TS} & B_{11}^{TT} & B_{12}^{TT} \\ B_{21}^{TR} & B_{22}^{TR} & B_{21}^{TS} & B_{22}^{TS} & B_{21}^{TT} & B_{22}^{TT} \end{pmatrix} \begin{pmatrix} F_1^{RS} & & & \dots & & 0 \\ 0 & F_2^{RS} & & & & \\ & & F_1^{SS} & & & \\ \dots & & & F_2^{SS} & & \dots \\ & & & & F_1^{TS} & \\ 0 & & & \dots & & F_2^{TS} \end{pmatrix} \cdots ①$$

and get a 6x6 matrix:

$$\begin{pmatrix} v_1^R B_{11}^{RR} F_1^{RS} & v_1^R B_{12}^{RR} F_2^{RS} & v_1^R B_{11}^{RS} F_1^{SS} & v_1^R B_{12}^{RS} F_2^{SS} & v_1^R B_{11}^{RT} F_1^{TS} & v_1^R B_{12}^{RT} F_2^{TS} \\ v_2^R B_{21}^{RR} F_1^{RS} & v_2^R B_{22}^{RR} F_2^{RS} & v_2^R B_{21}^{RS} F_1^{SS} & v_2^R B_{22}^{RS} F_2^{SS} & v_2^R B_{12}^{RT} F_1^{TS} & v_2^R B_{22}^{RT} F_2^{TS} \\ v_1^S B_{11}^{SR} F_1^{RS} & v_1^S B_{12}^{SR} F_2^{RS} & v_1^S B_{11}^{SS} F_1^{SS} & v_1^S B_{12}^{SS} F_2^{SS} & v_1^S B_{11}^{ST} F_1^{TS} & v_1^S B_{12}^{ST} F_2^{TS} \\ v_2^S B_{21}^{SR} F_1^{RS} & v_2^S B_{12}^{SR} F_2^{RS} & v_2^S B_{21}^{SS} F_1^{SS} & v_2^S B_{22}^{SS} F_2^{SS} & v_2^S B_{21}^{ST} F_1^{TS} & v_2^S B_{22}^{ST} F_2^{TS} \\ v_1^T B_{11}^{TR} F_1^{RS} & v_1^T B_{12}^{TR} F_2^{RS} & v_1^T B_{11}^{TS} F_1^{SS} & v_1^T B_{12}^{TS} F_2^{SS} & v_1^T B_{11}^{TT} F_1^{TS} & v_1^T B_{12}^{TT} F_2^{TS} \\ v_2^T B_{21}^{TR} F_1^{RS} & v_2^T B_{22}^{TR} F_2^{RS} & v_2^T B_{21}^{TS} F_1^{SS} & v_2^T B_{22}^{TS} F_2^{SS} & v_2^T B_{21}^{TT} F_1^{TS} & v_2^T B_{22}^{TT} F_2^{TS} \end{pmatrix} \cdots ②$$

Each element of ② , $v_i^m B_{ij}^{mn} F_j^{nS}$ represents that, the value added contents produced by country m sector i which is induced by the final demand of country S for country n sector j,[1] or simply country m sector i's exports in value added to S through country n sector j's final product exports. If we focus the 1st and 2nd rows, they means country R sector 1 and 2's exports in value added to S respectively.

Applying the same way and substitute gross export E for F, we can obtain a Value added exports matrix:

[1] In order to produce the intermediate products used by country n's sector j to produce the final demand of country S for country n sector j, country m sector i needs to produce $B_{ij}^{mn} F_j^{nS}$ gross output, multiplying it with v gets the value added parts generated by country m sector i.

$$VBE = \begin{pmatrix} v_1^R B_{11}^{RR} E_1^R & v_1^R B_{12}^{RR} E_2^R & v_1^R B_{11}^{RS} E_1^S & v_1^R B_{12}^{RS} E_2^S & v_1^R B_{11}^{RT} E_1^T & v_1^R B_{12}^{RT} E_2^T \\ v_2^R B_{21}^{RR} E_1^R & v_2^R B_{22}^{RR} E_2^R & v_2^R B_{21}^{RS} E_1^S & v_2^R B_{22}^{RS} E_2^S & v_2^R B_{12}^{RT} E_1^T & v_2^R B_{22}^{RT} E_2^T \\ v_1^S B_{11}^{SR} E_1^R & v_1^S B_{12}^{SR} E_2^R & v_1^S B_{11}^{SS} E_1^S & v_1^S B_{12}^{SS} E_2^S & v_1^S B_{11}^{ST} E_1^T & v_1^S B_{12}^{ST} E_2^T \\ v_2^S B_{21}^{SR} E_1^R & v_2^S B_{12}^{SR} E_2^R & v_2^S B_{21}^{SS} E_1^S & v_2^S B_{22}^{SS} E_2^S & v_2^S B_{21}^{ST} E_1^T & v_2^S B_{22}^{ST} E_2^T \\ v_1^T B_{11}^{TR} E_1^R & v_1^T B_{12}^{TR} E_2^R & v_1^T B_{11}^{TS} E_1^S & v_1^T B_{12}^{TS} E_2^S & v_1^T B_{11}^{TT} E_1^T & v_1^T B_{12}^{TT} E_2^T \\ v_2^T B_{21}^{TR} E_1^R & v_2^T B_{22}^{TR} E_2^R & v_2^T B_{21}^{TS} E_1^S & v_2^T B_{22}^{TS} E_2^S & v_2^T B_{21}^{TT} E_1^T & v_2^T B_{22}^{TT} E_2^T \end{pmatrix} \cdots ③$$

Note that E is computed as sum of intermediate and final use of other countries for the target sector, i.e. $E_i^m = \sum_j \sum_{n \neq m} I_{ij}^{mn} + \sum_{n \neq m} F_i^{mn}$. Therefore, $v_i^m B_{ij}^{mn} E_j^n$ gives the value added contents produced by country m sector i embedded in the exports of country n sector j. This matrix actually provides DVA, FVA and DVX in each sector's exports, as:

