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Essays on the Value-added Trade, Wage Inequality and Servicification of Manufacturing in the Global Value Chains

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Abstract

The rise of global value chains (GVCs) has dramatically changed the world production patterns, in which countries specialize in specific stages of production and cooperate to produce the final goods. The international fragmentation of production gives rise to the fact that gross trade is increasingly unrepresentative to trade in value added, as intermediate cross borders many times in GVCs. The misleading perception of gross trade in GVCs has imposed new challenges for trade theories whose underlying basis is value-added terms. It also provide new insights into economic policies which were evaluated with gross trade data. In this thesis, we use the global input-output framework to improve the measure of global supply chain activities with value-added data. We will focus on three particular questions in GVCs: (a) the role of human capital in determining international fragmentation patterns and bilateral value-added trade across countries; (b) the impacts of GVC activities on the wage inequality of skills within firms; (c) the ever-strengthening intersectoral production linkages between manufacturing and services in GVCs (servicification of manufacturing).

Chapter 1 introduces the background, research questions, and outline of this thesis. Chapter 2 reviews the literature regarding the measurement of GVCs, its labor market outcomes, and the servicification of manufacturing in GVCs. These studies give a full picture of GVC development and its impacts on labor market and services in recent decades.

Chapter 3 provides an analytical framework of how different skills across borders determine the international fragmentation patterns and the bilateral value-added trade between the source and destination countries. By incorporating the global input-output framework into a standard gravity model, we propose a new mechanism that the bilateral value-added trade depends not only on the human capital of reciprocal countries, but also on that of the third countries which have indirect production linkages with the source or destination country in GVCs. This chapter further quantifies the direct and indirect effects of human capital on bilateral value-added trade and highlights the complementarities of skills across borders in GVCs.

Chapter 4 studies how firms' participation or upgrading in GVCs affects the wage inequality of skills within firms. In this chapter, we develop a trade model of heterogeneous firms with intermediate trade, various skill inputs, and fair wage hypothesis to examine firms' wage premium changes via using imported intermediates for exports or moving up the GVCs. The model predicts that increasing firms' participation in GVCs, as measured by the share of foreign value-added content in exports (FVAR), improves firms' profits and thus amplifies the wage inequality between skilled and unskilled labor. Moreover, moving to upstream sectors in GVCs, as measured by the upstreamness of exporting varieties (or average distance from final use), raises firms' wage premium by increasing the productivity of skilled workers. Using detail Chinese firm-level data between 2000 and 2006, we find robust empirical evidence that China's FVAR is positively associated with skill wage premium within firms. We also observe that Chinese firms with higher upstreamness in GVCs tend to have larger wage inequality with more productive skilled workforces.

Chapter 5 reveals an evident trend of servicification of manufacturing in GVCs in Asian countries, which were rarely studied in previous studies. We find the level of servicification in Asian countries is lower than that of OECD countries, but it contains more foreign service value-added content. We also identify five key factors in driving the trend of servicification. Countries with broader participation and lower positions in GVCs tend to have higher levels of foreign servicification in manufacturing. Improvement in information and communication technology (ICT) also raises the level of foreign servicification. However, countries with the larger supply of service workers, better regulation quality, and less government governance have a higher level of domestic servicification in manufacturing.

Chapter 6 concludes and provides some policy implications. International cooperation on skill development is called for countries as various skills in different countries complement to each other to add value to the GVCs(Chapter 3). Firms' participation and upgrading in GVCs improve firms' performance while enlarging the wage inequality of skills, which emphasizes the importance of training for unskilled workers (Chapter 4). Moreover, servicification of manufacturing highlights the importance of service trade liberalization on manufacturing development(Chapter 5).

Key Words: Value-added Trade, Cross-border Linkages, Wage Inequality, Servicification of Manufacturing, Global Value Chains

Dedication

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‘In Global Value Chains, the contours of industrial competitiveness are now increasingly defined by the outlines of international production networks rather than the boundaries of nations... The tendency is towards a spatial sorting of skill-intensive industries to high-wage nations and labor intensive industries to low wage nations.’

Richard Baldwin
“The Great Convergence: Information Technology and the New Globalization”

Contents

Abstract **3**

Acknowledgements **7**

1 Introduction **1**

1.1 Background 1

1.2 Research Questions 5

1.3 Outline 7

2 Literature Review **9**

2.1 GVC Decomposition and Measurement 9

2.2 GVCs and Labor Market 15

2.3 Servicification of Manufacturing in GVCs 23

3 Trade, Human Capital and Cross-border Production Linkages in Global Value Chains **31**

3.1 Introduction 32

3.2 Model 37

3.3 Data and Empirical Strategy 43

3.3.1 Data 44
3.3.2 Measurement 47
3.3.3 Empirical Model 60
3.4 Results 62
3.4.1 Baseline Results 62
3.4.2 Robustness Check 65
3.5 Conclusion 70

4 Global Value Chains, Firms, and Wage Inequality: Evidence from China 72

4.1 Introduction 73
4.2 Theoretical Framework 79
4.2.1 Demand 79
4.2.2 Production 80
4.2.3 Fair Wage Hypothesis and Skill Wage Inequality 83
4.2.4 Firms' Decisions to Participate in GVCs 85
4.3 Data and Measures 91
4.3.1 Data description 92
4.3.2 GVC measurement 95
4.3.3 Skill Share and Wage Inequality 102
4.4 Estimation 104
4.4.1 Baseline Estimation 104
4.4.2 Endogeneity 110
4.4.3 Robust Estimates 114

4.5 Conclusion . . . 121

5 Unveiling Servicification of Manufacturing in Global Value Chains 124

5.1 Introduction . . . 125

5.2 Services in Global Value Chains . . . 128

5.2.1 Service Value Chains in Asian countries . . . 128

5.2.2 Servicification of Manufacturing . . . 133

5.3 Empirical Specification . . . 137

5.3.1 Determinants of Servicification . . . 137

5.3.2 Data and Empirical Model . . . 139

5.4 Results . . . 141

5.4.1 Baseline Results for All Countries . . . 141

5.4.2 Servicification in RCEP Countries . . . 145

5.4.3 Robustness Check . . . 148

5.5 Conclusion . . . 151

6 Conclusion 154

6.1 Concluding Remarks . . . 154

6.2 Policy Implications . . . 157

6.3 Future Research . . . 159

A Appendices 162

A Gross Trade versus Value-added Trade: Example of iPhone 4 . . . 162

B Skill Classification of WIOD Database by Education . . . 164

C Value-added Decomposition of Service Trade in GVCs 164

D Extra Estimation Results 167

Bibliography **170**

List of Tables

2.1 Description of Existing IIOTs 12

2.2 Labor Market Effects of Offshoring 22

2.3 Definitions and Trends of Servicification in Manufacturing 26

2.4 The Policy Implications of Servicification in Manufacturing 27

3.1 Variable Description 61

3.2 Baseline Estimation 63

3.3 The Heckman Two-step Estimates 66

3.4 GMM Estimation of the Dynamic Model 69

4.1 Matched Data Description 94

4.2 Exporting Firms by Trade Regimes 95

4.3 Variable description 105

4.4 Baseline Estimation Using 2004 Cross-sectional Data 107

4.5 Baseline Estimation Using 2000-2006 Panel Data 108

4.6 Heckman Two Step Estimation Results 112

4.7 2SLS Estimation with Fitted FVAR, 2000-2006 115

4.8 Robustness Checks with Labor Productivity and Profit 117

4.9 Further Robustness Using 2004 Data 119

4.10 Further Robustness Checks Using 2000-2006 Panel Data 120

5.1 Key Variables Description 141

5.2 Baseline Results for All Countries 143

5.3 Baseline Results for RCEP countries 147

5.4 Robustness check to Servicification with "Smile Curves" 149

B.1 Skill Classification by Education 164

D.2 Baseline Results for OECD countries 168

D.3 Robustness check to Servicification with "Smile Curves" 169

List of Figures

2.1 The Typical Structure of International Input and Output Tables 11

2.2 Employment Effect of Trade in Intermediates 17

3.1 Decomposition of Gross Exports into Value-added Terms 44

3.2 World's Gross Trade versus Value-added Trade, 2000-2014 47

3.3 The average value-added content as % of gross exports,2000-2014 48

3.4 Changes in Aggregated VAX ratios across countries,2000-2014 49

3.5 The Bilateral VAX Ratio between China and its Selected Partners, 2000-2014 . 50

3.6 The Forward and Backward GVC Participation by Country, 2000-2014 52

3.7 The Bilateral Forward Value-added Linkages between China and Selected Partners 53

3.8 The Bilateral Backward Value-added Linkage between China and Selected Partners 54

3.9 Changes in the Employment Share by Skills, 1995-2011 56

3.10 Changes in Share of Working Hours by Skills in Total Hours, 1995-2009 57

3.11 Changes in Wage Share by Skills in Total Labor Compensation, 1995-2009 . . . 58

3.12 Average GVC participation and Employment Share Changes by Skills 59

4.1 Firms' Wage Inequality and Profits Determination in the Autarky Economy . . 84

4.2 Industrial Equilibrium in Autarky and Trade 88

4.3 Domestic Firms' Wage Premium Changes in Open Economy 89

4.4 The Wage Premium Changes by Importing Intermediates and GVC Upgrading . 90

4.5 Country-level FVAR in Chinese Exports 98

4.6 Changes in the Distribution of FVAR by Firm Trade Regimes, 2000-2006 99

4.7 FVAR trend by industry during 2000-2006 99

4.8 Upstreamness Trend by Industry and Trade Regime,2000-2006 102

5.1 The Service Trade of Asian Countries (RCEP), 2000-2014 (US$ billion) 129

5.2 The Service Trade of Asian Countries (RCEP) by Sectors, 2000-2014 (US $billion) 129

5.3 Export Structure Comparison of RCEP Countries,1995-2011 130

5.4 New RCA Index of RCEP Countries 131

5.5 Service Value Added of Gross Export (%) for RCEP Countries 132

5.6 Share of Service Value-Added in Manufacturing Exports for RCEP Countries . . 134

5.7 Servicification in Manufacturing Sectors: OECD Versus RCEP Countries 135

5.8 Changes in the Value-added Components of Manufacturing Exports by Source Industries 136

A.1 Gross Trade versus Value-added Trade: Example of iPhone 4 162

C.2 Value-added Decomposition of Service Trade in GVCs 165

C.3 Share of Service Value-added Content in GDP, Exports and Value-added Trade . 166

C.4 Share of Service Value-added Content in Exports by Regions 167

Chapter 1

Introduction

1.1 Background

The recent growth of Global Value Chains (GVCs) has dramatically changed the production patterns of goods and services across countries. Also known as the second “unbundling” of production [Baldwin (2013)], GVCs slice up the production process of final goods into several stages (in which a specific set of tasks are undertaken) and relocate them in the country with the lowest costs. The history of GVCs can be traced back to the mid-1980s since American firms launched “twins plant” production[1] Mexico to seek higher profits from the large productivity-adjusted wage gaps between the two countries [Hanson (1997)]. The sharp fall in communication and trade costs developed the “short-distance” offshoring activities into global vertical production networks. The international fragmentation of production thereby provides new opportunities for countries, especially for developing economies, to integrate into the global economy.

Countries specialize in specific stages of production according to their comparative advantage in the stages of GVCs (also known as vertical specialization). Countries value-added contribution to the GVCs attributes not only to their production costs but also to the intermediates

[1]The “twin-plant” production pattern has one plant located in a U.S. border city which produces manufacturing components while the other plant located in the neighboring Mexico City which assembles the components into the final goods.

imported from the other countries to be incorporated in their exports. The rise of international fragmentation of production has stimulated a surge in intermediate trade. According to UNCTAD (2015), intermediates took the majority of world exports in recent years, increasing from $4 trillion in 2004 to almost $8 trillion in 2014, with an average annual growth rate of 8%. Some studies use the ratio of intermediate trade relative to gross trade to measure the extent of vertical specialization of countries in global vertical production networks [Yi (2003)]. The European Union was the largest trader of intermediates with 67.4 % of its imports and 57.8% of exports being intermediates in 2011 [OECD (2017)]. Asian countries have a higher share of intermediate trade in imports than in exports, corresponding to their role as the world factory in GVCs. For example, intermediates accounted for 81.6% of South Korean imports and 64.9% of exports in 2011. Similarly, 78.9% of Chinese imports were intermediates and components, while the intermediate share in exports was 52.3% in 2011 [OECD (2017)].

Global production sharing of GVCs is not exclusively about goods but also including services. Services play increasingly essential but various roles in GVCs. First, as enablers of GVCs, services are essential inputs of goods [Lanz et al. (2015)]. Service inputs accounted for 37% of total value-added in manufacturing exports for OECD countries in 2011, and the share was 32% for Asian countries. Second, as glues of GVCs, services facilitate the global production by connecting services, such as logistics, computer and information services (ICT), and communications [Gereffi (2015)]. Last but not the least, services create value chains in its own rights [Low (2013)]. Service value chains decompose service outputs into specific tasks and offshore them to different countries to create higher value-added final services. There have been several service value chains in different service sectors, including education, banking, finance, tourism, and business processing services.

In contrast to the intermediate trade of goods, the global production sharing of services is mainly through offshoring. Advances in communication and transport technology have increased the tradability of services, thereby leading to a surge of service offshoring in GVCs [Gereffi and Fernandez-Stark (2010)]. Service offshoring strengthens developed countries core competitiveness through the relocation of non-core services into developing countries. Some emerging economies also seized the opportunity to integrate into GVCs by supplying high-quality services at low costs to foreign countries. For example, India is the largest receiving country of service offshoring tasks, which account for around 52% of global sourcing of services in 2013.

Beyond cross-border linkages, the recent development of GVCs also strengthens the inter-sectoral linkages, especially that between manufacturing and services. An increasing number of manufacturing firms tend to use, produce, purchase, and export more services in GVCs, which is termed as the "servicification of manufacturing" [Lodefalk (2010)]. The trend of servicification has been well-observed in the manufacturing sectors of OECD countries such as Germany, Sweden, and France [Boddin and Henze (2014), Lodefalk (2010), Crozet et al. (2014)]. The shift of value-added activities towards services in manufacturing firms is due to many reasons, such as productivity improvement [Nordås (2010)], exporting variety diversification [Lodefalk (2014)], and lowering entry barriers to new markets [Baldwin et al. (2014)]. Servicification of manufacturing also alters trade and industrial strategies of governments. For example, the European Union used servicification as a potential approach to rejuvenate manufacturing industries [Lodefalk (2017)]. Servicification of manufacturing addresses the importance of trade and investment liberalization in service sectors, which is not only critical for service suppliers but also for manufacturing firms [Arnold et al. (2016)].

It is challenging to capture the cross-border and inter-sectoral production linkages using gross trade data. Thus, some recent studies used the international input-output tables to decompose gross trade flows into value-added terms and additional double-counting terms [Johnson and Noguera (2012a), Wang et al. (2013), Koopman et al. (2014)]. The value-added trade data enables us to trace the value embodied in final goods back to its sources, which provides detailed information about the international production network. With the new value-added data, capturing the input-output linkages across countries and sectors is achievable.

One major concern of the global input-output approach is that international input-output tables are compiled on the proportional hypothesis that all the firms within one sector are assumed to have the same ratio of foreign inputs in the production. However, in fact, firms are heterogeneous in GVCs. First, similar to exports, not every firm chooses to participate in GVCs. Only firms with more profits, higher productivity, and larger scales could successfully engage in GVCs [Baldwin et al. (2015)]. Moreover, even among GVC firms, there is also considerable heterogeneity concerning the engagement level, governance, and positions in GVCs [Antras and Helpman (2004)]. For example, processing firms tend to use a higher ratio of foreign intermediates to produce exports than the other firms. The negligence of firm heterogeneity in international input-output tables leads to aggregation biases in estimating the value-added trade [Kee and Tang (2016)].

Despite the high importance of firm heterogeneity in measuring and understanding GVCs, few studies embrace firm heterogeneity in GVC analysis. Kee and Tang (2016) used the customs data merged with enterprise survey data to estimate the value-added trade at the firm level. Bernard et al. (2012) and Baldwin et al. (2014) confirmed firm heterogeneity in GVCs by comparing the characteristics of GVC firms with non-GVC firms, such as firm productivity, profit, and size. There has been little research to focus on the GVC implications for firms, for example, the impacts of GVC participation on factor income and wage inequality.

The labor market outcome of GVCs has been addressed by policymakers but rarely studied empirically. It is well recognized that the vertical specialization pattern of GVCs is determined by the difference in labor costs across countries. Developed countries capture the majority of value-added in GVCs by specializing capital- or skilled labor-intensive tasks. Developing countries perform unskilled labor-intensive tasks and gain low value from GVCs [Baldwin and Venables (2013)]. Different types of skills from different countries specialize in distinct tasks that complement each other to produce final goods, which leads to the hierarchical division of human capital across countries in GVCs [Harrison and McMillan (2011)][2]. However, not all

[2] A good example is Apple, which has more than 200 suppliers worldwide to provide components and services for the production of iPhone. As we know, the iPhone is designed in California of the U.S. where numerous skilled

types of human capital benefit from GVCs. GVCs create jobs for skills that are competitive in production while imposing challenges for the uncompetitive skills to be unemployed or offshored.

The uneven distribution of employment and income of skills within countries in GVCs has drawn the worldwide attention of both academia and policymakers. However, it has been difficult to quantify the labor content of these production chains because of the direct and indirect production linkages across countries in GVCs. The recent release of international input-output tables (IIOTs) has made it feasible to decompose GVCs using the value-added approach and trace labor and capital that are directly or indirectly used for the production of final goods [Johnson and Noguera (2012b), Koopman et al. (2014)]. A strong shift towards skilled labor and capital is found in most developed countries which increasingly specialize in high-skilled intensive activities in GVCs [Timmer et al. (2014)].

In brief, the rise of GVCs has profound and lasting impacts on global production, trade, and labor markets. Studying GVCs is essential for understanding firms performance, globalization modes, and employment structures. Studies on GVCs also provide new insights into economic policies including but not limited to trade balance, trade protection, industrialization, unemployment, and wage inequality.

1.2 Research Questions

The prominent role of intermediates in trade has dramatically challenged the traditional framework of trade statistics. As intermediates may cross borders several times through global supply chains, the gross trade data contains substantial double-counting of intermediate value-added [Johnson (2014)]. The double-counting problem of gross trade leads to a misleading estimation of the factor content of trade, which is crucial in explaining the employment and

technicians perform the cognitive tasks. The high-value components of iPhone, such as microchips, display, and hard-disk drive, are produced by several developed countries in Asia and Europe which are abundant in capital and skilled labor. All the components are shipped to China for assembling and packaging. China has the comparative advantage in fabrication due to the economies of scale in unskilled labor. Apple offshore after-sales services to India, where large call centers are set up with employment of low-cost Indian service workers.

wage change arising from trade [Feenstra and Hanson (2000), Trefler and Zhu (2010)]. An emerging branch of literature has investigated value-added trade across borders and sectors using international input-output tables (IIOTs), but most of them say little about the ultimate sources of value-added, i.e., the role of human capital in value-added trade. *How does human capital determine the vertical specialization of countries and the value-added trade in GVCs?* This question will be addressed in Chapter 3.

The second question of this thesis focuses on firms' performance in GVCs. An extensive literature has studied the impacts of globalization on labor markets [Goldberg and Pavcnik (2007)], but most of them keep silent on two facts. The first fact is the implications of GVCs for the labor market. The second fact is firm heterogeneity in participating and upgrading in GVCs.*How large is the effect of firms GVC activities on their demand for skills and the wage inequality between skilled and unskilled labor within firms?* This question will be addressed in Chapter 4.

The third question of this thesis highlights the strengthening inter-sectoral linkages between services and manufacturing industries. The trend of servicification in manufacturing has been well-observed in many OECD countries, but it is rarely studied in emerging economies, especially for Asian countries. One possible reason is the lack of data which traces the service inputs embodied in the production of manufacturing products in the Asian countries. Another possible reason is that most Asian nations specialize in low-end manufacturing with small service inputs in GVCs. However, in fact, service and manufacturing activities related to GVCs have spread more extensively through the Asia region than in the rest of the world, implying the high importance of studying servicification in this region [Anukoonwattaka et al. (2015)]. *How important are services to the manufacturing of Asian countries from the value-added perspective of GVCs?* This question will be answered in Chapter 5 by tracing the service value-added embodied in manufacturing exports and exploring the determinants of servicification in Asian countries.

1.3 Outline

The rest of this thesis proceeds as follows. In Chapter 2, a review of the current literature regarding the measurement of GVCs, its labor market outcomes, and the servicification of manufacturing in GVCs was undertaken. We first provide a framework of GVC quantification using international input-output tables or firm-level data. Then we review the studies on how the intermediate trade and offshoring in GVCs affect the labor market, with a particular emphasis on employment and wage inequality. Last, we discuss the role of services in GVCs, especially its strengthening linkages with the manufacturing. We present the empirical evidence of servicification in manufacturing and summarize the determinants and policy implications of servicification.

In Chapter 3, there is an exploration of how human capital determines the vertical specialization of countries and their value-added trade in GVCs. By decomposing gross exports into bilateral value-added trade flows, we capture the implicit value-added transactions underlying gross trade. We provide an analytical framework of how the labor costs of different skills across borders determine the global fragmentation patterns and the bilateral value-added trade in GVCs. The model incorporates the global input-output linkages into a gravity model and proposes a new mechanism of value-added trade, where the bilateral value-added trade depends not only upon the human capital of the reciprocal countries but also upon that of the third countries in GVCs. We find a polarized effect of human capital from the exporting and importing countries on the bilateral value-added trade. Moreover, we observe a reverse impact of skills from the third countries that have indirect production linkages with the exporting and importing economies in GVCs on the bilateral value-added trade. These results highlight the complementarity of skills across borders in adding domestic value-added to the global production value-chains.

In Chapter 4, we examine the effects of firms GVC activities on the wage inequality between skilled and unskilled labor within firms. We develop a trade model of heterogeneous firms with intermediate trade, various skill inputs, and fair wage hypothesis to predict firms wage premium changes through participating and upgrading in GVCs. The model predicts that increasing firms participation in GVCs, as measured by the share of foreign value-added content in exports (FVAR), improves firms profits and amplifies the wage inequality between skilled and unskilled labor. Moreover, moving to upstream sectors in GVCs, as measured by the exporting varieties upstreamness (or average distance from final use), raises firms wage premium by increasing the productivity of skilled workers. Using detailed Chinese firm-level data from 2000 to 2006, we find robust empirical evidence that Chinas FVAR is positively associated with skill wage premium within firms. We also observe that Chinese firms with higher upstreamness in GVCs tend to have larger wage inequality with more productive skilled workforces.

In Chapter 5, we quantify the servicification of manufacturing in Asian countries from a value-added approach of GVCs. Servicification in manufacturing is defined as the share of service value-added in manufacturing exports. The service value-added in manufacturing sources from either domestically or overseas, which is measured by the domestic servicification and foreign servicification respectively. The trend of servicification is found in Asian countries, particularly in the 16 Asian nations associated with the Regional Comprehensive Economic Partnership (RCEP) negotiation. The selected Asian countries tend to have a lower domestic servicification level, but a higher foreign servicification level as compared to OECD countries. Countries with higher participation and lower positions in GVCs tend to have higher levels of foreign servicification but lower levels of domestic servicification in manufacturing. This chapter also highlights the role of information and communication technology (ICT) technology improvement, service employment, and institutions in driving the trend of servicification in GVCs.

In Chapter 6, we conclude the thesis and draw out some policy implications.

Chapter 2

Literature Review

This chapter contains three sections. The first section addresses the challenges of measuring GVC activities using gross trade data. A comprehensive review of studies on GVC measurement at the country-sectoral level, bilateral level, and firm-level respectively is provided in the first section, which laid the foundation for the empirical estimation of this thesis. The second section is related to Chapter 3 and Chapter 4 in this thesis, which explores the impacts of GVCs on the labor market, with particular emphasis on the role of intermediate trade, offshoring, and global production sharing. The third section is related to Chapter 5, which reviews the emerging literature on the servicification of manufacturing in GVCs.

2.1 GVC Decomposition and Measurement

The key to understanding GVCs is to figure out the global production linkages across countries and sectors. The traditional trade statistical system records the gross shipments of goods across borders. It can measure trade value-added when the finished products contain 100% of domestic value-added. However, it is increasingly inappropriate when imported intermediates account for the majority of value-added in final goods. Gross trade data over-counts the value-added of intermediates embodied in final products as intermediates, because intermediate inputs could cross borders multiple times through the global supply chains[Koopman et al. (2014)]. The over-counting problem has posed a considerable challenge to calibrate trade data to macroeconomic models, which are typically cast in value-added terms [Johnson and

Noguera (2012a)]. Gross trade data also distorts the estimations of trade balance [Johnson and Noguera (2012a)], comparative advantage [Koopman et al. (2014)], and the impacts of trade policies [Timmer et al. (2015)]. The shortcomings of gross trade data call for a new approach of data collection that traces the international value-added trade flows (and thus factors embodied therein) in the global supply chains [Grossman and Rossi-Hansberg (2012), Timmer et al. (2014)].

To address this challenge, some studies map the national input-output tables with international trade statistics to incorporate multiple countries in the international input and output tables (IIOTs) [Johnson and Noguera (2012a), Johnson and Noguera (2012b), Meng et al. (2013), Koopman et al. (2014)]. In IIOTs, the imports of each country are broken down by the source country and industry, while the exports are divided into intermediate use and final use by destinations. The IIOTs provide detailed information on how the inputs are shipped from source country and finally absorbed in the final use of destination country, which enables us to trace the contribution of each sector (country) to the value of final goods [Timmer et al. (2015)].

A typical structure of IIOTs is shown in Figure (2.1). In contrast to the national input-output tables, IIOTs contain multiple countries and industries with inputs and intermediates traded across borders and sectors. The row-wise direction of the IIOTs presents the demand structure of outputs across countries and sectors. The total use of outputs includes two parts: the intermediate use across country-industries and the final use across countries. The intermediate use is measured by a $MN \times MN$ matrix, which traces the intermediate transactions across N sectors and M countries. The final use is described as a $MN \times M$ matrix, indicating the use of final goods from the source country (in Column 2) to the destinations (country 1 to country M). The columns of the table demonstrate the input structure of gross outputs. The gross output of each sector (given as the last element of each column) equals the sum of inputs from all sectors and countries (given as all the elements in each column). The IIOTs reveal the inter-sectoral input and output flows within and across borders, avoiding the double-counting problem underlying the gross trade flows [Johnson (2014)].

			Use by country-industries							Final use by countries			Total use
			Country 1			…	Country M			Country 1	…	Country M	
			Industry 1	…	Industry N	…	Industry 1	…	Industry N		…		
Supply from country-industries	Country 1	Industry 1											
		…											
		Industry N											
	……												
	Country M	Industry 1											
		…											
		Industry N											
Value added by labour and capital													
Gross output													

Note: The figure is adopted from Timmer et al. (2015) which introduced the world input-output tables of the WIOD database.

Figure 2.1: The Typical Structure of International Input and Output Tables

A number of IIOTs have been released in the past decade as summarized in Table (2.1). The listed IIOTs differ in their coverage, time-consistency, reliability, transparency, and incentives. The world input-output tables from WIOD are featured by the longtime consistency, which enables us to trace the development of GVCs over time [Timmer et al. (2015)]. The OECD-WTO TiVA database also provides consistent value-added statistics from 1995 to 2011, with broad coverage of 35 OECD countries and 28 non-OECD countries, which makes it possible to make comparative analyses across regions [OECD-WTO (2012)]. The TiVA database is derived from the underlying Inter-Country Input-Output (ICIO) tables, covering 63 countries and 34 sectors between 1995 to 2011. The Asian international input and output tables (AIIOTs) are compiled by the Institute of Developing Economies-Japan External Trade Organization (IDE-JETRO) with 5-year intervals since 1975. It emphasizes the integration of Asian-Pacific countries into the global economy, which was rarely covered in the other databases[Meng et al. (2013)]. But the AIIOTs are not adaptable for time-series studies as they are compiled with different benchmark years[Meng et al. (2013)]. The Asian Development Bank Multi-Regional Input-Output Tables (ADB-MRIOT) are similar to AIIOTs except with fewer countries and a shorter period [Mariasingham (2014)]. There are also some multi-regional input-output tables matched with the environmental accounts, most notably as Eora and EXIOBASE. These databases are mainly used to explore the linkages between the global economy and non-monetary policies such as climate change and environmental burdens[Lenzen et al. (2013), Stadler et al. (2017)].

Table 2.1: Description of Existing IIOTs

IIOTs Category	Countries	Sectors	Time	Characteristics	Reference
World Input and Output Tables (WIOD)	43	56	2000-2014	continuous time series, data reliability	Timmer et al. (2015)
OECD-WTO Database on Trade in Value-Added(TiVA)	63	34	1995-2011	Wide coverage of developing countries	OECD-WTO (2012)
Asian International Input and Output Tables (AIIOTs)	10	76	1975-2005 with 5-year intervals	focus on Asia-Pacific countries	Meng et al. (2013)
ADB Multi-Regional Input-Output Tables (ADB-MRIOT)	5	35	2000, 2005-2008, and 2011	Data of Asian countries complementing to WIOD	Mariasingham (2014)
Eora multi-region Input and Output table (MRIO)	187	15,909	1990-2012	time series of input-output (IO) tables with matching environmental and social satellite accounts	Lenzen et al. (2013)
EXIOBASE3	44	163	1995-2011	detailed data on energy, resource extraction,agricultural production, trade	Stadler et al. (2017)

Note: This table is compiled by the author. The table excludes the Global Trade Analysis Project (GTAP) database. Although some studies use the input-output tables of GTAP database to construct multi-country tables [Koopman et al. (2014), Johnson and Noguera (2012a)], there is no official IIOTs available in GTAP database.

Some recent studies used IIOTs to decompose gross exports into value-added terms by sources and additional double-counting terms, which enable us to trace the value-added trade flows from their sources to the final use [Johnson and Noguera (2012a), Johnson and Noguera (2012b), Johnson (2014), Koopman et al. (2014)]. The value-added decomposition of GVCs captures the bilateral production linkages (e.g., The intermediate trade between America and China) as well as the complex multi-country production linkages (e.g., The trade of final goods between China and America also contains imported intermediates from the third countries like Korea or Japan) in GVCs [Koopman et al. (2014)]. This approach also quantifies the contribution of primary factors to each stage of global production and elicits the direct and indirect flows of labor and capital across borders via intermediate trade or offshoring activities [Timmer et al. (2014)].

The value-added approach is widely used to measure the extent of vertical specialization in GVCs [Yi (2003), Trefler and Zhu (2010), Los et al. (2012), Johnson and Noguera (2012b)]. The share of domestic value-added content embodied in gross exports (VAX ratio) is used to measure the extent of international fragmentation. The VAX ratio was observed as declining dramatically in recent decades, suggesting a higher level of international fragmentation of production in GVCs [Johnson and Noguera (2012b)]. The VAX ratio is smaller than 1 at the at the aggregated country level, but not at the sectoral level or bilateral level [Johnson and Noguera (2012b), Koopman et al. (2014)]. At the sectoral level, the VAX ratio may be greater than 1 when this sector also contributes to the exports of other sectors as intermediates (e.g., the value-added exports of services may exceed the gross exports of services because services are used as inputs for manufacturing production and may be exported indirectly through manufacturing exports) [Lanz et al. (2015)]). Similarly, at the bilateral level, a country can export value-added content to its partner country directly (embodied in its own exports) or indirectly (embodied in the exports of the third country to the partner) [Noguera (2012)]. Inspired by the variation of global production at the bilateral-sector level, Wang et al. (2013) extended Koopman et al. (2014)'s framework to decompose gross exports into bilateral value-added terms, which enables us to distinguish the forward and backward linkages of sectors in GVCs.

The value-added approach was also used to measure the location of countries in GVCs and the length of GVCs [Fally (2012), Antràs et al. (2012), Wang et al. (2017), Miller and Temurshoev (2017), Johnson (2017), Antras and Chor (2018)]. The basic idea of GVC length is the total number of production stages from the input to the final output in the complex global production supply chains [Dietzenbacher and Romero (2007)]. Fally (2012) proposed two measurements of GVC length. One is the number of production stages embodied in each product. Another one is the average number of stages of the inputs from the final demand. Nonetheless, the measurement using input-output tables were extended by Antràs et al. (2012) to estimate the average distance of the input industry from final demand. Antràs and Chor (2013) defined the index of "upstreamness" to describe whether industries are located upstream or downstream of GVCs. Industries with a longer average distance to final goods are considered to be more upstream in GVCs with higher upstreamness indexes [Johnson (2017)]. Wang et al. (2017) further provided an alternative measurement of GVC length as the distance from the production of primary factors in one country (source of value-added) to the ultimate absorption of factors in final goods (destination of value-added), which traces the footprint of value-added creation. Antras and Chor (2018) developed a theoretical model to explain the determinants of GVC position, which addressed the roles of reducing trade costs and rising service share in positioning countries and industries in GVCs.

The value-added studies using IIOTs provided a sound picture of GVC activities at the country- and industry- level, but not at the firm level. One primary concern of the IIOTs is the negligence of firms' heterogeneity within sectors [INOMATA (2017)]. In IIOTs, firm-level data is aggregated to the sectoral level with the proportion hypothesis that all the firms within the same sector have an identical ratio of using imported intermediates in production. In reality, this hypothesis is inappropriate. Firms in the processing trade were observed to use a higher ratio of imported intermediates for the production of exporting than the other firms [Koopman et al. (2012)]. The negligence of firms' heterogeneity in IIOTs leads to an aggregation bias in estimating countries' value-added content of gross trade [Kee and Tang (2016)].

The research gap of GVC measurement at firm level has been filled by some recent studies which merged the enterprise survey data with customs data to identify firms' value-added content embodied in trade [Dean et al. (2011), Upward et al. (2013), Ahmad et al. (2013), Kee and Tang (2016)]. The share of foreign value-added content in exports measures the extent of vertical specialization for firms [Dean et al. (2011)], which is also termed as firms' backward participation in GVCs [Koopman et al. (2014)]. In contrast, the share of domestic value-added content in exports represents the real contribution of domestic inputs to the production of exports [Kee and Tang (2016)]. The GVC value-added decomposition at the firm level is essential to understand firms' participation and position in GVCs, which enables us to further study the impacts of firms' GVC activities on their performance, employment, and wage inequality [Antonietti and Antonioli (2011), Baldwin et al. (2014), Ma et al. (2015), Ju and Yu (2015)].

Another emerging branch of literature studies the GVC activities within firms such as how firms allocate their production stages in GVCs globally. Antràs and Chor (2013) studied the organization of GVCs within firms and developed the property-rights theory to explore how firms organize their production process along the sequence of GVCs within and across borders. Alfaro et al. (2017) testified Antràs and Chor (2013)'s predictions by constructing firm-level measures of upstreamness and linking firms' GVC position with their integration choices in GVCs. The upstreamness index demonstrated firms' positions in GVCs, which depends on firms' characteristics such as capital intensity, skill employment, productivity, profitability, and export structure [Ju and Yu (2015)].

The decomposition techniques of GVCs provide a value-added dimension that quantifies international trade and global production network at the country-, sectoral- and firm- level. The value-added trade data could be used to re-estimate the distorted trade statistics like trade balance, import competitiveness, and comparative advantage by differentiating the domestic value-added from the foreign value-added content embodied in gross trade. The value-added approach also provides new insights into the policy implications of trade on the labor market. In the next section, we review the vast literature on GVCs and its labor market outcomes.

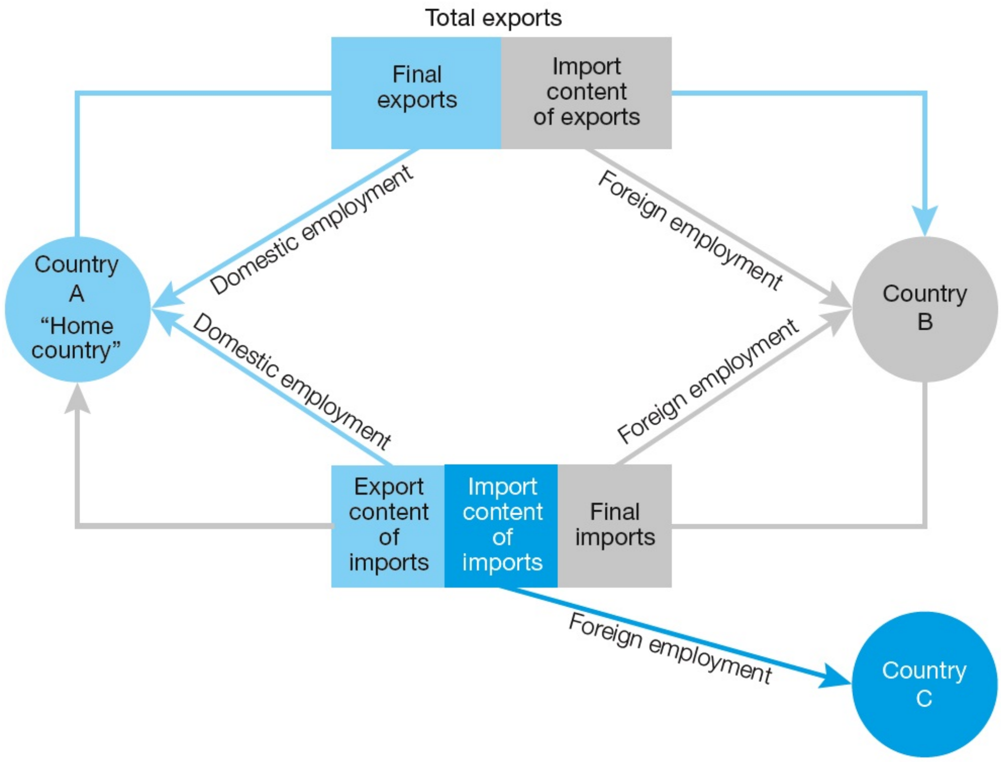
2.2 GVCs and Labor Market

GVCs are characterized by the growing international fragmentation of production across borders through intermediate trade and offshoring. In this section, we study the impacts of GVCs on the labor market by two aspects: (a) the employment effect of trade in the GVCs (b) the impacts of offshoring on employment and wage inequality. We further summarize the research gaps of current studies and state how this thesis fills the gaps.

An early attempt to quantify the employment effect with the consideration of intermediate trade was made by Feenstra and Hong (2010), which used China input-output tables to capture the direct and indirect demands for labor of both ordinary and processing exports[1]. Taking into account of exports, domestic demand and productivity growth, Feenstra and Hong (2010) stated that exports contributed to around 30% employment growth in China during 2000-2005. The employment embodied in ordinary exports was much higher than that of processing exports. Accounting for the role of intermediate inputs, Jiang (2015) decomposed the employment evolved from exports into three parts as shown in Figure (2.2): employment from exporting country, employment from the partner country and the employment from the other foreign countries. The first component contributes to the domestic value-added content of exports. And the last two components relate to the foreign value-added content in exports, which captures the backward participation of the exporting country in GVCs [Jiang (2015)]. Chen et al. (2012) estimated the employment embodied in the domestic value-added content of China's exports. They confirmed that the domestic employment embodied in processing exports was much lower than that of non-processing exports because processing exporters used a higher ratio of imported intermediates for the production of exports [Chen et al. (2012), Kee and Tang (2016)].

In the prevalence of intermediate trade, it was not easy to estimate the labor content of trade with the complex input-output linkages across borders. An emerging branch of literature combined the factor content of trade with the global input-output networks and estimated the employment evolved from value-added trade using the global input-output tables. For example, Trefler and Zhu (2010) tracked the movement of the intermediate inputs across borders using the Input-Output tables and estimated the factor content of trade in intermediate inputs and final goods respectively. Stehrer et al. (2010) decomposed factor content (capital, high-, medium- and low-educated labor) of value-added trade into foreign and domestic com-

[1]Chinese customs classifies trade into 19 regimes, including processing trade, ordinary trade, etc. In processing trade, firms could choose either to import intermediates for the production of exports(import-and assembly) or directly use foreign inputs for free in the production of exports(pure assembly). Processing trade enables producers to be an essential link in the global value chains. Ordinary trade refers to the unilateral imports or exports of goods and services. Processing trade used more foreign intermediates in the production than ordinary trade.



Source: The graph is adopted from Jiang (2015). The value of exports from A to B contains the employment of A and the foreign employment that contributes to the imported intermediates embodied in the exports.

Figure 2.2: Employment Effect of Trade in Intermediates

ponents. They found that developed countries tended to be the net exporters of high-educated labor while developing economies exported more capital and low-educated labor. Johnson and Noguera (2012a) developed a global input-output table to calculate the capital and labor factors embodied in value-added trade. Los et al. (2015) estimated the employment created by foreign demand by extending the global input-output methodology of Johnson and Noguera (2012a). They found that the effect of productivity growth offset the impact of foreign demand, so the net effect on employment was nil from 1995 to 2001 in China. Foreign demand raised 70 million jobs between 2001-2006. After 2006, the domestic demands of non-tradable goods turned to the most important source of employment growth in China. Timmer et al. (2014) traced the value-added trade flows by its underlying factors that were transacted across countries and sectors directly and indirectly. They found value is increasingly added by capital and skilled labor rather than unskilled workers in most GVCs. Developed countries were net exporters of skilled labor while emerging economies were the net exporters of capital and unskilled labor.

The prominent role of intermediate trade is partly as a result of the widespread emergence of offshoring [Baldwin and Robert-Nicoud (2014)]. Plenty of studies provided empirical evidence on how offshoring affected employment, but they did not yield a general rule. Amiti and Wei (2005) observed no negative employment effect of service offshoring because it displaced jobs in specific industries while creating new jobs in other industries at the same time. Hijzen and Swaim (2007) presented that the productivity gains from offshoring at the sectoral level increased sales and created more jobs, which could offset the unemployment effect of offshoring. Liu and Trefler (2011) found U.S. offshoring to China and India had significant but small effects on the unemployment and wage of the U.S. labor market. Harrison and McMillan (2011) suggested that offshoring to low-wage countries substituted for domestic employment. Ottaviano et al. (2013) explored the employment effect of offshoring and immigration by differentiating US native-born workers from offshore workers and immigrant workers. They found that offshore workers substituted for immigrants and native-born workers when offshoring costs fell. However, offshoring can generate efficiency gains by enabling native workers to specialize in tasks with comparative advantage. If the productivity gains are large enough, they may offset the displacement of offshoring and immigration.

Some studies found a non-monotonic relationship between offshoring and unemployment in the labor market with frictions. For example, Mitra and Ranjan (2010) used a two-sector model with search frictions in labor market to show that offshoring reduced unemployment in the market with sufficient inter-sectoral labor mobility. However, if the labor market has imperfect intersectoral labor mobility, unemployment of offshoring sector rises while unemployment in the non-offshoring sectors declines. Ranjan (2013) provided extra evidence to Mitra and Ranjan (2010)'s argument using a search model of labor unions. He suggested that offshoring reduced unemployment when the offshoring costs are high because offshoring induces the labor unions to lower wages to hire more domestic workers. However, when the offshoring costs are small, the unemployment of offshoring sectors would rise.