DVA in exports of country 1 sector 1

FVA in exports of country 1 sector 1

DVX in exports of country 1 sector 1

$$\begin{pmatrix} v_1^R B_{11}^{RR} E_1^R & v_1^R B_{12}^{RR} E_2^R & v_1^R B_{11}^{RS} E_1^S & v_1^R B_{12}^{RS} E_2^S & v_1^R B_{11}^{RT} E_1^T & v_1^R B_{12}^{RT} E_2^T \\ v_2^R B_{21}^{RR} E_1^R & v_2^R B_{22}^{RR} E_2^R & v_2^R B_{21}^{RS} E_1^S & v_2^R B_{22}^{RS} E_2^S & v_2^R B_{12}^{RT} E_1^T & v_2^R B_{22}^{RT} E_2^T \\ v_1^S B_{11}^{SR} E_1^R & v_1^S B_{12}^{SR} E_2^R & v_1^S B_{11}^{SS} E_1^S & v_1^S B_{12}^{SS} E_2^S & v_1^S B_{11}^{ST} E_1^T & v_1^S B_{12}^{ST} E_2^T \\ v_2^S B_{21}^{SR} E_1^R & v_2^S B_{12}^{SR} E_2^R & v_2^S B_{21}^{SS} E_1^S & v_2^S B_{22}^{SS} E_2^S & v_2^S B_{21}^{ST} E_1^T & v_2^S B_{22}^{ST} E_2^T \\ v_1^T B_{11}^{TR} E_1^R & v_1^T B_{12}^{TR} E_2^R & v_1^T B_{11}^{TS} E_1^S & v_1^T B_{12}^{TS} E_2^S & v_1^T B_{11}^{TT} E_1^T & v_1^T B_{12}^{TT} E_2^T \\ v_2^T B_{21}^{TR} E_1^R & v_2^T B_{22}^{TR} E_2^R & v_2^T B_{21}^{TS} E_1^S & v_2^T B_{22}^{TS} E_2^S & v_2^T B_{21}^{TT} E_1^T & v_2^T B_{22}^{TT} E_2^T \end{pmatrix}$$

If separating gross export into intermediate and final product exports, and by destination, we can obtain Koopman et al.(2014)'s 9-term decomposition (sectors aggregated):

$$E^R = v^R \left\{ \begin{array}{l} (\sum_{S \neq R} B^{RR} F^{RS} + \sum_{S \neq R} B^{RS} F^{SS} + \sum_{S \neq R} \sum_{T \neq R,S} B^{RS} F^{ST}) + \\ \left[(\sum_{S \neq R} B^{RS} F^{SR} + \sum_{S \neq R} B^{RS} A^{SR} (I - A^{RR})^{-1} F^{RR} \right] + \\ \sum_{S \neq R} B^{RS} A^{SR} (I - A^{RR})^{-1} E^R \end{array} \right\}$$
$$+ \sum_{T \neq R} \sum_{S \neq R} v^T \left\{ \left[B^{TR} F^{RS} + B^{TR} A^{RS} (I - A^{SS})^{-1} F^{SS} \right] + B^{TR} A^{RS} (I - A^{SS})^{-1} E^S \right\} \quad \cdots \quad ④$$

These 9 items are, respectively: ①sum of DVA of R's final products exports. ②sum of DVA of R's intermediate products exports, produced into domestically absorbed final products. ③sum of DVA of R's intermediate products exports, produced into final products re-exported to a third country. ④sum of DVA of R's intermediate products exports, produced into final products re-exported back to origin country R (re-imported value-added as final).⑤sum of DVA re-imported as intermediate products to produce domestic final use.⑥Pure-double counted intermediate products exports due to domestic source. ⑦sum of FVA of R's final products exports. ⑧sum of FVA of R's intermediate products exports, produced into domestically absorbed final products.⑨Pure-double counted intermediate products exports due to foreign source. A simple relationship between gross exports, DVA, DVX and FVA can be found in Koopman et al.(2014) and Aqib et al.(2017): 1. DVA + FVA = gross exports, 2. DVA = Directly absorbed contents + DVX, 3. DVX = IV(DVA in intermediates re-exported to 3rd country in final products) + Contents finally returns + Double Counting. Define GVC-related trade as DVX+FVA and unrelated trade as the contents absorbed by the direct importer.

Table2 gives an understanding of different kinds of flows of goods calculated by KPWW's 9 items respectively. Notice that the 9 terms from KPWW don't give DVA in exports that is re-exported to the 3rd country from in intermediate goods (i.e.$v^R B^{RS} A^{ST} X^T$) as Koopman et al.(2014) suggest, sum of ③~⑥ only provides a part of Hummels's VS1. Therefore, another more detailed method WWZ which is explained in Wang et al.(2013), is used to compute DVX.

Table 2 Implication of KPWW's 9-term decomposition[2]

#	Terms	Trade flows
①	$v^R \sum_{S \neq R} B^{RR} F^{RS}$	$R \xrightarrow{fin} S$
②	$v^R \sum_{S \neq R} B^{RS} F^{SS}$	$R \xrightarrow{\text{int}} S^{\exists} \xrightarrow{fin} S$
③	$v^R \sum_{S \neq R} \sum_{T \neq R,S} B^{RS} F^{ST}$	$R \xrightarrow{\text{int}} S^{\exists} \xrightarrow{fin} T$
④	$v^R \sum_{S \neq R} B^{RS} F^{SR}$	$R \xrightarrow{\text{int}} S^{\exists} \xrightarrow{fin} R$
⑤	$v^R \sum_{S \neq R} B^{RS} A^{SR} (I - A^{RR})^{-1} F^{RR}$	$R \xrightarrow{\text{int}} S \xrightarrow{\text{int}} R^{\exists} \xrightarrow{fin} R$
⑥	$v^R \sum_{S \neq R} B^{RS} A^{SR} (I - A^{RR})^{-1} E^{R}$	$R \xrightarrow{\text{int}} S \xrightarrow{\text{int}} R^{\exists} \xrightarrow{fin\ or\ \text{int}} Export$
⑦	$\sum_{T \neq R} \sum_{S \neq R} v^T B^{TR} F^{RS}$	$T \xrightarrow{\text{int}} R^{\exists} \xrightarrow{fin} S$
⑧	$\sum_{S \neq R} \sum_{T \neq R} v^T B^{TR} A^{RS} (I - A^{SS})^{-1} F^{SS}$	$T \xrightarrow{\text{int}} R \xrightarrow{\text{int}} S^{\exists} \xrightarrow{fin} S$
⑨	$\sum_{T \neq R} \sum_{S \neq R} v^T B^{TR} A^{RS} (I - A^{SS})^{-1} E^{S}$	$T \xrightarrow{\text{int}} R \xrightarrow{\text{int}} S^{\exists} \xrightarrow{fin\ \text{or int}} Export$

3-2 GVC indicators

Two well-known GVC indicators: GVC participation and GVC position, are defined as:

GVC participation = (DVX+FVA) / Gross Exports

GVC position = ln (1+ DVX / Gross Exports) - ln (1+ FVA / Gross Exports)

In the equations, DVX and FVA share in gross exports are defined as forward and backward participation, respectively. They indicate the formation of countries participating in GVC: as an exporter of intermediate products for producing other countries' exports, and as an importer who uses foreign intermediate products to produce exports.

In the other hand, GVC position is an index which shows if countries contribute more value added

[2] $\exists$ represents a process of producing finished products from intermediate products.

in other countries' exports, i.e. more upstream or reversely.

3-3 Data

It is known there are at least 6 kinds of globally ranged international Input-Ouput Table databases (see Inomata (2019)), covering different regions and sectors/products. Due to different versions, some databases built across years are not consistent (for example OECD-ICIO).

The database I use to compute DVA, FVA, DVX and other related indicators is EORA26 which covers 190 countries and 26 sectors during 2001-2016. In addition, data of other national accounts such as GDP, gross capital formation are taken from World Bank Database, the classification of income level is based on World Bank's threshold of countries' GNI per capita released in 2012: low(<$1005), lower middle(<$3975), upper middle(<$12275) and high income. The summary of main variables is as follows, note that countries relying on oil export are likely to have higher position index but less relativity to the idea of GVC upstreamness, such as R&D, design..so they are excluded.

Table 3: Summary statistics

Variable	*Obs*	*Mean*	*Std. Dev.*	*Within Std.Dev*	*Min*	*Max*
log(GDP per capita)	2718	8.56	1.62	0.41	2.97	12.15
log(DVA)	2718	15.46	2.52	0.47	9.71	21.35
log(DVX)	2718	14.41	2.63	0.49	8.74	20.34
log(FVA)	2718	14.15	2.75	0.52	8.32	20.59
log(Total)	2718	15.75	2.56	0.48	10.30	21.56
log(Gross capital formation per capita)	2187	0.15	1.65	0.48	-5.33	3.41
GVC participation	2718	0.52	0.13	0.03	0 .24	0.94
GVC position	2718	0.03	0.15	0.04	-0.41	0.49
Forward participation	2718	0.28	0.10	0.03	0.07	0.82
Backward participation	2718	0.24	0.13	0.03	0.00	0.68
Trade openness	2543	90.01	56.23	14.21	11.86	442.62

Figure2 shows forward, backward participation and GVC position indexes of some representative countries at different income level. Specifically, middle income: China, Philippines and Thailand, high income: USA, Japan and Germany. (GVC position indexes are scaled on the right axis). The results show that high income countries' GVC position indexes are decreasing and mid income countries' position indexes are rising. This reflects the characteristics of today's GVC trade, that is, as developing countries improve their skills in production, they shift more value added contents of mid and high tech products from imports to domestic production, as their DVX share increases and FVA share decreases, the GVC position indexes rise up.

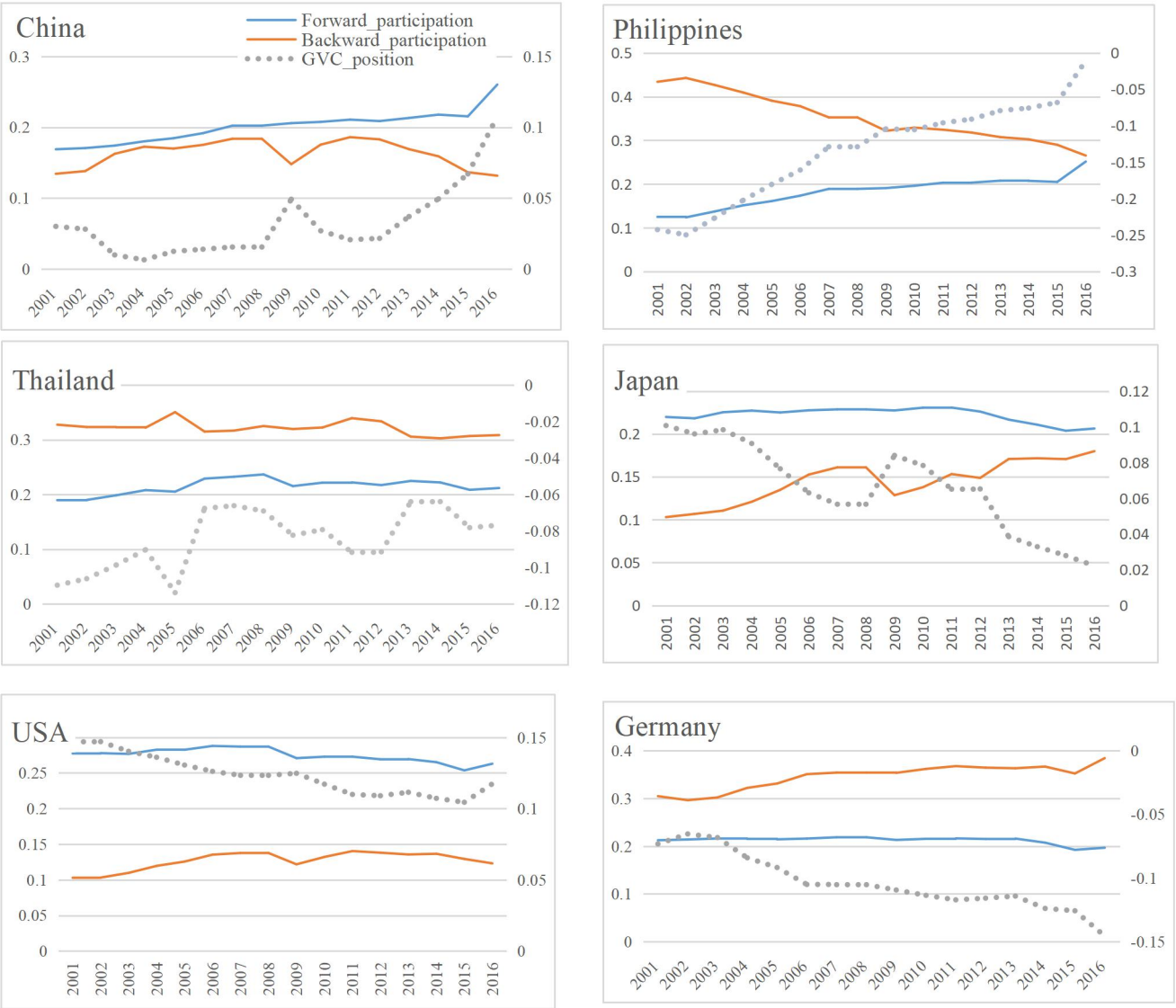


Figure 2: Forward / Backward participation and GVC position indexes of different countries

To check the changes of DVX and FVA at sector level, for each country above, I calculate the share of different sectors' DVX in the total GVC-related trade (namely, DtT ratio). Figure3&4 show the evolution during 1995-2015.