Moreover, a series of studies investigated the impact of offshoring on employment based on tasks[2] [Grossman and Rossi-Hansberg (2008), Egger et al. (2015), Egger et al. (2016)]. Grossman and Rossi-Hansberg (2008) proposed a new framework of global supply chains which focused on tradable tasks and studied how reducing offshoring costs affected the factor gains in the source country. They found that reductions in the cost of trade-in-tasks generated shared gains for all domestic factors as the productivity effect of offshoring could offset the employment loss in the offshoring sectors. However, Egger et al. (2015) developed a two-country general equilibrium model in which routine tasks are offshored to the low-wage country by heterogeneous firms. In the presence of fixed costs, more productive firms tend to select into offshoring, which led to a reallocation of domestic labor towards less productive production. As routine tasks tend to be semi-skilled intensive, Egger et al. (2016) further stated that offshoring of routine tasks lead to the polarization of labor market in high-income countries, where the employment of skilled and unskilled labor rose relative to semi-skilled workers.

Furthermore, some research investigated the impacts of offshoring on the employment of skills by occupation (or by education). Most studies concluded that offshoring increased the demands for skilled workers. Feenstra (1998) developed a North-South trade model in which the production of final goods is a collection of various stages with different skill intensities. The North imported unskilled-intensive intermediates from the South, and thus it had a higher demand for skilled labor. But the unskilled-intensive intermediates from the North appeared to be "skill-intensive" in the South relative to the skill structure of labor of domestic production level. Thus the offshoring of intermediates increased the demand for skilled workers in the South. This pattern was verified in both developed and developing countries with empirical evidence from the United States[Feenstra and Hanson (1999), the United Kingdom [Hijzen (2007)], Mexico [Feenstra and Hanson (2001)], China [Hsieh and Woo (2005)], and Eastern Europe [Marin (2006)]. Zhu and Trefler (2005) found that the offshoring of intermediates to the arms-length parties improved wage premium by redirecting the skill-intensive activities.

[2]Offshoring relocated the production stages overseas either within firm boundaries or at arms length [Hummels et al. (2016)]. Instead of producing one good in one country, now different countries specialize in specific stages of production, which are also termed as tasks. Trade-in-tasks is characterized by the increasing share of trade in intermediates due to the rising offshoring.

Hummels et al. (2016) found positive effects on the employment of offshoring on relatively skilled workers. Choi (2010) suggested that service offshoring increased employment in white-colour workers relative to less skilled occupations. Antonietti and Antonioli (2011) observed the skilled-biased employment growth when Italy manufacturing firms offshored production to both developing and developed countries. Crino (2012) found that service offshoring increased the relative demand for skilled and semi-skilled workers using comparable data of Western European countries. Becker et al. (2013) discerned tasks and skills by occupation from the plant-level data of German multinational enterprises (MNEs) and found that offshoring was positively associated with the employment of skilled workers conducting non-routine and cognitive tasks. Mion and Zhu (2013) explored how offshoring affected the employment of skilled workers using Belgian firm-level data and concluded that offshoring to China increased the share of skilled workers within firms.

The impacts of offshoring on the wage inequality of skills were also widely explored in the literature. Ebenstein et al. (2014) matched the worker-level wage data with the industry-level offshoring data and found that offshoring led to lower wage by switching workers away from high-wage manufacturing jobs to other sectors and occupations. Hummels et al. (2014) used the employer-employee data to study the impact of offshoring on wage inequality and found that offshoring declined unskilled wage while improving skilled wage within firms. Becker et al. (2013) conducted similar research using German firm-level data and concluded that offshoring was associated with more skilled workers who performed non-routine and cognitive tasks, leading to a larger wage inequality between the skilled and unskilled workers. Kasahara et al. (2016) suggested that importing intermediates facilitated skill upgrading and increased wage inequality of skills using the plant-level data of Indonesia. Baumgarten et al. (2013) controlled the within-industry and within-occupation variations to estimate the effects of offshoring on wage inequality. They found that offshoring enlarged wage inequality modestly within industries, but the effect became substantial with inter-industry spillovers. The results of Baumgarten et al. (2013) indicated that offshoring might be endogenous to skill employment and wage inequality. Controlling for the endogeneity of studying impacts of offshoring and intermediate trade on wage inequality is essential for the empirical estimation [Hummels et al. (2016)].

Some studies used the exogenous policy shocks as natural experiments to control for endogeneity. Trade liberalization effectively reduces the costs of offshoring and intermediate trade. Thus, it is widely used to identify the causal effect of globalization on the labor market [Amador and Cabral (2014)]. Amiti and Davis (2011) developed a theoretical model to study the impact of Indonesian trade liberalization on firms' GVC choice (whether to use imported intermediates for the production of exports) and their wages. They found output tariff reduction lowered import-competing firms' wage, but it increased the wage of exporting firms. Input tariff reduction declined the wage of firms which used imported intermediates for the production of exports. Sethupathy (2013) used two trade liberalization events in Mexico as the natural experiments to identify the causal effects of offshoring. They found that the exogenous reduction in offshoring costs would lead to wage growth in the firms offshored to the U.S. relative to non-offshoring firms. However, there is no evidence of job loss for both firms. There are also some studies focusing on the impact of trade liberalization on the wage inequality of skills. Amiti and Cameron (2012) suggested that import tariff reduction on the intermediate inputs would lower the skill premium within firms in Indonesia, a country highly abundant in unskilled workers. However, Chen et al. (2017) documented a rise in wage premium with a higher demand for skilled workers after the input trade liberalization in China.

In summary, GVCs have reshaped the labor market by redistributing labor and labor income across and within economies. It should be noticed that the employment effect embodied in gross trade requires to be re-estimated when intermediate trade dominates. A new branch of literature estimated the factor content of trade using IIOTs, which provides detail information about the direct and indirect demand for labor in GVCs. These studies found that developed countries tended to export high-skilled labor while emerging economies exported capital or unskilled labor in GVCs. Another branch of literature focuses on the labor market effect of offshoring, which relocates production tasks across countries with uneven effects on the income of skills by occupations or by education. As summarized in Table (2.2), the impacts of offshoring

Table 2.2: Labor Market Effects of Offshoring

Topics	Effect	Results	Literature
overall effect	positive or nil	Offshoring productivity gains offset the displacement of employment	Amiti and Davis (2011), Hijzen and Swaim (2007), Grossman and Rossi-Hansberg (2008), Ottaviano et al. (2013)
	negative or nil	Small but significant effect on unemployment	Liu and Trefler (2011)
		In general, offshoring to low-wage countries substitutes for domestic employment. But foreign and domestic employment are complements for firms that have significantly different tasks at home and abroad	Harrison and McMillan (2011)
	non-monotonic	Offshoring leads to rise in unemployment in offshoring sectors while reducing unemployment in non-offshoring sectors in the market with imperfect labor mobility	Mitra and Ranjan (2010)
		The unemployment of offshoring sectors first reduce then rises due to reduction in offshoring costs	Ranjan (2013)
effects on skill composition	higher skilled share	Offshoring increased the employment of relatively skilled workers	Feenstra (1998), Feenstra and Hanson (2000), Marin (2006), Hijzen and Swaim (2007), Crino (2012),Becker et al. (2013), Mion and Zhu (2013), Choi (2010), Antonietti and Antonioli (2011)
	lower skilled share	Productive firms self-select into offshoring, relocating domestic employment to less productive production	Egger et al. (2015)
	polarization	Offshoring of routine tasks reduced the employment of skilled workers while increasing employment of skilled and unskilled workers	Egger et al. (2016)
effects on wage	lower wage in the offshoring /import-competing sectors	Offshoring leads to lower wage by switching workers away from high-wage manufacturing jobs	Ebenstein et al. (2014), Amiti and Davis (2011)
	rising wage inequality between firms	Offshoring enlarges wage inequality between offshoring and non-offshoring firms	Sethupathy (2013), Baumgarten et al. (2013)
	rising wage inequality of skills	Offshoring widens wage inequality between skilled labor and unskilled labor within firms	Hummels et al. (2014), Becker et al. (2013),Chen et al. (2017)
	declining wage inequality of skills	Input trade liberalization narrows the wage inequality of skills in Indonesia	Amiti and Cameron (2012)

on employment and wage vary across countries and sectors.

However, it is challenging to capture the full picture of GVCs only from the studies on intermediate trade and offshoring. Two questions remain unanswered in the literature. First, how different types of skills in various countries contribute to the international fragmentation of production in the GVCs? Most current studies focus on the employment effect of trade or offshoring in the domestic country, but there is no evidence on how different countries cooperate to produce the final goods using different types of skills. Chapter 3 fills in this gap and answers this question using the cross-border sectoral input-output production framework. Second, how does participating and upgrading in the GVCs affect wage inequality of skills within firms? In Chapter 4, we follow Kee and Tang (2016)' to provide comprehensive measures of GVC participation and position at the firm level and explore how GVC activities affect the wage inequality within firms.

2.3 Servicification of Manufacturing in GVCs

The international fragmentation of production in GVCs has given rise to complex cross-border linkages as well as inter-sectoral linkages, especially between manufacturing and services. Vandermerwe and Rada (1988) first used the term "servicification" of manufacturing to denote the process of increasingly adding service value to the manufacturing production. Afterwards, servicification has been adopted by a range of studies to describe the growth in inputs and outputs of services in manufacturing, both regarding production and sales [Low (2013), Lodefalk (2010), Lanz et al. (2015), Miroudot (2017)]. The trend of servicification in manufacturing also reflects the increase of service-related employment in manufacturing sectors, e.g., engineers, computing, designers and business professionals, and so on. [Pilat and Wölfl (2005), Boddin and Henze (2014)].

Services are increasingly used as inputs in the production of manufacturing in recent decades [Nordås (2010)]. The share of service value-added in manufacturing exports has increased from

29% in 1995 to almost 35% in 2011 across all the manufacturing sectors in OECD countries [Lanz et al. (2015)]. Different service inputs are used in separate stages of manufacturing production. For example, manufacturing production tends to start with R&D, design and innovative activities while ending with marketing, distribution and retail services [Low (2013)]. Manufacturing firms purchase service inputs either domestically or from overseas. The recent development of technology in communication and transportation has dramatically improved the tradability of services, leading to higher ratios of imported services inputs in manufacturing production [Gereffi and Fernandez-Stark (2010)]. The rise in service offshoring improves the productivity of manufacturing firms [Amiti and Wei (2009), Schwörer (2011)] and shifts their employment towards skilled workforces [Amiti and Wei (2005), Crino (2010), Crino (2012)].

Services are also widely produced and sold in the manufacturing sectors [Miroudot and Cadestin (2017)]. Increasingly manufacturing firms sell and export manufacturing products bundled with various services to strengthen their competitiveness [Nordås and Kim (2013)] [3]. There was also an increasing share of services in the total turnover of manufacturing firms, notably in countries like Sweden and Finland [Pilat and Wölfl (2005)]. Moreover, the exports of services are observed to double in manufacturing firms of Sweden [Lodefalk (2014)]. In contrast to the vertical specialization of goods in GVCs, service outputs tend to distribute in GVCs in the form of spider network, in which various of services are produced simultaneously and add value to the final goods[Stephenson and Drake-Brockman (2014), Baldwin and Venables (2013), Heuser and Mattoo (2017)].

The trend of servicification in manufacturing has been observed in many OECD countries. Lodefalk (2010) described the trend of servicification in Swedish manufacturing. He found the share of bought-in service cost in total cost had more than doubled between 1975 and 2005. Moreover, the percentage of service sales in manufacturing firms increased by almost 60% in this period. Crozet et al. (2014) used firm-level data to show the shift towards service activities within French manufacturing firms. More than 83% of manufacturing firms in France provided

[3] For example, the iTunes and app store are crucial complementary services for Apple to boost the sales of iPhone.

service products, and the service production had dramatically increased in manufacturing firms from 1997-2007. Kelle and Kleinert (2010) and Kelle (2013) analyzed the role of services in German manufacturing exports and pointed out that manufacturing firms had a higher growth rate in service exports than manufacturing exports. Manufacturing firms exported more than a quarter of services in 2005. Boddin and Henze (2014) confirmed the rise of service activities within German manufacturing firms using the employer-employee data by occupations. There was a dramatic growth of service occupations in German manufacturing sectors between 1975 to 2010, suggesting the rise of service activities in manufacturing production.

The international input-output tables are used to assess the importance of service tasks in the production of manufacturing. Baldwin et al. (2015) decomposed the value of manufacturing exports by its source sectors and concluded that the share of value-added in manufacturing had shifted away from manufacturing activities towards service activities in most Asian countries. Lanz et al. (2015) estimated the share of service value-added content in manufacturing exports and differentiated it between domestic service value-added content and foreign service value-added content. He found that developing countries tended to have a lower ratio of domestic service content in manufacturing than the developed countries. However, the developing countries had a higher ratio of foreign service value-added content in manufacturing sectors from 1995 to 2011. Miroudot and Cadestin (2017) provided new evidence of servicification in GVCs such that service inputs accounted for around 37% of manufacturing value-added in OECD countries, which has increased with more service inputs in manufacturing. The percentage of service occupations in total employment of manufacturing firms varied from at least 25% to almost 60% across OECD countries. These results highlight the importance of servicification in manufacturing in OECD countries. The emerging trend of servicification of manufacturing in the OECD countries is summarized in the Table (2.3).

The servicification of manufacturing arises for several reasons. As the enablers of GVCs, services play an increasingly important role in the production of manufacturing products. While some of the "unbundling" or modularization of manufacturing production occurring

Table 2.3: Definitions and Trends of Servicification in Manufacturing

Definition	Evidence	Literature
Increasing use of service input in manufacturing production	Service value-added share in manufacturing exports increased from 29% in 1995 to 35% in 2011	Baldwin et al. (2015), Lanz et al. (2015), Miroudot and Cadestin (2017)
	Increasing share of in-house services in manufacturing firms	Lodefalk (2010), Lodefalk (2014), Lodefalk (2017)
	Higher share of imported service inputs in manufacturing production	Gereffi and Fernandez-Stark (2010)
Growing service outputs in manufacturing sectors	More manufacturing firms sell and export services	Nordås and Kim (2013),Crozet et al. (2014)
	Increasing share of services in the sales of manufacturing firms	Pilat and Wölfl (2005)
	Higher growth rate of service exports in manufacturing firms	Kelle and Kleinert (2010), Kelle (2013)
Increasing service-related employment in manufacturing production	Growing service occupations within manufacturing firms	Boddin and Henze (2014)

along GVCs, servicification appears by the exigencies of locational dispersion in output and consumption, or by regulatory requirements [Low (2013)]. Baldwin et al. (2015) identified four possible sources of servicification in GVCs: (a) reclassification of services [4], (b) the rise in the demand for the "connecting" services which link the fragmented production in GVCs [5], (c) the rise of demand for manufacturing products bundled with services [6], and (d) higher price of service inputs relative to manufacturing intermediates [7].

[4]The traditional data classifies the input and output of manufacturing firms into manufacturing activities despite the tasks performed [Baldwin et al. (2015)]. However, for those manufacturing firms which have service offshoring activities, their imports of services are classified as service activities when service offshoring occurs. The reclassification of services leads to a higher level of servicification without changes in the economic structure. The misclassified part of services was difficult to identify in traditional trade statistics, but it could be captured by the value-added flows from the international input and output tables.

[5]Services are seen as "glues" of GVCs, facilitating the global production and trade with services such as transportation, telecommunication, logistics, etc.

[6]Consumers increasingly prefer the manufacturing products bundled with related services, which tailor the products according to the diversified requirements of consumers.

[7]Offshoring of tasks tend to be more accessible for intermediate goods than services. Manufacturing intermediates are accessible with lower costs as a result of offshoring, which increases the share of service value-added in manufacturing exports without changing the task composition.

Some studies explored the reasons for servicification of manufacturing at the firm level. Servicification of manufacturing improved the productivity of manufacturing firms [Nordås (2010), Schwörer (2011), Arnold et al. (2016)]. Moreover, it strengthened the competitiveness of manufacturing products with tailored services [Lodefalk (2014), Lodefalk (2017)]. As the ”glues” of GVCs activities, services broke the entry barriers of foreign markets through service offshoring, third-party distribution, advertising and marketing [Lodefalk (2017)]. Servicification of manufacturing also generated higher profits for manufacturing firms by increasing the value of final goods and developing customers' loyalty as a result of customization [Mastrogiacomo et al. (2017)].

Table 2.4: The Policy Implications of Servicification in Manufacturing

Impact	Implications	Literature
Trade	Service trade liberalization improved manufacturing productivity	Arnold et al. (2011), Shepotylo and Vakhitov (2015), Beverelli et al. (2017)
	Service trade liberalization improved exporting performance of downstream manufacturing firms	Bas (2014), Lodefalk (2014), Hoekman and Shepherd (2017)
Industrial Development	Servicification brought a renewal of manufacturing industries in OECD countries	Bernard et al. (2017), Boddin and Henze (2014)
	Servicification of Manufacturing also facilate the development of both manufacturing and service sectors in developing countries	Anukoonwattaka et al. (2015), Miroudot and Cadestin (2017)
Labor Market	More service jobs are created in manufacturing sectors	Kizu et al. (2016), Bernard et al. (2017)
	Servicification increased employment of more skilled workers	Boddin and Henze (2014), Dauth et al. (2017)

The rise of servicification in manufacturing has profound implications for trade and industrial policies as shown in Table (2.4). First, servicification of manufacturing implies that trade liberalization in services is more critical for both manufacturing and service sectors. Arnold et al. (2011) found that service liberalization improved the productivity of downstream manufacturing firms when services were used as inputs for manufacturing products. Similar results were found in Shepotylo and Vakhitov (2015) using Ukrainian firms' data in 2001-2007, which suggested a standard deviation increase in service liberalization within firms was associated with a 9.2% growth in productivity. Beverelli et al. (2017) further pointed out that the productivity benefits of service trade liberalization highly relied on domestic institutions such that countries with high institutional quality benefited more from service openness. Service trade liberalization also improved the exporting performance of downstream manufacturing firms. Bas (2014) estimated that around 68.5 % of exporting probability of manufacturing firms was associated with services liberalization in India. Moreover, increasing the proportion of services in the production yielded a higher export intensity of manufacturing firms [Lodefalk (2014)]. Hoekman and Shepherd (2017) found FDI was the primary channel that service liberalization affected manufacturing exports by spilling service technology and knowledge across countries.

Second, the servicification of manufacturing is also seen as a potential approach to accelerate the process of industrialization in developing countries and renew the "re-industrialization" in developed countries. Declining manufacturing industries have been observed in most developed countries under the traditional trade statistical framework in the recent decades [Pilat and Wölfl (2005)].However, the latest value-added data reclassified service activities embodied in manufacturing firms, suggesting manufacturing industries of OECD countries had not declined as much as previously measured by gross trade [Lodefalk (2014)]. Servicification of manufacturing has shifted OECD countries from low-value manufacturing tasks (e.g., fabrication, package, etc.) towards high-value cognitive tasks (design, R&D,etc.) and thus created high-skilled service employment in manufacturing industries of these countries [Boddin and Henze (2014)]. This shift has brought a renewal of industrialization in OECD countries in terms of service specialization in GVCs[Bernard et al. (2017)]. Moreover, the offshoring of low-end manufacturing activities from developed countries would boost the industrialization of developing countries in GVCs [Anukoonwattaka et al. (2015)]. Servicification of manufacturing also facilitates the service development of some developing countries (e.g., India, Taiwan, Malaysia, etc.), which undertake the service tasks offshored from developed countries [Miroudot and Cadestin (2017)].

Third, the servicification of manufacturing also affects the demand and supply of human capital in the labor market. Kizu et al. (2016) quantified the number of "servicification" jobs in GVCs that depended on the demands of manufacturing. They found service jobs grew rapidly in manufacturing sectors for both developed and developing economies due to the improved tradability of services in GVCs [Kizu et al. (2016)]. Using employer-employee data of Danish firms, Bernard et al. (2017) found that many Danish manufacturing firms had shifted their production towards services sectors by abandoning fabrication but retaining service jobs. The servicification firms tended to have higher employment with a larger share of the skilled workforce. Similar evidence was provided by Boddin and Henze (2014) for Germany manufacturing firms. The servicification of manufacturing has increased the employment of high-skilled workers in manufacturing firms. Dauth et al. (2017) explored the channel through which the employment of manufacturing firms shifted to service workers. They concluded the shifts were due to young entrants and returnees from non-employment. They also suggested that trading with emerging countries in GVCs would increase the service jobs in the manufacturing industries of Germany.

In conclusion, the rise of GVCs has strengthened the cross-sectoral linkages between services and manufacturing industries. Servicification of manufacturing is well-observed in GVCs, such that services have been increasingly used, produced, purchased, and exported by manufacturing firms. Most developed countries have an evident trend of servicification in manufacturing, while the studies on the servicification of emerging economies are still scarce. In Chapter 5, we will study the emerging trend of servicification of manufacturing in the East Asian countries from a value-added trade perspective and compare the trend with that of OECD countries to fill the research gap. As shown in the literature review, the shift towards service activities in manufacturing sectors arises for various reasons, most of which are driven by the cost-saving and competitiveness-strengthening strategies. In Chapter 5, we also explore the determinants of servicification in manufacturing based on the literature. Studying servicification of manufacturing in Asian countries has far-reaching policy implications. As shown in the literature review, servicification of manufacturing boosts the performance of manufacturing firms associated with higher productivity and better exporting performance. It also strengthens the competitiveness of manufacturing products with tailored services. The servicification of manufacturing highlights the importance of service liberalization for manufacturing industries. It has also altered the traditional view that manufacturing is declining in most developed countries by proposing the new insight that the OECD manufacturing firms are rejuvenating with service-oriented manufacturing production in GVCs. Servicification has increased service-related jobs in the manufacturing industries of OECD countries. Meanwhile, it also brings an opportunity for emerging economies to undertake offshored manufacturing and service activities from developed countries, which accelerates the process of industrialization in these countries. As a result, it is important to rethink the new role of services in manufacturing sectors, especially in the Asian developing countries.

Chapter 3

Trade, Human Capital and Cross-border Production Linkages in Global Value Chains

Abstract

In this chapter, we incorporate the global input-output production linkages in the gravity model to explore the role of different skills in determining bilateral value-added trade. We propose a new framework that bilateral value-added trade depends not only on the human capital of the source and destination countries but also on that of third countries through which the value-added is transited en route through global supply chains. Using the cross-border sectoral input-output data across 43 countries and 34 sectors, we examine the impacts of three types of skills on the bilateral domestic value-added trade. We find a polarizing effect in both source and destination countries, in which increasing the unit wage of skilled and unskilled workers boosts their bilateral value-added trade while improving the unit wage of semi-skilled labor declines their bilateral trade in value-added. More importantly, we observe an opposite impact from third countries whose semi-skilled unit wage is positively associated with the domestic value-added trade between the source and destination countries. These results highlight the complementarity of countries in terms of different types of skills in adding value to the final goods in the global value chains (GVCs). (*JEL Code F16, F66*)

Key Words: Value-added Trade; Gravity Model; Skills; Cross-border Production Linkages; Global Value Chains

3.1 Introduction

Over the past two decades, there is a dramatic trend of international fragmentation by which different countries specialize in specific stages of production and cooperate to produce the final goods in the global value chains (GVCs). One of the fundamental drivers of international fragmentation, according to the common explanations of the origins of GVCs, is the difference in labor costs across countries [Helg and Tajoli (2005)]. The vertical specialization of global production enables countries to use specific types of labor in the production while exposing the other types of labor to the risk of displacement in GVCs [De Backer and Miroudot (2014)]. Which types of skills add value to domestic value-added trade while which types of skills being offshored in GVCs? Despite the vast literature on GVC measures and policy implications[1], few studies investigated the dynamic role of different types of skills in the vertical specialization of GVCs. In this chapter, we categorize human capital [2] into three types of skills (skilled, semi-skilled and unskilled labor) and investigate how different types of skills from different countries determine the bilateral value-added trade between the source country and the destination country.

One challenge to evaluate the role of human capital in GVCs is to identify the cross-border production linkages [Milberg and Winkler (2013)]. Most previous studies used gross trade data to estimate the labor content in the production of exports. This approach was feasible when the final goods were produced in one country with 100% domestic value-added content, but it is increasingly inapplicable with the rise of GVCs. The international fragmentation of production in GVCs enables intermediates to cross borders several times, which considerably overestimates

[1]Hummels et al. (2001) measured the value-added trade using input-output tables to capture the vertical specialization of countries. With the release of international input-output tables, recent studies including Johnson and Noguera (2012b), Wang et al. (2013) and Koopman et al. (2014) constructed the I-O based estimation of value-added flows at the sectoral level across countries. Another branch of studies estimated the value-added trade with firm-level data, including Upward et al. (2013), Dean et al. (2011) and Kee and Tang (2016). Global value chains have brought new opportunities for countries, especially for developing countries to integrate into the global economy[Fernandez-Stark et al. (2011)]. Participation in GVCs could improve productivity of firms [Baldwin et al. (2014)] and increase their exporting diversities [Morris and Staritz (2017)]. It also stimulates the employment growth within firms and raises the income of labor [Gereffi (2015)].

[2]Human capital refers to the three types of skills in general in this chapter. The three types of skills are categorized by educational level into unskilled labor, semi-skilled labor and skilled labor. The category follows the 1997 international standard classification of education (ISCED) in the Appendix B.

domestic value added(and thus domestic employment) embodied in gross trade[3] [Trefler and Zhu (2010), Timmer et al. (2014)]. To overcome this challenge, this chapter decomposes the gross trade into value-added terms. The value-added trade flows capture the input-output production linkages across countries. Moreover, they also indirectly trace the labor content embodied in final goods from sources to end-users, which avoid the "double-counting" problem in the gross trade [Koopman et al. (2014)].

In this chapter, I quantify the impacts of different types of skills on the bilateral value-added trade. In order to do this, we incorporate the international input-output structure into a standard gravity model and derive an approximate gravity model of bilateral value-added trade following Noguera (2012). In this model, the input bundle is assumed to contain both domestic value-added content and foreign value-added content. Labor is assumed to be the only factor that adds value to input bundle following an one-to-one production function[4]. Countries are linked directly via gross trade in intermediates and final goods and indirectly through engaging in the global supply chains. The equilibrium stated that the bilateral value-added trade flows are governed by the comparative advantage of labor costs across all the countries in the GVCs. In contrast to the standard gravity model, the domestic value-added trade between two countries is not only determined by the bilateral gravity variables (distance, RTA, common language, continuity, GDP, unit labor costs, etc.) but also those of third countries through which value added was transited en route from the source to the destination. We denote the labor inputs of the source and destination countries as the "direct" human capital, while defining the labor inputs from the third countries as the "indirect" human capital. We show the "indirect" human capital complements to the "direct" human capital in adding value to the bilateral value-added trade.

[3]See Appendix A for the example of biased estimation of labor content embodied in the gross trade deficit.

[4]Several quantitative analyses of gravity model adopted the Ricardian assumption of unit labor to simplify the models, such as Eaton and Kortum (2002), Arkolakis et al. (2012), Costinot and Rodriguez-Clare (2013), and Allen and Arkolakis (2014). Following these studies, we also assume that labor is the only factor in the model with a continuum of goods and constant elasticity of substitution (CES) utility.

Using the value-added trade data constructed from the world input-output tables (WIOT), we estimate the impacts of different types of skills[5] on the bilateral value-added trade across 43 countries (including 31 OECD countries) between 1995 and 2011. Increasing the unit wage of the skilled and unskilled workers of the source country improves the bilateral trade in value added between the source and destination. However, raising the unit wage of its semi-skilled labor declines the bilateral value-added trade. We also observe a similar effect in its partner country (or destination), where skilled and unskilled wage is also positively associated with bilateral value-added trade. More importantly, we find robust evidence that the human capital of third countries has an opposite effect on the bilateral value-added trade, which suggested that improving the unit wage of semi-skilled labor from third countries increases the bilateral value-added trade between the source and destination countries. These results highlight the complementarity of counties in terms of human capital across countries in the global value chains. To our best knowledge, the chapter is the first to examine the impacts of both "direct" and "indirect" human capital on the value-added trade in GVCs.

This chapter is highly related to the studies on vertical specialization, such as Hummels et al. (2001), Yi (2003) and Trefler and Zhu (2010). These studies explored the role of intermediate inputs in gross trade and measured the extent of international production fragmentation using the input-output tables. However, most of the studies used the national input-output tables which were unable to capture the international production linkages on a global scale. To address this problem, Koopman et al. (2014) developed a quantitative framework of GVCs which decomposed the gross exports into value-added terms at the aggregated country- and sector-level using the international input and output tables (IIOTs). The value-added trade traced the global production patterns from input sources to the final use across borders and sectors. Johnson and Noguera (2012b) adopted a similar approach to derive the domestic value-added content from the total value of exports. They further analyzed the changes of the value-added ratio (VAX) from the perspectives of the globe, individual country, and bilateral trade to describe the extent of global fragmentation in GVCs. Wang et al. (2013) considered the

[5] We did not incorporate the different types of skills in the theoretical model for simplicity. However, we include different types of skills in the empirical model to capture the distribution of skills in GVCs.

heterogeneous sectoral production linkages in bilateral value-added trade. They decomposed the export flows into bilateral value-added terms on the sectoral level. These studies quantified the real contribution of trade to the partners by value-added decomposition, which eliminates the "double-counting" problem in gross trade. In this chapter, we follow Wang et al. (2013)'s approach to estimate the bilateral value-added trade flows using the world input-output tables.

This chapter uses the modified gravity model to evaluate the human capital effect on bilateral value-added trade, which extends the gravity model in the estimation of value-added trade. The standard gravity model served as a workhorse in international trade [6], but it performs poorly in recent decades, especially since the intermediate trade dominates in world trade[7][Baldwin and Taglioni (2011), Baldwin et al. (2014)].To address this problem, some studies adjusted the economic masses (GDP) into sales-based indicators to find better proxies for import demands or export supplies [Baldwin and Taglioni (2011), Bergstrand et al. (2013)]. These studies explained the gross trade flows when intermediate trade dominates, but they say little about the global production linkages across economies [Anderson (2011)]. Another branch of studies decomposed gross trade into value-added terms and constructed an approximate gravity model to study the determinants of value-added trade[Noguera (2012)]. By incorporating the global input-output structure into gravity model, this approach unified the measurement of economic masses and gross trade into value-added terms, which eliminates the estimation bias of standard gravity model in GVCs [Koopman et al. (2014)]. The value-added trade flows track the production of final goods from origins to end-users, avoiding the "double-counting" problem in gross trade. Moreover, the value-added trade represents the factor demands of final goods directly, which

[6] Anderson (1979) and Bergstrand (1985) constructed the theoretical foundation of the gravity model and emphasized the role of multilateral prices in the bilateral trade flows. Eaton and Kortum (2002) developed an alternative theoretical framework of gravity model with similar goods, heterogeneous productivity, and unit labor inputs. Anderson and Van Wincoop (2003) emphasized the endogenous trade frictions in estimating gravity model and developed the method to estimate the gravity equation consistently and efficiently. Anderson and Van Wincoop (2004) and Bergstrand and Egger (2010) provided detailed information about the empirical work applying the gravity model.

[7] The standard gravity model is based on the proportional hypothesis that the economic masses (GDP) are the proxies for exporting supplies or importing demands. Gross trade is measured on the sales-value basis, whereas economic masses (GDP) are estimated on the value-added basis. The proportional hypothesis of the standard gravity model would no longer hold when intermediate trade dominates because gross trade fails to identify the value-added of the indirect trade from the third countries in GVCs. As a result, the standard gravity model performs poorly in estimating trade flows with prominent intermediates [Baldwin et al. (2014)].

enables us to explore the impacts of human capital on the global value chains (GVCs) [Noguera (2012)].

Furthermore, this chapter highlights the role of different skills in determining the value-added trade. The assumption of unit labor cost is adopted form the Ricardian model that labor in the only factor for production which is immobile across countries [Eaton and Kortum (2002)]. Similar to Eaton and Kortum (2002), this chapter finds the differences in unit labor costs across countries determine the breakpoints in the "global chain of comparative advantage." Countries specialize in the stages of production with the comparative advantage in labor costs and further trade for the intermediate inputs without comparative advantage [Alexander (2016)]. Thus, the bilateral value-added trade is determined by the labor costs of skills of all the countries in GVCs.

This chapter quantifies the impacts of different types of skills on bilateral value-added trade, which is related but not in common with the studies on the factor content of trade in GVCs [Trefler and Zhu (2010), Puzzello (2012), Stehrer et al. (2010), Baldwin and Robert-Nicoud (2014), Becker and Muendler (2015), Timmer et al. (2014)] [8]. These studies estimated the implicit labor content of the unilateral trade flows without identifying the bilateral relations from the value-added trade perspective. The approximate gravity model in this chapter enables us to explore the determinants of bilateral value-added trade with a particular focus on the roles of human capital costs.

This chapter also shares the same motivation with the policy papers of skill development in GVCs. Skills are crucial factors for countries to join, upgrade and compete in GVCs [Caliendo and Parro (2014)]. Human capital costs are the sources of comparative advantage and determine

[8] Trefler and Zhu (2010) used the input-output tables to estimate the net factor content of trade with prominent intermediate trade to examine its compatibility with the Vanek's factor content prediction. Puzzello (2012) used the Asian Input-output (AIO) tables to provide bilateral trade details and assessed the labor content of sourcing patterns.Stehrer et al. (2010) decomposed the factor content of value-added trade into the foreign and domestic components, and found the developed countries were net exporters of skilled jobs. Baldwin and Robert-Nicoud (2014) regarded offshoring as a form of "shadow migration," which moved the foreign labor content embodied in offshoring services to the domestic market. Becker and Muendler (2015) found that German workforces tended to specialize in tasks of non-offshored. Timmer et al. (2014) suggested that developed countries tend to be net exporters of skilled labor while emerging economies are net exporters of capital in GVCs.

countries specialization in tasks across countries [Costinot and Rodriguez-Clare (2013)]. Skill changes lead to a fluctuation in the production of GVCs. For example, the rapid growth of unskilled labor has made a name for Asia as the "factory of the world" in recent decades, which simultaneously reduced the unskilled jobs in Europe and US and enabled these countries to specialize in the cognitive and non-routine tasks [Milberg and Winkler (2013)]. The rise of international fragmentation in GVCs has arisen new requirements for the skills of countries in GVCs. Countries need to align their skills with the international standard of GVCs, which impose challenges for skill development in developing countries [Gereffi (2015)]. Inspired by these studies, in this chapter, we conduct an empirical analysis to investigate how different types of skills determine the value-added trade of GVCs. We also give important policy implications on how to improve the domestic value-added trade via human capital development.

The rest of the chapter is arranged as follows. Section 2 constructs the theoretical model following Noguera (2012)'s techniques to derive the gravity model of value-added trade with unit labor costs. We discuss how human capital affects the bilateral value-added flows through the direct and indirect production linkages across countries. Section 3 presents data and measurement methodology in this chapter, which also provides several stylized facts about value-added trade and skill development in GVCs. Section 4 constructs the empirical model and provides the baseline estimation results. Section 5 shows the robustness check, and section 6 concludes.

3.2 Model

This section commences with Noguera (2012)'s framework to incorporate the international input-output structure into the standard gravity model. Assume there are N countries producing differentiated products. The production could produce either intermediates or final goods, depending on the ex-post usage of products. The total output of country j (Y_j) is a Cobb-Douglas production function of the domestic value-added content (V_j) and the composition of intermediate inputs (X_j). The composition of intermediate inputs X_j contains imported intermediates and domestic intermediates. X_{ij} denotes the imported intermediates of country j from country i. When $i = j$, X_{jj} represents the domestic intermediate inputs of country j.

The output of country j is written in the Cobb-Douglas production function as follows:

$$Y_j = X_j^{\alpha_j} V_j^{1-\alpha_j} \quad while \quad X_j = (\sum_i \beta_i^{\frac{1-\rho}{\rho}} X_{ij}^{\frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}} \tag{3.1}$$

where ρ is the elasticity of substitution among intermediates across importing countries ($\rho > 1$). β_i is preference parameter of country i for imported goods. α_j is the share of domestic value-added content in the total output. Assume the representative household of country j has a constant elasticity of substitution (CES) preference over the final goods. Denoting F_{ij} as the imported final goods of country j from i, the consumption of final goods in country j is given as:

$$F_j = (\sum_i \beta_i^{\frac{1-\sigma}{\sigma}} F_{ij}^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}} \tag{3.2}$$

where σ is the elasticity of substitution of final goods across countries ($\sigma > 1$).

We further assume that the production is an one-to-one function of labor inputs. Labor is supplied inelastically, which is mobile across sectors but immobile across borders [Eaton and Kortum (2002), Arkolakis et al. (2012)][9]. The wage of labor in producing domestic value-added content equals to the price of domestic value-added content ($P_j^v = \omega_j$). Assume there is an iceberg cost in the international trade from country i to country j (τ_{ij}), the price of imported intermediates from country i would be $p_{ij} = p_i \tau_{ij} = \omega_i \tau_{ij}$. Denoting P_j^x is the aggregated price of composite intermediates X_j in country j, $P_j^x = [\sum_i (\beta_i \omega_i \tau_{ij})^{1-\rho}]^{\frac{1}{1-\rho}}$. As the production of intermediates or final products is assumed to be ex post, the aggregated price of final goods in country j could be written as $P_j^f = [\sum_i (\beta_i \omega_i \tau_{ij})^{1-\sigma}]^{\frac{1}{1-\sigma}}$. The price of total output Y_j satisfies $p_j = (\frac{\omega_j}{1-\alpha_j})^{1-\alpha_j} (\frac{P_j^x}{\alpha_j})^{\alpha_j}$ where p_j is the aggregated price index of total output.

[9] In fact, the model could accommodate more factors in production, including capital, land, etc. But the basic idea will be unchanged with multiple factors, such that countries still determine their vertical specialization pattern according to the differences in unit factor costs across countries. If we introduce capital in the model, the prices of intermediates and final goods (P_j^x and P_j^f) would be the functions of relative factor prices. Moreover, the bilateral value-added trade would be determined by the cross-country differences in relative factor prices. Several studies such as Chor (2010) and Costinot and Rodriguez-Clare (2013) have estimated the gravity equations with multiple factors and found that countries specialize in the production stages with the lowest costs of their factor endowments. In this chapter, we focus on the role of labor in shaping the bilateral value-added trade. For simplicity, we follow Eaton and Kortum (2002)'s assumption to assume that labor is the only factor in the production to capture the impact of cross-country difference in labor costs. However, the main idea would not change after incorporating capital in the studies.

Producers maximize profits by choosing V_j and X_j given the unit wage of labor in country i and country j (ω_i and ω_j). Following Noguera (2012), we denote the nominal value of intermediate goods as $x_j = P_j^x X_j$ and the nominal value of domestic value added as $v_j = \omega_j V_j$. The aggregated domestic value added ($\omega_j V_j$) also represents the disposable income of domestic households, which maximize utility with the budget constraint$\omega_j V_j$. Denoting the nominal value of total output in country j as $y_j = p_j Y_j$, in equilibrium, we get the following equations.

$$\begin{aligned} x_j &= P_j^x X_j = \alpha_j p_j Y_j = \alpha_j y_j \\ v_j &= \omega_j V_j = (1-\alpha_j) p_j Y_j = (1-\alpha_j) y_j \\ x_{ij} &= \omega_i \tau_{ij} X_{ij} = (\frac{\beta_i \omega_i \tau_{ij}}{P_j^x})^{1-\rho} \alpha_j y_j \\ f_{ij} &= \omega_i \tau_{ij} F_{ij} = (\frac{\beta_i \omega_i \tau_{ij}}{P_j^f})^{1-\sigma} (1-\alpha_j) y_j \end{aligned} \tag{3.3}$$

The output of country i equals to the total gross exports ($y_i = \sum_j e_{ij}$), where e_{ij} denotes the nominal exporting value from country i to country j and $e_{ii} = v_i$. The gross export to each country contains intermediate trade and the exports of final goods, thus $e_{ij} = x_{ij} + f_{ij}$. The total output of the world satisfies $y_w = \sum_i y_i$. We substitute equation (3.3) into $y_i = \sum_j (x_{ij} + f_{ij})$ to solve for the scaled wage $\beta_i \omega_i$ [10].The wage of country i (ω_i) could be written as follows.

$$\omega_i = \frac{1}{\beta_i} [\frac{y_i}{\sum_j \frac{\tau_{ij}}{P_j}^{1-\sigma} y_j}]^{\frac{1}{1-\sigma}} \tag{3.4}$$

In equation (3.4), country i's wage relies on the domestic output y_i and its trade partner's economic performance y_j. It is also determined by the aggregated price of P_j, which relies not only on trade of final goods with country j but also on the intermediate trade with the third countries in GVCs. We further follow the procedure of Anderson and Van Wincoop (2003) to derive the gravity-type equations of gross trade in intermediates and final goods as follows:

$$x_{ij} = \frac{y_i \alpha_j y_j}{y_w} (\frac{\tau_{ij}}{\Pi_i P_j})^{1-\sigma} \tag{3.5}$$

[10]Following Noguera (2012), we assume the elasticity of substitution among intermediates and final goods are same ($\rho = \sigma$), thus the aggregated price of intermediates P_j^x equals to the total price of final goods P_j^f. We denote them as the price of imported goods P_j.

$$f_{ij} = \frac{y_i(1-\alpha_j)y_j}{y_w}(\frac{\tau_{ij}}{\Pi_i P_j})^{1-\sigma} \tag{3.6}$$

where $\Pi_i = [\sum_j \theta_j (\frac{\tau_{ij}}{P_j})^{1-\sigma}]^{\frac{1}{1-\sigma}}$. θ_j is the share of country j's output in the nominal output of the world ($\theta_j = \frac{y_j}{y_w}$). Π_i describes the multilateral characteristics of country i with its trade partners. $P_j = P_j^x = P_j^f = [\sum_i (\beta_i \omega_i \tau_{ij})^{1-\sigma}]^{\frac{1}{1-\sigma}} = [\sum_i \theta_i \frac{\tau_{ij}}{\Pi_i}^{1-\sigma}]^{\frac{1}{1-\sigma}}$ represents the multilateral terms of country j and its trading partners. Equation (3.5) and (3.6) indicate that the bilateral flows of intermediates and final goods depend on the economic masses (y_i , y_j and y_w), the expenditure share of intermediates α_j, the bilateral trade cost τ_{ij}, and the multilateral resistance terms (Π_i and P_j). Π_i and P_j are further determined by the labor price $\boldsymbol{\omega}$ where $\boldsymbol{\omega}$ is the $N \times 1$ vector of unit wage for all countries trading with country i or country j. It suggests the bilateral trade flows of intermediate and final goods are determined by the labor costs of all the countries that have vertical production linkages with the source country (i) or destination country (j) in GVCs.