After joining in WTO, China has firstly shown an decrease in DtT ratio of mid/high tech manufacturing: *Electrical Machinery* & *Petroleum, Chemical and Non-Metallic Products* and after 2010, China's DVX of these sectors turned to increasing. Additionally, after the financial crisis, China's DVX of financial product exports has grown rapidly from 5.4% to 8% in the total GVC-related trade. In Philippines and Thailand, rapid growing of DtT ratios can be seen in *Electrical Machinery* and *Petroleum, Chemical and Non-Metallic Products* respectively. And for these countries, DtT ratios in low-tech manufacturing such as Agriculture, Mining or retail trade are all getting smaller. This phenomenon most likely means that as production ability increases and income rises up, the production of low-tech manufacturing in GVC will shift from where used to be low income countries to the countries at lower income level.

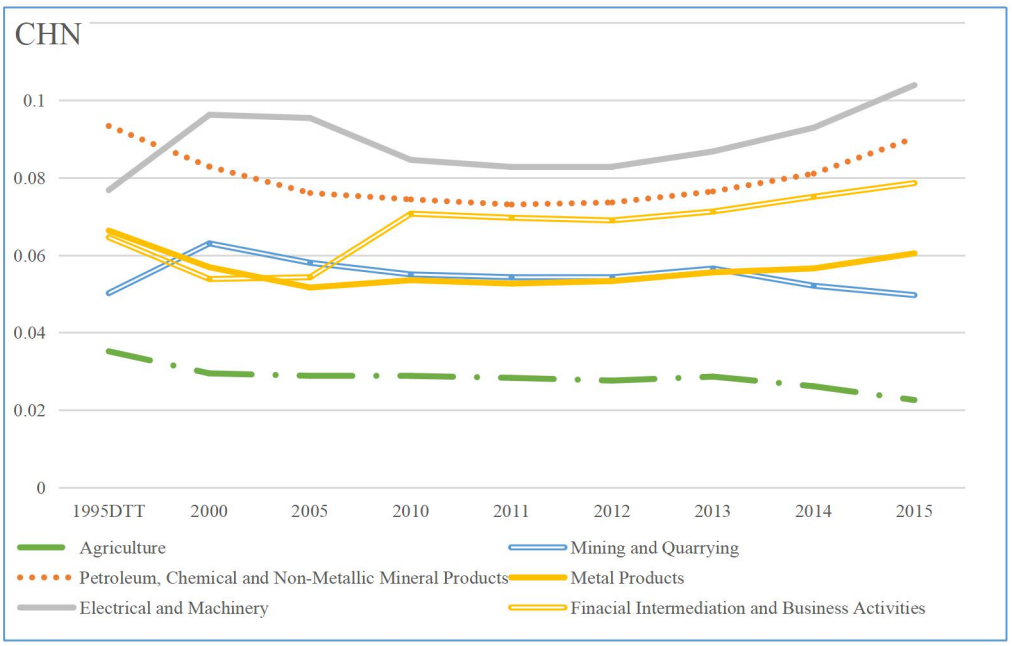


Figure 3: DVX / GVC-related trade of different sectors in China

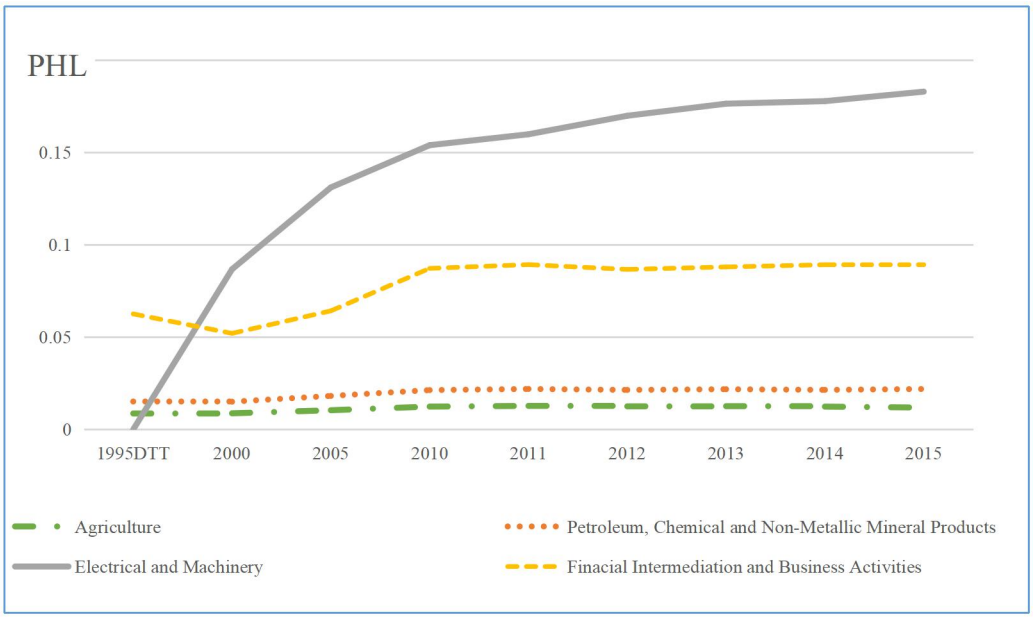


Figure4: DVX / GVC-related trade of main exporting sectors in Philippines

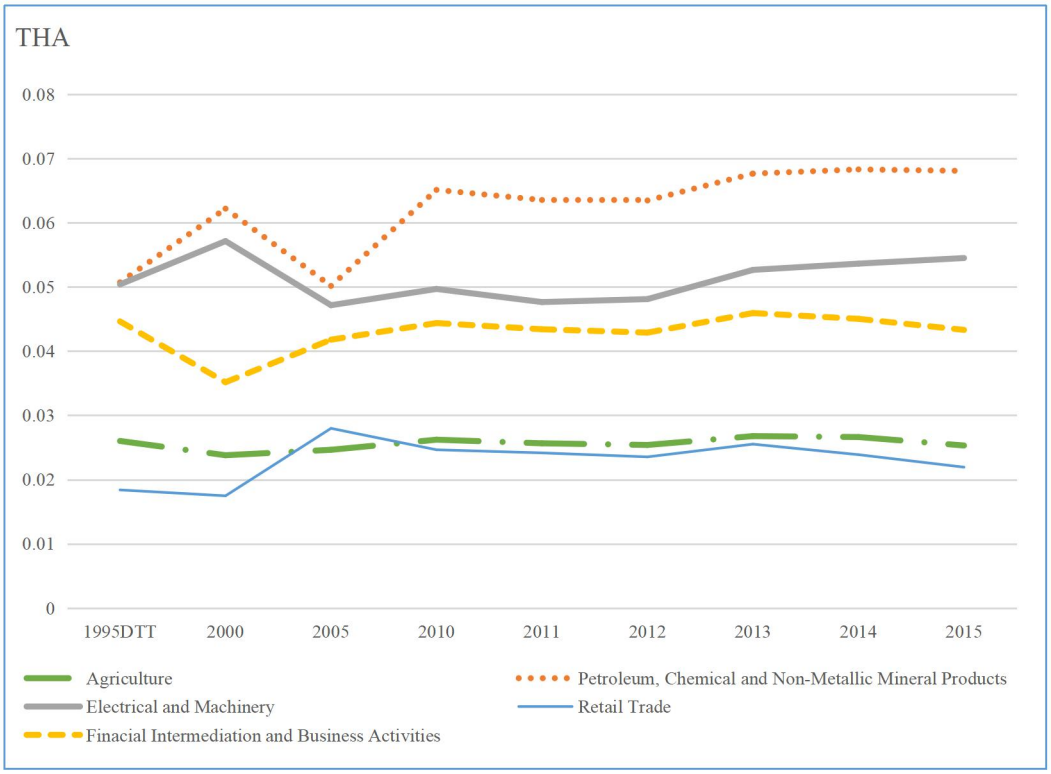
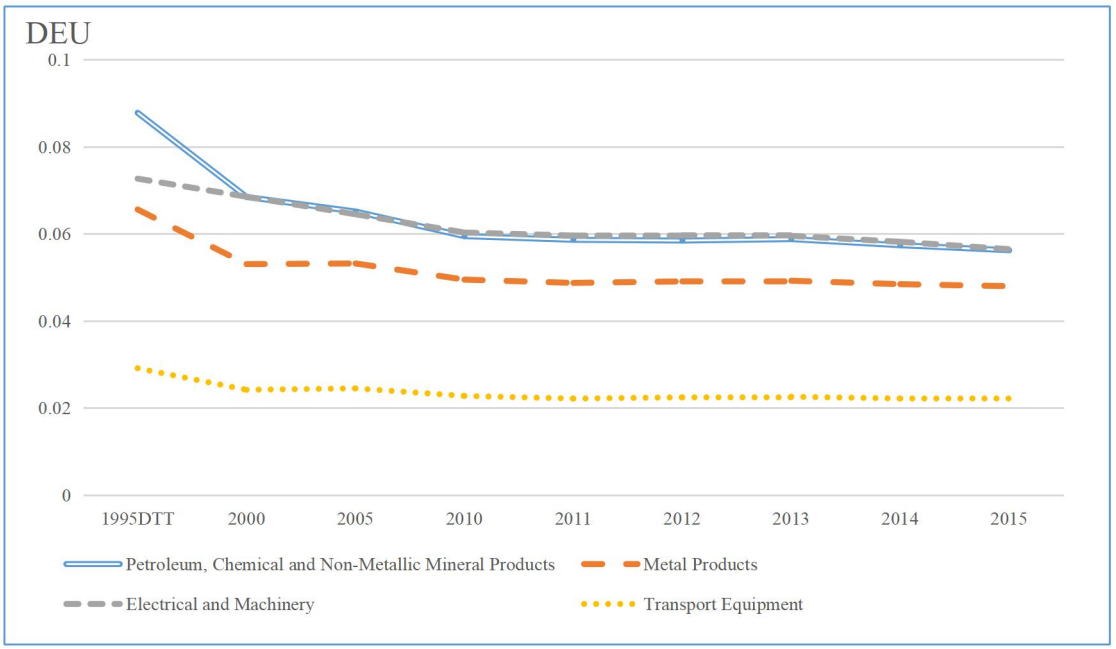


Figure 5: DVX / GVC-related trade of main exporting sectors in Thailand

On the contrary, DtT ratios of mid/high-tech manufacturing in high income countries have shown a downward trend in recent years (taking DEU and JPN for example: Figure6), which confirms the fact that middle income countries have improved their competitiveness in the production of mid/high-tech products.