Noguera (2012) further decomposed the bilateral trade flows into value-added terms and incorporated the global input-output framework into the standard gravity model. We follow his procedures to examine the role of labor costs in value-added trade. We define $\mathbf{y}$ as the $N \times 1$ vector of output and $\boldsymbol{f_j}$ as the $N \times 1$ vector of country j's demand for domestic and imported final goods. $\boldsymbol{A}$ is the $N \times N$ matrix where its ij^{th} element represents the share of imported intermediate from country i to country j in the output of country j ($\alpha_{ij} = x_{ij}/y_j$). From the input-output analysis, the output vector of country j is written as follows:

$$\begin{aligned} \boldsymbol{y} &= \sum_j (\boldsymbol{I} - \boldsymbol{A})^{-1} \boldsymbol{f_j} \\ \boldsymbol{y_j}(\boldsymbol{I} - \boldsymbol{A}) &= \boldsymbol{f_j} \end{aligned} \tag{3.7}$$

where $\boldsymbol{I}$ is the $N \times N$ identity matrix. $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is the "Leontief inverse matrix" and its ij^{th} element implies how much intermediate should be imported from country i to produce 1 unit of output in country j. $\boldsymbol{y_j}$ is the $N \times 1$ vector implying the contribution of all the countries to country j's output, which is written as $\boldsymbol{y_j}$=$[y_{1j}, y_{2j}...y_{Nj}]'$. The ij^{th} element of $\boldsymbol{y_j}$ satisfies

$$y_{ij} - \sum_k \alpha_{ik} y_{kj} = f_{ij} \tag{3.8}$$

where α_{ik} is the ratio of intermediate inputs shipped from country i to country k, but finally absorbed in the production of final goods in country j relative to the output of j. Defining $\hat{z} = \frac{z-z^*}{z}$, the change of country j's output $(\hat{y_{ij}})$ is decomposed by the first-order Taylor expansion of the equation (3.8) with the matrix operations. If the value-added of output from country i to country j is $v_{ij} = (1-\alpha_i)y_{ij}$[11], the change of the value-added flow ($\hat{v_{ij}}$) equals to the change of output from country i to country j $(\hat{y_{ij}})$. Assume b_{ik} is the ik^{th} element of the Leontief Inverse matrix $\boldsymbol{B} = \boldsymbol{(I - A)}^{-1}$, the change of value-added flows between country i and country j $(\hat{v_{ij}})$ is written as:

$$\hat{v_{ij}} = \sum_k \frac{(1-\alpha_i)b_{ik}f_{kj}}{v_{ij}}\hat{f_{kj}} + \sum_k \sum_l \frac{(1-\alpha_i)b_{ik}\alpha_{kl}y_{lj}}{v_{ij}}\hat{\alpha_{kl}} \tag{3.9}$$

where $\frac{(1-\alpha_i)b_{ik}f_{kj}}{v_{ij}} = s_{ikj}$ and $\frac{(1-\alpha_i)b_{ik}\alpha_{kl}y_{lj}}{v_{ij}} = \phi_{iklj}$. We have $\sum_k s_{ikj} = 1$ where s_{ikj} represents the ratio of value-added from country i to country k but ultimately absorbed in country j in the form of country k's exporting final goods relative to the bilateral value-added trade between country i and country j. Similarly, ϕ_{iklj} measures the ratio of value-added exports from country i, in the form of intermediate inputs crossing many other countries such as country k and country l, but finally absorbed in country j, over the bilateral value-added trade between country i and country j. The change of bilateral value-added trade flow between country i and country j relies not only on the changes of final goods exports $(\hat{f_{kj}})$ but also on the change of intermediate input coefficient with all the countries in GVCs $(\hat{\alpha_{kl}})$ [Noguera (2012)].

We further get the first-order Taylor approximation of equation(3.5) and (3.6) as follows:

$$\hat{x_{ij}} = \hat{f_{ij}} = \hat{y_i} + \hat{y_j} - \hat{y_w} + (1-\sigma)(\hat{\tau_{ij}} - \hat{\pi_{i\omega}}\hat{\boldsymbol{\omega}} - \hat{P_{j\omega}}\hat{\boldsymbol{\omega}}) \tag{3.10}$$

[11] $1-\alpha_i$ represents the share of value-added content in gross output and it is a constant.

Substituting equation (3.10) into (3.9), we get the estimation of bilateral value-added exports in an approximate gravity model of equation (3.11).

$$\hat{v_{ij}} = \sum_{k} s_{ikj}[\hat{y_k}+\hat{y_j}-\hat{y_w}+(1-\sigma)(\hat{\tau_{kj}}-\hat{\pi_{k\omega}}\hat{\boldsymbol{\omega}}-\hat{P_{j\omega}}\hat{\boldsymbol{\omega}})]+\sum_{k}\sum_{l}\phi_{iklj}[\hat{y_k}-\hat{y_w}+(1-\sigma)(\hat{\tau_{kl}}-\hat{\pi_{k\omega}}\hat{\boldsymbol{\omega}}-\hat{P_{l\omega}}\hat{\boldsymbol{\omega}})] \tag{3.11}$$

The value-added exports from country i to country j are embodied in the gross trade of both intermediates and final goods. The first term of equation (3.11) shows the exports of domestic value-added embodied in the final goods from country i to country j. We scale the international input-output structure with the parameter s_{ikj} to describe the ratio of value-added exports in final goods relative to the total value-added trade between country i and j. The value-added exports from country i to j in final goods could be either through the direct exports from i to j (when $k = i$) or through indirect exports from country i to country k and then to country j (when $k \neq i$). The second term of equation (3.11) represents the exports of value-added from country i to country j as intermediates through the third countries (k or l), which have vertical production linkages with country i and j. The process is scaled by term ϕ_{iklj},measuring the share of value-added from country i to country j through indirect intermediate trade with the third countries in the total value added of exports between i and j.

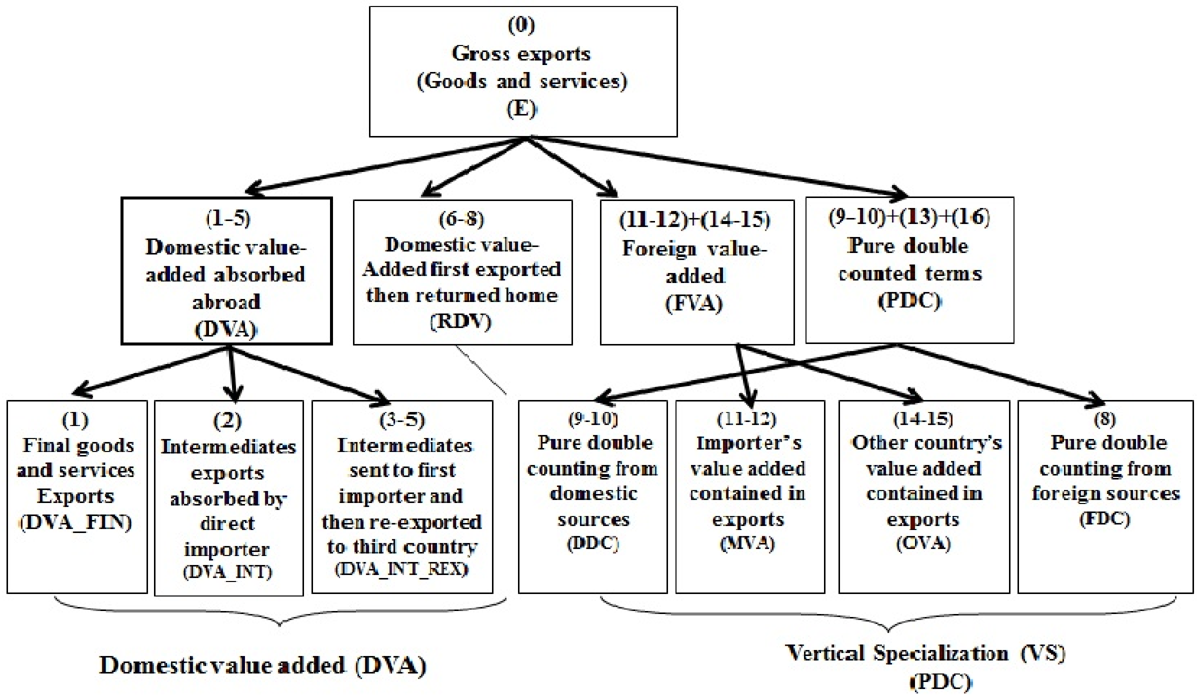
Despite in an approximate gravity-type form, equation (3.11) is different from the standard gravity model. Equation (3.11) is characterized by its global input-output structure, which links all the countries in GVCs through direct and indirect value-added trade. The bilateral value-added trade flows between country i and j are determined not only by the characteristics of the source and destination countries that have direct gross trade linkages but also by that of the third countries which have indirect production linkages with the source and destination countries through GVCs [Noguera (2012)]. Moreover, the gravity model of value-added trade identifies new determinants that do not appear in the standard gravity model: the economic masses of the third countries($\hat{y_k}$), the bilateral trade costs with the third countries ($\hat{\tau_{kj}}$), and the unit wage of third countries ($\hat{\boldsymbol{\omega}}$). Compared to the ambiguous role of labor in gross trade, the bilateral value-added flows are determined by labor not only from the source and destination countries but also from the third countries through which bilateral value-added flows transit en route.

There are five factors that determine the bilateral value-added trade flows in equation (3.11). The first factor is the economic masses of bilateral countries (y_i and y_j). The second one is the economic masses of the third countries in GVCs (y_k, $k \neq i; k \neq j$), which highlights the indirect production linkages across countries in the global production networks. The third factor is the total output of the world (y_w), and the fourth one is the direct or indirect trade costs between country i and country j. As we know, the bilateral value-added flows are determined by not only the bilateral trade costs between the source country and its partner but also the trade costs with the third countries in GVCs [Noguera (2012)]. The last factor is the labor-related multilateral resistance terms ($\hat{P_{l\omega}}$ and $\hat{\pi_{k\omega}}$). The model predicts that the bilateral value-added trade between the source country and the destination country is determined by the labor costs of all the countries along the GVCs.

This section identifies the direct and indirect linkages between labor and bilateral value-added trade with a simple theoretical model. In the next part, we will provide some statistical analyses of the value-added trade and give several stylized facts about GVCs and labor market.

3.3 Data and Empirical Strategy

In this section, we discuss the data and derivation of the empirical variables in our model. An empirical specification is derived from the equation (3.11) to examine the role of human capital in bilateral value-added trade. We also provide several stylized facts about the value-added trade and human capital development of sample countries in GVCs.



Source: The graph is compiled from Wang et al. (2013). Please see the paper for more details about the decomposition.

Figure 3.1: Decomposition of Gross Exports into Value-added Terms

3.3.1 Data

In this chapter, we follow the procedures of Wang et al. (2013) to decompose the gross trade into value-added terms using the world input-output tables from 1995 to 2014. The world input-output tables (WIOD) enable us to track the value of intermediates and final goods by sources and destinations[Banga (2013)]. The WIOD contains 31 OECD countries and 12 emerging economies, accounting for almost 85% of the world GDP [Timmer et al. (2015)]. This dataset constructs a closed world economy of 44 regions and 56 sectors by taking the rest of the world as a single region named "ROW". The WIOD database is compiled annually from 1995 to 2014, providing a consistent analysis of value-added trade across time, sectors and countries. In this paper, we use the World Input-Output tables from WIOD to estimate the sectoral-level bilateral value-added trade across 43 countries.

Following Wang et al. (2013)'s framework in Figure (3.1), the value-added contents embodied in gross exports are divided by sources into the domestic value-added content (DVA), the foreign value-added content (FVA) and additional double-counting terms. The domestic value-added content of exports is further decomposed into the domestic value added absorbed by the partner country in the form of intermediates or final goods (DVA_INT or DVA_FIN), the domestic value added absorbed in the third countries by intermediate exports (DVA_INT_REX), and the domestic value-added re-imported to the home country (DDC). The foreign value-added content includes the foreign value added from the partner country (MVA)and the foreign value added from the third countries (OVA). The foreign value-added embodied in intermediates may cross borders several times, leading to the double-counting of foreign value-added embodied in gross exports (FDC).

We calculate the ratio of value-added content to gross exports (VAX ratio) as a proxy for vertical specialization of countries in GVCs [Johnson and Noguera (2012b)]. The VAX ratio depicts the extent of global production fragmentation at an aggregated country level without revealing the sectoral linkages of production within countries [Wang et al. (2013)]. As suggested by Wang et al. (2013), we adopt two additional indicators to measure the extent of international fragmentation across sectors. The first measure is the share of "indirect domestic value-added exports" in gross exports (DVX), which measures the ratio of domestic value added that exports through the third countries as intermediates relative to total exports. The indirect domestic value-added exports through the third countries are measured by $DVX = DVA\_INT\_REX + RDV$ as in Wang et al. (2013). The measurement captures the contribution of domestic sectors to the third countries' exports and provides rough information about the country's GVC participation via forward-based production linkages. We also calculate the share of foreign value-added content in the gross exports (FVX), which captures the usage of foreign intermediate inputs in domestic exports. The FVX also measures the country' backwards-linkage integration into GVCs. The sum of DVX and FVX gives a full picture of countries' participation in GVCs.

In this chapter, we study the role of human capital in determining the bilateral domestic value-added trade. We incorporate different types of human capital in the empirical study to capture the impacts of various skills on GVCs. The human capital is categorized into three kinds of skills by education: the skilled, semi-skilled and unskilled workforces. Workers with the college degree or over are categorized as the skilled labor, while workers with primary education or below are defined as unskilled labor [Barro (1991), Barro and Lee (1993), Nehru et al. (1993)]. The unit wage per hour for each skill is calculated at the sectoral level across countries, which represents the average cost of skills for production[Mulligan and Sala-i Martin (1995)]. The skilled workers are observed to have larger unit wages than unskilled labor in our sample of 43 countries.

The labor data of this chapter comes from the Socio-Economic Accounts (SEAs) of the WIOD database. The SEAs contain detailed information about capital, investment, output, and labor on the sectoral level across 43 countries, most of which are OECD countries. As previously stated, the workforce in the database is classified into the skilled, semi-skilled, and unskilled labor by education following the 1997 International Standard Classification of Education (ISCED) classification (See Appendix B). There are 35 industries in SEAs, covering 18 service sectors and 17 manufacturing sectors. The SEAs are available from 1995 to 2014 annually, but some critical human capital indicators are only available until 2009. The SEAs data was matched with the bilateral value-added trade data compiled from WIOD between 1995 to 2009 [12].

We also consider the trade cost indicators in the empirical model, including distance, cultural linkages, land-locking, and colonial relationships. We define the distance between the urban agglomerations weighted by populations as the distance between the two countries. The weighted distance comes from the CEPII GeoDist database, which contains country-specific geographical variables for 225 countries. CEPII GeoDist database also provides different measures of bilateral cultural distance such as common languages, land-locking, and colonial linkages. We further include regional trade agreements (RTA) as an essential factor that affects the bilateral value-added trade cost. The RTA data is collected from the WTO website from 1995 to 2009.

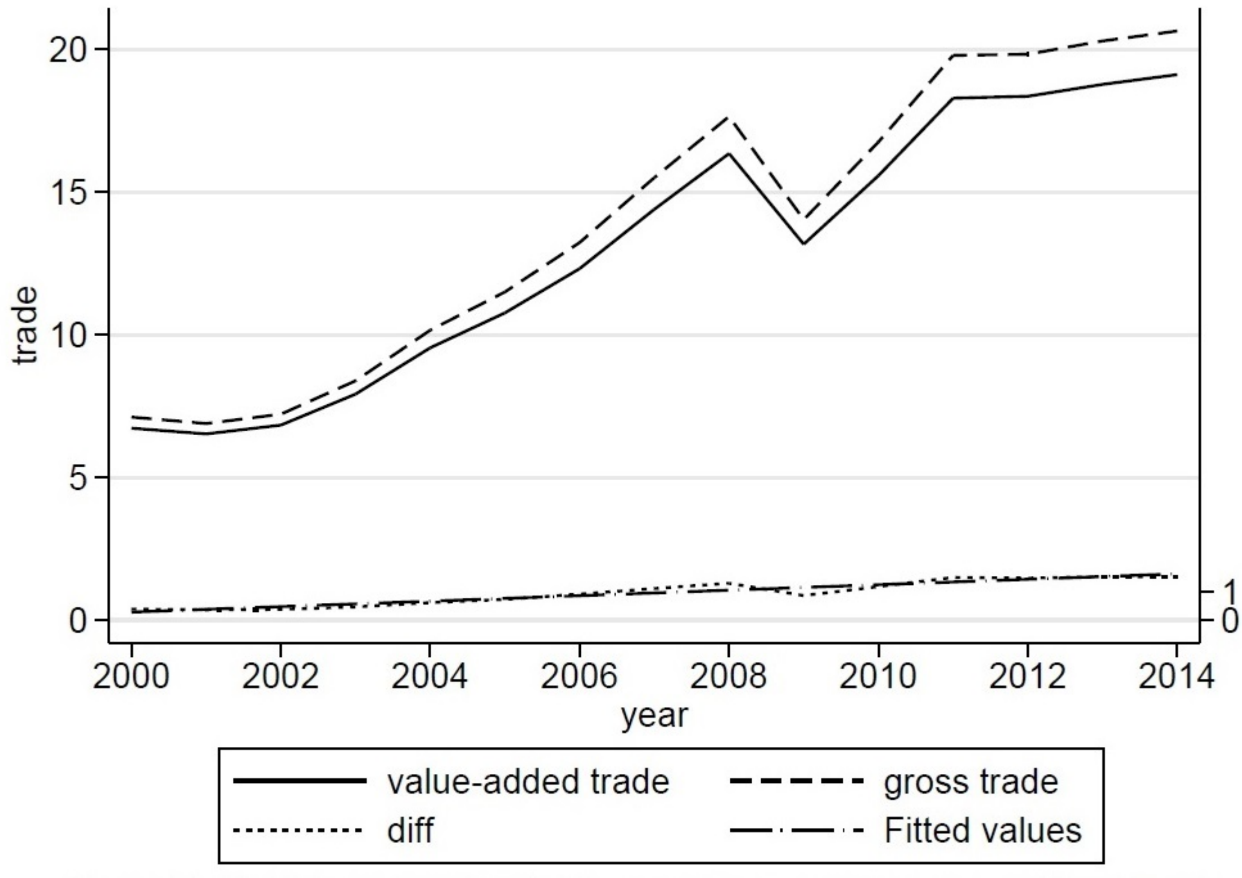
[12] As the SEA data is in millions of local currency, we use the annual exchange rate data of the OECD database to convert them into US dollars. We also adjust the SEA data into the 1995 constant price level using the Constant Price Index (1995=100) from the World Bank database.

3.3.2 Measurement

In this part, we provide several stylized facts of value-added trade, international fragmentation, and human capital development across 43 countries with 34 sectors in our data.

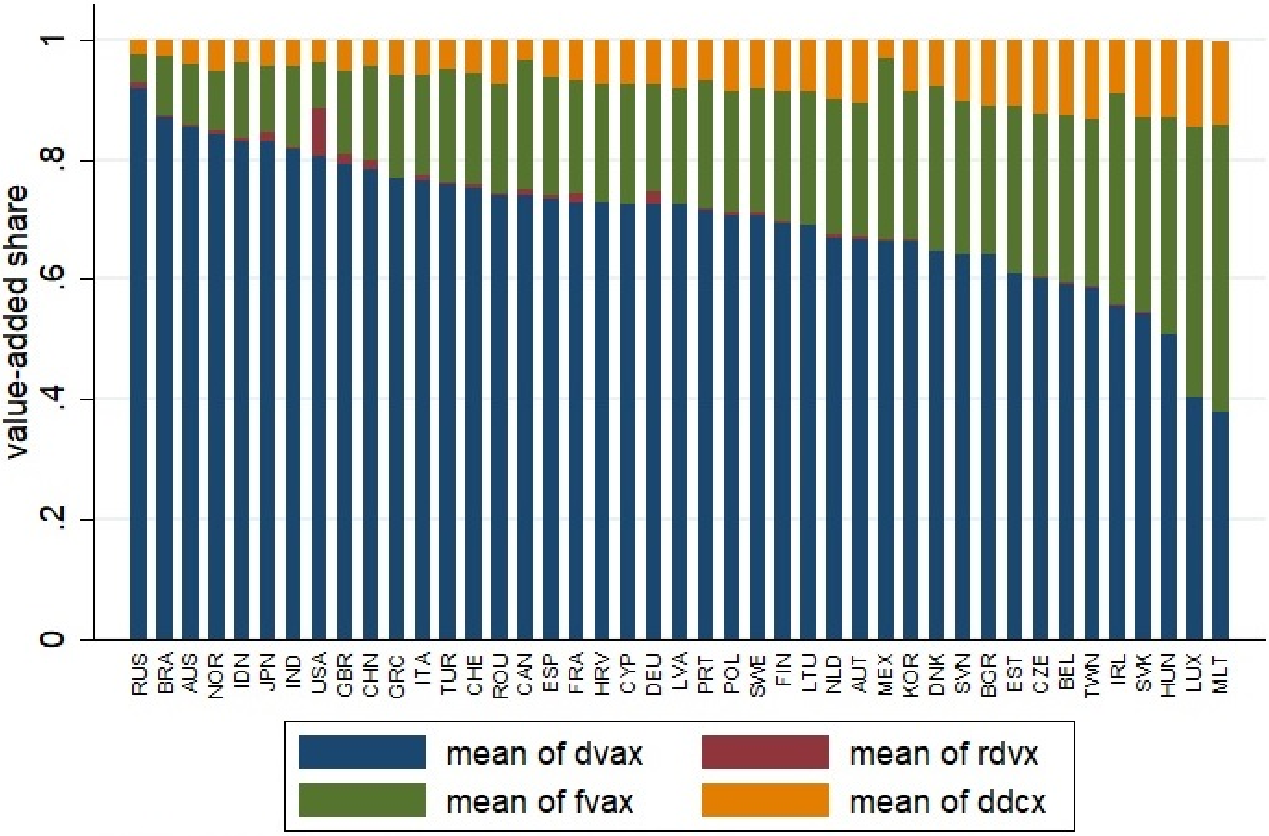
3.3.2.1 Value-added Trade

We have addressed the poor performance of gross trade in explaining the vertical production networks of GVCs. As shown in Figure (3.2), gross trade is increasingly unrepresentative of value-added trade with their discrepancy dramatically widening from 389.5 billion US dollars in 2000 to 1528.5 billion US dollars in 2014. The growing discrepancy is due to the rapid growth of intermediate inputs trade in recent decades.



Note: The value-added data is compiled by the author following the procedures of Wang et al. (2013). The international input-output tables come from the World Input-Output Database (WIOD).The value-added trade and gross trade are in thousands of billion US dollars.

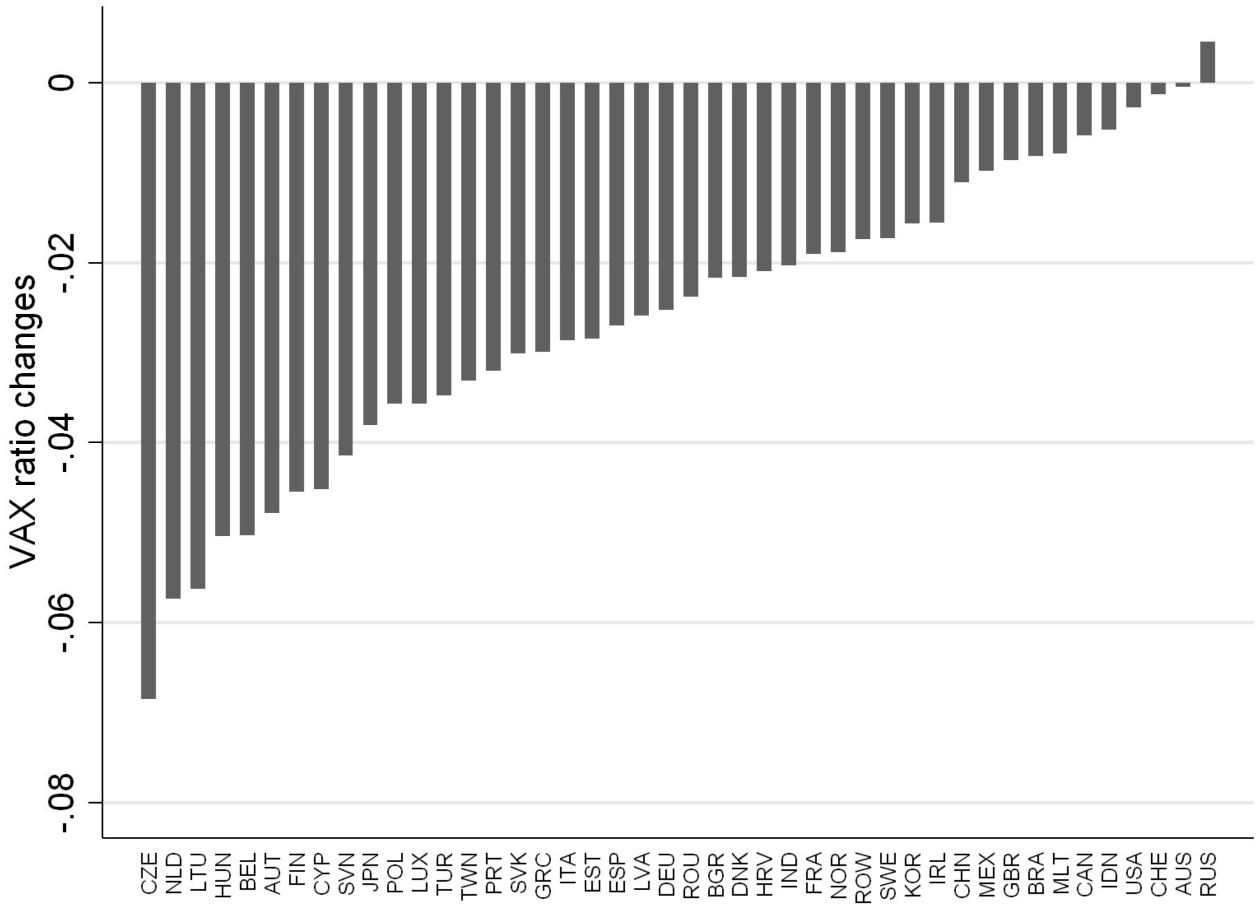
Figure 3.2: World's Gross Trade versus Value-added Trade, 2000-2014



Note: The value-added data is compiled by the authors using the international input-output tables from the World Input-Output Database (WIOD). DVAX refers to the ratio of domestic value-added content absorbed abroad relative to gross exports. RDVX is the ratio of domestic value-added content returning home relative to gross exports. FVAX represents the share of foreign value-added content in exports. DDCX is the share of double counting content in exports.

Figure 3.3: The average value-added content as % of gross exports,2000-2014

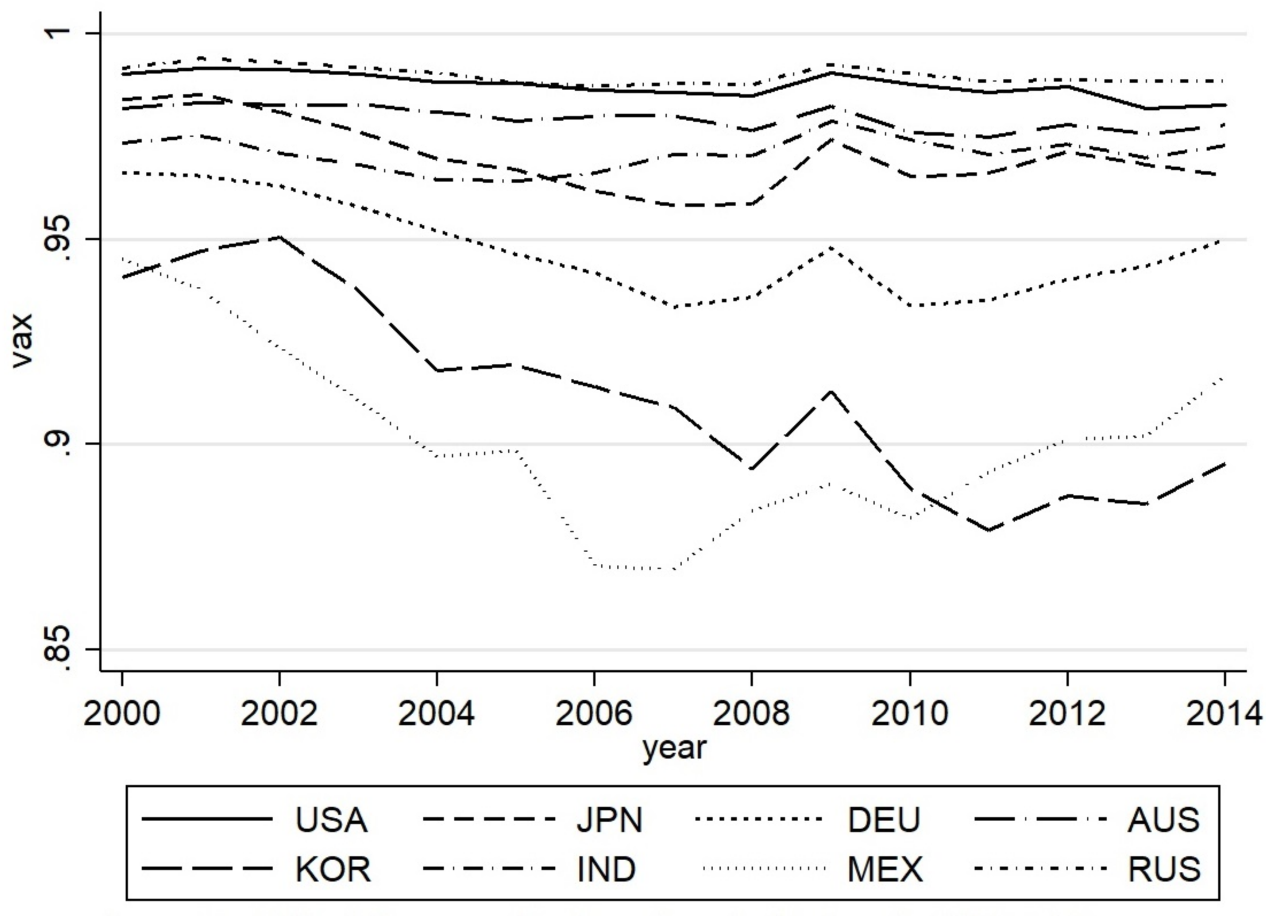
Figure (3.3) shows the value-added composition of gross exports across the sample countries. The gross exports are decomposed into four value-added contents by sources including the domestic value-added content absorbed abroad (DVA), the domestic value-added content returning home (RDV), the foreign value-added content (FVA) and the pure double-counting content (PDC). DVA and RDV constitute the total domestic value-added content in gross exports (SUMDVA). We observe significant heterogeneity across countries in their value-added composition of gross exports in Figure (3.3). Countries in the abundance of natural resources, such as Russia, Brazil, Australia and Indonesia, tended to have higher ratios of domestic value-added content in exports (DVAX). Some advanced economies (e.g., Japan, the United States, UK, and Germany) also had high ratios of domestic value-added content in exports (DVAX) with a large share of RDV in exports (RDVX). For example, in the United States, around 8% of domestic value added were re-imported and consumed at home during 2000-2014 (e.g., a large amount of iPhone produced abroad are sold to the US market). The high ratio of RDV leads to the double counting problem in gross trade. We also observed that European countries tend to have higher ratios of foreign value-added content in exports (FVAX) than the other countries. They also had larger shares of pure double-counting terms in the bilateral gross trade flows (DDCX). One possible reason for the large DDCX in European countries is the existence of the European Union, which facilitates the flows of intermediate trade across countries and leads to a high share of foreign value-added in exports with large double-counting content (DDCX). We also observed that economies with larger economic scales tend to have higher domestic value-added shares than small countries.



Note: The VAX ratio is the share of value-added exports in gross exports which measures the extent of international fragmentation of countries in GVCs. In this figure, it is aggregated to the country level using the sectoral value-added trade data compiled from the world input-output tables of the WIOD database.

Figure 3.4: Changes in Aggregated VAX ratios across countries,2000-2014

Figure (3.4) describes the changes of VAX ratio across countries during 2000-2014. Following Johnson and Noguera (2012b), the VAX ratio is the share of value-added trade in gross trade. If the VAX ratio declines, the double-counting content of gross trade (DDCX) becomes larger, and the extent of international production fragmentation rises. As shown in Figure (3.4), except for Russia, all the countries in the sample had declining VAX ratios since 2000. The VAX ratio had declined more in European countries than in other countries. The decline of the VAX ratio in developing economies (for example in China, Mexico, and India) was smaller than that of industrialized countries such as the United States and Canada. The resource-abundant countries such as Australia, Indonesia, and Russia had the smallest or even negative decline in VAX during this sample period.

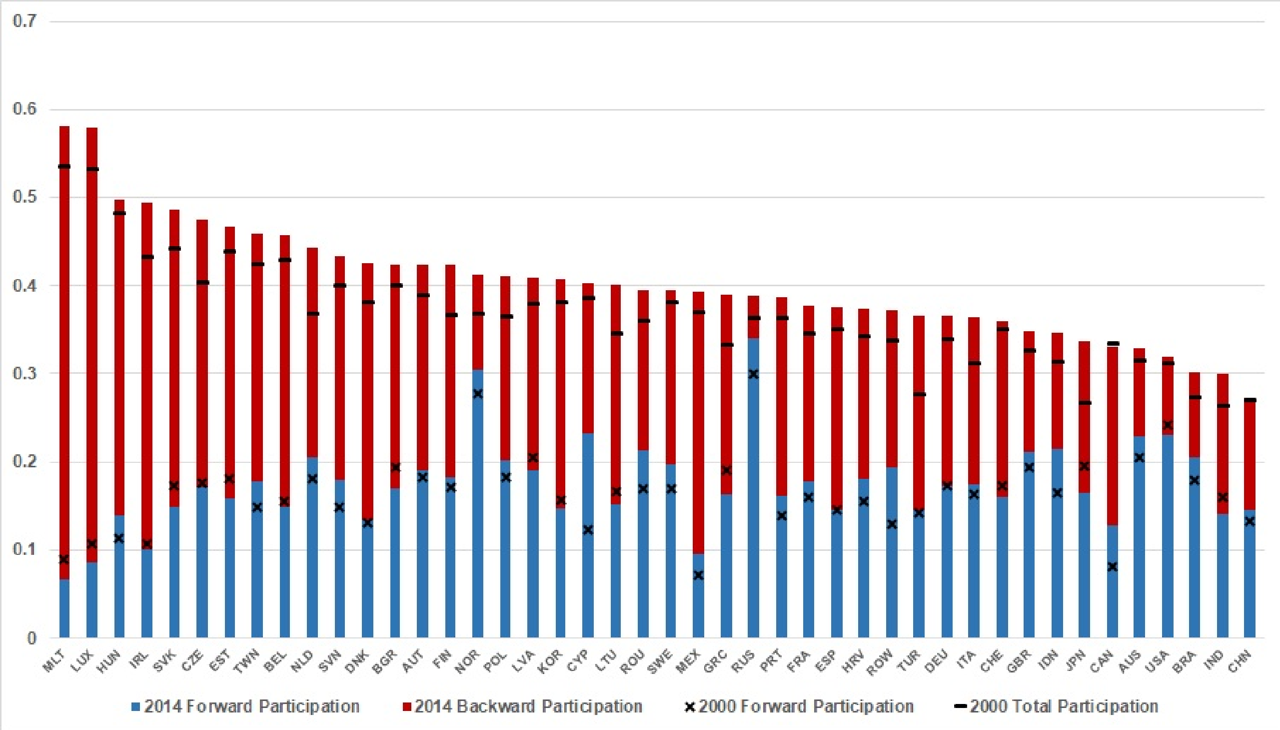


Note: The VAX ratio is calculated by the author based on the international input-output tables from the WIOD database.

Figure 3.5: The Bilateral VAX Ratio between China and its Selected Partners, 2000-2014

We further decompose the VAX ratio at the bilateral level to capture the vertical production linkages between the exporting country and its partner. We give the example of China and its largest eight trading partners in Figure (3.5). The overall trends of VAX ratio between China and its main trading partners were decreasing during the sample period. However, the variation of VAX ratio differed across destinations. We observed a slight decline of less than 1% in the bilateral VAX ratios between China and its partners including the United States, Russia, Australia, and India during the sample period. The bilateral VAX ratios of China with Japan and Germany indicated a moderate decline of around 2% during the sample period. The VAX ratio with Mexico declined by 3%, which experienced a sharp decrease during 2000-2007 and a moderate rise afterward. We observed a similar but moderate trend between China and Germany. China had the most significant decline in bilateral VAX ratio with Korea, dropping from 94% in 2000 to 89% in 2014. These results indicate that China has a rising trend of international production fragmentation in GVCs, but the extent varies across destinations. The bilateral VAX ratio measures the extent of international fragmentation between the source country and the destination country, but it fails to provide information about the sectoral composition of value-added trade. For example, China had similar VAX ratio in its gross exports to the United States and Russia. However, there were more foreign value-added contents embodied in China's exports to the United States than to Russia, which was barely captured in the aggregated VAX ratios.

To capture the sectoral linkages within the value-added trade, we consider the forward and backward production linkages between the exporting countries and their partners. The forward production linkages trace the domestic value-added content in exports by destinations, which captures the country-sector participation in GVC from the producer's perspective. The forward linkages measure the value-added contribution of the exporting country to its partner (via direct exports) or the third countries (via indirect exports). The indirect exports enable countries which have no gross trade to have value-added trade [Wang et al. (2013)]. Koopman et al. (2014) defined the share of domestic value-added embodied in third countries' exports as the forward participation index of GVCs. The backward production linkages trace the value-added

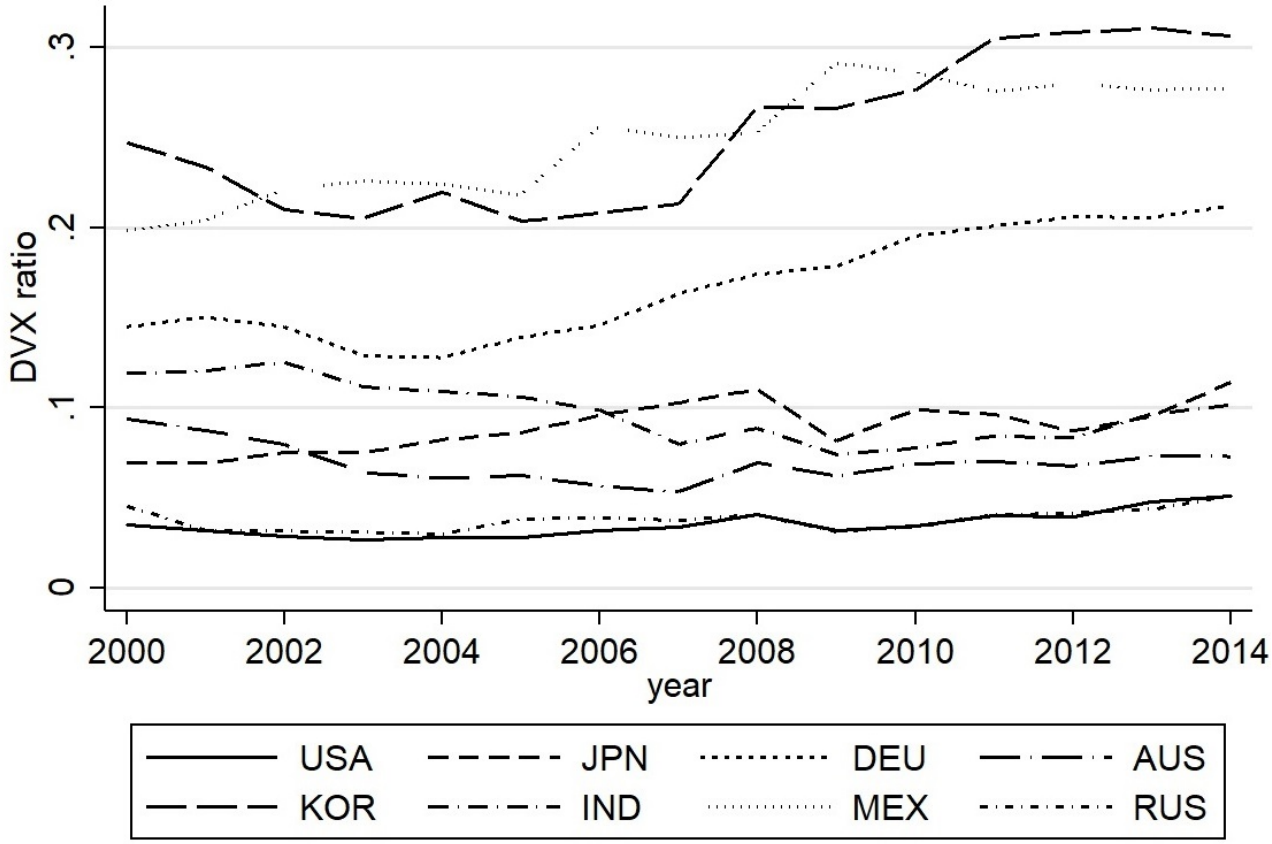


Note: The forward participation index is defined as the share of domestic value-added embodied in third countries' exports[Koopman et al. (2014)]. The backward participation is defined as the share of foreign value-added content in gross exports [Koopman et al. (2014)]. The total participation is the sum of the forward and backward participation index. The value-added data is compiled by the author using the WIOD database.

Figure 3.6: The Forward and Backward GVC Participation by Country, 2000-2014

of exports by sources from the users' perspective. It captures the contribution of the foreign countries to exports. Koopman et al. (2014) defined the share of foreign value-added in gross exports as the backward participation index of GVCs. The forward and backward production linkages give a complete picture of countries' participation to GVCs.