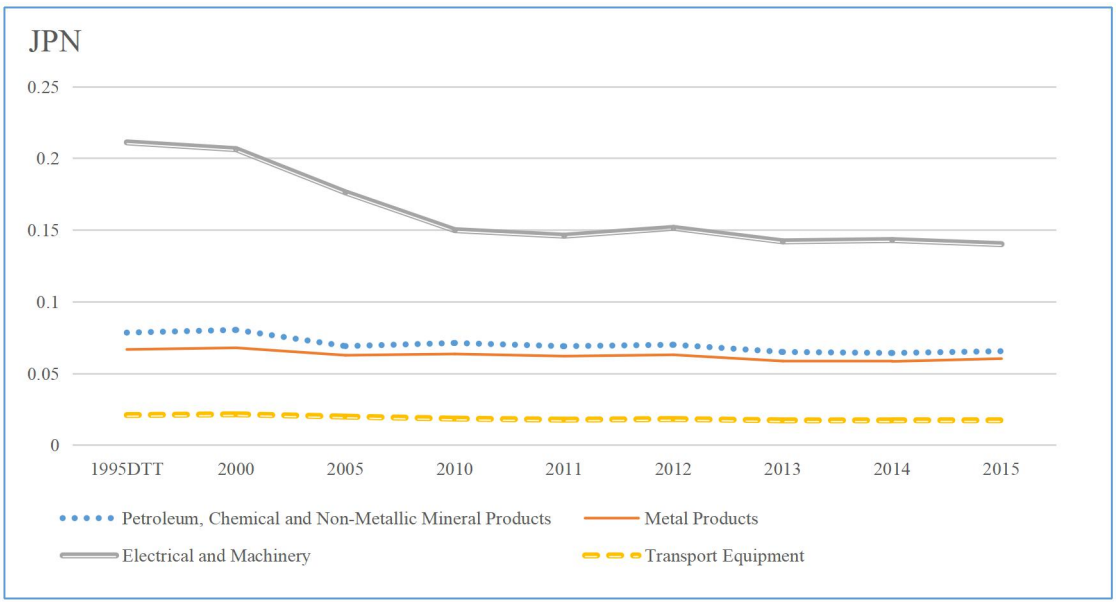


Figure 6: DVX /GVC-related trade of mid/high-tech manufacturing in high income economies

3-4 Regression model

Referring to Kummritz (2015) and Anna Ignatenko et al.(2019), to estimate the impact of GVC participation on income per capita, the following equation is used:

$$\ln\left(\frac{Y}{N}\right)_{i,t} = X_{i,t\text{-}1} + Control + u_i + v_t + \varepsilon_{it} \quad \cdots ⑤$$

Y/N denotes dependent variables divided by population, such as GDP (according to OECD(2005), this paper uses GDP per capita to represent national income per capita), and the factors of production. X denotes GVC-related variable. Because it is difficult to find a valid instrument variable which can fully represent the economical meanings of GVC participation or position, lagged variables are taken to reduce the bias caused by endogeneity and reverse causality along with the two-way fix effects. In addition, Kummritz (2015) suggests that another reason to take lagged variables is that the effect of GVC participation on domestic value added is always on the next period.

When comparing countries at different income levels, I add dummy variables multiplied by explanatory variables to form interaction terms for regression.

4. Results

Table4 shows the result of estimating GVC participation's effects on GDP per capita and its contribution factors in a Cobb-Douglas production function. Average years of schooling is used to approximate a country's human capital (see OECD: human capital), and growth of productivity is calculated as residual of the equation: log(*GDP per capita*) = log(*GCF per capita*) + *Year of*

Schooling +u. Lag in GDP is controlled when independent variables includes share of trade in GDP, in order to rule out the possibility that the share increases by a decline in GDP.

Table 4: Estimates of GVC-related trade's impacts on GDP per capita and its contribution factors[3]

	log(GDP per capita)		log(Capital per capita)	Year of Schooling	Factor productivity
	（1）	（2）	（3）	（4）	(5)
GVC-related trade in GDP	0.195**		-0.957**	1.275	0.971***
	（0.090）		（0.379）	(1.024)	(0.150)
GVC-unrelated trade in GDP	0.000		0.375	-2.462	-0.315
	（0.160）		(0.770)	(1.337)	(0.305)
log(GVC-related trade)		0.472***			
		(0.048)			
log(GVC-unrelated trade)		0.247***			
		(0.038)			
Adj. R squared	0.92	0.75	0.76	0.68	0.68
Obs	2405	2405	2050	2004	1993
Fixed effect	Country,Year				
Controls	Lag in GDP, Trade Openness	Trade Openness	Lag in GDP, Trade Openness		

Column(1) shows that the higher the proportion of GVC-related trade in GDP is, the higher the income per capita in the next period will be. And when controlling share of GVC-related trade in GDP, increasing share of GVC-unrelated trade in GDP does not give a statistically significant effect on income per capita. This result is consistent with Anna et al.(2019). Column(2) confirms this relationship by estimating elasticity of income per capita with respect to GVC-related and unrelated trade: when increasing by 10%, GVC-related trade has a larger effect on income than unrelated trade by about 2.7%.

[3] Note: *,**,*** represents statistically significant at 10%,5% and 1% level and heteroskedasticity -corrected standard errors are reported in parentheses.The same applies to all the following tables.

Column(3)-(5) shows the effect of GVC-related trade on production factors: unlike the previous study, I get a significant negative relationship between GVC-related trade and gross capital formation, which implies GVC-related contents in exports should be the cause of elimination of less competitive firms when facing international trade - leading to a decrease in capital investment - instead of GVC-unrelated contents. And for productivity, there is a significant positive relationship which indicates the effect of GVC on technology acquirement (technology spillover effect) and productivity improvement. However, in column(4) I didn't find a significant relationship between human capital and either GVC-related or unrelated trade, this suggest the need to use a better variable rather than years of schooling.

In the next section, I estimate the effect of GVC participation on income, including forward and backward participation across different income levels. Results are shown in Table 5. Overall, GVC participation has a positive impact on income per capita. In colomn(2), after classifying countries into four economic levels, the results show that the higher the economic level, the greater the effect of GVC participation on national income. Among them, low-income countries do not show significant results. In order to further analyze this result, I divide GVC participation into forward and backward participation, and interact them with income-level dummy variables respectively. The result is shown in column(4). It should be noted that in column(3), the coefficients of forward and backward participation are very close, so a F-test is used to test whether they are significantly different, however, the result doesn't allow to reject the null hypothesis (p-value = 0.1808), that is to say, on the overall level, forward and backward participation may have a similar effect on income.

Table 5: Estimates of GVC participation's impacts on GDP per capita across income levels

	log(GDP per capita)			
	(1)	(2)	(3)	(4)
GVC participation	2.051***			
	(0.565)			
GVC participation:low income		0.747		
		(0.846)		
GVC participation:lower middle income		1.362*		
		(0.708)		
GVC participation:upper middle income		1.753***		
		(0.602)		
GVC participation:high income		1.809***		
		(0.573)		
Forward participation			2.229***	
			(0.587)	
Backward participation			1.964***	
			(0.629)	
Forward participation:low income				-0.004
				(1.004)
Forward participation:lower middle income				0.980
				(0.817)
Forward participation:upper middle income				1.937***
				(0.584)
Forward participation:high income				1.818***
				(0.552)
Backward participation:low income				1.651**
				(0.737)
Backward participation:lower middle income				1.510**
				(0.594)
Backward participation:upper middle income				1.119
				(0.744)
Backward participation:high income				1.350*
				(0.690)
Adj. R squared	0.76	0.78	0.75	0.79
Obs	2405	2389	2405	2389
Fixed effect	Country,Year			
Controls	Lag in Unrelated Trade,Trade Openness			

The result in column(4) suggests that backward participation has a significant income-increasing effect for low and lower middle income countries, while for upper middle and high income countries, the effect becomes weaker and less significant. However, as for forward participation, the result is just the opposite: for upper middle and high income countries, the effects of forward participation are higher than backward participation but not significant for low and lower middle income countries. That is to say, there exists heterogeneity in the impacts of forward and backward participation on income across countries at different income levels.

When estimating the relationship between GVC position and national income per capita, I find that the heterogeneity of the impact of GVC participation on countries at different income levels is also reflected in GVC position(See Table 6). In the equations of column(2) and (4), *trade openness* is used to control the size of a country's trade when changing GVC position.

Table 6: Estimates of GVC position's impacts on GDP per capita across income levels

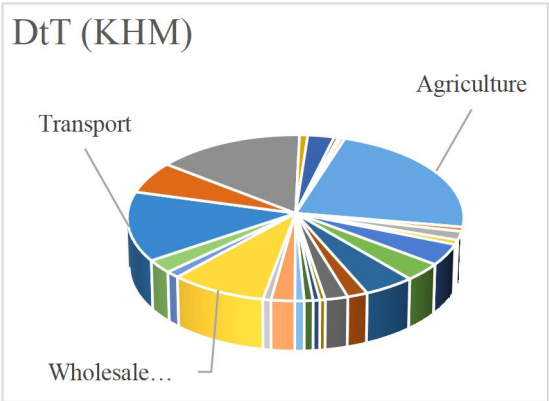
	log(GDP per capita)			
	（1）	（2）	(3)	（4）
GVC position	1.140**	0.327		
	（0.449）	（0.400）		
GVC position:low income			-1.062**	-1.278**
			(0.478)	(0.497)
GVC position:lower middle income			0.309	-0.103
			(0.312)	(0.295)
GVC position:upper middle income			1.445***	1.051**
			(0.467)	(0.513)
GVC position:high income			1.267***	0.662*
			(0.337)	(0.395)
Adj. R squared	0.74	0.76	0.78	0.79
Obs	2567	2405	2519	2389
Fixed effect	Country,Year			
Controls	Lag in Unrelated Trade, Gross Exports	Lag in Unrelated Trade, Gross Exports, Trade Openness	Lag in Unrelated Trade, Gross Exports	Lag in Unrelated Trade, Gross Exports, Trade Openness

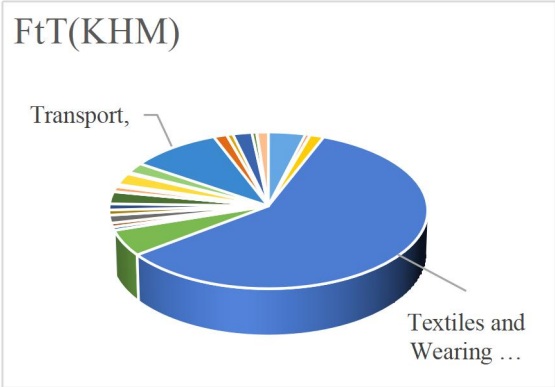
The results indicates a higher GVC position has a negative effect on income for lower income level countries, and a positive effect for higher income level countries. It is not surprising after estimating the effects of forward and backward participation in the former section but the question is why the heterogeneity occurs.

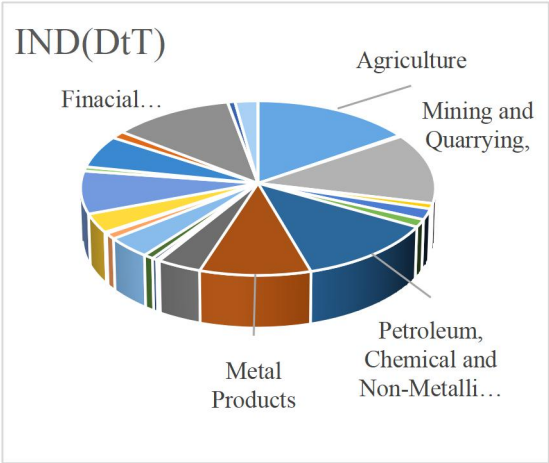
The result can be understood by analyzing the differences in the production sectors of DVX and FVA of countries at different income levels. For example, lower income level and less technologically developed countries do not have the ability to produce diverse products domestically, so increasing forward participation for them is nothing more than increasing the proportion of simple, low-tech products in the export of intermediate goods, while expanding low-tech production is very limited in raising national income, on the other hand, increasing backward participation means increasing the import of diverse products from foreign countries, so that they can improve their own productivity or production diversity through learning by doing and technology spillover effects, thereby increasing national income. A characteristic of this learning by doing behavior is that exporting sectors of producing DVX and using FVA in low-income countries are different, they need to use FVA from sectors where they are not good at producing DVX (See Figure 7).We can see that Cambodia uses a lot of FVA of *Textiles and Wearing Apparel* sector which is not a major proportion in DVX. Similarly, in India's GVC-related trade, DVX mainly comes from low/mid-tech manufacturing while high-tech manufacturing sector such as *Electrical and Machinery* has a large FVA share.

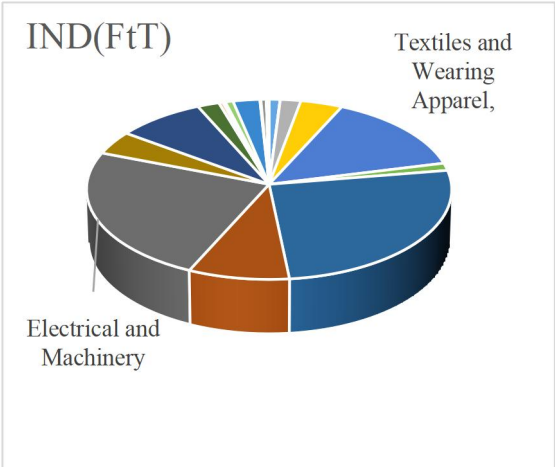
For upper middle income countries, the result turns to be different. Because of a higher level of technology, DVX embedded in their exports mainly comes from mid/high-tech sectors, so the

effects of GVC participation on income also mainly comes from forward participation. See China and Philippines, both countries produce large DVX of *Electrical and Machinery* while also using large FVA of the same sector, suggesting an effect of technology upgrading - especially Philippines's DtT ratio of *Electrical and Machinery* increased by about 71.3% and FtT ratio decreased by about 38.2% from 2000 to 2015[4]. However, as upper middle income countries are approaching developed countries in terms of productivity and capacity, the motivation of technology upgrading provided by the backward participation is becoming smaller. For high income countries, the effects of backward participation mainly come from benefits of vertical specialization and lower cost through outsourcing, therefore both forward and backward participation have positive effects on income.