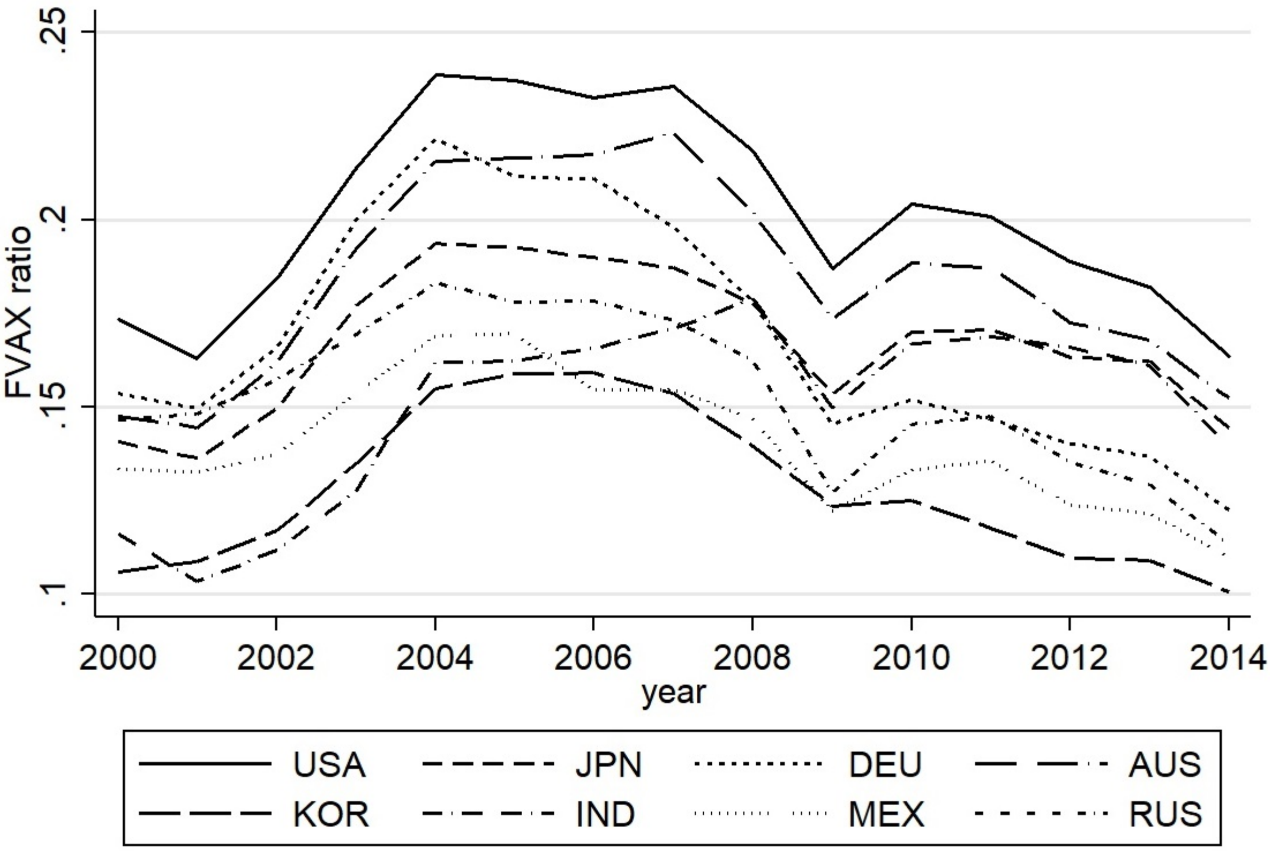
Figure (3.6) depicts the forward and backward participation of countries in GVCs. Small open economies such as Malta, Luxembourg, Hungary, and Ireland had high participation in GVCs with a prominent proportion of foreign value-added embodied in exports (backward participation index). Large OECD countries such as the UK, Japan, Australia, and the USA tended to have higher forward participation but lower backward participation in GVCs than the small OECD countries. Compared to the developed countries, most emerging economies had lower participation in GVCs. Large developing countries (e.g., China, India, Brazil, etc.) tended to participate more in the forward production linkages of GVCs than small emerging economies like Mexico and Bulgaria. The resource-abundant countries, such as Russia, Indonesia, and Australia, were more likely to integrate into GVCs via the forward production linkages.



Note: The DVX ratio is the share of domestic value-added content embodied in the partners' exports. It measures the bilateral forward linkages between the exporting country and its partners. The value-added data is compiled by the author using IIOTs from the WIOD database.

Figure 3.7: The Bilateral Forward Value-added Linkages between China and Selected Partners

Figure (3.7) further considered the forward sectoral linkages at the bilateral level with the example of China and its selected partners. China had the most extensive forward linkages with Korea and Mexico, suggesting an increase of Chinese domestic value-added content embodied in the exports of Korean and Mexico. China had a moderately growing forward linkage with Germany and Japan, suggesting a strengthening forward linkage of China with these countries. However, China had a declining forward linkage with India and Australia. The United States and Russia had the least forward linkages with China, indicating the exports of the two countries barely contained the domestic value-added content of China. These results suggested that China lay at the downstream position relative to the United States and Russia in GVCs. However, China tended to be at the more upstream position in GVCs than Korea and Mexico.



Note: The FVAX ratio represents the share of foreign value-added embodied in exports. It measures the bilateral backward linkages between the exporting country and its partners. The value-added data is compiled by the author using the WIOD database.

Figure 3.8: The Bilateral Backward Value-added Linkage between China and Selected Partners

Figure (3.8) describes the bilateral backward linkages between China and its selected partners. The FVAX ratio measures the foreign value-added content of China's trade partner embodied in Chinese exports. It captures the extent of China using its partners' intermediates in domestic production for exports. The overall trend of backward linkages increased during 2000-2007 but declined since the global financial crisis, suggesting China tends to substitute imported intermediates for domestic materials in recent years. We also observe that China had more backward linkages with the large developed countries, such as the United States, Germany, Australia, and Japan, than the emerging economies like India, Russia, and Mexico. Despite having similar VAX ratio with the United States and Russia, China had different backward linkages with the two countries. The share of American value-added content in China's exports was about 20% in 2014, but the share was 11% with Russia. It suggests that the exports between China and the United States were more vertically fragmented than that of Russia.

The above analyses reveal the increasing discrepancy between value-added trade and gross trade due to the growing double-counting terms. We use the VAX ratio to measure the extent of international production fragmentation at the country level. The declining VAX ratio suggests a higher level of vertical specialization across countries. EU countries had the steepest decline in the VAX ratio, closely followed by developing countries such as China and Mexico. We further analyze the forward and backward sectoral linkages at the bilateral level. Countries' forward and backward linkages for production constitute the GVC participation index, which is related to countries' economic scales, openness, and production activities in GVCs. Small open economies tend to have large backward participation in GVCs, while large industrialized economies generate strong forward linkages to GVCs. Resource exporters have a higher share of domestic value-added content embodied in the third countries' exports, which locates them in the relatively upstream sectors of GVCs. The forward and backward industrial linkages are heterogeneous across destinations at the bilateral level. We explore the bilateral sectoral linkages using the example of China. With the large production base and domestic market, China has deep backward linkages with developed countries, such as the US, Japan, and Germany, and it also has forward linkages with emerging economies like Mexico. The forward and backward linkages identify the indirect trade across countries, through which economies without gross trade flows could be connected by value-added trade in GVCs.

3.3.2.2 Human Capital Development

In this section, we summarize the human capital characteristics of sample countries. A recent trend of polarization of skills appeared in the labor markets of many OECD countries, where the employment of semi-skilled labor is observed to be "hollowing out" relative to the skilled and unskilled labor. As shown in Figure (3.9), the semi-skilled employment declined in most OECD countries between circa 1995 and circa 2011. Meanwhile,the employment of skilled and

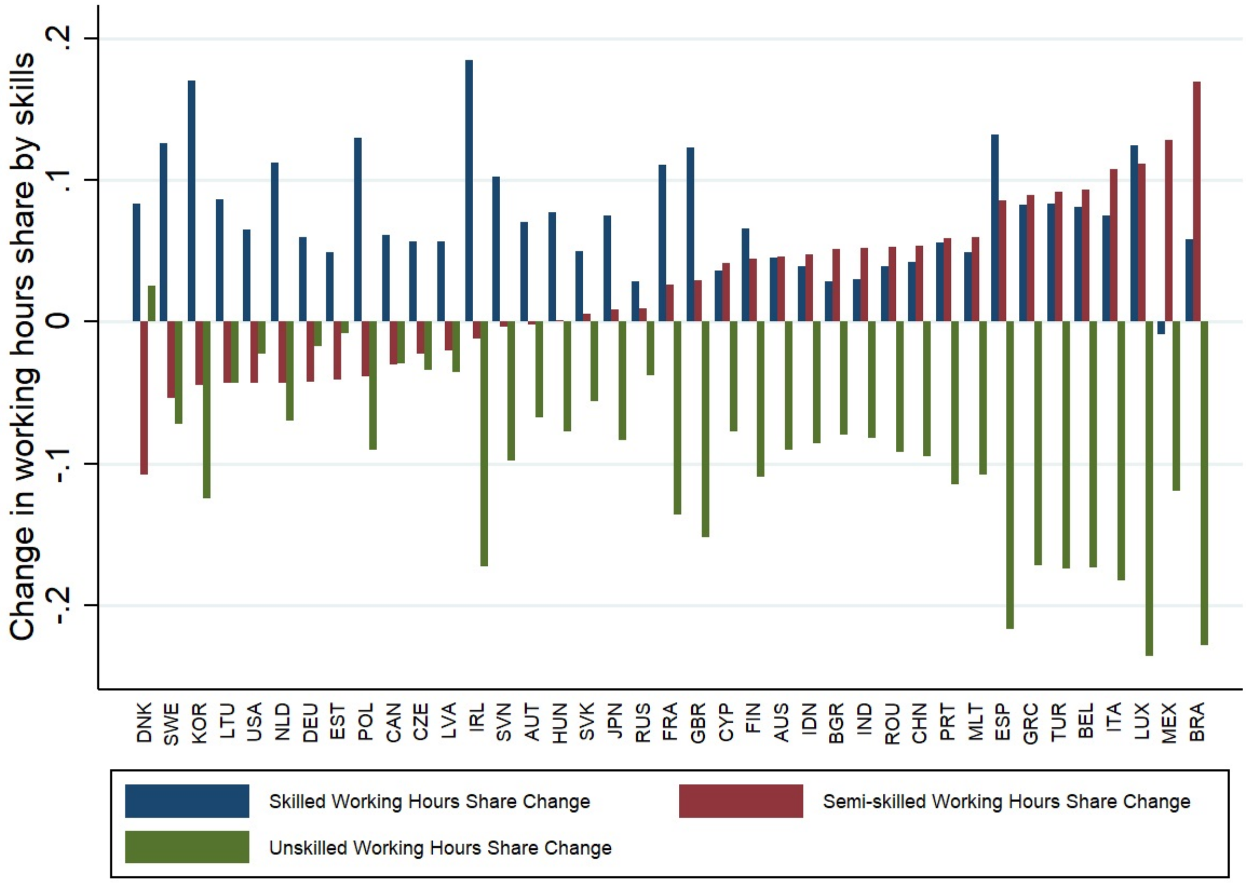
Note: The employment data by skills comes from the ILO Key Indicators of the Labor Market (KILM) database. The Chinese employment data comes from the National Bureau of Statistics of China. Skills are categorized by education based on the International Standard Classification of Education (ISCED) in Appendix B. This figure shows the employment share changes between circa 1995 and circa 2011. We use the data of the year next to 1995 or 2011 as substitutes if the employment data is not available for the specific year

Figure 3.9: Changes in the Employment Share by Skills, 1995-2011

unskilled labor grew in the same period[13]. In contrast, we observe a growing share of semi-skilled employment in China in contrast to the declined semi-skilled jobs in OECD countries.

Figure (3.10) displays the changes in the share of working hours by skills in total working hours between 1995 and 2009. For most countries, the share of unskilled working hours declined during 1995-2009, which could be partly explained by the development of new technologies. We

[13]Several studies have highlighted several possible reasons for the skill polarization in OECD countries. Some studies explained job polarization with the development of technologies, which replaces labor in routine tasks with computer technologies [Autor (2003), Autor et al. (2006), Goos et al. (2009), Autor (2013), Goos et al. (2014)]. Another possible channel is offshoring, through which the routine jobs are offshored to countries with low labor costs [Autor and Dorn (2013), Oldenski (2014), Goos et al. (2014)].

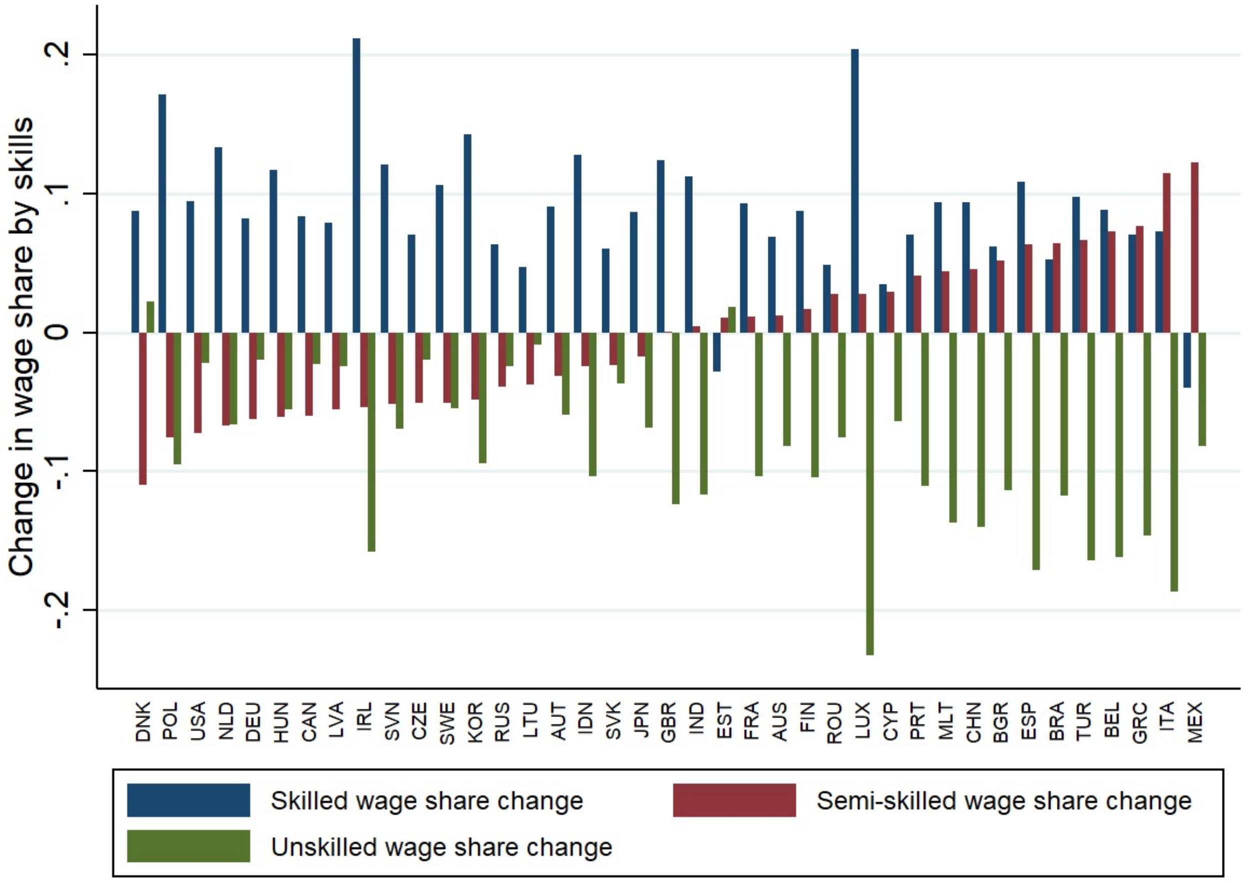


Note: The data comes from the Socio-Economic Accounts of WIOD database. Skills are categorized by education based on the International Standard Classification of Education (ISCED) in Appendix B. This figure shows the changes in the share of working hours with exceptions different skills between 1995 and 2009.

Figure 3.10: Changes in Share of Working Hours by Skills in Total Hours, 1995-2009

observe that the decline is more significant in OECD countries than in emerging economies. The share of semi-skilled working hours decreased in many highly industrialized OECD countries such as the United States, Germany, Denmark, Korea, and Sweden. However, the share of semi-skilled working hours increased in some emerging economies between 1995 and 2009 (e.g., Mexico, India, Indonesia, China, Brazil, etc.). This phenomenon is likely to be linked to the offshoring of semi-skilled jobs from the advanced industrialized countries to developing countries. Moreover, the share of skilled working hours grew in all the countries except Mexico with a more significant growth rate in developed countries than in developing countries.

Figure (3.11) decomposes the total labor compensation by skills and shows the changes in the skill wage share between 1995 and 2009. We observe a high level of heterogeneity

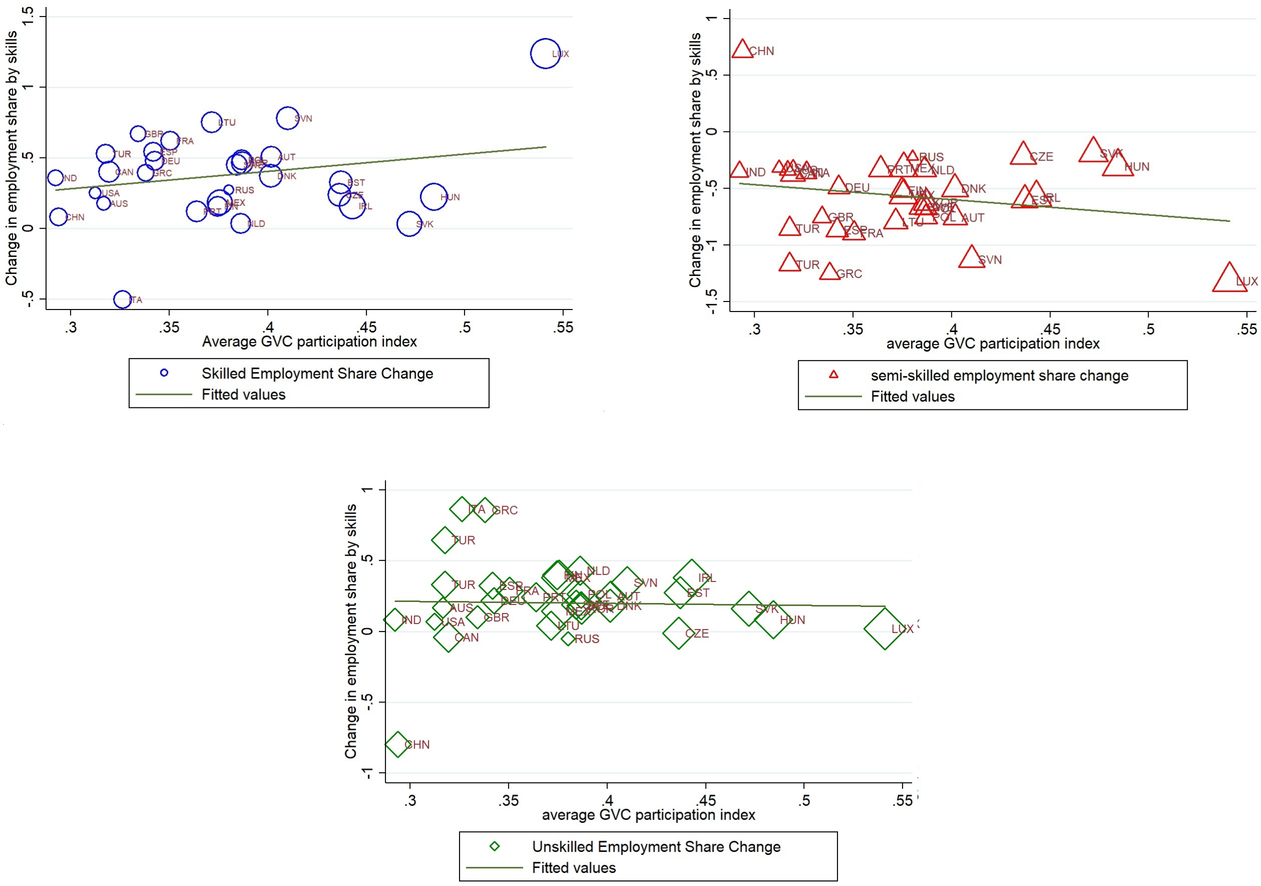


Note: The data comes from the Socio Economic Accounts of WIOD database. Skills are categorized by education based on the International Standard Classification of Education (ISCED) in Appendix B. This figure shows the changes in the share of wages by skills in total working hours between 1995 and 2009.

Figure 3.11: Changes in Wage Share by Skills in Total Labor Compensation, 1995-2009

in the changes of wage share by skills across countries. The share of skilled wage increased in all countries except in Estonia and Mexico. The share of semi-skilled wage declined in most industrialized OECD countries, but rose in some small OECD countries (e.g., France, Finland, Luxembourg, Turkey, etc.) and most emerging countries (e.g., India, Brazil, China, and Mexico). The unskilled wage share declined in all countries except Denmark and France. However, the countries which are abundant in natural resources such as Russia, Indonesia, and Australia are exceptions to these trends.

As analyzed, GVCs break up production process across borders and reshape the labor market by relocating jobs to specific countries with comparative advantage. The skill-polarization in OECD countries, in fact, corresponds to the growth in semi-skilled employment in some



Note: The employment data by skills comes from the ILO Key Indicators of the Labor Market (KILM) database. The value-added data is compiled by the author using the WIOD database. Skills are categorized by education based on the International Standard Classification of Education (ISCED) in Appendix B. We calculate the changes in the employment share of skills in total employment between 2000 and 2011. The GVC participation index is the average of annual participation index, which is the sum of the forward and backward participation indexes. The size of bubbles is weighted by the backward participation index. This Figure depicts the correlations between employment share changes and average GVC participation the changes in the share of wages by skills between 2000 and 2011.

Figure 3.12: Average GVC participation and Employment Share Changes by Skills

emerging economies, which inspire us to explore the linkages between GVC participation and polarization. In Figure (3.12), we link the polarization of OECD countries with their GVC participation. There is a positive correlation between skilled employment changes and average GVC participation index of OECD countries. It suggests that countries deeply involved in GVCs tend to have higher growth in skilled employment. We also observe that countries with more backward linkages in GVCs (larger size of the bubbles) tend to have more significant skilled employment growth. In contrast, there is a negative correlation between semi-skilled employment changes and GVC participation. Countries with broader participation in GVCs decline more in semi-skilled employment. Moreover, for countries with a higher share of foreign value-added content in exports, the semi-skilled employment decline tends to be larger. In contrast, we observe no significant correlation between GVC participation and unskilled employment share changes from the sample countries.

3.3.3 Empirical Model

In this section, we empirically explore the roles of different types of human capital (skills) in bilateral value-added trade. The classification of skills enables us to capture the polarization in OECD countries and explore the nexus between value-added trade of GVCs and human capital costs.

According to equation (3.11), the bilateral value-added trade flows rely upon the bilateral and the third countries' economic masses, the output of the world, the multilateral trade costs and the human capital of countries in GVCs. We derive the empirical specification based on equation (3.11) as follows :

$$\begin{aligned} lnv_{ijgt} = {} & \beta_1 lny_{igt} + \beta_2 lny_{jgt} + \beta_3 ln\tau_{ijt} + \beta_4 lnw^h_{igt} + \beta_5 lnw^m_{igt} + \beta_6 lnw^l_{igt} + \beta_7 lnw^h_{jgt} \\ & +\beta_8 lnw^m_{jgt} + \beta_9 lnw^l_{jgt} + \beta_{10} lnw^h_{kgt} + \beta_{11} lnw^m_{kgt} + \beta_{12} lnw^l_{kgt} \\ & +\zeta_{ij} + \zeta_t + \zeta_g + \varepsilon_{ijgt} \end{aligned} \tag{3.12}$$

where i represents the value-added source country and j denotes the destination country. g refers to the sector and t is time. lnv_{ijgt} is the logarithm of bilateral domestic value-added exports between country i and j of sector g at time t. y refers to the bilateral economic masses. As GDP is not a perfect measurement of import demands or export supplies when intermediate trade dominates, we use the total output instead of GDP in the estimation [Baldwin and Taglioni (2011)]. τ_{ijgt} represents the bilateral trade costs between country i and j. It is a function of bilateral distance ($lndis_{ijt}$), RTA (rta_{ijt}), and other bilateral characteristics such as common language, colony, and continuity. All the variables are adjusted by the constant 1995 US price.

The baseline model in equation (3.12) explores the role of different skills in bilateral value-added trade. As discussed, we use the unit wage per hour as the proxy for the average cost of skills. Thus w^h, w^m and w^l measure the unit wage per hour of skilled, semi-skilled and unskilled workers respectively. We control the impacts of human capital of third countries by taking the average of the unit wage of other countries in GVCs except for the source and destination countries, which is written as w^h_{kgt}, w^m_{kgt} and w^l_{kgt} respectively. We include the importer-time (ζ_{it}) and exporter-time fixed effects (ζ_{jt}) to control for the other factors of the inwards and outwards multilateral terms (Π_{it} and P_{jt}). We also control the pair and sector fixed effects in the regression. The primary variables of baseline model are summarized as follows:

Table 3.1: Variable Description

Variable	Description	Obs	Mean	Std. Dev.
lnSUMEXGR	ln gross exports	476,031	0.438	4.161
lnSUMDVA	ln domestic value-added trade	476,031	0.174	4.144
lnGO	ln sectoral output in exporting/partner country	508,935	8.616	2.401
contig	1 for continuity	488,730	0.060	0.237
comlang	1 for common language	488,730	0.053	0.224
colony	1 for pairs ever in colonial relationship	488,730	0.040	0.197
lndisij	ln weighted distance	488,730	7.997	1.147
rta	1 if countries have RTAs	514,850	0.534	0.499
lnW_H	ln wage per hour for skilled workers in i or j	507,931	2.124	1.734
lnW_M	ln wage per hour for semi-skilled workers in i or j	508,038	1.629	1.829
lnW_L	ln wage per hour for unskilled workers in i or j	508,467	1.394	1.909
lnW_H_k	ln average wage per hour for skilled workers in k	514,850	2.934	0.380
lnW_M_k	ln average wage per hour for semi-skilled workers in k	514,850	2.519	0.392
lnW_L_k	ln average wage per hour for unskilled workers in k	514,850	2.350	0.406

Note: The gross trade and value-added trade are bilateral data between country i and j. k is the third country which has indirect trade with country i or country j. We adopt the unit wage by skills to measure the labor cost of each country.

In the next section, we will estimate the baseline model and present the results with OLS and fixed effects. We also provide two alternative estimations to establish the robustness of our results: Poisson and Heckman estimation. The Poisson Pseudo-Maximum Likelihood (PPML) method reduces the Jensens inequity bias with heteroscedasticity [Silva and Tenreyro (2006)]. The Heckman selection model controls for the possible endogenous problem in the regression. We further consider the dynamic effects of human capital on value-added trade and estimate the dynamic model with system GMM as the robustness check.

3.4 Results

3.4.1 Baseline Results

The first column of Table (3.2) highlights the standard gravity model with gross trade flows for comparison. The second column shows the bilateral value-added trade flows with different types of skills in an approximate gravity model on the value-added basis. The first two columns compare the results using the ordinary least square regression (OLS). The economic masses and trade costs have the expected signs that both gross and value-added trade increase with the economic sizes, while declining with trade costs. The domestic skills have significant effects on the gross exports but have no significant impacts on value-added trade. The skills of the third countries affect the bilateral value-added flows significantly. It should be noticed that the OLS results are severely biased in the log-linearized gravity model, especially in the presence of heteroscedasticity [Silva and Tenreyro (2006)]. Hence, we control the unobserved heterogeneity by including the export-importer pair fixed effects, the time fixed effect and sectoral fixed effect in the columns (3)-(4).

After controlling for the fixed effects in columns (3) and (4), we observe a polarization effect of domestic skills on the gross bilateral trade as well as value-added trade. Increasing the unit wage of skilled and unskilled labor leads to a rising bilateral trade, while increasing semi-skilled wage reduces the bilateral trade in both gross and value-added terms. A similar effect exists in the partner country, except for the unskilled labor, which has no significant impact on both trade flows. We also study the indirect effect of human capital from the third countries on bilateral value-added trade. Contrary to the positive coefficients of skilled wage in the source and destination country, we observe a negative and significant impact of skilled labor from the third countries on the bilateral value-added trade. However, we find no significant effects of the semi-skilled and unskilled labor from the third countries on bilateral trade.

Table 3.2: Baseline Estimation

	OLS		Fixed Effect		PPML
	(1)	(2)	(3)	(4)	(5)
	lnSUMEXGR	lnSUMDVA	lnSUMEXGR	lnSUMDVA	SUMDVA
lnW_Hi	0.589***	0.186	0.665***	0.687***	0.001*
	(0.15)	(0.14)	(0.04)	(0.04)	(0.00)
lnW_Mi	-0.500**	-0.228	-0.974***	-0.948***	-0.012*
	(0.21)	(0.21)	(0.04)	(0.05)	(0.01)
lnW_Li	-0.007	-0.098	0.104***	0.085***	0.014**
	(0.12)	(0.13)	(0.03)	(0.03)	(0.01)
lnW_Hj	-0.011	-0.454***	0.202***	0.216***	0.008
	(0.17)	(0.16)	(0.03)	(0.03)	(0.01)
lnW_Mj	0.372	0.718***	-0.183***	-0.182***	-0.020*
	(0.24)	(0.23)	(0.04)	(0.04)	(0.01)
lnW_Lj	-0.187	-0.288*	-0.030	-0.030	0.008*
	(0.15)	(0.15)	(0.03)	(0.03)	(0.00)
lnW_H_ROW		7.835***		-1.213***	-0.023**
		(0.37)		(0.18)	(0.01)
lnW_M_ROW		-11.557***		-0.015	0.090***
		(0.48)		(0.29)	(0.01)
lnW_L_ROW		6.304***		0.344	-0.095***
		(0.30)		(0.29)	(0.02)
lnGOj	0.736***	0.845***	1.020***	0.995***	0.000***
	(0.02)	(0.02)	(0.01)	(0.01)	(0.00)
lnGOj	0.492***	0.562***	0.263***	0.261***	0.000
	(0.02)	(0.01)	(0.00)	(0.00)	(0.00)
contig	0.907***	0.607***	-0.408	-0.924*	2.046***
	(0.17)	(0.16)	(0.51)	(0.51)	(0.06)
comlang	-0.360	-0.020	-3.357***	-3.452***	0.737***
	(0.28)	(0.26)	(0.15)	(0.15)	(0.02)
colony	0.850***	0.699***	2.020***	2.015***	0.586***
	(0.28)	(0.25)	(0.12)	(0.12)	(0.01)
lndisij	0.700***	0.660***	4.243***	4.150***	-0.000***
	(0.20)	(0.21)	(0.17)	(0.16)	(0.00)
rta	-1.009***	-1.187***	-0.071	-0.439	0.176
	(0.08)	(0.08)	(0.33)	(0.33)	(0.11)
cons	0.016	-0.018	0.413***	0.409***	2.716***
	(0.16)	(0.15)	(0.04)	(0.04)	(0.18)
Time FE	NO	NO	YES	YES	YES
Sector FE	NO	NO	YES	YES	YES
Pair FE	NO	NO	YES	YES	YES
N	446968	446968	446968	446968	466768
adj. R2	0.324	0.392	0.679	0.676	-

Note: Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$. i is the exporting country(source). j is the importing country(destination). *ROW* are third countries through which value added is transited en route from country i to country j. FE denotes fixed effects. All the variables in PPML estimation are not logarithm.

The log-linearized gravity model may still produce misleading conclusions as a result of Jensen's inequality even after controlling for the fixed effects [14]. Another problem with the log-linearized gravity model is the treatment of zero values. Our dependent variable is the bilateral value-added trade flows, which inevitably includes a mass of zero values. The OLS estimation drops the zeros directly in the regression, which leads to the selection bias problem. Hence, we use the Poisson Pseudo-Maximum Likelihood (PPML) and estimate the gravity model in multiplicative form to solve the Jensens inequity bias with heteroscedasticity. The method is robust to different patterns of heteroscedasticity and mitigates the bias from the omitted zeros in the trade data [Silva and Tenreyro (2011)]. The PPML result is reported in column (5) [15]. As expected, we still observe the polarization effect of skills of the source country on their domestic value-added trade. However, the skilled labor in the partner country has no significant impact on value-added trade using PPML. The coefficient of semi-skilled labor in the destination country is significantly negative. The PPML method improves the estimation of the unskilled labor in the partner country with a weak but significant positive effect on bilateral value-added trade flows. Moreover, the skills of the third countries, which are indirectly linked with the respective countries through GVCs, have significantly anti-polarization impacts on the bilateral value-added trade, which is in contrast to the polarization effect of skills in the source and destination. Increasing the unit wage of skilled and unskilled workers in the exporting country improves its domestic value-added exports to its partner but increasing the unit wage of semi-skilled workers in the third countries boosts the domestic value-added exports between the exporting country and its partner. Thus it is beneficial for the exporting country to reduce the inputs of semi-skilled jobs and offshore them to the third countries, which complement the production of exporting country regarding human capital in GVCs.

From the baseline results, we observe that the bilateral value-added trade is determined by the human capital not only directly from the source and destination countries but also indirectly

[14] The Jensen's inequality implies that $E(lny) \neq lnE(y)$, which leads to biased estimation with OLS when the gravity model is estimated in the linear form with many zero values.

[15] The p-value of White test for heteroscedasticity is 0.000, indicating the importance of heteroscedasticity in the log-linearized gravity model. The null hypothesis that the model has no omitted variables is rejected with p=0.000 in the OLS estimation by the RESET test. But it further accepts the null hypothesis by p=0.7031 after using the PPML.

from the third countries in GVCs. The human capital of source and destination countries has a polarization effect on the bilateral domestic value-added trade, in which improving the unit wage of skilled and unskilled workers increases the domestic value-added content of bilateral exports. The human capital of the third countries in GVCs complements to the polarization effect of source and destination countries with an anti-polarization impact. These findings support the prediction of the model that the human capital of all countries in GVCs affect the cross-border production through the direct and indirect production linkages of GVCs.

3.4.2 Robustness Check

3.4.2.1 Heckman Two-step Selection Estimation

Following Heckman (1979) and Helpman et al. (2008), we adopt the Heckman two-step estimation as a robustness check for the OLS and PPML to deal with the possible endogenous problem. The Heckman two-step estimation has two procedures: the selection procedure regressing the export possibility with a variety of independent variables, and the outcome procedure depicting the determinants of value-added trade after controlling for the export choices. The key to Heckman estimation is to find at least one variable, affecting the export possibility but not the value-added trade. In this chapter, we use the market-entry variables as instruments[16]. The market-entry documentary process affects the countries' choice in the exporting market, and it is expected to have no significant impact on the export volume [Helpman et al. (2008)].

Table (3.3) reports the results for the Heckman two-step selection model. The significance of the Inverse Mills ratio indicates that the Heckman two-step estimation has corrected the missing zero-value problem. In the selection model, two countries with geographical contiguity, colonial relationship and regional trade agreements (RTAs) tend to have larger possibilities to export with each other. Moreover, the markets with high-efficient but low-cost export documentary

[16] We chose trade time and trade costs (excluding tariffs) associated with border compliance within the overall process of exporting a shipment of goods as instruments. The cost of documentary compliance to export (CED) and the time of documentary compliance to export (TED) come from the World Bank Doing Business Database, which provides objective measures of the business environment in 189 countries at the subnational level.

Table 3.3: The Heckman Two-step Estimates

	lnSUMEXGR		lnSUMDVA	
	(1)	(2)	(3)	(4)
	First Step	Second Step	First Step	Second Step
contig	0.571***	2.599***	0.571***	1.945***
	(0.01)	(0.55)	(0.20)	(0.54)
comlang	-0.071**	-1.889***	-0.071	-1.665***
	(0.01)	(0.21)	(0.18)	(0.20)
colony	0.341***	3.834***	0.341***	3.903***
	(0.02)	(0.22)	(0.19)	(0.21)
lndisij	0.486***	-1.321***	0.486***	-1.083***
	(0.00)	(0.40)	(0.02)	(0.40)
rta	0.837***	-0.060	0.837***	-0.041
	(0.01)	(0.08)	(0.08)	(0.03)
TED	-0.018***		-0.018***	
	(0.00)		(0.00)	
CED	0.001***		0.001***	
	(0.00)		(0.00)	
lnW_Hi		0.664***		0.687***
		(0.03)		(0.02)
lnW_Mi		-0.976***		-0.951***
		(0.04)		(0.04)
lnW_Li		0.106***		0.086***
		(0.04)		(0.02)
lnW_Hj		0.202***		0.216***
		(0.03)		(0.03)
lnW_Mj		-0.186***		-0.185***
		(0.04)		(0.04)
lnW_Lj		-0.029		-0.028
		(0.03)		(0.03)
lnW_H_ROW				-1.208***
				(0.19)
lnW_M_ROW				-0.008
				(0.27)
lnW_L_ROW				0.335
		(0.29)		(0.28)
lnGOi		1.020***		0.995***
		(0.01)		(0.01)
lnGOj		0.262***		0.261***
		(0.01)		(0.01)
cons	-2.694***	-7.056*	-2.682***	-6.133*
	(0.02)	(3.81)	(0.02)	(3.73)
Inverse Mills ratio		-2.519***		-2.400***
		(0.352)		(0.353)
Time FE	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES
Pair FE	YES	YES	YES	YES
Observations	484208	484208	484208	484208

Note: Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$. *ROW* are third countries through which value added is transited en route from country i to country j. The market-entry variables are used as exclusion variables that appear in the selection model but not in the outcome model.

procedures are more likely to export. The outcome estimation has no symmetric difference in the signs of coefficients from the estimation with fixed effects, indicating the robustness of our results. However, in the presence of heteroscedasticity, the Heckman results are different from the PPML in the significance of semi-skilled and unskilled labor of the third countries. But we still observe a similar polarization effect in the domestic and its partner country and an anti-polarization impact in the third countries of GVCs despite the insignificant coefficients.

3.4.2.2 Alternative Specification with Dynamic Model Estimation

Another concern of the baseline model is the value-added trade may have a high level of persistence, which means the current value-added trade flows depend not only on the contemporaneous variables but also on their past status. To deal with the possible persistence problem, we further incorporate the lagged dependent variables in the model and construct the dynamic panel models to improve the baseline model as follows:

$$lnv_{ijg,t} = \gamma lnv_{ijg,t-s} + \beta \mathbf{X_{gt}} + \zeta_t + \varepsilon_{ijgt} \tag{3.13}$$

where $lnv_{ijg,t-s}$ is the lagged logarithm of domestic value-added exports between country i and j in the sector g at time $t-s$. $\mathbf{X_{gt}}$ denotes the vector of control variables as shown in Table (3.1). The time dummy ζ_t is included in the regression to reduce the autocorrelation across the countries in idiosyncratic disturbances [Roodman et al. (2009)]. We estimate the dynamic specification with the difference GMM and system GMM respectively. Compared to the difference GMM, system GMM improves the estimation efficiency with weak instruments [Arellano and Bond (1988), Roodman et al. (2009)]. Both methods are estimated in two steps with the finite sample corrected standard errors [Windmeijer (2005)].

As trade flows are highly persistent, we include the five-year lagged bilateral exports in the dynamic estimation. Moreover, the human capital of the source country and destination country may be endogenous as a result of reverse causality. For example, countries with a large share of domestic value-added in exports are located in the relatively upstream position of GVCs, which tend to employ more skilled workers than downstream sectors. The possible endogenous problem would lead to biased estimation in OLS estimation. Thus, we use the 5-period lags of human capital as instruments to eliminate the simultaneous reverse causality in the dynamic model. The results are reported in Table (3.4).

Column (1) and (2) show the results of difference GMM estimation. The coefficient of skilled wage in the exporting country keeps positive but insignificant for both gross exports and the domestic value-added exports. However, the coefficients of semi-skilled and unskilled wage keep significant and robust. The human capital in the partner country still has a robust polarization impact on the bilateral value-added trade. The skilled and semi-skilled labor of the third countries keep the consistent anti-polarization effect on the bilateral value-added trade, but the coefficient of unskilled labor is not statistically significant. The AR(1) and AR(2) reports the p-value for autocorrelation in the first and second orders. All the columns reject the null hypothesis of AR (1), while accepting the null hypothesis of AR (2). The Sargan test reports the p-values of the null hypothesis that the overidentifying restrictions are valid. The first column accepts the null hypothesis at the 5% significance level but the second column accepts the null hypothesis at 1% level, indicating the possible existence of weak instruments in the difference GMM regression.

To solve the problem of weak instruments, we adopt the system GMM in column (3) and (4). We also control the time-invariant trade cost variables in the last two columns, which were omitted in the regression of difference GMM. The coefficients of system GMM are more significant than those of the difference GMM with smaller standard errors. The results pass the Sargan test at the 10% significance level, indicating overidentifying restrictions are valid. In column (4), the coefficients of skilled wage for the source and destination countries are significantly positive, and the coefficients of semi-skilled workers are significantly negative. We still observe a significantly positive impact of unskilled wage in the source country, but it is insignificant in the partner country. For the third countries in GVCs, the skilled wage still has the positive impact on the bilateral domestic value-added trade between the source and

Table 3.4: GMM Estimation of the Dynamic Model

	2-DIff GMM		2-Sys GMM	
	(1)	(2)	(3)	(4)
	lnSUMEXGR	lnSUMDVA	lnSUMEXGR	lnSUMDVA
l.lnSUMEXGR	1.189***		1.268***	
	(0.33)		(0.29)	
l.lnSUMDVA		1.125***		1.318***
		(0.31)		(0.27)
lnW_Hi	2.015	2.390	3.356***	3.635***
	(1.80)	(2.01)	(1.18)	(1.08)
lnW_Mi	-5.775*	-6.155*	-8.021***	-7.966***
	(3.17)	(3.63)	(2.14)	(2.09)
lnW_Li	3.655**	3.705**	4.354***	4.037***
	(1.49)	(1.67)	(1.27)	(1.27)
lnW_Hj	6.615***	6.884***	7.446***	8.181***
	(2.13)	(2.44)	(1.90)	(1.92)
lnW_Mj	-6.182***	-7.216**	-7.010***	-8.376***
	(2.34)	(3.20)	(2.21)	(2.54)
lnW_Lj	-1.870	-1.106	-1.898	-1.335
	(1.46)	(1.32)	(1.35)	(1.24)
lnW_H_ROW		-8.242**		-10.442***
		(3.55)		(2.04)
lnW_M_ROW		9.245***		11.273***
		(3.52)		(2.06)
lnW_L_ROW		-0.937		-0.644
		(0.69)		(0.65)
lnGOi	0.192	0.199*	0.263***	0.288***
	(0.12)	(0.10)	(0.10)	(0.08)
lnGOj	1.123***	1.023***	1.106***	1.039***
	(0.16)	(0.17)	(0.16)	(0.17)
cons	-12.376***	-9.452***	-13.437***	-10.487***
	(2.10)	(1.70)	(1.69)	(1.44)
Lags	6	5	6	5
controls	No	No	Yes	Yes
AR(1)	[0.000]	[0.000]	[0.000]	[0.000]
AR(2)	[0.188]	[0.185]	[0.294]	[0.427]
Sargan Test	[0.055]	[0.045]	[0.148]	[0.142]
N	186970	233985	186970	233985

Note: Standard errors in parentheses. P-value in the square brackets. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$. i is the exporting country(source). j is the importing country(destination). *ROW* are third countries through which value added is transited en route from country i to country j. All the models include the time dummies and are estimated with the two-step GMM with at least 5-year lags. The human capital of the source and destination country is endogenous. The control variables include the time-invariant variables such as distance, continuity, common language, and colony. The minimum lag that used as instruments in the GMM estimation is 5 and we only report the first lag of dependent variable due to page limit. The AR(1) and AR(2) report the p-value for the first and second autocorrelation tests. The Sargan test presents the p-values for the null hypothesis that the over-identifying restrictions are valid.

destination country. Also, increasing the semi-skilled unit wage of third countries still improves the bilateral domestic value-added trade. However, we find no significant impact of the unskilled labor in third countries. The system GMM results keep robust to the baseline regression, even after controlling for the dynamic effects and endogeneity.

3.5 Conclusion

One of the essential driving forces of international fragmentation is the difference in human capital costs across countries. In this chapter, the global input-output structure was incorporated in the standard gravity model to explore the role of different skills in determining bilateral value-added trade. The study emphasizes the indirect production linkages with the third countries, through which the domestic value-added is transited en route from the source to the destination in GVCs. The indirect impacts of human capital from the third countries were highlighted on the bilateral domestic value-added trade flows between the source and destination country. The results propose a new mechanism that the bilateral value-added trade depends not only on the human capital of the source and destination but also on the human capital of the third countries in GVCs.

This chapter found a polarizing effect of the skilled, semi-skilled, and unskilled unit wage of the source and destination countries on their bilateral domestic value-added trade. It suggests the source country and its trading partner should increase the unit wage of the skilled and unskilled labor while declining the wage of semi-skilled labor to improve their domestic value-added contents in exports. Moreover, the opposite impact of the human capital from the third countries was observed, which has vertical production linkages with the source and destination country in GVCs. It suggests that improving the unit wage of semi-skilled workers in the third countries leads to higher domestic value-added trade between the source and destination country but increasing the rewards of skilled and unskilled workers in the third countries reduces the bilateral domestic value-added exports. Our findings highlight the indirect effect of human capital from the third countries on the international fragmentation and value-added trade, which was rarely studied in previous research.

These results have important policy implications. On the one hand, despite the importance of domestic human capital, our results show that a large part of domestic value-added trade growth ascribes to the human capital of third countries in GVCs, which is essential to understand the complementary of countries in terms of human capital across borders. Countries are likely to benefit more from integration in the GVCs by only specializing in specific production stages where the intensively-used skills are available at competitive domestic prices while offshoring the other stages to the third countries. In this chapter, we show that OECD countries would have higher domestic value-added trade by relocating their semi-skilled intensive tasks (routine tasks) overseas while keeping the skilled- (cognitive tasks) and unskilled- intensive (physical tasks) domestically. The semi-skilled workers in the third countries undertake the offshored tasks and add value to the value-added trade between OECD countries. In this sense, greater efforts are required to strengthen cross-border production collaboration. Countries should participate more in the GVCs with more open markets and deeper integration. Meanwhile, protectionism aimed to save local jobs harms domestic value-added exports and should be forbidden. It is more beneficial to keep their competitive skills at home while offshoring the others overseas.

On the other hand, not every type of human capital will benefit from GVCs within countries. The human capital development policies should be tailored according to the countries' vertical specialization requirements in GVCs. For the skills that are intensively used in the vertical specialization, more investment should be secured to develop the skills and move into higher value-added production. For those "uncompetitive" skills which are exposed to the risk of offshoring, strengthening training would facilitate their re-employment. Similarly, training is also crucial for the countries undertaking offshored jobs to align the competitiveness of their skills with the international standard in GVCs.

Chapter 4

Global Value Chains, Firms, and Wage Inequality: Evidence from China

Abstract

How does participating or upgrading in the global value chains (GVCs) affect firms wage inequality between skilled and unskilled labor? In this chapter, we develop a model of heterogeneous firms with intermediate trade and various skill inputs, which applies the fair wage hypothesis to predict the wage premium changes according to firms GVCs activities. The model predicts that increasing participation in GVCs, as measured by the share of foreign value-added content in exports (FVAR), improves a firms profits and enlarges the wage inequality between skilled and unskilled workers. Moreover, moving to upstream sectors in GVCs, as measured by the exporting varieties' upstreamness (or average distance from final use), raises a firms wage premium by increasing the productivity of skilled workers. Using detail Chinese firm-level data from 2000 to 2006, a Mincer-type empirical model is developed to study the wage premium changes associated with FVAR and upstreamness. We find robust empirical evidence that China's FVAR is positively associated with the wage inequality of skills within firms. We also observe that Chinese firms with higher upstreamness in GVCs tend to pay higher wage premiums and employ more skilled workers.

JEL code: F12; F16; F66

Key Words: Firm Heterogeneity; GVC Participation; Upstreamness; Wage Inequality

4.1 Introduction

The impacts of globalization on employment and wage inequality between skills have been extensively studied [Goldberg and Pavcnik (2007), Helpman et al. (2010), Helpman (2016)], but few studies are focused on the impacts of GVC activities[1] on the wage premium, especially at the firm level. Recent years have seen a dramatic rise in the global value chains (GVCs), in which each country specializes in specific stages of production and cooperates to produce the final goods[OECD-WTO (2012)]. The international fragmentation in GVCs is also known as the second "unbundling" of production[Baldwin (2011)], which allow firms to use more imported intermediates for production. In this chapter, we quantify the participation and position of firms in GVCs and explore how participating and upgrading in GVCs affect the wage premium within Chinese manufacturing firms.

The extent of firms' vertical specialization in GVCs is measured by the ratio of foreign value-added content in exports relative to total exports ($FVAR$)[2]. As suggested by the recent literature, most countries have a rising level FVAR as deepening their participation in GVCs [Vries et al. (2014), Koopman et al. (2014), Johnson and Noguera (2012a), Los et al. (2015)]. However, as one of the largest export markets with abundant labor resources, China plays an essential role in global production. Despite its deep engagement in GVCs, however, a trend of rising levels of FVAR is not observed in China. In fact, recent evidence suggests that the average FVAR of Chinese firms has declined from 35% in 2000 to 30% in 2007 [3] [Kee and Tang (2016)]. The decline of FVAR in China is partly due to the substitution of domestic

[1]Recent evidence indicated that international production fragmentation is undertaken across borders where skills and other inputs are available at competitive price[Globerman (2011)]. The process of international fragmentation is characterized by the prominent role of intermediate trade across borders, in which GVC firms tend to use more imported intermediate inputs for production through gross trade and offshoring. Firms in different countries specialize in different stages of production and tend to move to higher value-added sectors by upgrading in the GVCs. In this chapter, the GVC activities of firms refer to their participation and upgrading their position in GVCs.

[2]The recent availability of international input and output tables enables us to decompose gross trade into multiple value-added terms by origins and destinations. The share of domestic value-added in exports is defined as $DVAR$, measuring the domestic contribution to the exports. The share of foreign value-added in exports is defined as FVAR, measuring the extent of international fragmentation across borders. $DVAR + FVAR = 1$ at the aggregated level.

[3]Koopman et al. (2014) found the trend of declining FVAR in China using the international input and output tables. Upward et al. (2013) confirmed the trend using the Chinese firm-level data.

materials for imported intermediates by Chinese processing firms [Kee and Tang (2016)]. The substitution of domestic materials has changed the demands for domestic skills, which has important implications for the wage premiums [Vries et al. (2014)].

To capture these changes and identify their effects on the wage premium at the firm level, we build a model of heterogeneous firms in which we include both skilled and unskilled workers as inputs. We then seek to explain variations in firms' wage premiums in terms of changes in their GVC activities. These include, in particular, include using imported intermediates for the production of exports (measured by the share of foreign value-added in exports, FVAR), and moving up to upstream sectors (measured by the upstreamness of firms in GVCs). In the model, we follow the setup of Melitz (2003) and Amiti and Davis (2011). We also apply the fair wage hypothesis in order to link the wage premium to firms' performance [Chen et al. (2017)]. The fair wage hypothesis assumes that workers determine their efforts by the difference between the real wage and the wage they perceive to be fair for their role [Egger and Kreickemeier (2009)]. Workers in more profitable firms expect a higher fair wage [Egger et al. (2013)]. Thus, in equilibrium, profitable firms tend to pay high wages to workers to elicit their efforts [Egger and Kreickemeier (2009),Egger et al. (2013),Amiti and Davis (2011)]. However, these studies assume there is only one type of labor in the firm. We introduce both skilled and unskilled labor in this paper. Following Chen et al. (2017), we further assume the only skilled workers have bargaining power in their wages according to firms' performance while unskilled workers accept the minimum wage of the relevant industries and provinces[4]. Thus, more profitable firms tend to pay higher wage premiums [Chen et al. (2017)].

[4]The assumption is to simplify the model. This assumption is consistent with the fact that unskilled workers are extremely abundant in China and barely have bargaining power in their wages. The results will be the same if we assume that skilled labor has larger bargaining power on wages than unskilled workers, which has been testified by Chen et al. (2017). The intuition is that more profitable firms have a larger value-added surplus to share among specific skill groups. If the skilled labor has larger bargaining power as noted, they will be paid higher wages than unskilled workers. Helpman et al. (2010) also discussed the case in which different skills have the same bargaining power in their wages. However, as skilled workers can generate more value-added surplus than unskilled workers, they still receive higher fair wage than unskilled workers. In all cases, profitable firms tend to pay higher wages to skilled workers than unskilled workers.

In our model, firms make decisions on participating in GVCs by importing intermediates for the production of exports. Only firms with higher productivity or larger scale can participate in GVCs in the existence of sunk costs of entering foreign markets. Similar to Amiti and Davis (2011), GVC firms tend to be more profitable and pay higher wages to skilled workers than non-GVC firms. Moreover, firms with a larger share of foreign value-added in exports (FVAR) tend to have higher profits and pay a higher wage premium. Moving to upstream sectors in GVCs depends on the higher productivity of skilled workers, which not only improves firms' profits but also increases the wage premium.

We examine the predictions of the model using the Chinese enterprise survey data combined with transactional-level customs data from 2000 to 2006. This dataset enables us to trace value-added trade on the firm level. Most recent literature used the international input-output tables (IIOTs) to decompose gross exports to trace value-added trade [Koopman et al. (2012),Koopman et al. (2014), Johnson and Noguera (2012b)]. Despite the advantage of capturing global input-output structure across borders and sectors, the input-output approach using IIOTs assumes that all firms within a sector use the same ratio of imported intermediates for production [INOMATA (2017)]. However, firms are heterogeneous in value-added trade. For example, processing exporters tend to use a higher proportion of imported intermediates than ordinary exporters. Thus, in some developing countries with prominent processing trade (e.g., China, Vietnam, Philippines, etc.), the oversampling of processing firms in the construction of IIOTs leads to aggregation biases in the estimation of DVAR [Koopman et al. (2012), Kee and Tang (2016)]

This chapter embraces firm heterogeneity in the estimation of GVC indicators. The firm-level GVC participation index is measured by the share of foreign value-added content in exports (FVAR), which captures firms' participation in GVCs through backward production linkages. We measure firms' positions in GVCs by the upstreamness index[5], which represents the "distances" of firms' outputs to the final demands in the international input-output tables

[5]We follow Antràs et al. (2012)'s approach to identify the sectoral upstreamness of exporting varieties and then calculate the firm-level upstreamness using the share of exporting varieties in total exports as weights.

(IIOTs). The more stages the output takes to reach the final use, the more upstream it is located in the GVCs. As noted, we find that firms in China show a declining trend in FVAR between 2000 and 2006, which is consistent both with the firm-level analysis of Kee and Tang (2016) and Upward et al. (2013) and input-output studies of Koopman et al. (2014) and Johnson and Noguera (2012b). We also observe a rising trend of upstreamness, indicating that Chinese manufacturing firms are moving from downstream sectors to more upstream sectors in GVCs.

This chapter examines the impacts of GVC activities on wage inequality at the firm level. Many studies investigated globalization and wage inequality among skills at the country-level, within sectors, and across firms. However, there are few studies on the wage inequality within firms, especially for China [6]. One major obstacle in investigating wage inequality within Chinese firms is the lack of data of skilled wage and unskilled wage. Only data of average wage is available at the firm level. In this chapter, we develop a Mincer-type econometric framework to construct the firm-level wage premium from the average wage and the share of skilled labor[7]. We introduce measures of both firm-level GVC participation and GVC position into the empirical specification as predictors of wage inequality. We find two key results. First, we find firms' FVAR is positively associated with their wage premium, indicating firms with higher backward participation in the GVCs tend to have larger wage inequality between skilled and unskilled workers[8]. Second, upgrading from downstream to more upstream sectors in the GVCs enlarges the wage inequality between the skilled labor and unskilled labor within firms. These findings are consistent with the idea that firms share the additional surplus generated from GVC participation and GVC upgrading mostly with skilled workers rather than unskilled

[6] Verhoogen (2008) and Galiani and Sanguinetti (2003) found trade liberalization increased skill wage premium in Mexican and Argentinean firms, but limited studies explored the firm-level wage inequality of China due to data limitation. Li and Xu (2008) observed an increasing trend of wage inequality of skills within firms using a small survey sample. Chen et al. (2017) studied the firm-level wage inequality changes in response to input trade liberalization and found a rising skill wage inequality within Chinese manufacturing firms.

[7] In the Mincer-type wage equation, the average wage of a firm is the average wage of skilled labor and unskilled labor in this firm weighted by the skill share of labor. Following Chen et al. (2017), after a logarithmic transformation, the average wage is determined by the firms wage premium, their skill share and the wage of unskilled labor. Average firm-level wage is available in the Chinese Manufacturing Survey data during the sample period. However, the employment share of skills at the firm level is only available for 2004. We provide more details on how to construct the measured employment share of skills at the firm level in the following sections.

[8] The average declining FVAR in China narrowed the wage inequality between skilled and unskilled workers and led to a lower share of skilled workers in the total employment

workers.

One challenge in this paper is the possible endogenous nexus between GVC participation and firms' wage premiums. As we know, not every firm participates in GVCs. Recent studies found that the GVC firms are more productive, larger in scales and higher in profits than non-GVC firms [Baldwin et al. (2014)] [9]. Similar to exports, firms with better performance are more likely to overcome the sunk costs and enter the GVCs. The self-selection effect of firms in participating GVCs may lead to biased estimation [Antras and Helpman (2004)]. To address the challenge, we use the correlated random coefficient model to allow for heterogeneous effects of GVC activities combined with the self-selection effect of GVCs. We predict the fitted value of FVAR after controlling for the self-selection effect and use one-lag of fitted FVAR as the proxy for GVC participation. Moreover, we adopt a one-year lagged upstreamness measure as the instrument for GVC position to eliminate the reverse causality between upstreamness and wage premium. The empirical results remained robust after controlling for endogeneity.

This chapter is closely related to studies on vertical specialization and value-added trade. Some studies decomposed the international input-output tables to measure the extent of vertical specialization on the aggregated country level[10]. To address firm heterogeneity in GVCs, recent studies merged enterprise survey data with customs data to estimate firms' value-added content embodied in trade, which provided firm-level measurement of DVAR and FVAR [Dean et al. (2011), Upward et al. (2013), Ahmad et al. (2013), Kee and Tang (2016)]. This chapter combines the procedures of Kee and Tang (2016) and Upward et al. (2013) to estimate the share of foreign value-added content in exports (FVAR). In addition, this paper also relates to the literature on GVC length and organization [Fally (2012), Antràs et al. (2012), Wang et al. (2017), Miller and Temurshoev (2017), Johnson (2017), Antras and Chor (2018)]. Following Antràs et al. (2012)

[9] Similar evidence can also be found in studies about offshoring firms and non-offshoring firms [Antras and Helpman (2004), Geishecker and Görg (2008), Wagner (2011)].

[10] Hummels et al. (2001) traced the use of imported inputs in producing goods that are exported using the multi-national input-output tables to measure the extent of vertical specialization. Several studies developed Hummels et al. (2001)s approach to construct the international input-output tables (IIOTs), which revealed the global input-output structure of production across borders and sectors [Johnson and Noguera (2012b), Koopman et al. (2014), Timmer et al. (2015)]

and Ju and Yu (2015), we calculate the average upstreamness of export varieties at the firm level using export share as weights.

This chapter is related but relatively independent of the previous research of globalization and wage inequality[11]. Some recent studies addressed the prominent role of intermediate trade in GVCs and studied their impacts on labor market. For example, Mion and Zhu (2013) concluded that offshoring to China in both intermediates and final goods increased the share of skilled workers in Belgian manufacturing firms. Kasahara et al. (2016) suggested that importing intermediates increased the demand for educated workers at the plant level. Some studies focused on offshoring in GVCs and concluded that offshoring hurts labor performing routine tasks while benefiting to the workers performing tasks which are complementary to offshored jobs [Feenstra and Hanson (1996), Criscuolo and Garicano (2010), Goos et al. (2009)]. Nevertheless, these studies only focused on specific aspects of GVCs (intermediate trade, offshoring, etc.), and none of them gives the full picture of firms' GVC activities and their linkages with the wage premium. To the best of our knowledge, this chapter is the first one that provides both theoretical and empirical framework on how participating and up-grading in GVCs affects the wage inequality of skills within firms.

The rest of the chapter proceeds as follows. In section 2, we develop the model of heterogeneous firms to link skill wage premium changes with firms GVC participation and position. In section 3, we describe the dataset and provide the firm-level measurement of GVC indicators. We also derive the empirical model from theoretical specifications. In section 4, we show the empirical results with a robustness check. In section 5, we conclude and provide some policy implications.

[11] Goldberg and Pavcnik (2007) provided a detailed summary of the relevant literature on globalization and wage inequality, concluding trade liberalization increases skill wage premium at the country-level, within sectors, and within firms. But most of the studies use the gross trade data to estimate the labor market outcomes, which may overestimate the employment effect of trade[Jiang (2015)]. It is the domestic value-added trade that represents the real demands for domestic labor [Timmer et al. (2014)]. The discrepancy between domestic value-added trade and gross trade is enlarging with the rise of GVCs [Johnson and Noguera (2012b)].

4.2 Theoretical Framework

In the section, we develop a theoretical trade model of heterogeneous firms, in which firm wage premium depends on its decision and extent of participating in GVCs. This model defines GVC firms as those importing intermediate inputs for the production of exports and investigates how firms participate in GVCs. The model incorporates firms upstreamness in GVCs to illustrate the relationship between upstreamness, profits, and wage inequality.

In this model, there are n countries with identical factor endowments. Each country has M firms, which are ex-ante homogeneous but face two uncertainties in their production. One is their production cost determined by their productivity and labor costs. Another is their trade pattern. Firms have to overcome sunk costs to enter the domestic and international markets. Each firm produces one variety, which is ex-ante given and unaffected by firms' productivity and trade pattern. The setup of the model is as follows:

4.2.1 Demand

A representative consumer consumes a continuum variety of final goods ω with the CES preference to minimize total expenditure E. The demand arises from the following expenditure function:

$$MinE = \int p(\omega)x(\omega)d\omega \qquad s.t.[\int x(\omega)^{\frac{\sigma-1}{\sigma}}d\omega]^{\frac{\sigma}{\sigma-1}} = U \tag{4.1}$$

where $p(\omega)$ is the price of the variety ω. $x(\omega)$ is the demand for variety ω. σ is the elasticity of substitution between final goods with $\sigma > 1$. The consumer has a CES preference over the continuum varieties, thus the demand for the variety ω equals to $x(\omega) = [\frac{p(\omega)}{P}]^{-\sigma}Q$ $(Q \equiv U)$. Similarly, the revenue from selling final product ω is $r(\omega) = p(\omega)x(\omega) = [\frac{p(\omega)}{P}]^{1-\sigma}R$, where R is the total revenue of the country satisfying $PQ = R$ and P is the aggregate price index in the form of $P = [\int p(\omega)^{1-\sigma}d\omega]^{\frac{1}{1-\sigma}}$.

4.2.2 Production

We assume that each firm produces one variety of final goods ω. The value of variety ω origins from two sources: the domestic value-added content ($D(\omega)$) and the foreign value-added content ($F(\omega)$). The domestic value-added content ($D(\omega)$) is produced by the domestic inputs, while the foreign value-added content ($F(\omega)$) is embodied in the imported intermediates. The production of final goods ω follows a Cobb-Douglas function as follows:

$$x(\omega) = \varphi D(\omega)^{\alpha} F(\omega)^{1-\alpha} \tag{4.2}$$

where φ is the firm-specific productivity following the distribution of a probability density function as $g(\varphi)$. α is the share of domestic value-added content in output with $\alpha \in (0,1)$. The domestic value added $D(\omega)$ is further assumed to be produced with domestic skills following the CES production function as indicated below:

$$D_{\omega}(S,U) = [\Phi_u^{\frac{1}{\rho}} U(\omega)^{\frac{\rho-1}{\rho}} + \Phi_s(z)^{\frac{1}{\rho}} S(\omega)^{\frac{\rho-1}{\rho}}]^{\frac{\rho}{\rho-1}} \tag{4.3}$$

where $S(\omega)$ and $U(\omega)$ are the skilled and unskilled labor inputs in producing the domestic value-added content D_{ω}. ρ is the elasticity of substitution between skilled and unskilled labor ($\rho > 1$). Φ_u and Φ_s are productivity parameters of unskilled labor and skilled labor respectively, which are affected by variety ω's upstreamness in GVCs. We assume there is a larger productivity difference between skilled and unskilled labor in the upstream sectors of GVCs than that in the downstream industries. If we denote the sector-level upstreamness as z, $\frac{\Phi_s}{\Phi_u}$ is an increasing function of the firm's upstreamness z. Increasing z motivates firms to improve the productivity of skilled workers relative to unskilled labor. For simplicity, we assume the exporting variety is ex-ante given; thus, the sector-level upstreamness is exogenous and barely affected by firms' performance and wage premium.

ω_s and ω_u are denoted as the unit wage of skilled and unskilled labor. Under the constraint of cost minimization, the wage premium of skilled and unskilled workers in this firm is written as follows:

$$W_\omega = \frac{w_s}{w_u} = [\frac{\Phi_s}{\Phi_u}(z)]^{\frac{1}{\rho}}[\frac{S}{U}]^{-\frac{1}{\rho}} \tag{4.4}$$

Equation (4.4) suggests that the wage premium of skilled and unskilled labor is determined by the input ratio of skilled and unskilled workers and firms' upstreamness. Increasing the inputs of specific skill would reduce the relative wage of this skill over the other. Moving to upstream sectors improve firms' productivity of skilled labor, which further enlarges the wage inequality between skilled and unskilled workers.

The marginal cost of domestic value-added content is thus written as follows:

$$c_d^\omega(z, W_\omega) = [\Phi_u \omega_u^{1-\rho} + \Phi_s \omega_s^{1-\rho}]^{\frac{1}{1-\rho}} = \Phi_u^{\frac{1}{1-\rho}} \omega_u [1 + \frac{\Phi_s}{\Phi_u}(z)(\frac{\omega_s}{\omega_u})^{1-\rho}]^{\frac{1}{1-\rho}} \tag{4.5}$$

Equation (4.5) describes the determinants of domestic value-added content. For simplicity, we assume productivity parameter of unskilled labor is fixed. The marginal cost of domestic value added is determined by the skill wage premium (W_ω), the upstreamness of the firm (z), and the unskilled wage (ω_u). Improving the wage premium of skills increases the marginal cost of producing domestic value-added content. Upstream firms have a smaller marginal cost of domestic value-added content than the downstream firms. The marginal cost of domestic value added c_d^ω is an increasing function of wage inequality whereas a decreasing function of upstreamness.

Firms also use the imported intermediates for production. Let i represents the domestic market, firms import intermediates from the other $n-1$ countries. The foreign value-added content of ω is written as a CES function of imported intermediates as follows:

$$F(\omega) = [\sum_j \beta_j^{\frac{1-\gamma}{\gamma}} f_{ij}^{\omega\,\frac{\gamma-1}{\gamma}}]^{\frac{\gamma}{\gamma-1}} \tag{4.6}$$

where β_j measures the preference of consumers for intermediates from country j. γ is the elasticity of substitution among intermediates from all the countries ($\gamma > 1$). f_{ij}^ω is the value of intermediates imported from country j. Country i has to bear the iceberg cost of importing intermediates from country j as $\tau_{ij}^{m} > 1$. Let $p_{ij}^{\omega} = p_j * \tau_{ij}^{m}$ equal to the importing price of firm ω from country j. We assume that the price of domestic intermediates equals to 1 for simplicity, and the import price satisfies $p_j\tau_{ij}^{m} \leq 1$ [12]. The price of foreign intermediate composite equals to $P^f = [\sum_j(\beta_j p_j \tau_{ij}^{m})^{1-\gamma}]^{\frac{1}{1-\gamma}}$ satisfying $P^f \leq 1$ under the constraint of $\gamma > 1$ and $p_j\tau_{ij}^{m} \leq 1$.

As a result, the marginal cost of producing the variety ω becomes:

$$c_\omega(\varphi, W_\omega, z, \tau) = \frac{\kappa c_d^{\alpha} P_f^{1-\alpha}}{\varphi} \tag{4.7}$$

where $\kappa = \alpha^{-\alpha}(1-\alpha)^{\alpha-1}$. As the price of variety ω equals to $p_\omega = \frac{c_\omega}{\mu}$ with $\mu = 1 - \frac{1}{\sigma}$, the revenue of producing variety ω could be written as:

$$r(\omega) = p_\omega x(\omega) = [\frac{\kappa c_d^{\alpha} P_f^{1-\alpha}}{\mu\varphi}]^{1-\sigma} R P^{\sigma-1} \tag{4.8}$$

Following Amiti and Davis (2011), we define $\Gamma_{m\omega} = [P_f^{1-\alpha}]^{1-\sigma} = [\sum_j(\beta_j p_j \tau_{ij}^{m})^{1-\gamma}]^{\frac{(1-\alpha)(1-\sigma)}{1-\gamma}}$ as the "import globalization" factor, which contains the factors affecting import price. As $\gamma > 1$,$\sigma > 1$ and $\beta_j p_j \tau_{ij}^{m} < 1$, we have $\Gamma_{m\omega} > 1$. Using imported intermediates improves firms' revenue. Similar to import, we assume that firms need to pay sunk cost f_x and the iceberg cost $\tau_{x\omega}$ for exports. The revenue of firms that export to n identical countries could be written as $(1 + n\tau_{x\omega}^{1-\sigma})r(\omega)$, where $n\tau_{x\omega}^{1-\sigma}$ represents the aggregated iceberg costs of exporting to n foreign markets . We denote $\Gamma_{x\omega} = (1 + n\tau_{x\omega}^{1-\delta})$ as the "export globalization factor" with $\Gamma_{x\omega} > 1$, indicating exporters tend to have higher revenues than domestic firms. We further define GVC firms as exporters which use the imported intermediates for the production of exports, while defining the other firms as non-GVC firms. The profits of firms depend not only on their marginal costs but also on their globalization modes, which could be written as follows:

[12] Only when the imported intermediates have lower costs than domestic inputs, the firm chooses to import intermediates.

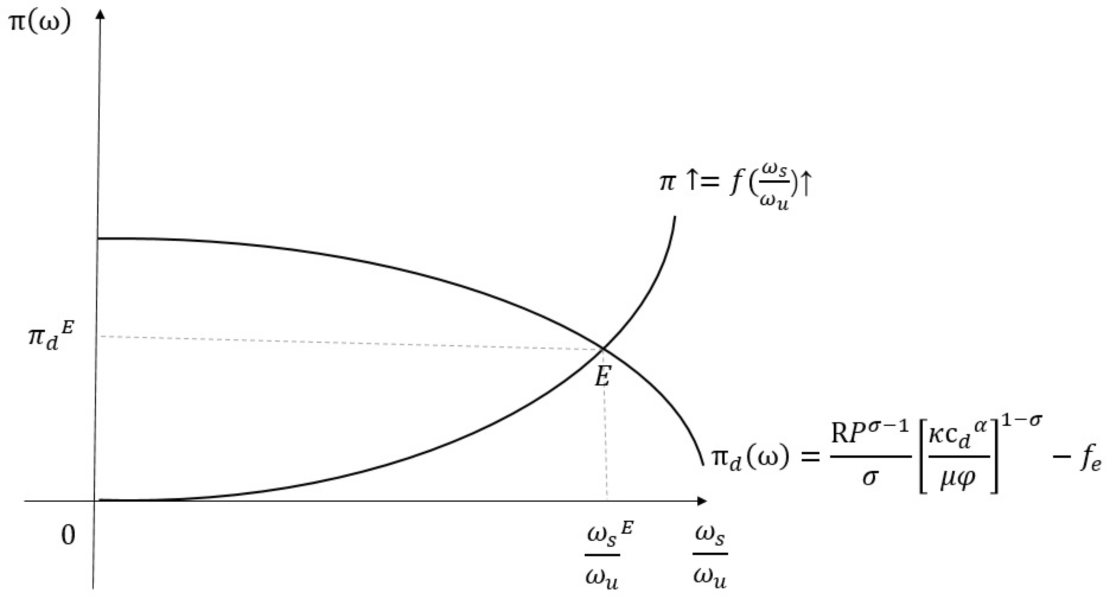
$$
\pi(\omega) = \begin{cases}
0 & \text{exited firms} \quad (4.9) \\
\frac{RP^{\sigma-1}}{\sigma}[\frac{\kappa c_d^{\alpha}}{\mu\varphi}]^{1-\sigma} - f_e & \text{domestic firms only} \quad (4.10) \\
\Gamma_{m\omega}\frac{RP^{\sigma-1}}{\sigma}[\frac{\kappa c_d^{\alpha}}{\mu\varphi}]^{1-\sigma} - f_e - nf_m & \text{domestic firms with imported intermediates} \quad (4.11) \\
\Gamma_{x\omega}\frac{RP^{\sigma-1}}{\sigma}[\frac{\kappa c_d^{\alpha}}{\mu\varphi}]^{1-\sigma} - f_e - nf_x & \text{exporters using domestic inputs only} \quad (4.12) \\
\Gamma_{m\omega}\Gamma_{x\omega}\frac{RP^{\sigma-1}}{\sigma}[\frac{\kappa c_d^{\alpha}}{\mu\varphi}]^{1-\sigma} - f_e - n(f_m + f_x) & \text{exporters using imported intermediates} \quad (4.13)
\end{cases}
$$

where f_e is the fixed cost of entering domestic markets while f_m and f_x are the sunk costs of importing and exporting respectively. As shown in Equation (4.13), despite the extra fixed costs of importing or exporting, the GVC firms could gain extra revenue either by importing intermediates with low costs ($\Gamma_{m\omega} > 1$) or by exporting to multiple foreign markets ($\Gamma_{x\omega} > 1$) [13]. Moreover, given the variety's upstreamness in GVCs, firms' profits increase with the growth of productivity while lessening with the wage premium. Ceteris Paribus, in autarky economy, the negative relationship between wage premium and the firm's profit is depicted by the declining curve in Figure (4.1).

4.2.3 Fair Wage Hypothesis and Skill Wage Inequality

To tie the firm's wage premium with the firm's performance, we follow Amiti and Davis (2011) to introduce the fair wage constraint into the model. The fair-wage constraint is based on the premise that workers have the motivation to adjust their efforts according to the difference between the real wage that they receive and the reference wage that they expect to get which is fair for their efforts[Akerlof (1982), Egger et al. (2013)]. Workers who fail to get the reference wage tend to reduce their efforts to ensure fairness. For firms with better economic performance, workers have higher reference wages [Akerlof and Yellen (1990)]. As a result, profitable firms tend to give higher fair wages to elicit labor efforts [Danthine and Kurmann (2004)]. Following Amiti and Davis (2011), we assume that there is no cost to employ workers and the fair wage

[13] Following Amiti and Davis (2011), we assume $f_x > \frac{f_e}{n}\Gamma_{x\omega}$ and $f_m > (\frac{f_e}{n}\Gamma_{m\omega})$.The first condition ensures the zero-profit firms would not export. The second condition makes sure that zero-profit firms would not import intermediates.



Note: Without loss of generality, the macro variables (i.e., R and P) are assumed to be exogenous. The sector-level upstreamness z is en-ante given. Firms' productivity follow a given distribution with intensity $g(\varphi)$. All else given, we get a unique equilibrium between the firm's profit and its wage premium.

Figure 4.1: Firms' Wage Inequality and Profits Determination in the Autarky Economy

of zero-profit firms is the numeraire. We further assume that different skills have different bargaining power in their fair wage [14]. Following Chen et al. (2017), we suppose the skilled workers would adjust their efforts according to their firms' performance. Thus, the skilled wage is an increasing function of firms' profits. However, the unskilled workers barely have bargaining power in their wages[15], and thus unskilled wage is unrelated to firms' performance. As a result, the firm-level wage premium of skills is positively correlated with firms' profits, as shown by the rising curve in Figure (4.1).

[14]We assume that skilled labor has a larger bargaining power on wages than unskilled workers following Chen et al. (2017). Chen et al. (2017) also discussed the possibility that the skilled and unskilled labor have the same bargaining power in wages but the results are unchanged because skilled workers tend to gain more additional surplus with higher productivity. As a result, we follow Chen et al. (2017)'s assumption and assume that only skilled workers have the bargaining power in wages to simplify the model. It should be noticed that the predictions with the equal bargaining power of both skills should keep robust.

[15]As China was abundant in unskilled workers in the sample period, the unskilled workers have little bargaining power in their wages as a result of supply surplus. Moreover, the labor union in China tend to be systemic, which also have no power in negotiating unskilled wages. Thus most of unskilled workers accepted the sectoral minimum wage.

Figure (4.1) depicts the determination of firms' wage inequality and their profits in autarky. As shown in Equation (4.10), the profits of firms decrease with the marginal cost of domestic value-added content, which further positively correlates to wage premium. Thus increasing skill wage premium would reduce domestic profits of firms. According to the fair wage hypothesis, profitable firms tend to commit higher fair wage to skilled workers to elicit their efforts, which enlarges the wage inequality between skilled and unskilled workers. All else equal, there would be a unique equilibrium between firms' profits and the wage premium of skills[Amiti and Davis (2011)].

We further follow the procedures of Melitz (2003) to analyse the wage premium changes in the open economy. As shown in equation (4.11)-(4.13), after opening up to trade, firms choose their globalization modes by which the GVC firms tend to have higher profits than non-GVC firms. In the following section, we analyze firms' decision in participating GVCs and its impacts on the wage inequality of skills.

4.2.4 Firms' Decisions to Participate in GVCs

For potential market entrants, their expected profit from the market is written as $V(c_\omega) = max\{0, \sum_0^\infty (1-\delta)^t \pi(c_\omega)\} = max\{0, \frac{1}{\delta}\pi(c_\omega)\}$ where δ is the exogenous probability of firms' exit [Melitz (2003)]. Only firms with positive expected profits ($V(c_\omega) \geq 0$) choose to enter the market. The profit of the marginal firm ω^* satisfies $\pi(c^*_\omega) = 0$ with cut-off productivity φ^*. Inspired by Amiti and Davis (2011), we assume that each firm has to pay the fixed cost f_e to produce the final product ω. The production follows a random draw of $\lambda_\omega = (\varphi, z_\omega, \tau)$ which depends on productivity, the upstreamness of the variety, and the marginal trade cost of imported intermediates. The joint probability density function of λ_ω is $g(\lambda_\omega)$, and its marginal probability density function could be written as $g_\Phi(\varphi) = \int_z \int_\tau g(\lambda) d\tau dz$. The probability of firms entering the market successfully becomes:

$$v(\varphi) = \begin{cases} \dfrac{g_\Phi(\varphi)}{1 - G_\Phi(\varphi^*)} & \text{if } \varphi > \varphi^* \quad (4.14) \\ 0 & \text{otherwise} \quad (4.15) \end{cases}$$

where $G(\varphi)$ is the cumulative distribution function of $g_\Phi(\varphi)$ and φ^* is the cut-off productivity of the marginal firm that enters the domestic market successfully. For successful entrants of domestic market, their average costs are $\tilde{c_\omega}(\varphi, W_\omega) = [\int_{\varphi^*}^{\infty} c_\omega(\varphi, W_\omega)^{\sigma-1} v(\varphi) d\varphi]^{\frac{1}{\sigma-1}}$ where W_ω denotes the wage premium within firms. And the average profit of the domestic market would be $\bar{\pi}(c_\omega) = \frac{1}{\delta} r(\tilde{c_\omega}) - f_e = \frac{1}{\delta}\int_{\varphi^*}^{\infty} r(c_\omega)^{\sigma-1} v(\varphi) d\varphi - f_e$. The free entry condition (FE) ensures the expected value of firms equals to zero where the expected revenue equals to the sunk cost f_e with $\int V(c_\omega)^{\sigma-1} g(\varphi) d\varphi = f_e$. The free-entry condition (FE) satisfies:

$$\bar{\pi}(c_\omega) = \frac{\delta f_e}{1 - G_\Phi(\varphi^*)} \tag{4.16}$$

Equation (4.16) reveals the relationship between the average market profit and the cut-off productivity. Higher cut-off productivity indicates a lower cut-off marginal cost c_ω^* with the smaller possibility for firms to enter the market. In this case, firms would expect to get higher profits to overcome the fixed costs. As a result, the average market profit decreases with the cut-off marginal cost c_ω^*.

The marginal firms get zero profits (ZCP) in equilibrium [Melitz (2003)], which is written as $\pi(c_\omega^*) = \frac{1}{\delta} r(c_\omega^*) - f_e = 0$. c_ω^* represents the cut-off marginal cost. The average market profit conditional on c_ω^* would be:

$$\bar{\pi}(c_\omega) = \{[\frac{\tilde{c_\omega}}{c_\omega^*}]^{1-\sigma} - 1\} f_e \tag{4.17}$$

Equation (4.17) indicates that the average profit depends on the cut-off marginal cost c_ω^*, which is further determined by cut-off productivity φ and wage premium W_ω^*. Lower cut-off cost c_ω^* expels the inefficient firms out of the market and decreases the average profit of the market due to the tougher competition. The zero-profit condition (ZCP) suggests the positive correlation between the average industrial profit and marginal cost c_ω^*.

Given the macro variables as exogenous, the marginal cost c_ω^* would be uniquely determined by the free-entry and zero-profit conditions as shown in Figure (4.2).Only those firms with the marginal cost $c_\omega < c_\omega^*$ could enter the domestic market successfully. For the marginal firms with the cut-off productivity, their profits in the market equal to zero. The wage premium of the marginal firms satisfies $W_\omega^* = \frac{\Phi_s}{\Phi_u}(z)^{\frac{1}{\rho-1}}\{\eta[\frac{\mu\varphi^*}{\kappa}]^{\frac{1-\rho}{\alpha}} - 1\}^{\frac{1}{1-\rho}}$ given $\eta = \Phi_u \omega_u^{\rho-1}[\frac{\sigma f_e}{RP^{1-\sigma}}]^{\frac{1-\rho}{\alpha(1-\sigma)}}$ as exogenous. Higher cut-off productivity leads to a larger wage inequality between skilled and unskilled workers in the marginal firms. Moreover, given a higher z, the wage premium of firms would be improved by increasing the productivity shifter of skilled labor.

Similar to Melitz (2003), firms choose to import or export after opening up, which lowers the cut-off marginal cost of domestic firms and forces inefficient firms to exit the market. For example, for importers, the marginal firms of imports have the zero profit and marginal cost c_ω^m* to enter the foreign market. These firms have to bear extra sunk cost of importing (f_m), and their expected profits is written as $\frac{r_d(c_\omega^{m*})\tau_{ij}^{m\,1-\sigma}}{\sigma} - f_m - f_e = 0$. Thereby the marginal cost of importing could be written as $c_\omega^{m*} = \frac{1}{\tau_{ij}^m}(\frac{f_e}{f_m+f_e})^{\frac{1}{\sigma-1}} c_\omega^*$ where c_ω^* is the marginal cost in autarky economy. As we know $\tau_{ij}^m > 1$ and $\sigma > 1$, the cut-off cost for importing firms(c_ω^{m*}) is smaller than the that of domestic firms(c_ω^*), which rules the high-cost domestic firms out of the importing market.

Moreover, the probability of entering the foreign market is written as $prob_m = \frac{1-G_\Phi(\varphi_m^*)}{1-G_\Phi(\varphi^*)}$ where φ_m^* is the cut-off productivity for marginal importing firms. For importing firms, their average cost of importing equals to $\tilde{c_m} = [\int_{\varphi_m^*}^{\infty} c(\varphi, W_\omega)^{\sigma-1} prob_m \cdot v(\varphi)d\varphi]^{\frac{1}{\sigma-1}}$. And their average profit of importing intermediates from one country becomes $\bar{\pi}_{mj}(\tilde{c_m}) = f_m[(\frac{\tilde{c_m}}{c_w^{m*}})^{1-\sigma} - 1]$. If firms import from N countries at the same time, the average profits from importing would equal to $\bar{\pi}_m(\tilde{c_m}) = \sum_j^N prob_m \cdot f_m[(\frac{\tilde{c_m}}{c_w^{m*}})^{1-\sigma} - 1]$. And their average profit from domestic market and importing markets becomes:

$$\bar{\pi}(c_\omega) = f_e[(\frac{\tilde{c}_\omega}{c_\omega^*})^{1-\sigma} - 1] + \sum_j^N prob_m \cdot f_m[(\frac{\tilde{c_m}}{c_w^{m*}})^{1-\sigma} - 1] \tag{4.18}$$

Equation (4.18) indicates the average profit for firms using imported intermediates are higher than that of the closed economy. Firms could lower their average cost and gain extra profits by importing intermediate inputs. According to Melitz (2003), the same pattern exists for

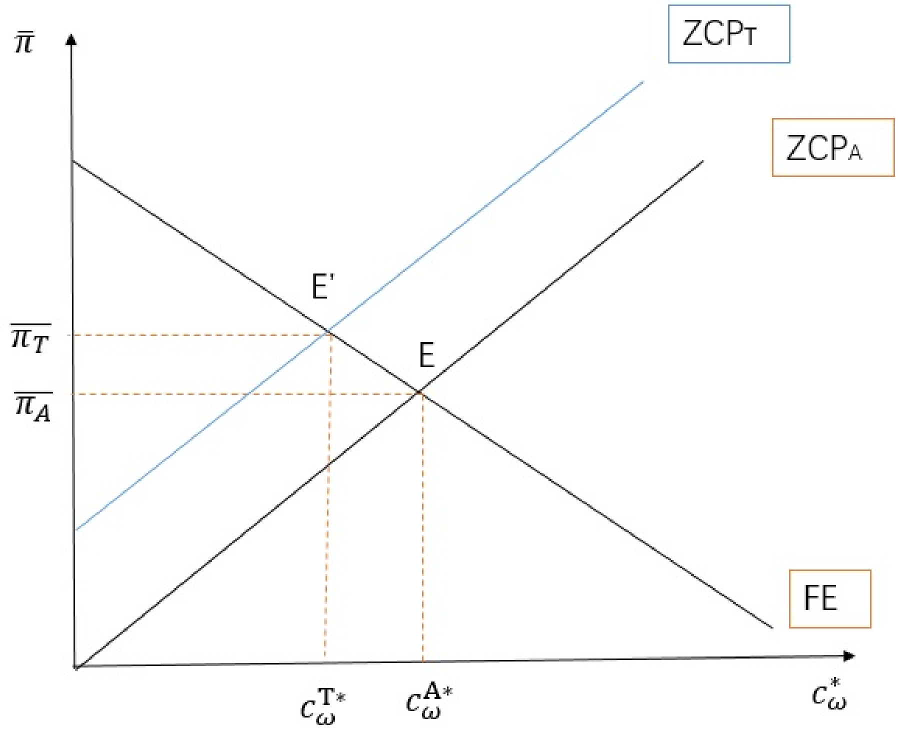


Figure 4.2: Industrial Equilibrium in Autarky and Trade

firms of exporting. As shown in Figure (4.2), there is a unique equilibrium with the free-entry and zero-profit conditions in autarky, which determines the cut-off marginal costs of entering the market and the average industrial profit. Trade liberalization moves the zero-profit curve upwards while keeping the free-entry condition unchanged, which lowers the marginal cost of entering the market. The high-cost firms are ruled out of the market, which further improves the average profit of the industry.