[4] Author's calculation

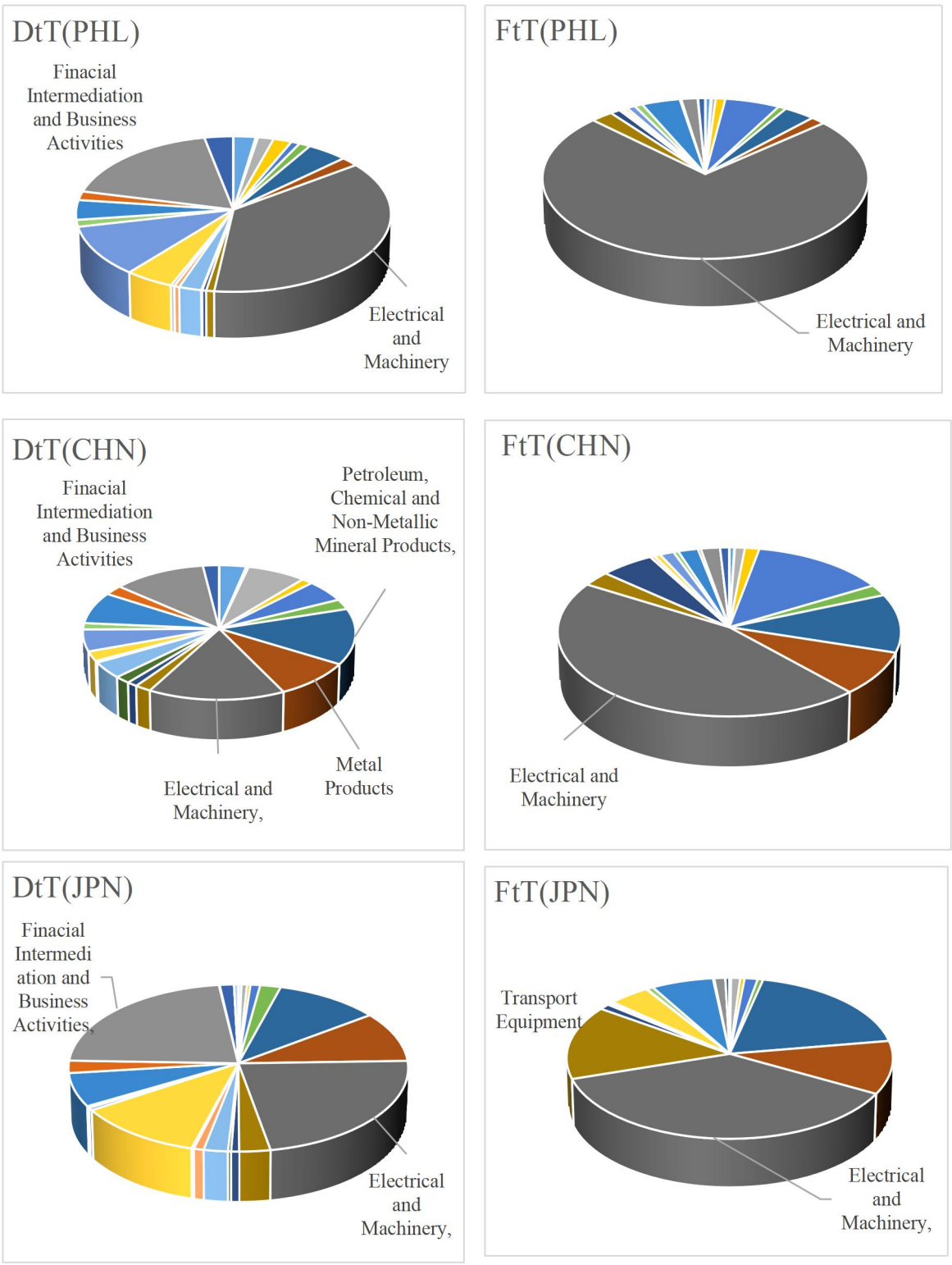


Figure 7: Composition of sectors producing DVX/ using FVA in different countries (2015)

5. Concluding remarks

In this paper, I firstly decompose the EORA Global MARIO tables (Eora26) by using KPWW and WWZ methods to obtain GVC indicators. Secondly, through regressions, I come to the following conclusions: 1. there is heterogeneity across countries at different economic levels in the impacts of GVC participation on pulling income per capita. Low and lower middle income countries benefits more through backward participation, upper middle and high income countries benefits more through forward participation. 2. As a extension of 1, GVC position index also has different effects on countries at different economic levels, for low-income countries, lower GVC position has a positive effect on national income, while it is the opposite for high income countries. Finally, I make an explanation by comparing sectors which produce or use DVX / FVA across countries: lower income countries use FVA of diversified intermediates from other countries to increase the variety of exports, and get technology upgrading through learning by doing. And for higher income countries, playing a role as suppliers of DVX of mid/high-tech intermediate products is a driver of economic growth.

To summarize, the biggest contribution of this paper is that, compared to previous research, I use data covering a wider range of time and regions to analyze not only GVC participation, but also the impacts of forward and backward participation as well as GVC position index on national per capita income, and the heterogeneity of the impacts across countries at different income levels.

However, there still remains some problems that need to be further studied in this research, for example: when discussing the technology spillover effect, the method in this paper is to use the residual of the C-D production function, as an approximation of this effect,while this method is criticized by many researchers. It is necessary to find a better approach to calculate TFP and the

technology spillover effect. Moreover, although Eora26 covers the most countries, the classification of sectors of it is too general, in order to analyze different countries' performances in GVC by looking into more detailed sectors' DVX/FVA , other I-O tables are required.

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