For the domestic firms, their profits are reduced by opening up from $\pi_d(\omega) = f_e[(\frac{c_\omega}{c_\omega^*})^{1-\sigma} - 1]$ in autarky to $\pi_d^T(\omega) = f_e[(\frac{c_\omega}{c_\omega^{T*}})^{1-\sigma} - 1]$ in open economy as $c_\omega^{T*} < c_\omega^*$. The fierce competition after opening up reduces domestic firms' profit from $\pi_d(\omega)$ to $\pi_d^T(\omega)$ in Figure (4.3). According to the fair wage hypothesis, firms with low profits would cut the skilled workers' fair wage to reduce their costs. The change narrows the wage inequality between skilled and unskilled workers within the firms. The same trend exists in the marginal importers or exports, which enter the foreign markets with zero profits. The profits from foreign markets could not make up the loss in the domestic market, and as a result, the marginal importers or exporters would

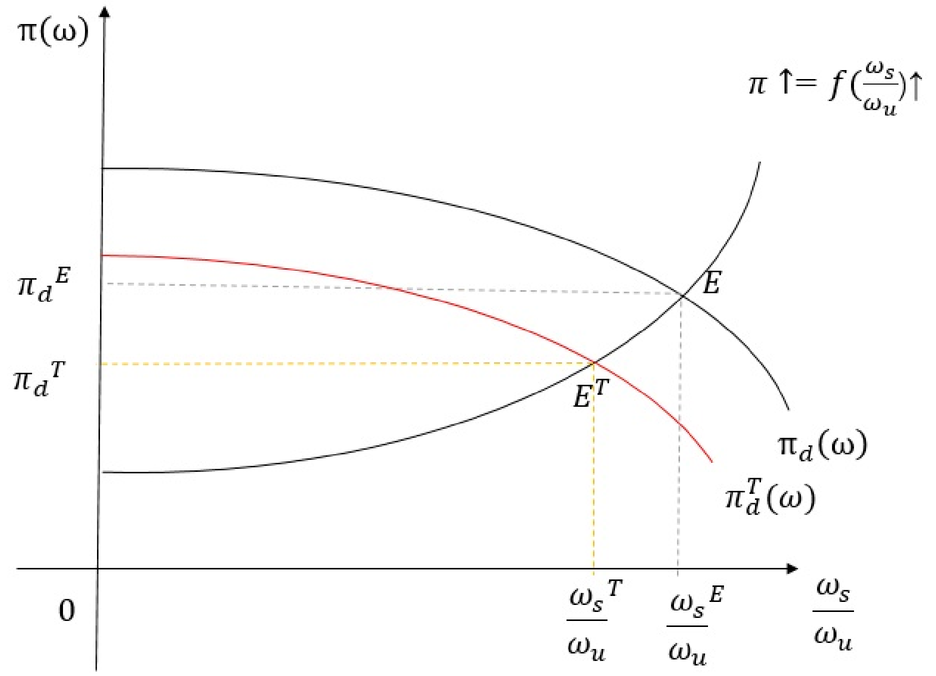


Figure 4.3: Domestic Firms' Wage Premium Changes in Open Economy

like to reduce their wage premium to maintain the profits in the open economy as shown in Figure (4.3).

Firms would choose to import intermediates for the production of exports if their marginal costs satisfy the following condition:

$$c_\omega^{T*} < c_\omega^* < c_\omega^{T*}(\Gamma_{m\omega}\Gamma_{x\omega})^{\frac{1}{\sigma-1}} \tag{4.19}$$

where c_ω^{T*} is the cut-off marginal cost of trade. c_ω^* is the cut-off marginal cost in autarky. $\Gamma_{m\omega}$ is the import globalization factor and $\Gamma_{m\omega} > 1$. $\Gamma_{m\omega}$ is determined by the CIF price of imported intermediates $(p_{ij}\tau_{ij}^m)$ and the number of importing countries $(N,\ j \in N)$. $\Gamma_{x\omega}$ is the export globalization factor with $\Gamma_{x\omega} > 1$. The GVC firms gain extra profits by importing intermediates and export to foreign markets, which is shown in Figure (4.4). Under the fair wage constraint, the rising profits enable GVC firms to pay higher wages to the skilled workers, which increases the skill wage premium from equilibrium point E to E^T.

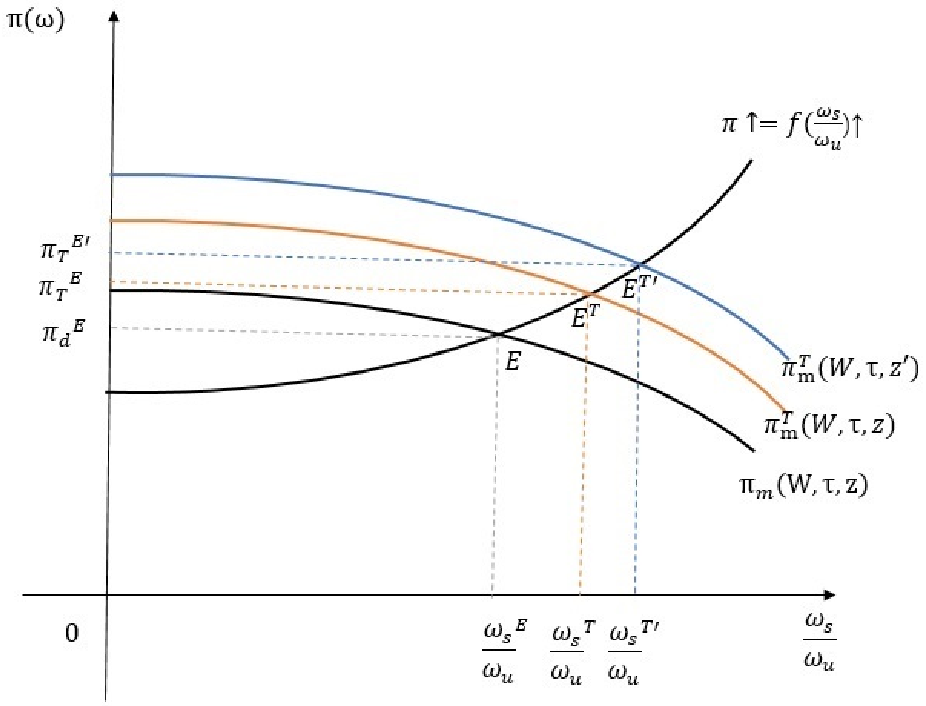


Figure 4.4: The Wage Premium Changes by Importing Intermediates and GVC Upgrading

Moreover, as shown in equation (4.13), the profits of GVC firms are negatively correlated to the marginal cost of domestic value added (c_d) where $c_d = \Phi_u^{\frac{1}{1-\rho}}\omega_u[1+\frac{\Phi_s}{\Phi_u}(z)(\frac{\omega_s}{\omega_u})^{1-\rho}]^{\frac{1}{1-\rho}}$. Given the macro-variables R and P, the unskilled productivity parameter (Φ_u) and the sector-level upstreamness z as exogenous, the GVC firms have a unique equilibrium at E^T after opening up, where they have higher profits as well as skill wage premiums than those in autarky. Suppose moving to the upstream sectors generates no extra fixed cost, a larger upstreamness index z' would lead to an increase in the productivity shifter $\Phi_s(z)$ and reduce the marginal cost of domestic value-added c_d. The lower marginal cost of domestic value-added increases GVC firms' equilibrium profit from $\pi_m^T(W,\tau,z)$ to $\pi_m^T(W,\tau,z')$, suggesting upgrading in GVCs requires firms to be more profitable. The higher upstreamness z' also improves the productivity of skilled labor, which widens the equilibrium wage premium from $\frac{w_s}{w_u}^T$ to $\frac{w_s}{w_u}^{T'}$ in Figure (4.4).

According to the Cobb-Douglas production function, the share of domestic value-added in total inputs equals to α (DVAR), which is assumed to be exogenous with $\alpha \in (0,1)$. Thus the share of foreign value-added content in output is $1-\alpha$. The partial derivative for the log profit of GVC firms over α equals to $\frac{\partial ln\pi}{\partial\alpha} = -\frac{1-\sigma}{1-\gamma}lnP^f + (1-\sigma)[-ln\alpha - ln(1-\alpha +$

$lnc_d)] < 0$. As a result, firms with higher shares of foreign value-added content (smaller α) tend to have larger profits and wage inequality. This result is consistent with the intuition that using more imported intermediate inputs reduces the marginal costs of exporters and increases the profitability of firms. The wage of skilled workers is positively correlated to firm performance, therefore increasing FVAR increases the profits of firms, which in turn raises firms' wage premium between skilled and unskilled labor. The predictions of wage premium changes in reaction to the GVC participation, GVC upgrading, and rising FVAR are summarized as follows:

Proposition 1 *Compared to the domestic and non-GVC firms, the GVC firms are more profitable and associated with larger wage inequality between skilled and unskilled workers.*

Proposition 2 *All else equal, firms with a higher share of foreign value added in the production tend to have larger wage inequality of skills.*

Proposition 3 *Moving to more upstream sectors in the global value chains enlarges firms' wage inequality.*

4.3 Data and Measures

In this section, we first extend the procedures Kee and Tang (2016) and Upward et al. (2013) to measure the share of foreign value-added in exports (FVAR) as the proxy for GVC participation. Then we follow Antràs et al. (2012) to measure the upstreamness of exporting varieties and calculate firms' positions in GVCs by aggregating the upstreamness of exporting varieties to the firm level. Finally, we adopt Chen et al. (2017)'s approach to develop a Mincer-type econometric model that estimates the firm-level wage premium with the average wage and skill share.

4.3.1 Data description

We use two micro-datasets of China to construct the firm-level GVC indicators: (a) the Chinese manufacturing enterprise survey data from China's National Bureau of Statistics (NBS), (b) the Chinese transaction-level trade data from China's General Administration of Customs (GAC). The NBS dataset is an annual survey covering two types of manufacturing firms: the state-owned (SOE) enterprises and the non-SOEs with annual sales over RMB 5 million (around the US $770,000). The NBS enterprises in the sample account for almost 95% of China's manufacturing outputs. The NBS dataset provides detailed information about firms with more than 130 financial indicators. The data in our study covers from 2000 to 2006, during which China entered the WTO and rapidly integrated into the global economy.

As a survey dataset, the NBS data inevitably contains some statistical discrepancies such as abnormal values, missing variables and misreporting. Despite the high consistency, the NBS database fails to identify firms across years without the uniform identification code. Thus, we first encoded enterprises by their name and address to form a unique identification code for each firm across time [Brandt et al. (2014)]. Following Cai and Liu (2009), we eliminated the misreporting information. First, we omitted the duplicates and abnormal values from the sample and then removed the observations with missing critical values, e.g., profits, inputs, employment, fixed assets, etc. Second, we deleted the small-scale firms with less than eight employees to rule out extreme values. Third, we removed companies that break the "Generally Accepted Accounting Principles (GAAP)[16]. Around 1,560,004 observations of 79,810 firms were omitted from the NBS database after the data filter, accounting for 5.1% of the sample.

Another limitation of the NBS data is the lack of detailed information about skills within firms, except for the year 2004. In the NBS dataset, firms' employment and average wage are available annually, but the detailed information of skills, categorized by education and occupation, is only available for the 2004 survey data. Inspired by Chen et al. (2017), we

[16]For example, total asset exceeds cash or capital; net value of fixed assets is smaller than the total asset; capital is less than 0 or exports are higher than the sales.

construct the firm-level employment of skills by assuming skills have an identical growth rate in the same province. We get the province-level growth rate of skills from the China Statistical Yearbook [17]. Meanwhile, the 2004 NBS data enabled the calculation of the real employment of skilled and unskilled workers within firms by education[18]. Under the assumption of identical skill growth rate within provinces, we derived the firm-level employment of skills using the 2004 firm-level skill employment data and the province-level skill growth rate in the other years. This approach makes up the data limitation with consideration of firm heterogeneity. We further measure the wage of unskilled workers using provincial data. The unskilled workers are assumed to have no bargaining power in their salaries. Thus, the unskilled workers accept the minimum wage, which is assumed to be the 25 percentiles of the province-level average salary[19]. The average wage of provinces is collected from the Chinese Trade Unions Statistics Yearbook.

To calculate the share of imported intermediates exports, we match the NBS dataset with the Chinese Customs dataset. China's GAC dataset provides detail trade information at the transaction level. In each transaction, three types of information are covered: (a) trading firm's characteristics such as name, address, postcode and telephone number; (b) the shipment information such as trade volume, quantity, destinations or origins; and (c) the trading regime information such as ordinary trade, processing trade, and the others. We matched the NBS database with the GAC data following the procedures of Feenstra et al. (2014)[20]. We consider firms with the same name, telephone number (the last seven digits) and postcode across time as the same firm. The matched firms account for around 20% of the NBS samples and 35% of firms in the GAC databases. We summarize the matched data in Table (4.1).

[17] The China Statistical Yearbook provides the employment data by province and education. There are seven categories of education including illiteracy, primary education level, secondary school education level, high school education level, college, undergraduate, postgraduate and over. We categorize the employees with the college degree and above as the skilled workers while considering the others as the unskilled workers.

[18] We also provide an alternative categorization of skills by occupation in the section of robustness checks, and the results keep unchanged.

[19] The minimum wage regulations of China started since 2004, which partly overlaps with our sample period. We follow Chen et al. (2017) to use the 25 percentile of the provincial average wage as the proxy for the unskilled wage. We also provide an alternative measurement in the section of robustness checks by using the rural wage as the alternative proxy for the unskilled wage.

[20] The NBS and GAC databases both have identification code of firms, but they belong to different systems and unable to match directly.

Table 4.1: Matched Data Description

Year	Observations	Firms	ratio in NBS	ratio in GAC
2000	1,168,745	21,584	15.02%	26.90%
2001	1,302,202	31,248	19.75%	35.75%
2002	1,473,416	34,041	19.91%	35.03%
2003	1,682,256	37,436	19.87%	33.09%
2004	2,257,771	56,650	21.47%	42.00%
2005	2,204,878	53,804	20.45%	38.44%
2006	2,370,679	82,479	28.24%	41.76%

Note: The table reports the matched result of NBS and GAC databases. The ratio refers to the number of matched firms over the total number of firms in the two databases.

Firms participate in the GVCs by using imported intermediate inputs for the production of exports. According to trade regimes, GVC firms are further categorized into three types: (a) the ordinary exporters, (b) the processing exporters and (c) the mixed exporters performing processing trade and ordinary trade at the same time[21]. China exempts the tariff of imported intermediates for processing exports to boost export growth. The tariff-free policies require processing exporters to use all imported intermediate inputs for the production of exports. The ordinary exporters do not receive the tariff exemption on imported intermediates; thus, they could use the imported intermediate inputs for domestic production and sales. The categorization of Chinese exporters by trade regimes is summarized in Table (4.2). We observe around 60% of China's exporters engage in processing trade in the sample period. It suggests that the estimation of FVAR using international input-output tables (IIOTs) could be biased without considering the heterogeneity of processing firms in using foreign intermediates [Kee and Tang (2016)].

We use the World Input and Output tables (WIOD) to measure the upstreamness of exporting varieties. The WIOD dataset traces the input and output linkages of production across 43 countries and 35 sectors from 2000 to 2014. We follow Antràs et al. (2012)'s procedures to measure the upstreamness of varieties using the WIOD dataset. The upstreamness of each

[21]In processing trade, firms import the raw materials and intermediates for processing, and export the finished products, in the form of final goods or intermediates, to the other countries. Processing exports are massive in China, accounting for more than 45% of the total exports in 2010 [Feenstra et al. (2014)]. Processing exporters use more imported intermediates in production than ordinary exporters[Koopman et al. (2012).]

Table 4.2: Exporting Firms by Trade Regimes

Year	Ordinary exporters	Processing exporters	Mixed Exporters	Total	Share of NBS	Share of GAC
2000	6,105	2,991	7,542	16,638	11.58%	20.74%
2001	10,455	3,419	9,123	22,997	14.54%	26.31%
2002	12,729	3,172	10,170	26,071	15.25%	26.83%
2003	15,919	3,188	11,138	30,245	16.05%	26.73%
2004	25,208	4,787	15,140	45,135	17.11%	33.46%
2005	26,738	4,855	15,253	46,846	17.81%	22.46%
2006	32,645	5,334	15,754	53,733	18.40%	27.21%

Note: We define firms that use imported intermediates for exports as GVC firms. According to trade regimes, the GVC firms could be categorized into firms in ordinary trade, firms in processing trade and firms in both ordinary and processing trade (Mixed exporters).

variety is estimated by its weighted average "distance" to the final demand. The matched dataset of NBS and GAC enables us to identify the exporting varieties of each firm and calculate the firm-level average upstreamness weighted by the export share of each variety in the total exports of the firm[Ju and Yu (2015)].

4.3.2 GVC measurement

4.3.2.1 Firm-level GVC participation

The backward GVC participation index is defined as the share of foreign value-added content in exports (FVAR) [Koopman et al. (2014)]. FVAR sources either from the imported intermediates or the foreign value-added embodied in the domestic materials in the production [Kee and Tang (2016)]. Chinese processing exporters have to use all their imported intermediates for the production of exports. However, the ordinary exporters could use part of imported intermediates for domestic sales [22]. We estimate the share of foreign value added in exports (FVAR) for processing firms as follows:

$$FVAR_i^p = \frac{Import_i^p}{Export_i^p} + \frac{\sigma_i^F}{Export_i^p} \tag{4.20}$$

[22] The excessive importers and exporters are ruled out from the sample following Kee and Tang (2016). The excessive importers are the firms which import more intermediates than they need and sell the imported intermediates to the other firms, leading to an overestimation of FVAR. The excessive exporters are the firms that import intermediates from other domestic firms rather than foreign countries, and thus underestimates the FVAR.

where $Import_i^p$ is the imported intermediates of the processing exporter i. σ_i^F denotes the foreign value-added content embodied in domestic materials that are used for exporting production [23]. In this chapter, we use Kee and Tang (2016)'s estimation of σ_i^F to calculate the share of foreign value added in domestic materials for exporting production ($\frac{\sigma_i^F}{Export_i^p}$).

The measurement of FVAR for non-processing exporters is more complicated than that of processing exporters. Apart from importing intermediates, the non-processing exporters also import capital and final products for consumption[24]. We use the United Nations Broad Economic Categories (BEC) to distinguish the imported intermediates from capital and equipment imports and estimate the total value of imported intermediates. Let $Import_i^{o\text{-}int}$ denote the total value of imported intermediates of firm i, where "o" refers to ordinary exporters while "int" stands for the imported intermediate. The imported intermediates of ordinary exporters are used for either exports or domestic sales. However, it is challenging to calculate the ratio of imported intermediate inputs in exports over the total imported intermediates. We further assume the share of inputs in the production of exports is proportional to the share of exports in total sales, which ensures the same ratio of imported intermediate inputs in both domestic sales and exports[25]. Under the proportion assumption, the FVAR of ordinary exporters and mixed exporters is written as follows:

$$FVAR_i^o = \frac{import_i^{o\_int}}{Export_i^o + dom\_sales} + \frac{\sigma_i^F}{Export_i^o} \tag{4.21}$$

[23]From the GVC perspective, the imported intermediates also contain domestic value added σ_i^D , which should be subtracted from the value of imported intermediates. Koopman et al. (2014) estimated the share of domestic value added in imported intermediates (σ_i^D) and found σ_i^D only accounts for 0.7% of the ordinary exports and almost 0% of the processing exports. Kee and Tang (2016) neglected σ_i^D in calculating the share of domestic value added in Chinese processing exports. We follow Kee and Tang (2016) to assume that $\sigma_i^D = 0$ for processing exporters.

[24]The imported capital and equipment of processing firms are listed separately in the category of "Equipment for Processing Trade" in GAC database. Thus $Import_i^p$ only measures the value of imported intermediates of processing exporters. But we have to distinguish the imported intermediates from imported capital and equipment in the ordinary trade.

[25]This proportional assumption could be observed from the firm-level survey data in the sample period. The input-export ratio is around 1.6 times of the export-sales ratio across years from 2000 to 2006. The assumption is less binding if firms produce same products for both domestic sales and exports. It may be restrictive if firms produce different products in the domestic market and the export market. Unfortunately, the current data is unable to identify the varieties for domestic sales. However, compared to the sector-level proportionality assumption widely used in the literature, this assumption considers firms' heterogeneity in the ratio of exports relative to total sales, which leads to less restrictive estimation results [Kee and Tang (2016)].

$$FVAR_i^m = \frac{Import_i^p}{Export_i} + \frac{\frac{import_i^{o\_int}}{export_i^o + dom\_sales} * export_i^o}{Export_i} + \frac{\sigma_i^F}{Export_i} \tag{4.22}$$

The mixed exporters conduct processing exports and ordinary exports at the same time. As shown in Equation (4.22), the superscripts p and o denote processing trade and ordinary trade. "*int*" refers to the import of intermediates. "*dom_sales*" represents the domestic sales of firms. $Export_i$ is the gross exports of mixed exporters, while $export_i^o$ stands for the part of ordinary exports. Mixed exporters have to use all the imported intermediates of processing trade in exports. Thus the foreign value-added share of the processing export is shown in the first item of Equation (4.22). The share of imported intermediates by ordinary imports in exports is shown in the second item of Equation (4.22). The share of foreign value added embodied in the domestic materials for exports lies in the third item.

We further calculate the aggregated industry- and country-level FVAR index with the firm-level FVAR data using firms exporting share as weights [26] [Kee and Tang (2016)]:

$$FVAR_j = \sum_{i \in \Omega_j} \frac{EXP_i}{\sum_{i \in \Omega_j} EXP_i} FVAR_i \tag{4.23}$$

$$FVAR = \sum_j \sum_{i \in \Omega_j} \frac{EXP_i}{\sum_j \sum_{i \in \Omega_j} EXP_i} FVAR_i \tag{4.24}$$

China's aggregated FVAR index is aggregated to the country level by trade regimes in Figure (4.5). We observe a higher FVAR in processing exports than in ordinary exports, which is consistent with the findings of Koopman et al. (2012) and Kee and Tang (2016). We also find that the average FVAR of Chinese manufacturing firms decreased from 0.42 in 2000 to 0.30 in 2006 respectively. The declining FVAR is primarily due to the processing exporters, whose FVAR dropped from 0.51 to 0.45 in the sample period. The FVAR of ordinary exports also reduced from 0.16 in 2000 to 0.13 in 2006. Figure (4.6) gives the distribution changes of FVAR

[26] The approach applies to firms in one sector with direct trading. For firms in multiple industries, extra constraints should be applied to rule out excessive processing importers[Kee and Tang (2016)].

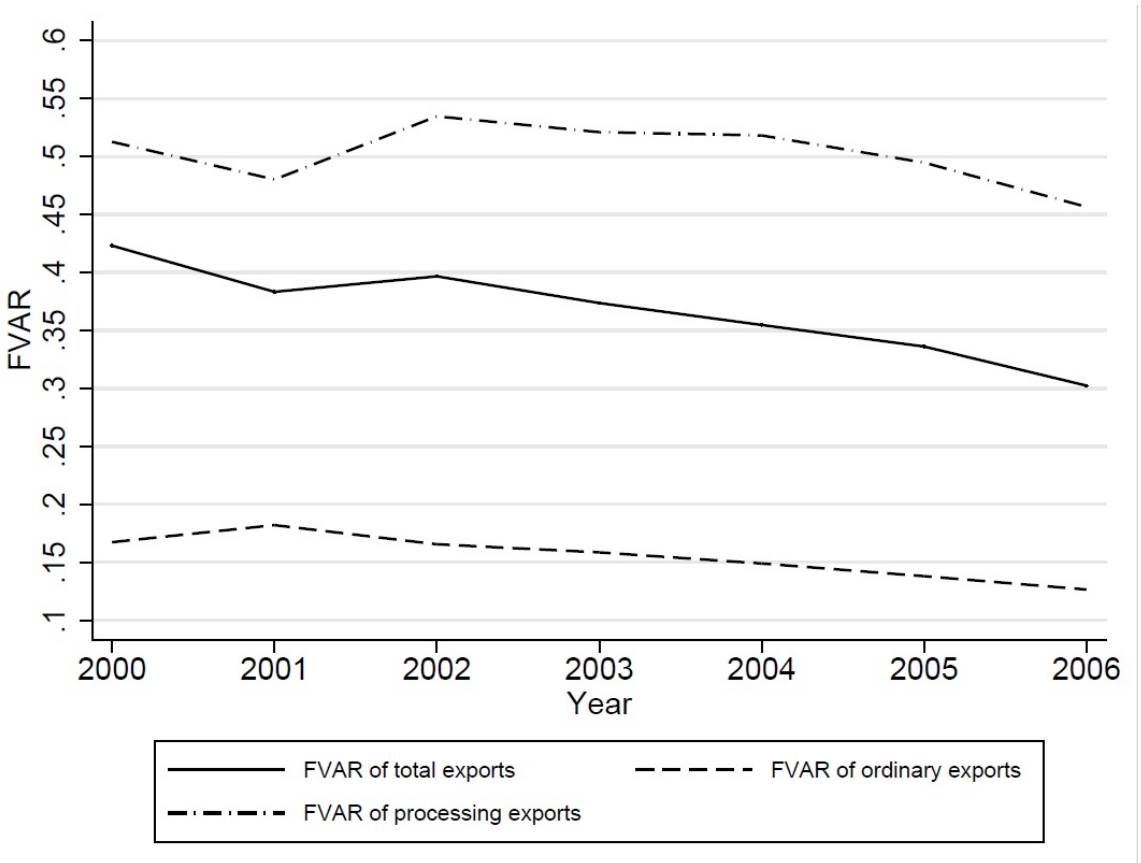


Figure 4.5: Country-level FVAR in Chinese Exports

between 2000 and 2006. The median of FVAR also decreased from 2000 to 2006 in the three types of trade regimes. The FVAR of processing exporters varies less than ordinary exporters and mixed exporters.

We further plot the FVAR trend by different manufacturing industries in Figure (4.7). Except for the industry of base metal, all the manufacturing sectors in China had a declining trend of FVAR during the sample period. We find that the industries with prominent processing trade, such as textile, machinery and non-metallic processing, experienced the most significant declines in FVAR by 21%, 17%, and 15% respectively during 2000-2006. It suggests that the Chinese manufacturing exporters tended to substitute domestic materials for the imported intermediates. It may because the domestic materials in China are available at lower prices and with more varieties in the process of trade liberalization[Kee and Tang (2016)].

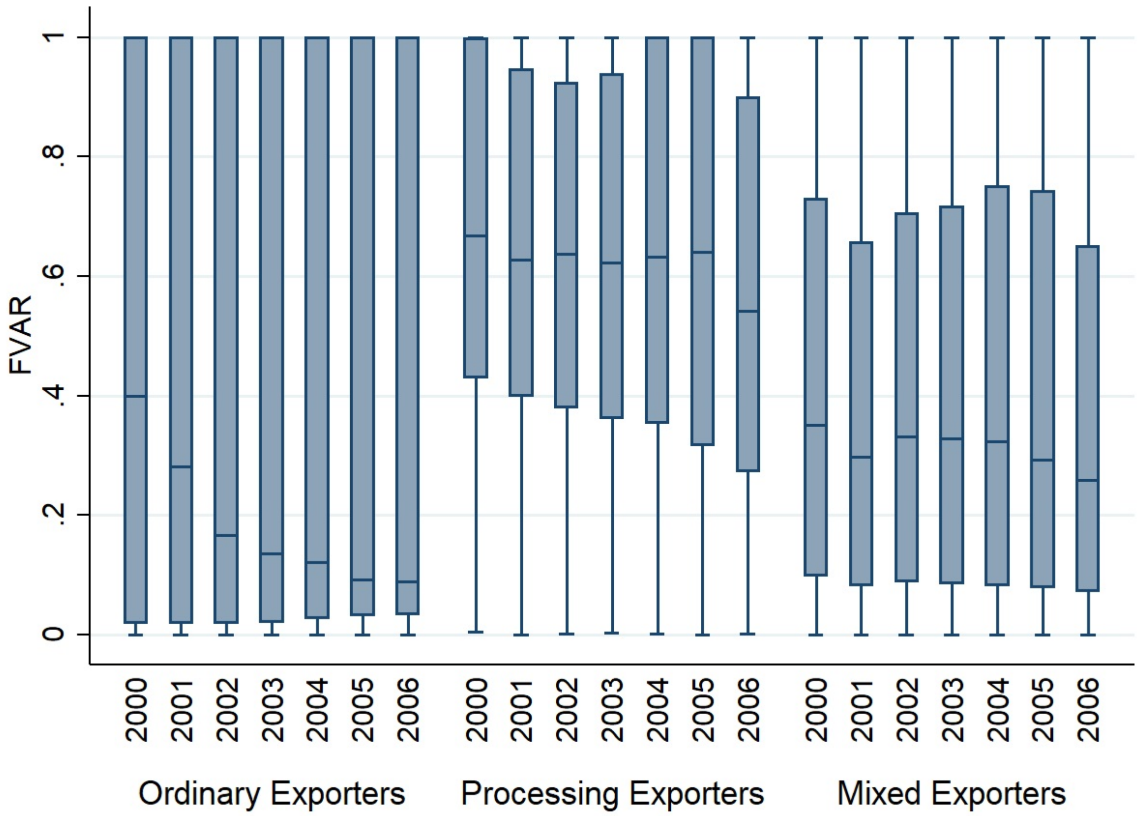


Figure 4.6: Changes in the Distribution of FVAR by Firm Trade Regimes, 2000-2006

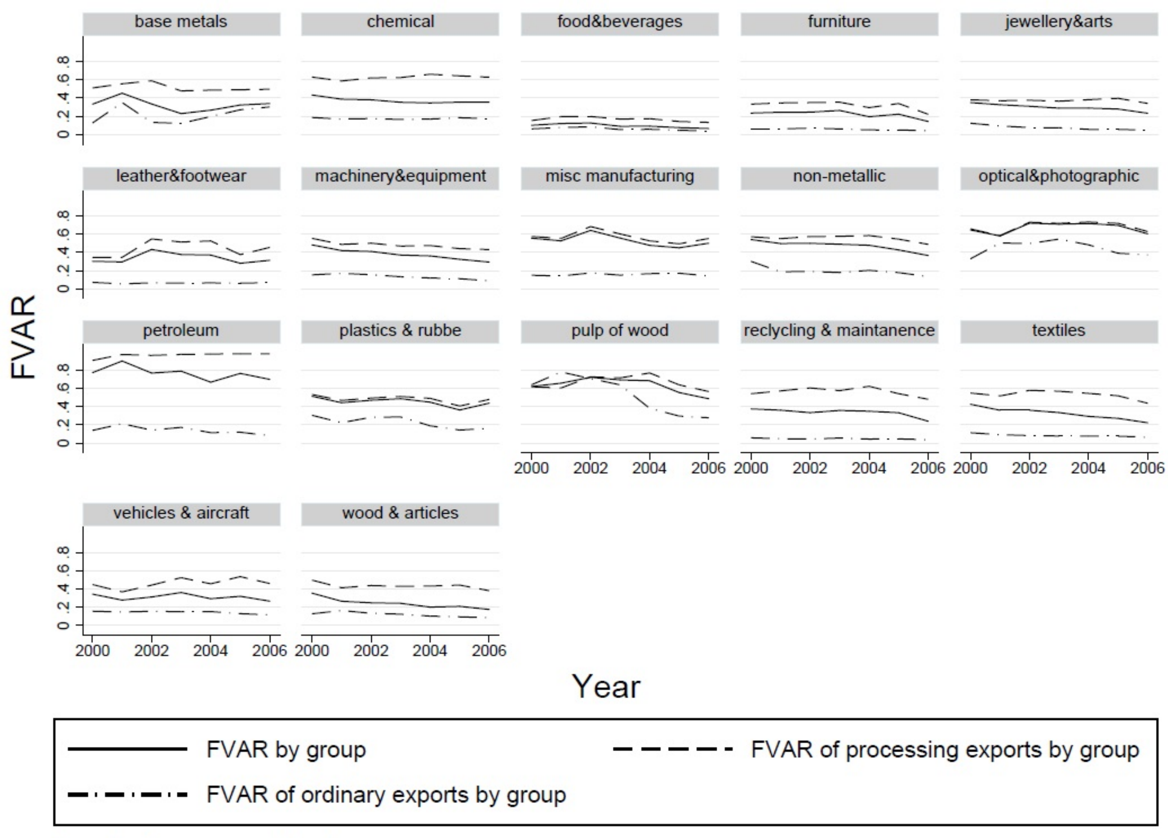


Figure 4.7: FVAR trend by industry during 2000-2006

4.3.2.2 Firm-level GVC position

Mapping firm's position in GVCs is crucial to study firms' GVC activities and their impacts on the labor market. Antràs et al. (2012) proposed the methodology to measure the position of sectors in GVCs, which was named as the "upstreamness" of industries in GVCs. The sector-level upstreamness is the weighted average distance from this industry to the final demands through GVCs. The distance is measured by the number of steps from the industry to the final goods in the international input-output tables. As we know, the manufacturing firms export several varieties at the same time and we derive the upstreamness of each exporting variety in GVCs in our sample.

For any variety j, its output (Y_j) could be either used as intermediates of other sectors (I_j) or consumed as final goods directly (F_j). As we know, $Y_j = I_j + F_j$. Assume there are N industries in GVCs, the total output of j is written as $Y_j = \sum_{k=1}^{N} d_{jk}Y_k + F_j$, where d_{jk} refers to the amount of j's output as intermediates to produce 1 unit of industry k's final goods. In the international input-output tables, the variety j's output could be iterated with infinite terms as follows:

$$Y_j = F_j + \sum_{k=1}^{N} d_{jk}F_k + \sum_{k=1}^{N}\sum_{m=1}^{N} d_{jm}d_{mk}F_k + \sum_{k=1}^{N}\sum_{m=1}^{N}\sum_{n=1}^{N} d_{jn}d_{nm}d_{mk}F_k + ... \tag{4.25}$$

Equation (4.25) shows the outputs of industry j could be absorbed either directly or indirectly in the final demand. The second right term of Equation (4.25) indicates that the output of industry j is directly used in the production of final goods k, by which the distance between industry j and the final demand is one step. The third right term of Equation(4.25) suggests that industry j's output is firstly used as intermediates of industry m and then absorbed the final goods k, then the distance between industry j and final demand is two steps. Similarly, the distance of industry j to the final demand in the fourth right term is three steps, suggesting industry j's output comes into the final use through two industries. We can get the distance of all the intermediates from industry j to the final goods k and measure its average distance to the final goods using its input coefficients as weights in Equation (4.26):

$$U_j = 1\times\frac{F_j}{Y_j}+2\times\frac{\sum_{k=1}^{N} d_{jk}F_k}{Y_j}+3\times\frac{\sum_{k=1}^{N}\sum_{m=1}^{N} d_{jm}d_{mk}F_k}{Y_j}+4\times\frac{\sum_{k=1}^{N}\sum_{m=1}^{N}\sum_{n=1}^{N} d_{jn}d_{nm}d_{mj}F_k}{Y_j}+.. \tag{4.26}$$

where U_j denotes the upstreamness of industry j relative to the final demand in the international input-output tables. d_{jk} stands for the $(j,k)^{th}$ element in the $N\times N$ input matrix of the international input-output tables. It represents how many output of variety j should be used to produce 1 unit of final goods k. Y_j is the total output of variety j.

The larger the distance between variety j and the final demand is, the more upstream position the variety j lies in GVCs. A firm could export multiple varieties at the same time. Thus we estimate the firm-level GVC position by taking the weighted average of upstreamness across industries using the share of each variety's exports in total exports of the firm as the weight. The measurement is shown in Equation (4.27).

$$F\_Upstreamness_i = \sum_{j}^{N} U_j \frac{exp_{ij}}{exp_i} \tag{4.27}$$

where U_j is the industry-level upstreamness of variety j. exp_{ij} is firm i's gross exports of variety j. exp_i is firm i's total exports of all the varieties. We identify the exporting varieties and their exporting values from the GAC dataset.

Figure (4.8) shows the average upstreamness index of Chinese manufacturing firms by industries and trade regimes. The upstreamness index varied from 1.9 (leather and footwear) to 4.4 (petroleum) during 2000-2006. The energy and raw material industries (petroleum, base metals, pulp, and wood) locate at the upstream of GVCs. The high-tech manufacturing industries, such as machinery, optical and photographic equipment, vehicles and aircraft, have higher positions in GVCs than the unskilled-labor intensive sectors such as textile, furniture, leather, and footwear. All the manufacturing industries in China have a rising trend of upstreamness, indicating the upgrading of Chinese manufacturing firms to upstream sectors of GVCs. There is no significant difference between the position of processing exporters and that of ordinary

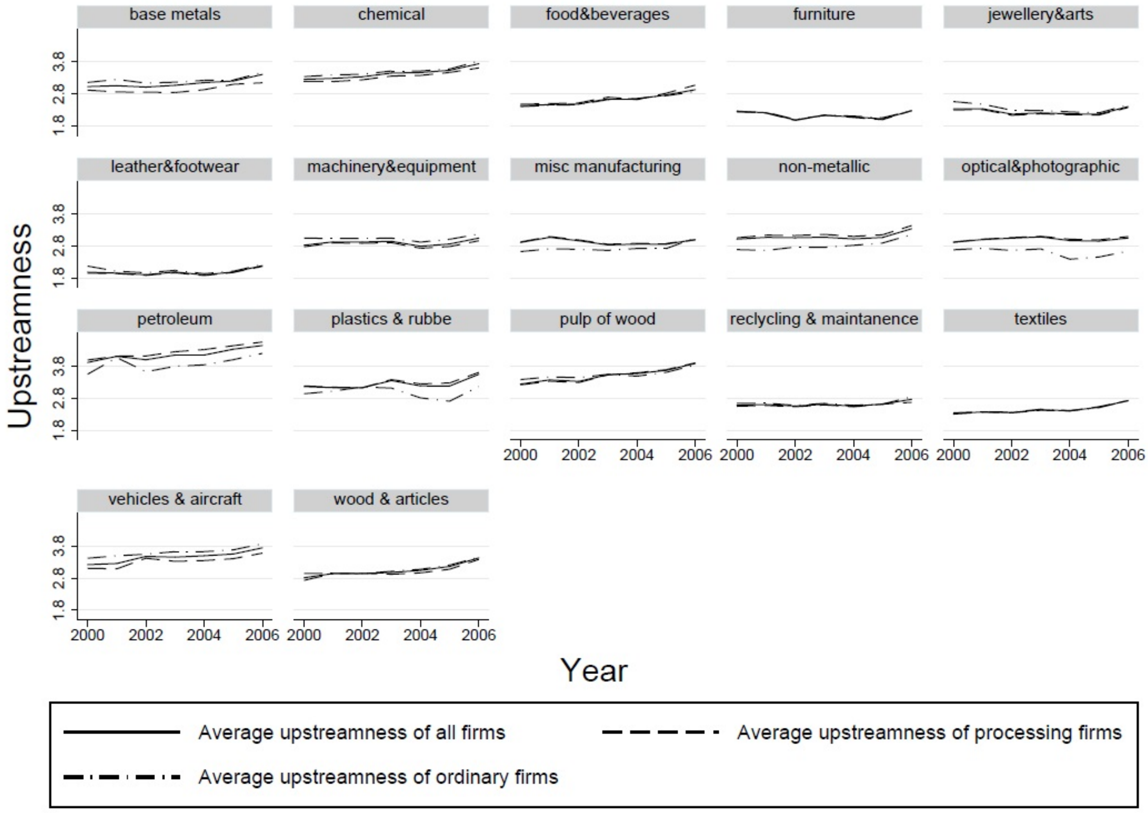


Figure 4.8: Upstreamness Trend by Industry and Trade Regime,2000-2006

exporters for most industries.

4.3.3 Skill Share and Wage Inequality

In this chapter, we categorize firms' employees into the skilled and unskilled labor by education. There are five categories of education in the NBS dataset: postgraduate or above, undergraduate, college, high school, and secondary school or below. According to the International Standard Classification of Education (ISCED 2011), employees with a college degree or above are categorized as skilled labor, while those with high school education or below are classified as unskilled workers. As discussed in the data part, the details of employment by skills are only available in 2004. We measure the skill share using the 2004 firm-level data and the provincial skill share in the other years during 2000-2006.

We denote the skill employment in 2004 as $emp^s_{ijl,2004}$ where i is the firm, j is the industry, l is the province. ς_{lt} is the growth rate of skilled employment in province l. The skill share

θ_{ijlt} of firm i in time t could be estimated by $\theta_{ijlt} = emp^s_{ijl,2004}(1+\varsigma_{lt})/emp_{ijlt}$[27].The wage of skilled and unskilled workers of the firm are written as w^s_{ijlt} and w^u_{jlt}. As discussed, w^s_{ijlt} relies on firm i's profits, but w^u_{jlt} is assumed to be determined by the provincial-level minimum wage. Following Chen et al. (2017), the average wage of firm i is $\bar{w_{ijlt}} = \theta^s_{ijlt} w^s_{ijlt} + (1-\theta^s_{ijlt}) w^u_{jlt}$, which equals to $\frac{\bar{w_{ijlt}}}{w^u_{jlt}} = \theta_{ijlt}(\frac{w^s_{ijlt}}{w^u_{jlt}} - 1) + 1$. Assuming $s_{ijlt} = \frac{w^s_{ijlt}}{w^u_{jlt}} - 1$ as a monotonic function of wage premium $\frac{w^s_{ijlt}}{w^u_{jlt}}$, the logarithmic of average wage in firm i is written as follows:

$$ln\bar{w_{ijlt}} = lnw^u_{jlt} + ln(1+\theta_{ijlt}s_{ijlt}) \approx lnw^u_{jlt} + \theta_{ijlt}s_{ijlt} \tag{4.28}$$

The average wage of the firm equals to the aggregated wage of skills weighted by skill share. It can be further written as a function of skilled share θ_{ijlt}, wage premium $\frac{w^s_{ijlt}}{w^u_{jlt}}$ and unskilled wage. When $\theta_{ijlt}s_{ijlt}$ is small enough, $ln(1+\theta_{ijlt}s_{ijlt}) \approx \theta_{ijlt}s_{ijlt}$. We get the approximate Mincer-type income function at the firm level.

According to the theoretical model, the wage inequality of skills is affected by firms' characteristics and their GVC activities. For simplicity, we suppose the function of wage premium s_{ijlt} is a linear form of firm characteristics and GVC indicators as follows:

$$s_{ijlt} = \sum_{g=0}^{G} \gamma_g x^g_{ijlt} + \varepsilon_{ijlt} \tag{4.29}$$

where x^g_{ijlt} is the vector of indicators that affect the skill wage inequality. It includes firms' participation index (FVAR) and position index (upstreamness) of GVCs and other firm-level characteristics. Substituting equation (4.29) into equation (4.28), we get a Mincer-type empir-

[27]As labor data by skills are quite limited in China, we only have the skill share in each province. The proportional assumption of skill growth considers firm heterogeneity of skilled labor by adopting the 2004 data and predict the skill share by multiplying with provincial-level skill growth rate. This assumption may be restrictive, so we use the 004 data to conduct the principal analysis and the measured data for 2000-2006 for robustness checks. Chen et al. (2017) used the provincial-level skill share multiplied with 2004 firm-level skill share to give the proxy but concluded similar results. Table (4.3) gives the mean and standard deviation of both 2004 skill share and measured skill share.

ical specification as follows:

$$ln\bar{w}_{ijlt} = \gamma_0 + \gamma_u lnw^u_{jlt} + \gamma_1\theta_{ijlt}FVAR_{ijlt} + \gamma_2\theta_{ijlt}F\_Upstreamness_{ijlt} + \boldsymbol{\gamma\theta_{ijlt}X_{ijlt}} + \sigma_i + \sigma_{jl} + \sigma_t + \epsilon_{ijlt} \tag{4.30}$$

where $\epsilon_{ijlt} = \varepsilon_{ijlt}\theta_{ijlt}$. lnw^u_{jlt} is the unskilled wage at the provincial level. The interactions between firm-level GVC indicators and skill share (θ_{ijlt}) investigate whether firms' GVC activities affect the skill wage inequality via changing skill shares. $FVAR_{ijlt}$ measures firms' backward participation in the global value chains and $F\_Upstreamness_{ijlt}$ captures firms' position in the global value chains. As predicted in the theory, using more foreign content in exports (FVAR) enlarges firms' wage inequality between skilled and unskilled labor. Thus we expect γ_1 to be positive and statistically significant. We also predict that moving to upstream sectors widens firms' wage inequality of skills. Thus γ_2 is also expected to be significantly positive. $\boldsymbol{X_{ijlt}}$ is a vector of control variables interacted with skill share (θ_{ijlt}) including firm size, age, capital-labor ratio, dummy for state-owned enterprises, foreign ownership and processing trade. Firm size is measured by the ratio of the firm's sales over the industrial sales to control for the within-industry heterogeneity. The model also controls the time-specific, firm-specific and sector-province specific fixed effects. We describe the main variables in the regression in Table (4.3).

4.4 Estimation

4.4.1 Baseline Estimation

In the baseline estimation, we use both 2004 cross-section data and 2000-2006 panel data to explore the nexus between GVC activities and the wage inequality of skills within firms. The advantage of 2004 data is the availability of firm-level skill share. Despite the measured skill share, the panel data between 2000 and 2006 provides a better understanding of the skill premium variation within firms in response to the GVC activities. The baseline estimation results are shown in Tables (4.4) and (4.5) respectively.

Table 4.3: Variable description

	2004			2000-2006		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
log Firm Average wage	45,698	7.814	1.236	245,121	7.900	1.271
log Unskilled Wage	45,735	8.502	0.256	245,381	8.467	0.350
skill share	45,735	0.143	0.176	209,405	0.131	0.168
FVAR	24,561	0.449	0.382	133,547	0.442	0.377
Firm-level Upstreamness	41,177	2.782	0.664	220,742	2.871	0.666
log Firm size	45,735	-5.496	1.282	245,381	-5.310	1.339
Firm age	45,729	7.887	8.467	245,201	8.870	16.887
log TFP by OP	45,117	1.769	0.146	244,393	1.774	0.152
log TFP by LP	45,589	1.886	0.198	244,296	1.907	0.186
log capital labor ratio	45,690	3.662	1.425	244,769	3.721	1.419
SOE dummy	45,735	0.029	0.167	245,381	0.040	0.197
processing firm dummy	45,735	0.105	0.306	245,381	0.113	0.317
foreign ownership dummy	45,735	0.474	0.499	245,381	0.481	0.500
log value added per worker	35,229	-3.476	1.432	244,950	3.873	1.154
log profit per worker	22,217	0.250	0.132	193,348	-3.495	1.414
fitted FVAR by Heckman	21,812	0.256	0.131	152,793	0.254	0.131

Note: The first three columns describe the variables of the 2004 cross-section data where skill share is available. The last three columns summarize the panel data between 2000 and 2006 with measured skill share.

Table (4.4) reports the estimation of the cross-sectional regression. Column (1) examines the determinants of firm-level wage inequality with a simple ordinary least square (OLS) regression. Column (2) regresses the determinants interacted with skill share following the empirical specification of Equation (4.28) without controlling for the fixed effects. As predicted, the interaction between FVAR and skill share is significantly positive, suggesting that firms with higher FVAR are associated with larger wage inequality between skilled and unskilled workers. The interaction between upstreamness and skill share, however, is not significant in column (2). We also observe that the interactions of firms' size and capital-labor ratio are significantly positive. It means the large-scale firms and capital-intensive firms tend to use more skilled labor in the production, which in turn raises the firm's skill premium. We control for the industry-, province- and province-sector specific fixed effects in the last three columns. Column (3) reports the OLS regression of wage determinants with fixed effects. Column (4) reports the estimation of Mincer-type wage model with controlling for the fixed effects. The coefficient of FVAR interacted with the skill share is still positive and significant, suggesting increasing FVAR enlarges the wage inequality of skills at the firm level. The interaction coefficient between upstreamness and skill share turns to be significant after controlling for the fixed effects. It means that firms in the upstream sectors tend to have larger skill wage premiums and skill shares than those in the downstream industries. The estimation results of firms' size and capital intensity keep robust in the column (4) after controlling for the fixed effects.

We also consider the difference between processing exporters and ordinary exporters in GVCs. As analyzed above, processing exporters decrease more in FVAR than ordinary exporters as they substitute domestic for imported intermediates [Kee and Tang (2016)], which indirectly substitute domestic skills for foreign workforces. To examine the impact, we include a triple interaction among FVAR, skill share, and the dummy for processing firms in the column (5). The coefficient of the triple interaction is significantly negative with the net effect equals to $0.116 + (0.606 - 2.046) \times 0.143 = -0.09 < 0$ given the average skill share in 2004 as 0.143. It suggests the declining FVAR in processing firms has raised the wage inequality of skills, which seems to be contrary to the effect of the overall FVAR on skill premium. One possible explanation is that the imported intermediates of processing trade tend to be skill-biased inputs[Feenstra and Hanson (1996), Ho et al. (2005)]. The substitution of imported intermediate inputs with domestic materials has shifted the demands for foreign skilled workers embodied in imported intermediates to the domestic labor market. As a result, the net effect of FVAR on wage premium is smaller for processing exporters than ordinary firms, which partially offset the net effect of FVAR on skill premium via changing firms' profits according to the fair wage hypothesis. Another possible reason for the coefficient is the existence of unobserved variables correlated with the GVC participation and processing dummy that may lead to biased estimation of the baseline model. We will correct the endogenous problem in the next section. For the ordinary firms, the net effect of FVAR on wages equals to $0.116 + 0.606 \times 0.143 = 0.203 > 0$, which suggests the declining FVAR lower firms' skill wage premium. We also observe a positive coefficient of the triple interaction among upstreamness, skill share, and processing dummy, suggesting the processing firms in the upstream sectors have higher wage premium of skills than those in the downstream sectors. The result is similar to ordinary firms with a significantly positive coefficient of upstreamness interacted with the skill share.

Table 4.4: Baseline Estimation Using 2004 Cross-sectional Data

	(1)	(2)	(3)	(4)	(5)
		× Skill share		× Skill share	×Skill share×processing
ln unskilled wage	0.300***	0.310***	0.843**	0.864**	0.881**
	(0.030)	(0.030)	(0.386)	(0.380)	(0.380)
Skill share (θ_{ijlt})	-0.299***	-1.076***	-0.497***	-1.667***	-1.675***
	(0.048)	(0.316)	(0.059)	(0.385)	(0.384)
FVAR	0.304***	0.185***	0.225***	0.098***	0.116***
	(0.021)	(0.028)	(0.022)	(0.029)	(0.030)
f_upstreamness	-0.152***	-0.153***	-0.052***	-0.079***	-0.082***
	(0.012)	(0.016)	(0.017)	(0.021)	(0.021)
lnsize	-0.015**	-0.041***	0.013	-0.027**	-0.027**
	(0.006)	(0.008)	(0.009)	(0.011)	(0.011)
lnK/L	0.069***	0.017**	0.089***	0.028***	0.029***
	(0.006)	(0.008)	(0.007)	(0.008)	(0.008)
age	0.041***	0.041***	0.039***	0.039***	0.039***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Foreign ownership	-0.015	0.043**	-0.037**	-0.023	-0.026
	(0.017)	(0.022)	(0.018)	(0.022)	(0.022)
Processing firm	-0.267***	-0.247***	-0.406***	-0.379***	-0.380***
	(0.022)	(0.028)	(0.025)	(0.030)	(0.030)
SOE	0.567***	0.574***	0.390***	0.429***	0.430***
	(0.051)	(0.078)	(0.063)	(0.092)	(0.092)
θ_{ijlt}*FVAR		0.615***		0.600***	0.606***
		(0.111)		(0.127)	(0.127)
θ_{ijlt}*upstreamness		0.105		0.197**	0.200**
		(0.067)		(0.081)	(0.081)
θ_{ijlt}*lnsize		0.250***		0.280***	0.279***
		(0.036)		(0.044)	(0.044)
θ_{ijlt}*lnK/L		0.384***		0.419***	0.417***
		(0.030)		(0.036)	(0.036)
θ_{ijlt} foreign		-0.409***		-0.145	-0.142
		(0.093)		(0.111)	(0.111)
θ_{ijlt}*processing		-0.359*		-0.375	
		(0.212)		(0.242)	
θ_{ijlt}*SOE		-0.133		-0.199	-0.206
		(0.264)		(0.348)	(0.348)
θ_{ijlt}*FVAR* processing					-2.046***
					(0.590)
θ_{ijlt}* upstreamness*processing					0.345**
					(0.151)
Constant	5.241***	5.234***	-0.411	-0.434	-0.585
	(0.260)	(0.262)	(3.140)	(3.090)	(3.091)
Province-sector FE	NO	NO	YES	YES	YES
Observations	24521	24521	24521	24521	24521
r2	0.114	0.126	0.199	0.212	0.213

Note: Standard errors clustered at the firm level are listed in parentheses. $*p < 0.10, **p < 0.05, ***p < 0.01$. We control the province-, sector- and province-sector specific fixed effects in the last three columns to eliminate the effects of unobservable variables.

Table 4.5: Baseline Estimation Using 2000-2006 Panel Data

	(1)	(2)	(3)	(4)	(5)
		× Skill share		Skill share	×Skill share×processing
ln unskilled wage	0.878***	0.870***	-0.014	1.013***	1.013***
	(0.016)	(0.019)	(0.024)	(0.016)	(0.016)
skilled share (θ_{ijlt})	0.193***	-1.034***	0.233***	-1.683***	-1.679***
	(0.040)	(0.217)	(0.089)	(0.315)	(0.315)
FVAR	0.017*	-0.011	-0.015	-0.067***	-0.062***
	(0.010)	(0.013)	(0.011)	(0.015)	(0.015)
upstreamness	0.026***	0.018*	-0.062***	0.022	0.022
	(0.008)	(0.011)	(0.013)	(0.015)	(0.015)
ln size	-0.038***	-0.040***	-0.016***	-0.039***	-0.039***
	(0.004)	(0.004)	(0.005)	(0.007)	(0.007)
ln K/L	-0.027***	-0.051***	-0.099***	-0.094***	-0.094***
	(0.005)	(0.005)	(0.006)	(0.007)	(0.007)
age	0.004*	0.000	0.000	0.001	0.001
	(0.002)	(0.002)	(0.000)	(0.001)	(0.001)
foreign	-0.000	-0.007	0.033***	0.004	0.004
	(0.009)	(0.012)	(0.011)	(0.015)	(0.015)
processing	-0.111***	-0.089***	-0.065***	-0.056***	-0.060***
	(0.009)	(0.012)	(0.010)	(0.013)	(0.012)
SOE	0.268***	0.369***	0.067***	0.119***	0.119***
	(0.021)	(0.028)	(0.018)	(0.027)	(0.027)
θ_{ijlt}*fvar		0.188***		0.114*	0.121*
		(0.058)		(0.065)	(0.065)
θ_{ijlt}*upstreamness		0.050		0.144**	0.143**
		(0.051)		(0.066)	(0.066)
θ_{ijlt}*lnsize		0.034		-0.134***	-0.133***
		(0.024)		(0.028)	(0.028)
θ_{ijlt}*lnK/L		0.194***		0.040	0.040
		(0.027)		(0.036)	(0.036)
θ_{ijlt}age		0.033**		0.001	0.001
		(0.014)		(0.006)	(0.006)
θ_{ijlt}*foreign		0.054		0.270***	0.269***
		(0.065)		(0.084)	(0.084)
θ_{ijlt}*processing		-0.330***		-0.321***	
		(0.105)		(0.117)	
θ_{ijlt}*SOE		-0.469***		-0.344***	-0.344***
		(0.103)		(0.104)	(0.104)
θ_{ijlt}*fvar*processing					-0.622***
					(0.222)
θ_{ijlt}*upstreamness*processing					0.046
					(0.057)
Constant	0.407***	0.615***	10.380***	0.377	1.876***
	(0.122)	(0.144)	(0.271)	(0.307)	(0.226)
Year FE	NO	NO	YES	YES	YES
Firm FE	NO	NO	YES	YES	YES
Province-sector FE	NO	NO	YES	YES	YES
Observations	114697	114697	114697	114697	114697
R^2	0.208	0.204	0.261	0.230	0.230

Note: Standard errors in parentheses. $*p < 0.10, **p < 0.05, ***p < 0.01$. All the regressions use the robust estimator of variance. Column(1) reports the determinants of firms' wage using OLS without fixed effects.Column(2) add the interactions with skill share. Column(3) control the firm-, time- and province-sectoral fixed effects. Column (4) reports the results with interactions and fixed effects. Column (5) examines the net effect of GVC activities on firm wages for processing firms.

The regression results using the panel data of 2000-2006 are shown in Table (4.5). The first two columns demonstrate the estimation of wage determinants without controlling for the fixed effects. As shown in Column (2), the coefficient of FVAR interacted with the measured skill share keeps positive and significant, suggesting rising FVAR leads to higher wage premium within firms. The interaction between skilled-share and upstreamness is insignificant without controlling for the fixed effects. Large-scale and capital-intensive firms tend to be more skill-intensive in their production and have higher wage premium of skills. We control the year-specific, province-sector specific and firm-specific fixed effects in the last three columns. The interactive coefficient of FVAR is robust in column (4), suggesting the decline of China' overall FVAR narrows firms' wage inequality between skilled and unskilled labor over the sample period. The coefficient of upstreamness interaction is positive and significant, indicating moving to upstream sectors along GVCs increases the wage premium of skills. Column (5) considers the heterogeneity of processing firms in the global value chains over the sample period. The coefficient of triple interaction among FVAR, skill share, and processing firms is significantly negative. It suggests Chinese processing firms have an overturned effect of FVAR on skill wage premium as they switch their demand for skilled labor from imported intermediate inputs to domestic materials. However, the result may be biased due to endogeneity in the model. There is also no significant difference between processing firms and non-processing firms in terms of GVC upgrading on wage premium because the triple interaction among upstreamness, processing dummy and skill share is statistically insignificant.

The baseline results highlight several interesting implications for the impacts of GVC activities on the wage premium at the firm level. Firstly, increasing FVAR induces skill-biased production and widens the wage inequality of skills within firms. This result is consistent with the prediction of the theory. Imported intermediates reduce firms' marginal costs and thus leads to higher profits. According to the fair wage hypothesis, more profitable firms tend to pay higher wages to their skilled workers to elicit their efforts, leading to a higher wage inequality of skills of these firms. For Chinese manufacturing firms, on average, the declining FVAR reduces firm-level wage premium and narrows the wage inequality between skilled and unskilled workers. However, this effect is different for processing firms, which decrease their FVAR by replacing imported intermediate inputs with cheaper domestic inputs and induce new demands for the skilled workforce. Besides, moving up to upstream sectors along the GVCs raises the wage premium of skills at the firm level. This result supports the intuition that upgrading positions in the global value chains encourage firms to employ more skilled workers, which widens the wage inequality of skills of these firms.

4.4.2 Endogeneity

One critical problem of the baseline estimation is endogeneity. Similar to exporting, participating in GVCs incurs sunk costs, e.g., the fixed costs of equipment, new plant, communication, and logistics network. The sunk costs make it impossible for every firm to participate in GVCs. Only firms with higher productivity, larger size, or higher profits are more likely to overcome the sunk costs and engage in GVCs [Baldwin et al. (2014)]. The self-selection of firms into the GVCs may lead to an endogeneity problem in estimating the effect of GVC participation on firm wage. Moreover, the upstreamness of firms in the global value chains may also have a reciprocal relationship with their wage inequality where skill-intensive firms are more likely to upgrade in the global value chains. These unobserved factors could be partly absorbed by the year- and sector-province specific fixed effects. However, if the unobserved variables are time variant, the estimation of the baseline model would be biased without controlling for the endogeneity in the estimation.

We first control for the self-selection effect in GVCs. The decision to participate in GVCs is endogenous to firm within industries due to self-selection effect. Moreover, the extent of engagement in GVCs($FVAR$) is also endogenous due to reciprocal causality if skill-intensive firms participate more in GVCs. The coefficient of $FVAR_{ijlt}$ in the baseline model varies across firms, and its heterogeneity is correlated with covariates within industries. One way to solve the endogenous problem is to replace the endogenous variable $FVAR$ with the Heckman corrected value of FVAR and re-estimate the baseline model with the fitted FVAR [28]. The estimation is

[28] Several studies have used the approach to deal with the endogeneity of self-selection effect such as Feenstra et al. (2014) which studied the impacts of credit constraint on exports and Yu (2015) which explored the

implemented by bootstrap to correct standard errors [Wooldridge (2008)].

We use the Heckman two-step selection model to predict the fitted value of FVAR after controlling for the self-selection effect. GVC firms use imported intermediates for the production of exports. Thus, we define the exporters that have no imports or only import capital and consumption goods as non-GVC firms. The probability of participating in GVCs ($E_{ij,t}$) is written as:

$$Prob(Enter_{ijlt} = 1) = \Phi(\alpha_i + \alpha_t + \gamma \boldsymbol{Z_{ijlt}}) \tag{4.31}$$

where $\boldsymbol{Z_{ijlt}}$ is the vector of exogenous variables affecting the decision of entering the GVCs. We use the one-period lagged $\boldsymbol{X_{ijl,t}}$ (e.g., size, SOE, foreign ownership, capital/labor ratio and unskilled wage) as regressors of $\boldsymbol{Z_{ijlt}}$. ADB (2017) found that older companies are more likely to join in GVCs as they tend to have better infrastructure and performance to overcome the sunk costs of GVCs. We choose the lagged one-period of firm's age as the excluded variable that affects firms' entering decision but has no impact on the extent of participation in GVCs.

The estimation results are shown in Table (4.6). The 1^{st} step of Heckman two-step selection model shows firms with higher productivity[29] are more likely to participate in GVCs. The capital-intensive firms, state-owned firms, and foreign firms also have a higher possibility of entering the GVCs. Older firms are more likely to enter the GVCs than young firms. The large-scale firms are less likely to participate in GVCs than small companies, but they tend to have higher FVAR once they entered. The inverse Mills ratio is significant at the significance level of 0.05, rejecting the null hypothesis that there is no endogenous problem in the estimation.

The Heckman two-step selection model predicts the fitted value of FVAR conditional on the unobserved self-selection effect. The outcome equation of FVAR after controlling for the

endogenous processing trade's impacts on productivity

[29] We use the approach ofOlley and Pakes (1992) to estimate the productivity of firms. We also adopt the methodology of Petrin and Levinsohn (2012) to measure the alternative productivity in the robustness check

Table 4.6: Heckman Two Step Estimation Results

	1^{st} Step	2^{nd} Step
	$Pr(Enter)$	FVAR
lagged size	-0.009**	0.004***
	(0.004)	(0.001)
lagged K/L	0.090***	0.030***
	(0.003)	(0.001)
lagged SOE	0.147***	-0.022***
	(0.018)	(0.008)
lagged unskilled wage	0.144***	-0.015
	(0.054)	(0.020)
lagged foreign	0.690***	-0.020**
	(0.008)	(0.008)
lagged age	0.001***	
	(0.000)	
lagged TFP by OP	0.515***	
	(0.026)	
Constant	-2.797***	0.554***
	(0.479)	(0.181)
Inverse Mills Ratio		-0.375***
		(0.022)
Year Fixed Effect	Yes	Yes
Sector-Province Fixed Effect	Yes	Yes
Observations	152793	152793

Note: Standard errors in parentheses. $*p < 0.10, **p < 0.05, ***p < 0.01$. Column(1) reports the first stage of Heckman two-step regression. $Pr(Enter)$ refers the possibility of engaging in GVCs. Column (2) shows the $2nd$ step of Heckman regression. Both columns control for the time fixed effects and sector-province specific fixed effects.

self-selection effect is written as follows:

$$FVAR_{ijlt} = E(FVAR_{ijlt}|Z_{ijlt}) + \epsilon_{ijlt},\ with\ E(\epsilon_{ijlt}|Z_{ijlt}) = 0 \tag{4.32}$$

We reestimate the baseline model with the predicted FVAR following the empirical specification as below:

$$
\begin{aligned}
ln\bar{w_{ijlt}} = \gamma_0 + \gamma_u lnw^u_{jlt} + \gamma_1 \theta_{ijlt} E(FVAR_{ijlt}|Z_{ijlt}) + \gamma_2 \theta_{ijlt} F\_Upstreamness_{ijlt} \\
+ \boldsymbol{\gamma X_{ijlt}} + \sigma_i + \sigma_{jl} + \sigma_t + \epsilon_{ijlt}\theta_{ijlt}
\end{aligned}
\tag{4.33}
$$

where $E(FVAR_{ijlt}|\boldsymbol{Z_{ijlt}})$ is the fitted value of FVAR, which absorbs the unobserved self-selection effects. $F\_Upstreamness_{ijlt}$ represents the firms' position in GVCs. It's challenging to find a perfect instrument for the upstreamness. Inspired by Amiti and Davis (2011) and Chen et al. (2017), we use the one-year lag of upstreamness as the instrument of GVC position. The lagged upstreamness is less likely to be affected by the current wage, which eliminates the reverse causality between upstreamness and wage inequality. We report the 2SLS estimation results with fitted FVAR and instrument for upstreamness in Table (4.7).

Column (1) of Table (4.7) reports the coefficients of wage determinants with the FVAR fitted value and the instrument of upstreamness. Column (2) demonstrates the regression results with the interactions of skill share. The coefficient of fitted FVAR interacted with skill share is significant and positive, which is consistent with the baseline results. The interaction between upstreamness and skill share also keeps significantly positive, suggesting moving up to upstream sectors raises firms' wage premiums with more skilled workforces. The 2SLS estimation results of the other control variables also keep robust to the baseline estimation, which confirms that large-scale and capital-intensive firms have wider wage inequality than the other firms. We also consider the heterogeneity of processing firms in determining wage premiums in column (3). The triple interaction among the wage premium, fitted FVAR and processing dummy turns to be insignificant, suggesting the opposite result of processing dummy in the baseline model may be due to endogeneity.

We also test the validity of instruments as shown at the bottom of the table (4.7). The Kleibergen-Paap rk LM statistic reports the null hypothesis that the excluded instrument is relevant to the endogenous regressors is rejected at the 1% significance level. The Cragg-Donald

Wald F statistic and Kleibergen-Paap Wald F statistic also reject the null hypothesis of the weak instrument at the 1% significance level, suggesting the instrument is strong and valid. As the model is just identified, we do not report the over-identification test in the table.

4.4.3 Robust Estimates

4.4.3.1 Mechanism

In this section, we provide more detailed evidence on how GVC participation or GVC upgrading improves the skill wage premium within firms. As shown in theory, importing intermediate inputs lowers the marginal costs of firms and increases their profits, which enlarges the wage inequality between skilled and unskilled labor. Upgrading in GVCs requires higher productivity of skilled labor. In order to elicit the efforts of skilled workers, the upgrading firms have to commit a higher wage for the skilled workforces, which increases the wage premium of skills. The fair wage model has tied firms' wage premium with their GVC activities by adjusting profits and productivity. In this section, we examine the mechanism of the model with fair wage hypothesis empirically.

Inspired by Chen et al. (2017), we use the value-added per worker as a proxy for labor productivity and include its interaction with the FVAR and upstreamness in the empirical model. The labor productivity interactive coefficients are expected to be significantly positive, indicating rising FVAR or upgrading in GVCs improve firms' wage premium of skills via increasing productivity. Moreover, we measure the firm's average profit by calculating the profit per worker at the firm level. We also interact the average profit with FVAR and upstreamness. According to the fair wage hypothesis, profitable firms are more likely to pay high wages to skilled workers. Thus the coefficients of interactions between GVC indicators and average profit are also expected to be positive as using more foreign value-added and upgrading in GVCs increase the skill premium via raising profits. We re-estimate Equation (4.28) with the new interactions using the 2004 data and 2000-2006 panel data respectively. The results are shown in Table (4.8).

Table 4.7: 2SLS Estimation with Fitted FVAR, 2000-2006

	(1)	(2)	(3)
		× Skill share	× Skill share ×processing
ln unskilled wage	-0.096*	-0.106*	-0.106*
	(0.058)	(0.057)	(0.057)
Skill share	-0.135***	-1.586***	-1.584***
	(0.032)	(0.216)	(0.216)
$E(fvar \vert Pr(enter))$	2.140***	1.804***	1.809***
	(0.064)	(0.072)	(0.072)
upstreamness	-0.050***	-0.063***	-0.063***
	(0.008)	(0.009)	(0.009)
ln size	0.035***	-0.006	-0.006
	(0.004)	(0.005)	(0.005)
ln K/L	0.029***	-0.017***	-0.017***
	(0.003)	(0.004)	(0.004)
age	0.013***	0.005	0.005
	(0.004)	(0.003)	(0.003)
Foreign ownership	-0.349***	-0.261***	-0.262***
	(0.022)	(0.020)	(0.020)
Processing firm	-0.245***	-0.239***	-0.236***
	(0.013)	(0.015)	(0.015)
SOE	0.650***	0.702***	0.702***
	(0.055)	(0.056)	(0.056)
Skill share× E(fvar*—Pr(select))		1.972***	1.984***
		(0.394)	(0.394)
Skill share× upstreamness		0.087**	0.086**
		(0.044)	(0.044)
Skill share× lnsize		0.304***	0.304***
		(0.022)	(0.022)
skill share × lnK/L		0.380***	0.380***
		(0.023)	(0.023)
skill share× age		0.096***	0.096***
		(0.010)	(0.010)
skill share× foreign		-0.571***	-0.569***
		(0.107)	(0.107)
skill share× processing		-0.141	
		(0.122)	
skill share × SOE		-0.898***	-0.898***
		(0.187)	(0.187)
skill share × upstreamness× processing			0.057
			(0.091)
skill share× $E(fvar \vert Pr(enter))$× processing			-1.060
			(0.805)
Constant	8.253***	8.492***	8.486***
	(0.539)	(0.530)	(0.530)
Kleibergen-Paap rk LM statistic		2.2e+04***	1.2e+04***
Cragg-Donald Wald F statistic		6.0e+05***	1,9e+05***
Kleibergen-Paap Wald F statistic		2.5e+05***	2.9e+05***
Year Fixed Effect	Yes	Yes	Yes
Sector-Province Fixed Effect	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes
Observations	125734	125734	125734
R2	0.177	0.197	0.197

Note: Standard errors in parentheses. $*p < 0.10, **p < 0.05, ***p < 0.01$.

Column (1) reports the OLS regression using the 2004 cross-sectional data with variables interacted with labor productivity. The coefficient of interaction between FVAR and labor productivity is significantly positive, suggesting rising FVAR leads to a higher wage premium of skills via increasing labor productivity. Similarly, the coefficient of upstreamness interacted with log value-added per worker is also significantly positive. It means that upstream firms are more productive than the downstream firms with larger wage premiums. Column (2) explores the impact of GVC activities on wage inequality via adjusting firms' profits. The significantly positive coefficient of FVAR interacted with the log of average profit suggests firms with higher FVAR tend to be more profitable and have larger wage inequality between skilled and unskilled workers. Moreover, we also observe upstream firms have wider wage inequality than the downstream firms with higher average profits. Columns (3) and (4) use the panel data of 2000-2006 to explore the mechanism of GVCs affecting the firm-level skill premium. We still use the fitted value of FVAR from the Heckman two-step estimation to control for the self-selection effect and use the one-year lagged upstreamness as the instrument. Again, the 2SLS estimation results are consistent with the OLS estimates using 2004 data. The coefficients of FVAR and upstreamness interacted with labor productivity are statistically significant and positive. Moreover, the interactions between GVC indicators and average profit, in column (4), are statistically significant and positive. Both results confirm the fact that rising firms' FVAR or upstreamness of GVCs boost their skill wage premiums via improving profits and hence labor productivity of firms.

4.4.3.2 Further Robust Estimates

In this section, we include some additional robustness checks in the estimation using both cross-sectional and panel data. Skills are categorized by education in our previous estimation. In this part, we re-estimate the empirical model with the skill share categorized by occupation. The NBS dataset reports seven occupations of employees: Senior engineers, intermediate engineers, primary engineers, senior technicians, technicians, specialized workers and ordinary workers. According to the International Standard Classification of Occupations (ISCO), we define the engineers and technicians as skilled labor. The average skill share of Chinese manufacturing

Table 4.8: Robustness Checks with Labor Productivity and Profit

	2004 ×ln value-added per worker	2004 × ln profit per worker	2000-2006 ×ln value-added per worker	2000-2006 ×ln profit per worker
	(1)	(2)	(3)	(4)
ln unskilled wage	-0.792	-1.487**	-0.118**	-0.120*
	(0.743)	(0.724)	(0.055)	(0.065)
FVAR	-0.202***	0.103***	-0.841***	1.378***
	(0.069)	(0.037)	(0.162)	(0.095)
Upstreamness	-0.253***	-0.087***	-0.148***	-0.079***
	(0.043)	(0.025)	(0.023)	(0.011)
ln value-added per worker	0.033		-0.024	
	(0.051)		(0.027)	
ln profit per worker		0.053		-0.014
		(0.037)		(0.020)
skill share	-0.644***	-0.570***	-0.209***	-0.218***
	(0.060)	(0.071)	(0.030)	(0.033)
ln size	-0.121***	-0.025**	-0.143***	0.003
	(0.021)	(0.013)	(0.011)	(0.006)
age	0.001	0.034***	-0.018***	0.008*
	(0.004)	(0.002)	(0.004)	(0.005)
foreign ownership	0.025	0.043	0.243***	-0.144***
	(0.058)	(0.027)	(0.048)	(0.030)
processing	-0.017	-0.316***	-0.088**	-0.176***
	(0.061)	(0.033)	(0.038)	(0.016)
SOE	0.131	0.495***	0.659***	0.920***
	(0.207)	(0.100)	(0.116)	(0.082)
interaction with fvar	0.112***	0.069***	0.745***	0.011***
	(0.018)	(0.013)	(0.039)	(0.001)
interaction with upstreamness	0.052***	0.027***	0.024***	0.010***
	(0.011)	(0.008)	(0.006)	(0.004)
interaction with lnsize	0.034***	0.017***	0.044***	0.017***
	(0.005)	(0.004)	(0.003)	(0.002)
interaction with age	0.010***	0.004***	0.011***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)
interaction with foreign	-0.012	-0.040***	-0.144***	-0.111***
	(0.015)	(0.011)	(0.012)	(0.009)
interaction with processing	-0.118***	-0.089***	-0.049***	-0.044***
	(0.018)	(0.015)	(0.011)	(0.007)
interaction with SOE	0.078	0.007	-0.016	-0.091***
	(0.054)	(0.036)	(0.027)	(0.022)
Constant	24498	20.417***	8.545***	8.613***
	0.210	(6.193)	(0.525)	(0.609)
Kleibergen-Paap rk LM statistic			2.2e+04***	1.8e+04***
Cragg-Donald Wald F statistic			3.0e+05***	2.4e+05***
Kleibergen-Paap Wald F statistic			1.2e+05***	9.5e+04***
Year FE	NO	NO	YES	YES
Firm FE	NO	NO	YES	YES
Province-sector FE	YES	YES	YES	YES
Observations	24498	18485	125779	103159
R^2	0.210	0.219	0.202	0.205

Note: Standard errors in parentheses. $*p < 0.10, **p < 0.05, ***p < 0.01$. Column (1)-(2) are OLS regression with robust standard errors clustered at firm-level. Column(3)-(4) report the 2SLS regression results with the Heckman corrected FVAR and one-year lagged upstreamness as the instrument. The interacted terms are shown at the top of each column.

firms by occupation turns to be 0.134 in 2004, which is slightly lower than the skill share categorized by education. The estimation results with alternative skill share are shown in column (1) of Table (4.9). The coefficient of interaction between FVAR and the alternative skill share by occupation is positive and statistically significant. It indicates firms with higher FVAR tend to be skilled-intensive and have large skill premium. The coefficient of upstreamness interacted with the alternative skill share is also significantly positive, confirming the fact that upstream firms tend to use more skilled workers and have larger skill wage inequality than downstream firms.

In the Column (2), we estimate the empirical model with alternative variables. As we know, the unskilled wage is measured by the 25^{th} percentile of the average wage by provinces [Chen et al. (2017)]. In this part, we use the rural wage of provinces as an alternative indicator of unskilled wage [30]. We also replace firms' capita-labor intensity with their productivity measured by the Olley and Pakes (1992)'s approach. The new regression results are shown in the second column of the table (4.9). We observe the coefficients keep robust with alternative indicators. Considering the heterogeneity of processing firms in FVAR, we rule out the processing firms from the sample in column (3) and keep processing firms only in the estimation of column (4). The estimation without processing firms is consistent with the baseline results in column (3) that FVAR is positively associated with skill wage premium and upgrading in GVCs improves skill wage premium with more skill workforces. However, the estimation with processing firms in column (4) shows no significant impacts of GVC activities on skill wage premium in 2004.

We also include the alternative indicators of unskilled wage and the capital-labor ratio in the regression of panel data between 2000 and 2006. The results are shown in the column (1) of Table (4.10). The panel data is still regressed with 2SLS using the Heckman corrected FVAR and the lagged one-period upstreamness as instruments. The results confirm that rising FVAR increases skill share and enlarges wage inequality between skilled and unskilled labor. It also conforms to our previous finding that upgrading in GVCs expands the skill wage inequality

[30] The wage of rural areas of each province is collected from the China Rural Household Survey Yearbook, which provides annual survey data of Chinese rural population

Table 4.9: Further Robustness Using 2004 Data

	(1)	(2)	(3)	(4)
	×skill share by occupation	×skill share by occupation with alternative indicators	drop processing	processing only
ln unskilled wage	-0.333	-0.192	0.938**	2.746***
	(0.888)	(0.134)	(0.384)	(0.594)
skill share	-1.027***	-4.455***	-2.002***	-0.869
	(0.342)	(0.669)	(0.394)	(1.907)
FVAR	0.166***	0.155***	0.186***	-0.338***
	(0.026)	(0.025)	(0.032)	(0.075)
upstreamness	-0.092***	-0.125***	-0.071***	-0.122**
	(0.019)	(0.018)	(0.024)	(0.048)
ln size	-0.008	-0.043***	-0.030**	-0.010
	(0.010)	(0.009)	(0.012)	(0.028)
ln K/L	0.038***		0.054***	-0.059***
	(0.007)		(0.009)	(0.018)
ln TFP by OP		2.509***		
		(0.066)		
age	0.044***	0.040***	0.030***	0.028***
	(0.002)	(0.001)	(0.002)	(0.005)
foreign	0.045**	0.121***	-0.083***	0.227***
	(0.020)	(0.020)	(0.024)	(0.061)
processing	-0.378***	-0.277***		
	(0.027)	(0.025)		
SOE	0.262***	0.322***		
	(0.092)	(0.083)	0.475***	0.479
skill share ×FVAR	0.278**	0.190*	(0.097)	(0.352)
	(0.115)	(0.108)	0.443***	1.169
skill share ×upstreamness	0.261***	0.376***	(0.131)	(0.720)
	(0.071)	(0.065)	0.203**	0.108
skill share ×lnsize	0.088**	0.085**	(0.085)	(0.363)
	(0.036)	(0.035)	0.269***	0.355
skill share ×age	-0.021***	-0.016***	(0.045)	(0.216)
	(0.004)	(0.004)	0.373***	0.169
skill share ×lnK/L	0.289***		(0.038)	(0.131)
	(0.035)		0.052***	0.067
skill share ×foreign	-0.542***	-0.618***	(0.009)	(0.044)
	(0.097)	(0.092)	0.001	-0.219
skill share ×processing	-0.041	0.107	(0.114)	(0.501)
	(0.169)	(0.154)		
skill share ×SOE	0.256	0.338	-0.477	-3.535*
	(0.248)	(0.224)	(0.381)	(1.910)
skill share ×lntfpop		2.293***		
		(0.334)		
Constant	10.103	4.303***	-1.126	-14.768***
	(7.784)	(0.924)	(3.122)	(5.142)
Province-sector FE	YES	YES	YES	YES
Observations	24338	24001	20484	3854
R^2	0.205	0.292	0.234	0.172

Note: Standard errors in parentheses. $*p < 0.10, **p < 0.05, ***p < 0.01$.

Table 4.10: Further Robustness Checks Using 2000-2006 Panel Data

	(1) alternative indicators	(2) drop processing	(3) processing only	(4) Pre-WTO period
ln unskilled wage	0.485***	-0.046	0.697**	-0.019
	(0.089)	(0.059)	(0.339)	(0.116)
skill share	-4.850***	-1.549***	-1.682*	-2.104***
	(0.380)	(0.219)	(0.989)	(0.589)
FVAR	0.990***	1.939***	1.240***	2.013***
	(0.063)	(0.079)	(0.191)	(0.170)
upstreamness	-0.104***	-0.065***	-0.069***	-0.145***
	(0.009)	(0.010)	(0.027)	(0.023)
lnsize	-0.040***	-0.008	0.014	-0.015
	(0.004)	(0.005)	(0.014)	(0.011)
age	0.005	0.004	0.016***	0.001
	(0.003)	(0.003)	(0.003)	(0.002)
foreign ownership	-0.043**	-0.302***	0.077	-0.357***
	(0.020)	(0.022)	(0.047)	(0.043)
processing	-0.130***			-0.267***
	(0.015)			(0.030)
SOE	0.817***	0.700***	0.170	0.702***
	(0.055)	(0.056)	(0.145)	(0.064)
lnK/L		-0.005	0.014	-0.031***
		(0.005)	(0.014)	(0.010)
ln TFP by OP	2.327***			
	(0.186)			
skill share ×FVAR	3.461***	1.681***	3.822**	1.633
	(0.327)	(0.406)	(1.714)	(1.214)
skill share ×upstreamness	0.351***	0.301***	0.154	0.318***
	(0.021)	(0.023)	(0.209)	(0.064)
skill share ×lnsize	0.351***	0.301***	0.187*	0.394***
	(0.021)	(0.023)	(0.104)	(0.112)
skill share ×lnK/L		0.364***	0.293***	0.480***
		(0.024)	(0.104)	(0.073)
skill share ×age	0.092***	0.099***	0.071***	0.120***
	(0.011)	(0.010)	(0.024)	(0.011)
skill share ×foreign	-1.022***	-0.488***	-1.206***	-0.934***
	(0.097)	(0.110)	(0.444)	(0.311)
skill share ×processing	-0.167			-0.297
	(0.121)			(0.275)
skill share ×SOE	-0.964***	-0.900***	2.204**	-1.383***
	(0.178)	(0.186)	(1.022)	(0.366)
skill share ×lnTFP by OP	2.327***			
	(0.186)			
Constant	-0.601	7.928***	2.418	7.441***
	(0.735)	(0.541)	(2.670)	(1.047)
Kleibergen-Paap rk LM statistic	1.3e+04***	1.2e+04***	1815.5***	3567.529***
Cragg-Donald Wald F statistic	2.8e+05***	2.4e+05***	3.3e+04***	5.9e+05***
Kleibergen-Paap Wald F statistic	4.9e+04***	4.1e+04***	1.1e+04***	1.9e+04***
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Province-sector FE	YES	YES	YES	YES
Observations	125554	111119	12411	23352
R^2	0.278	0.210	0.165	0.240

Note: Standard errors in parentheses. $*p < 0.10, **p < 0.05, ***p < 0.01$.

with more skilled workforces. Similarly, we drop the processing firms from the sample and re-estimate the empirical model in the column (2). The coefficients keep significant and robust with ordinary companies. We also regress the model using only processing firms in the sample and report the results in column (3). The results show that the coefficient of FVAR interacted with skill share of processing firms is significantly positive, suggesting rising FVAR is also associated with higher wage inequality of skills within processing firms. However, we fail to observe a significant impact of GVC upgrading on firm-level wage premium for the processing firms.

Our sample period contains a special event that China entered the WTO on 11 December 2001. Entering WTO has boosted the process of China's trade liberalization and deepened the integration of China into the global economy. China's tariff on manufacturing products was lowered from 35% to 17% in the first five years. Moreover, the foreign producers, which were forbidden to ship directly to Chinese firms, are allowed to export without the trade dealers since 2002. To ensure our results not driven by these factors, we add a placebo test that limits the estimation in the pre-WTO period (2000-2001) in the column (4). The estimation of the sub-sample shows that the coefficients are similar to the baseline results, suggesting entering WTO has no significant effect on our results.

4.5 Conclusion

Despite the massive literature on trade and wage inequality, there are few studies on the impacts of global value chains(GVCs), featured by vertical specialization and intermediate trade, on wage inequality within firms. In this chapter, we provide a theoretical and empirical study on how participating and upgrading in GVCs affect the wage inequality between skilled and unskilled labor. Inspired by Amiti and Davis (2011) and Chen et al. (2017), we develop an open economy model of heterogeneous firms with intermediate input trade and different types of skill inputs to investigate the wage premium changes associated with firms' GVC activities. Firms GVC activities include GVC participation, in which firms import intermediate inputs for the production of exports, and GVC upgrading by which firms move to more upstream sectors along the global value chains. In this chapter, skilled workers are assumed to have higher bargaining power over wages than unskilled workers according to firms' performance. Profitable firms tend to pay higher wages to skilled labor. Our model predicted that importing intermediates increase firms' profits and raises firms' wage inequality between skilled and unskilled workers. All else equal, firms with a higher share of foreign value added in exports (FVAR) tend to have larger skill wage premiums. Moreover, moving to upstream sectors also enlarges the firm's wage inequality via increasing the productivity of skilled workers.

Using detailed China's firm- and transaction- level data during 2000-2006, we measure the share of foreign value added in exports (FVAR) at firm level as a proxy for firms' backward participation in GVCs [Koopman et al. (2014)]. We further estimate firms' upstreamness as the proxy for their GVC position. We observe a declining share of foreign value-added content in exports (FVAR) of Chinese manufacturing firms, which is consistent with the estimation of Kee and Tang (2016). We also find a rising trend of upstreamness for Chinese manufacturing firms, suggesting the Chinese manufacturing firms tend to upgrade from downstream to upstream sectors of GVCs.

As the firm-level data of skills is only available in 2004, we introduce the fair wage hypothesis in the model and follow Chen et al. (2017) to develop a Mincer-type econometric approach to estimate the wage premium of firms. The results of this chapter strongly support the predictions of the theory, and they are robust to different estimations and robustness checks. We found that rising FVAR leads to an increase in the skill wage premium of firms with more skilled workforces. Similarly, if a firm moves from downstream to upstream sectors of GVCs, its wage inequality between skilled and unskilled labor would be widened with higher demands for skilled workers.

To the best our knowledge, this chapter is the first research studying the impacts of GVC activities on the wage inequality within firms. Our results have critical policy implications for developing countries. Imported intermediate inputs are necessary substitutes for domestic materials, which increase firms' profits as shown in our model. However, participating in GVCs would enlarge the wage inequality between skilled and unskilled workers. For most developing countries with rising FVAR, this result imposes a dilemma of deepening the integration into GVCs and reducing the wage gaps of skills. Moreover, upgrading in GVCs calls for more productive skilled workers, which imposes new requirements for skilled workforces of emerging economies. Developing countries should tailor their training program for the different level of skills to meet the new demands of participating and upgrading in GVCs.

Chapter 5

Unveiling Servicification of Manufacturing in Global Value Chains

Abstract

This chapter investigates the trend of servicification in global value chains (GVCs). The degree of servicification is measured as the share of service value added in manufacturing exports. Service inputs are either from the domestic market or foreign countries, which are measured by the domestic servicification and the foreign servicification respectively. Using the international input-output tables from 1995 to 2011, we estimate the degree of servicification across 61 countries with a particular focus on Asian nations which have rarely been studied in previous research. We observed an evident trend of servicification in manufacturing in the Asian countries, especially in the 16 countries associated with the Regional Comprehensive Economic Partnership (RCEP). Asian countries tend to have a lower level of domestic servicification but a higher level foreign servicification than OECD countries. We also identified five key factors in driving the trend of servicification. Countries with broader participation and lower positions in GVCs tend to have higher levels of foreign servicification in manufacturing. Improvements in information and communication technology (ICT) also raise the level of foreign servicification. However, countries with a larger supply of service workers, better regulation quality, and less government governance have a higher level of domestic servicification in manufacturing. (*JEL code: F14, F55*)

Key Words: Global Value Chains; Servicification; Manufacturing; Institutions; RCEP

5.1 Introduction

As opposed to the traditional belief that the manufacturing sectors are relatively independent of service sectors, the recent trends in OECD countries have revealed that manufacturing industries are increasingly using service inputs in production as well as selling services directly to the consumers[OECD (2014), Lodefalk (2017), Boddin and Henze (2014)]. The increasing use, production and sales of services in the manufacturing sectors are described as the servicification of manufacturing [Elms and Low (2013), Lodefalk (2010)].

Servicification is a crucial activity of manufacturing for several reasons. Firstly, services activities are enablers of countries to participate, connect and integrate into the global value chains (GVCs [Lodefalk (2017)]. For example, the call centers in India and Philippines provide low-cost services for overseas manufacturing firms in GVCs. Secondly, services are recognized as "linkages" or "glues" of GVCs, which facilitates the global production of manufacturing products by connecting services such as information and communication services (ICT), transportation, logistics, etc. [Gereffi and Fernandez-Stark (2011)]. Thirdly, servicification of manufacturing is also seen as a renewal of industrialization in the OECD countries, which creates value-added to manufacturing firms with more service revenues and profits [Kizu et al. (2016), Boddin and Henze (2014)]. Moreover, servicification enables manufacturing firms of OECD countries to upgrade from low-end fabrication tasks to high-end service jobs (e.g., the factory-less goods producers), which upgrades their positions in the value-added activities of GVCs [Lodefalk (2017)]. Lastly, servicification also improves the performance of manufacturing firms with more innovation, higher productivity [Nordås (2010),Anukoonwattaka et al. (2015)], more diversified exporting varieties [Kelle (2013)], better access to foreign market [Lodefalk (2017)] and larger profits [Mastrogiacomo et al. (2017)].

Despite the high importance of services in manufacturing, the level of servicification was difficult to measure using traditional trade statistics. For example, services account for about 20 percent of world trade in the balance of payment terms (BOP), while taking up almost 70 percent of world GDP in the national accounts [Lanz et al. (2015)]. The significant discrepancy is partly due to the widespread use of service inputs in manufacturing production. The recent release of international input and output tables (IIOTs) enables us to identify the role of services in manufacturing sectors [Timmer et al. (2015)].The international input and output tables (IIOTs) decompose the global production into value-added terms and distinguish the value-added content into direct services exports (service trade in the balance of payment account) and indirect service exports (service value-added embodied in manufacturing trade) [Koopman et al. (2014), Timmer et al. (2015)]. The new value-added trade data re-evaluates the role of services in the global production by capturing the input-output linkages across sectors and borders[Lanz et al. (2015), Anukoonwattaka et al. (2015)]. This chapter adopts the value-added approach to measure the level of servicification as the share of service value-added (service content) in manufacturing exports (SVA).

The trend of servicification has been well recognized in the OECD countries [Lodefalk (2010)]. Services accounted for around 35% of the total value-added of manufacturing exports for OECD countries in 2011, and the share was up to 40% for European countries [Lanz et al. (2015)]. Lodefalk (2014) found an evident trend of servicification of Sweden manufacturing firms. Boddin and Henze (2014) observed a dramatic increase in the share of service occupations in the manufacturing sectors. Crozet et al. (2014) showed a similar trend of servicification in manufacturing for French firms. However, there is only a limited number of studies focusing on the servicification of manufacturing in the developing countries, especially in the Asian countries. In fact, service and manufacturing activities related to GVCs have been more intensive in the Asia region than in the rest of the world, implying the high importance of examining the role of services in this region [Anukoonwattaka et al. (2015)]. Baldwin et al. (2015) found the value-added source of manufacturing products has shifted decisively away from manufacturing activities towards service activities since the 1990s in Asian countries, which suggests an emerging trend of servicification in this region. However, they did not explore the determinants of servicification and its linkage with GVCs. This chapter will fill this gap by examining the trend of servicification of manufacturing in Asian economies and investigates the determinants of servicification with a comparison between OECD and Asian countries.

In this chapter, we use the share of service value-added in manufacturing exports (SVA) to measure the level of servicification in manufacturing. The service value added of manufacturing could source either domestically or internationally. The ratio of domestic service value-added content in manufacturing exports (DSVA) is defined as domestic servicification. Similarly, the share of foreign service value-added content in manufacturing exports (FSVA) measures the level of foreign servicification, which estimates the contribution of foreign service suppliers to domestic manufacturing exports. The FSVA is also an alternative indicator to measure the extent of service offshoring in the manufacturing sectors.

In this chapter, we estimate the domestic and foreign servicification at the sectoral level across 61 countries with regard to GVC activities from 1995 to 2011. We compare the servicification levels for the Asian countries, in particular, those associated with the Regional Comprehensive Economic Partnership (RCEP), with that of the OECD countries. By decomposing the value-added content of manufacturing exports by sources, we find the main value-added source activities in manufacturing industries have shifted away from manufacturing tasks to service tasks for most Asian countries. The RCEP countries tend to have a lower domestic servicification level whereas a higher foreign servicification level as compared to the OECD countries. This chapter further explores the possible driving factors of servicification, including service labor supply, economic growth, improvement in information and telecommunications technology (ICT), institutions, and GVC activities [Gereffi and Fernandez-Stark (2011), Baldwin et al. (2015), Miroudot (2017)]. We distinguish the effects of these determinants on the domestic servicification and foreign servicification and highlight the impacts of GVC participation and upgrading on the servicification of manufacturing.

The rest of chapter is organized as follows. Section 2 examines the role of services from a value-added perspective in GVCs and highlights the recent trends of servicification of manufacturing in Asian countries. Section 3 discusses the driving factors of servicification and identifies the impacts of these factors on the domestic servicification and foreign servicification in the empirical model. Section 4 presents the empirical results and robustness check. Section 5 concludes and provides the policy implications of this study.

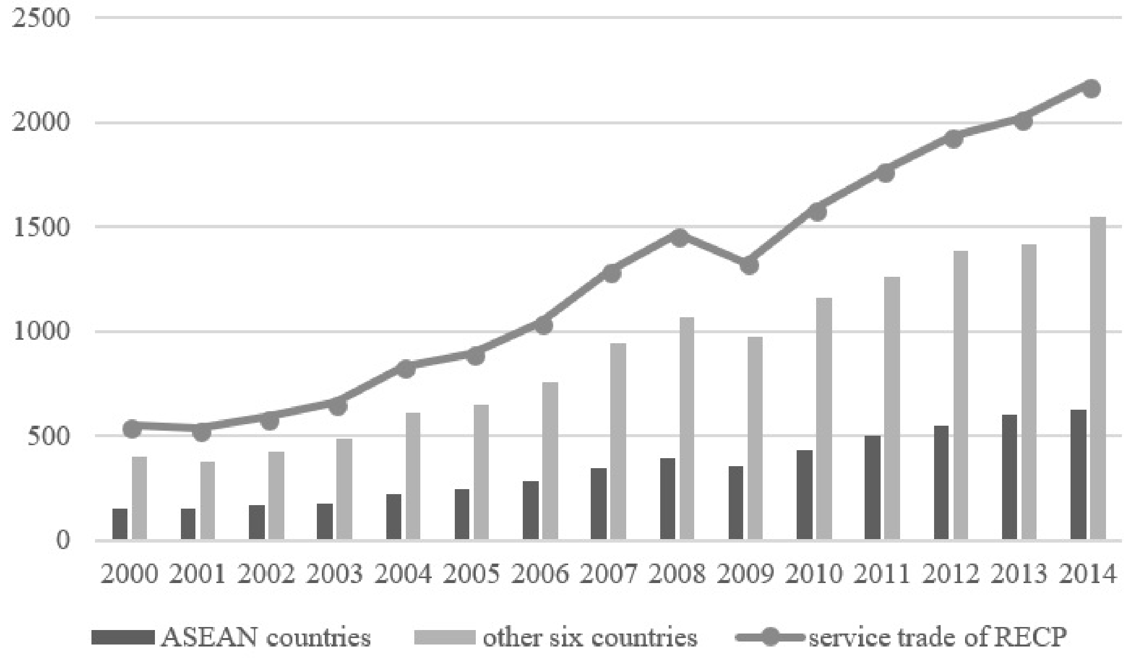
5.2 Services in Global Value Chains

5.2.1 Service Value Chains in Asian countries

Over the past two decades, there has been a sharp increase in the number of Free Trade Agreements (FTAs) among Asian countries, which significantly facilitates trade and investment in this region. In 1992, the first major free trade agreement was signed among the Southeast Asian countries which formed the ASEAN Free Trade Area (AFTA). In recent years, ASEAN has completed vital bilateral FTAs with six major trading countries that include China, Japan, Korea, India, and Australia-New Zealand respectively. In 2012, ASEAN started the larger regional FTA named the Regional Comprehensive Economic Partnership (RCEP) including all the six FTAs. The RCEP is expected to cover most of the Asian countries with a combined GDP of $17 trillion, accounting for about 40 percent of world trade[Rahman and Ara (2015)]. One of the key objectives of RCEP is to promote the freer trade of goods and services with more investment among the FTA members.

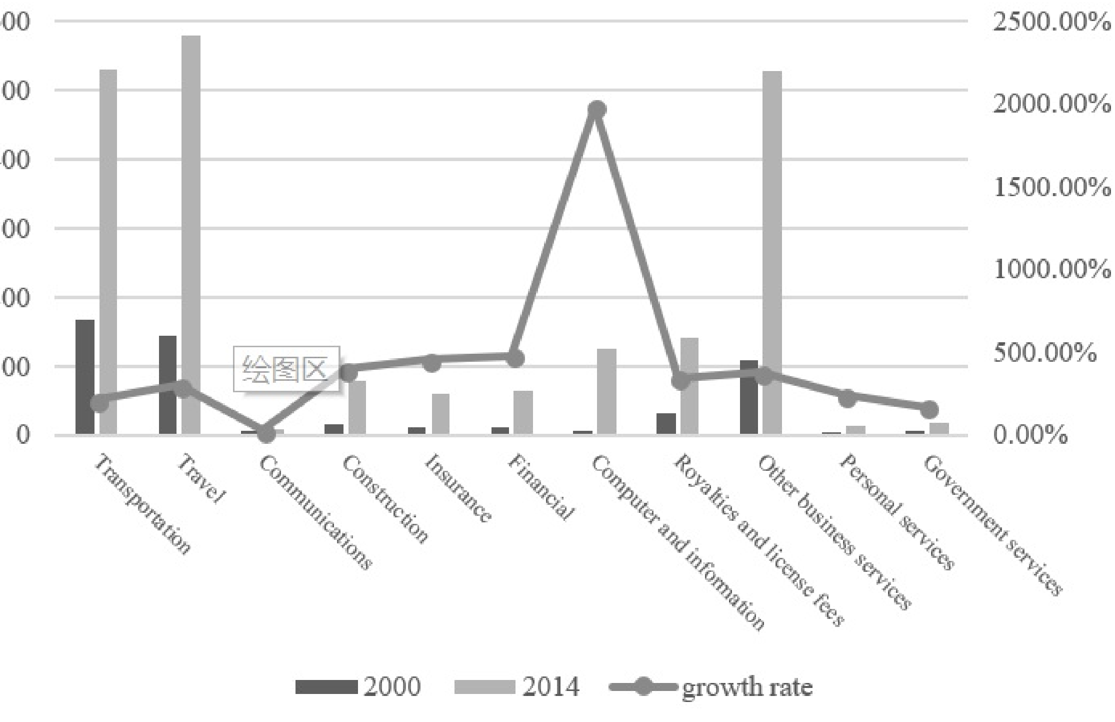
The growth of service trade in RCEP countries is shown in Figure (5.1) and (5.2). We observe a strong growth of service trade for RCEP countries, which has almost quadrupled in 2014 as compared to 2000. Among the RCEP members, the ASEAN countries expanded the service trade from US$150 billion in 2000 to nearly US$630 billion in 2014, with an average annual growth rate of almost 11.8%. Meanwhile, the other six RCEP members except for ASEAN economies increased their service trade from the US $396 billion in 2000 to the US $1550 billion in 2014, with an average annual growth rate of 10.6%.

In Figure (5.2), we observe a strong growth of service trade of different sectors between 2000 and 2014. Transportation, tourism, and other business service sectors have experienced the



Source: UN ComTrade Database. The other six countries include China, Japan, Korea, India, Australia, and New Zealand, which belongs to RCEP but outside ASEAN.

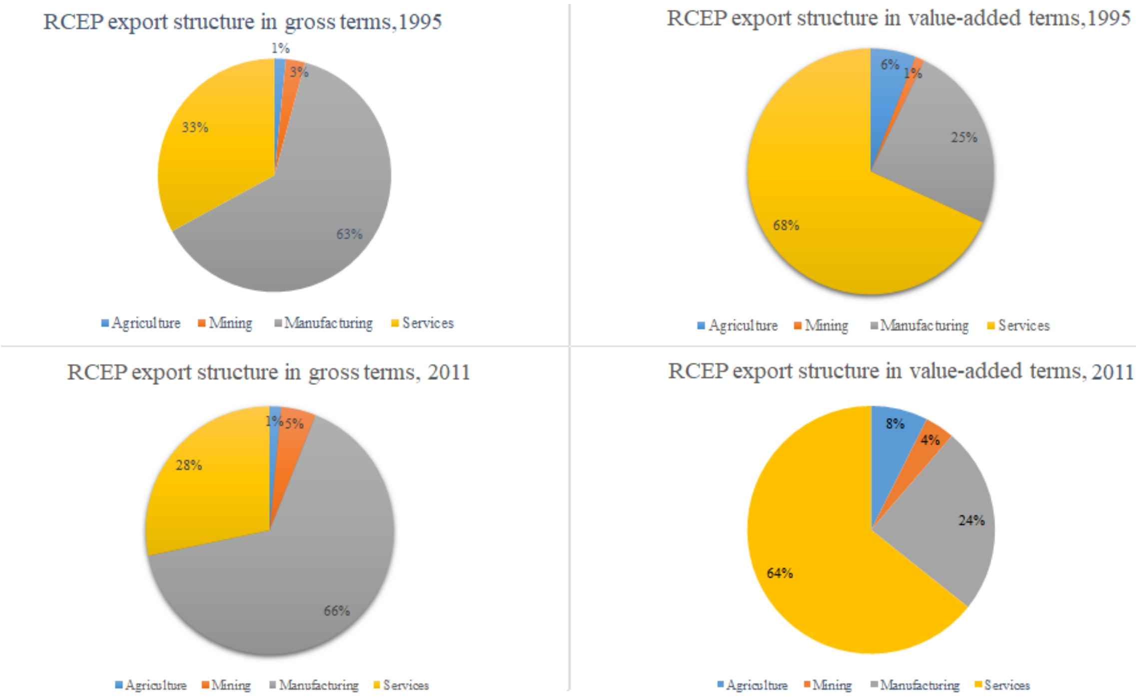
Figure 5.1: The Service Trade of Asian Countries (RCEP), 2000-2014 (US$ billion)



Source: UN COMTRADE Database.

Figure 5.2: The Service Trade of Asian Countries (RCEP) by Sectors, 2000-2014 (US $billion)

most significant increase in services trade of the RCEP countries. We also observe positive growth in the services trade of sectors such as construction, finance and insurance, computer and information services, royalties and license and other business services. Across the sectors, the computer and information service sector has experienced the fastest growth in service trade as compared to the other sectors.

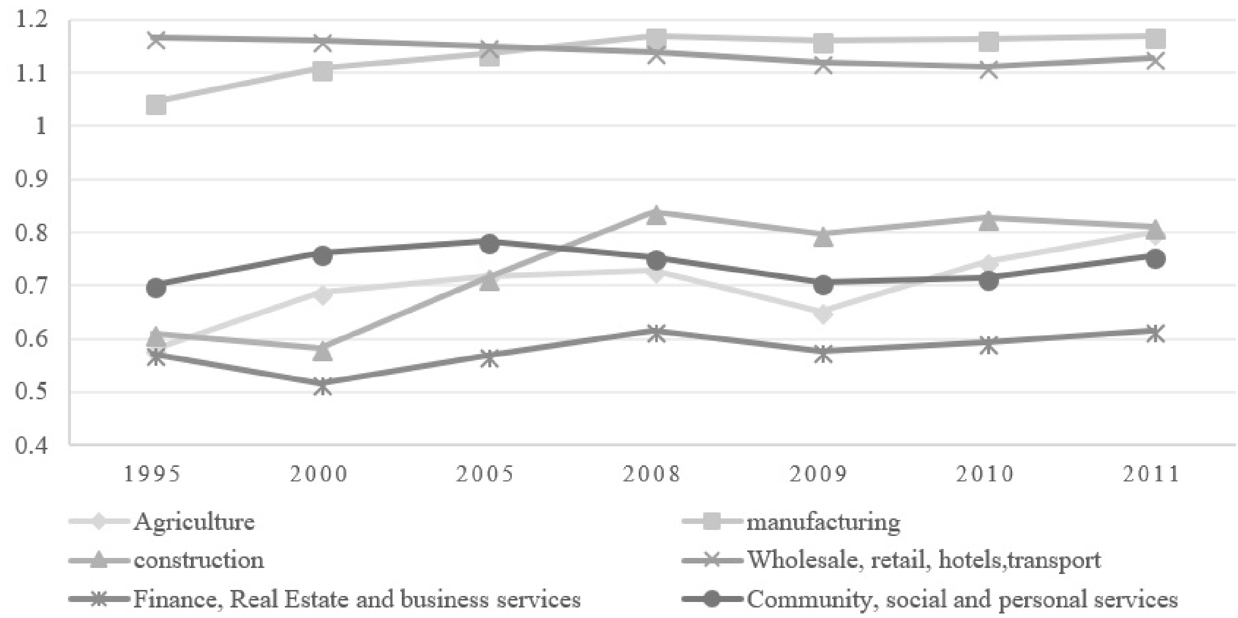


Source: OECD TIVA database

Figure 5.3: Export Structure Comparison of RCEP Countries,1995-2011

The dramatic growth of services trade reveals the importance of services in the Asian countries. Moreover, the RCEP countries, especially its Asian members, are increasingly structured around the global value chains activities in the recent decades [De Backer and Miroudot (2014)]. The global value chains have fragmented production across borders, with each country specializing in several different tasks. Services tend to play a complex and essential role in the GVCs, which is significantly underestimated by the cross-border service trade. The estimated share of service trade is just over one-fifth of total trade in 2011[WTO (2016)], but the estimate will be very different if considering the content of services embodied in manufacturing products, which is traded indirectly across borders through trade of goods. In Figure (5.3), we decompose the composition of the export structure by gross exports and value-added exports. As shown in Figure (5.3), in 1995, the share of service trade in total trade of RCEP countries account for 33% in gross terms, while it accounts for 68% in value-added terms. Even though the share of services has slightly declined in both measurements from 1995 to 2011, it is still more substantial than the other components of economic activities.

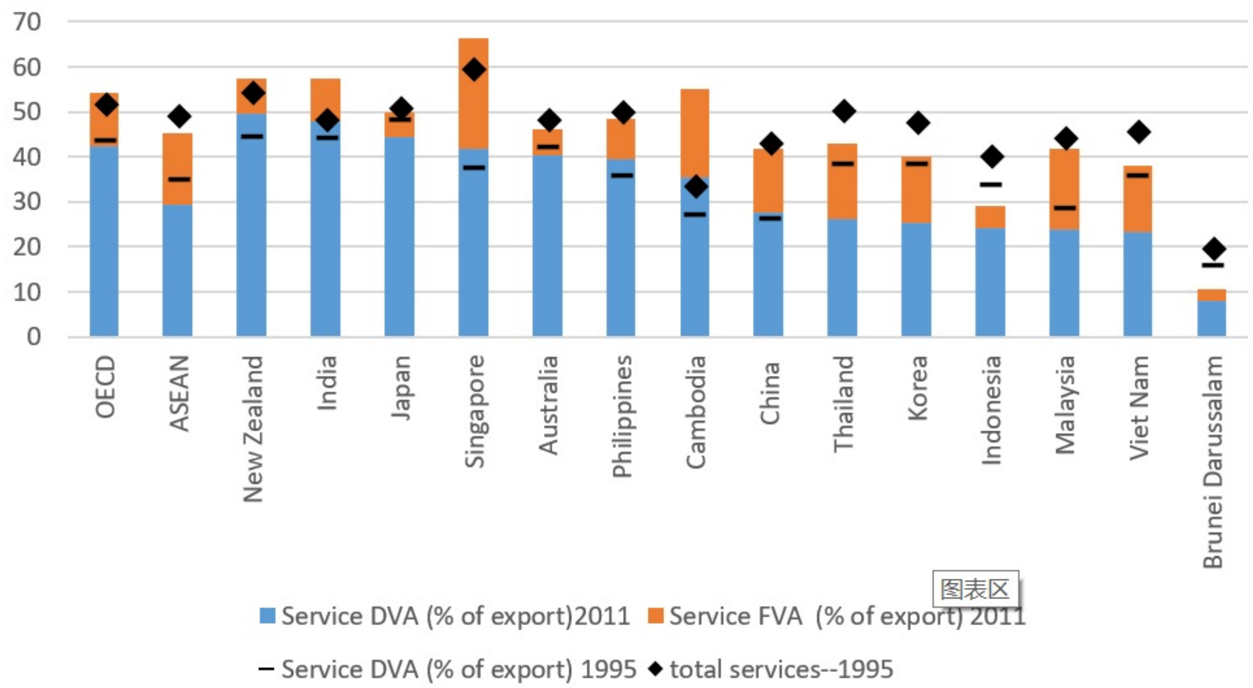
The vast discrepancy between gross trade and value-added trade has three possible reasons. Firstly, the traditional service trade only records service transactions across borders. However, it hardly captures the value of service inputs embodied in manufacturing, which are exported indirectly by trade in goods. Secondly, the traditional service trade generates the double-counting problem because service inputs would cross borders several times through the global value chains. Lastly, service trade contains not only the domestic service value-added content but also the foreign service value-added from the other countries. The foreign service value added in exports represents the extent of service offshoring, which should be eliminated from the domestic value of exports. In a nutshell, traditional service trade fails to capture the role of services in manufacturing and we need to re-estimate the importance of services from a global value-added perspective.



Source: Data from OECD TIVA (2015) database and calculated by the authors.

Figure 5.4: New RCA Index of RCEP Countries

A new Revealed Comparative Advantage Index (RCA) based on the value-added approach was developed by Koopman et al. (2014) to re-estimate the importance of services in trade. As opposed to the traditional RCA, the new RCA excludes the foreign value-added content,the pure double-counting terms, and the domestic value added generated in the other sectors[Koopman et al. (2014)]. It corrects the distorted image of services in international production patterns[Koopman et al. (2014)]. Figure (5.4) describes the new value-added based RCA index for RCEP countries (the index is given as the average of new RCA of the RCEP countries). The new RCA for manufacturing sectors in RCEP countries is 1.05 in 1995 and rise to 1.17 in 2011, which indicated an increasing comparative advantage of RCEP counties in manufacturing industries. Also, we found RCEP countries have a comparative advantage in traditional service sectors, including wholesale, retail, hotel, restaurant, and transportation sectors. However, RCEP countries have no comparative advantage in advanced services such as construction, finance, real estate and business services, or community,social and personal services.



Source: Data from OECD TIVA (2015) database and calculated by the author. DVA represents the domestic service value-added share , and FVA denotes the foreign value-added share.

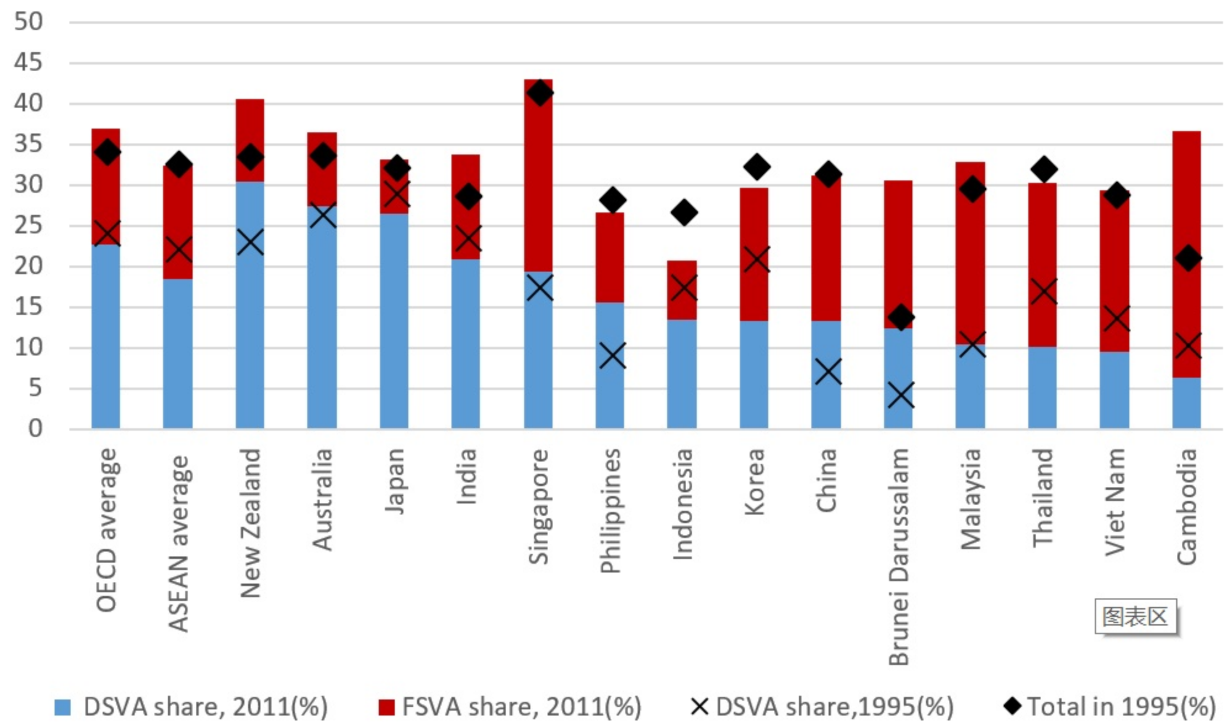
Figure 5.5: Service Value Added of Gross Export (%) for RCEP Countries

The share of service value added in the gross exports of the RCEP countries is given in Figure (5.5). From the value-added perspective, services accounted for 54% of total exports for OECD countries, while taking above 45% of the gross exports of ASEAN countries. Singapore had the highest proportion of service content in gross exports of about 66%. However, around 25% of the service value added in Singaporean exports originated from overseas as measured by the share of foreign service value-added content in exports. We also observed the share of domestic service value-added in exports had increased in New Zealand, India, Singapore, Cambodia, Philippines, and China from 1995 to 2011. However, there was a decline in using domestic services for exports in Japan, Australia, Thailand, Korea, Indonesia, Vietnam, Malaysia and Brunei Darussalam. Most of ASEAN countries used more foreign services instead of domestic services in gross exports with their average domestic service value-added share decreasing from 35% in 1995 to 29% in 2011.

5.2.2 Servicification of Manufacturing

Some studies have considered servicification as an essential structural shift in domestic and international production networks [Lodefalk (2010)]. For example, Lodefalk (2014) decomposed the 1975-2005 input-output tables of Sweden and found that the service input share in manufacturing had doubled from 12% in 1975 to 25% in 2005. A similar trend is also found in Germany [Kelle and Kleinert (2010), Kelle (2013), Boddin and Henze (2014)] and France [Crozet et al. (2014)]. However, few studies focused on the servicification of manufacturing in developing countries.

In this chapter, we study the servicification of manufacturing in the RCEP countries and compare the trend of servicification between RCEP and OECD countries. Following the previous studies, the servicification index is calculated as the share of service value added in manufacturing exports (SVA). The importance of service activities for manufacturing is given in Figure (5.6). On average, service activities accounted for 37% of the total value of manufacturing exports in OECD countries while taking up to 32% in ASEAN countries. It suggested the servicification level in OECD countries was higher than in ASEAN countries. The share

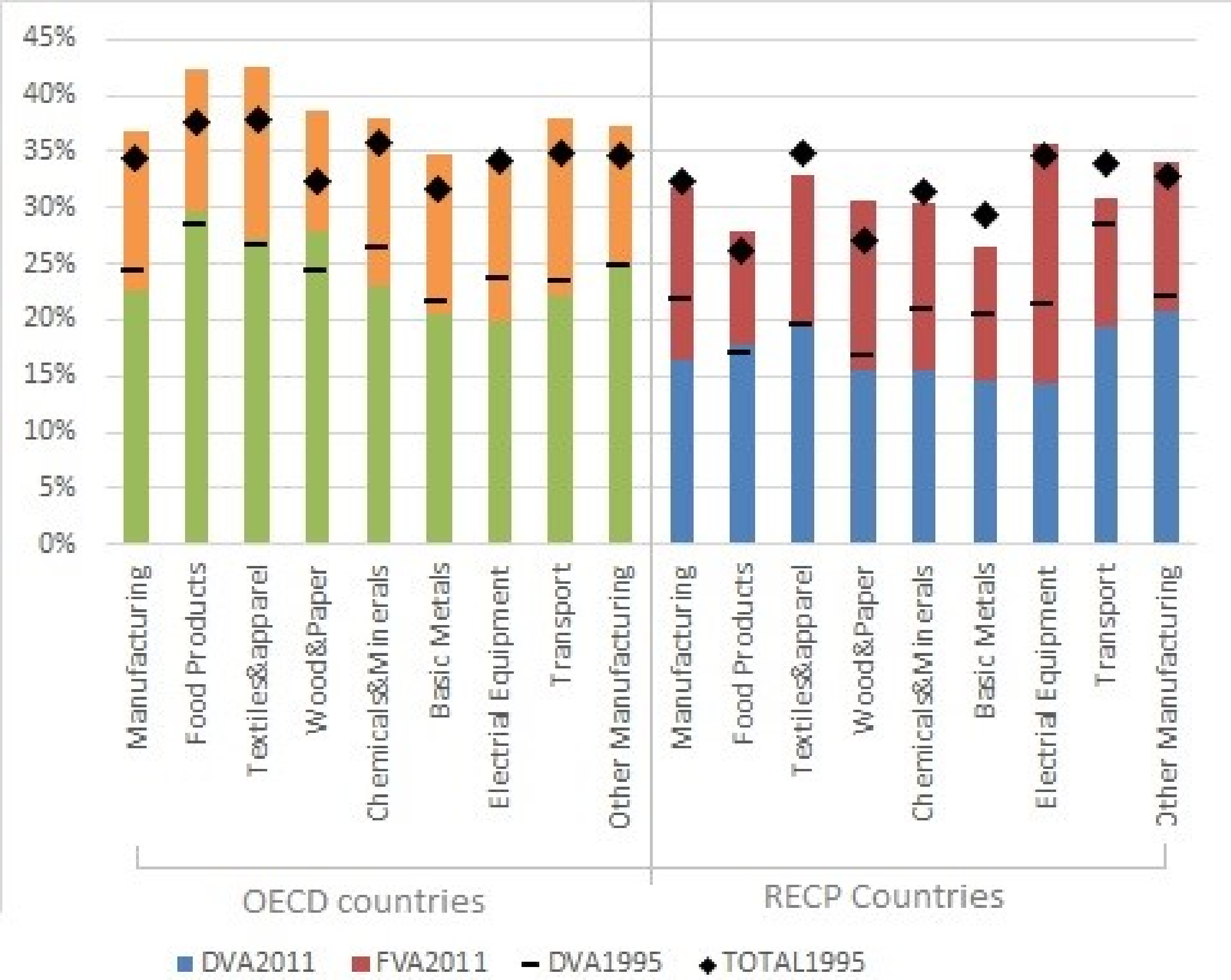


Source: Data comes from OECD TIVA (2015) database and calculated by the author. DSVA represents the share of domestic service value-added in manufacturing exports. FSVA denotes the share of foreign service value-added in manufacturing exports.

Figure 5.6: Share of Service Value-Added in Manufacturing Exports for RCEP Countries

of service value added in manufacturing exports varied from 22% of Indonesia to 47% of Singapore across ASEAN countries. Most of the RCEP countries, except Indonesia, Philippines, Thailand, and Korea had experienced an expansion of servicification in manufacturing since 1995. The rising level of servicification of manufacturing in these countries is mainly due to the increasing use of foreign service content in manufacturing exports, suggesting a high reliance on offshoring services for RCEP manufacturing sectors. The foreign service content in manufacturing could have two sources: the foreign affiliates of domestic multinational companies or the overseas service suppliers. Due to data limitation, it is difficult to tell whether offshoring services are kept in-house [Miroudot et al. (2009)] or outsourced to another firm with arms-length contracts[Contractor et al. (2010)] [1].

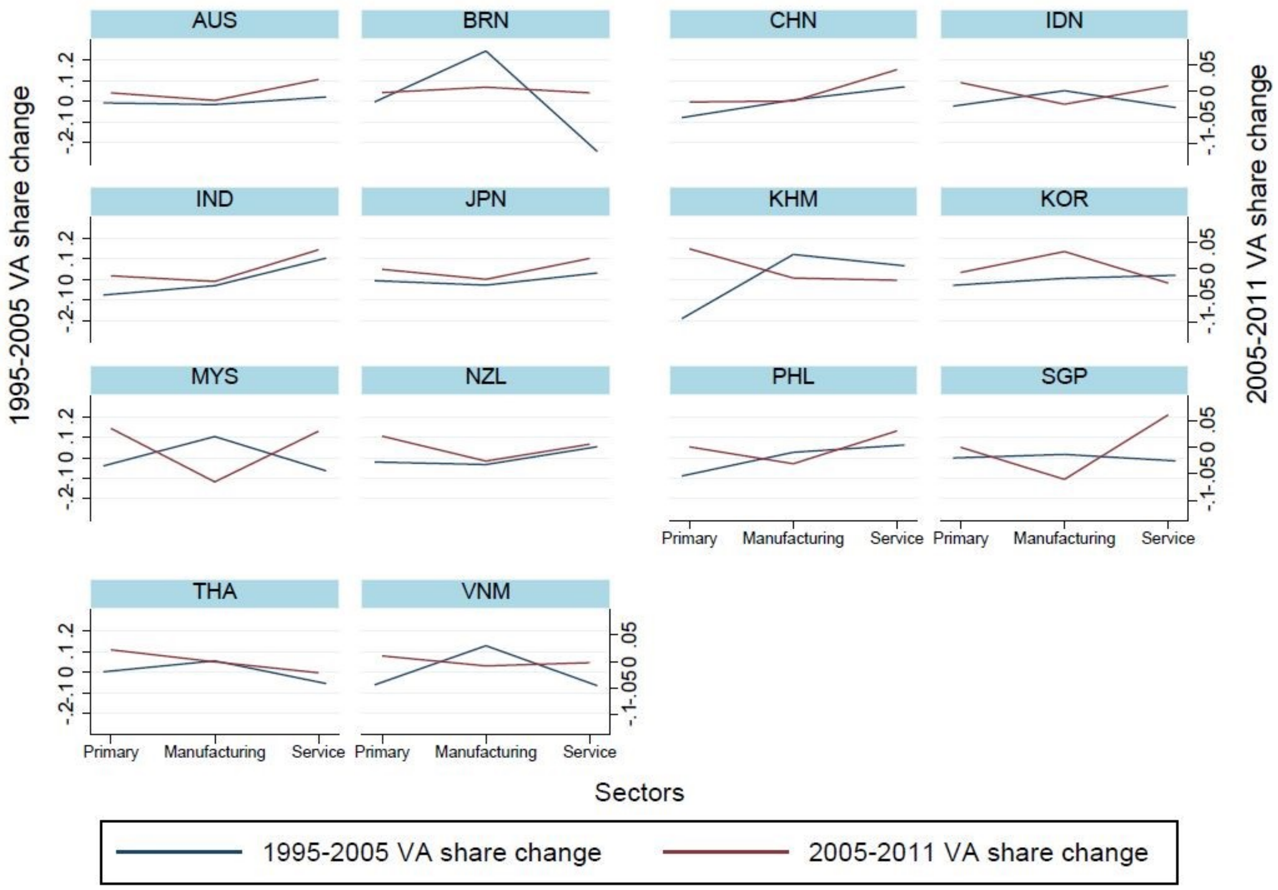
[1]The source of foreign value-added is linked to the service offshoring of multinational organizational activities[Helpman (1984)] and their organization in the global value chains [Fujita and Thisse (2006)]. For more information about the organization of multinationals, please refer to the literature on the growing role of multinational corporations in the global economy [Feenstra (2010)], their offshoring choices within boundaries [Antras and Helpman (2004), Antràs and Chor (2013)] and their organization structure in the global value chains [Alfaro et al. (2017), Antras and Chor (2018)].



Source: Data from OECD TIVA (2015) database and calculated by the author(s). DVA2011 and DVA 1995 represent the level of domestic servicification in 2011 and 1995. FVA2011 measures the level of foreign servicification in 2011. Total1995 refers to the total level of servicification in 1995, which is the sum of DVA1995 and FVA1995.

Figure 5.7: Servicification in Manufacturing Sectors: OECD Versus RCEP Countries

We also compare the sectoral-level servicification of the RCEP economies with that of OECD countries in Figure (5.7). In 2011, the share of service value-added content in manufacturing exports of RCEP countries was nearly 34%, which was slightly lower than that of the OECD countries at 37%. The servicification level of OECD countries increased by 4% between 1995 and 2011, whereas the servicification of Asian countries slightly declined from 32% to 31% during this period. The decline mainly occurred in the textile and apparels, chemical and minerals, base metals and transportation equipment sectors. In contrast, the level of servicification increased in all the manufacturing sectors of OECD countries, in particular for the food products, textile and apparels, wood and paper and transport sectors.



Source: Data from OECD TIVA (2015) database and calculated by the author(s). We track the source of value-added in the manufacturing sector by industries and decompose the origins into primary, manufacturing, and service sectors. Figure 5.8 shows an increasing share of service value-added in manufacturing over the period of 2005-2011, indicating an emerging trend of servicification in RCEP countries.

Figure 5.8: Changes in the Value-added Components of Manufacturing Exports by Source Industries

One of the most commonly used diagrams in describing the trend of servicification in global value chains is the smile curve. In Figure (5.8), we decompose the value-added of manufacturing exports by its source sectors: the primary sector, the manufacturing sector, and the service sector. The trend of servicification could be examined by the prominent changes in the share of the source sectors value-added content in the total value of the manufacturing. During 1995-2005, services had no growth advantage over the manufacturing and primary activities for most RCEP members. In the countries such as Brunei Darussalam, Cambodia, Malaysia, Philippines and Vietnam, manufacturing activities experienced the fastest growth between 1995 and 2005, which acted as the main source of value added for manufacturing exports. However, in recent years during 2005-2011, we observed a stronger growth of services in adding value to manufacturing exports than the other sources. Except for Brunei Darussalam, Cambodia, Korea and Thailand, the value-added source of manufacturing exports had shifted from manufacturing activities towards service activities during 2005-2011. In most RCEP countries, services had the maximum growth rate in the share of value-added content in manufacturing exports, as shown by the "smile curve" of the period 2005-2011 in Figure (5.8). The value-added shifting from manufacturing activities to service content highlights the growing importance of services in the value-added activities of manufacturing sectors, which is also described as the emerging trend of servicification manufacturing of selected Asian countries [2].

The above analyses have confirmed the existence of servicification in manufacturing sectors in RCEP countries as well as OECD economies. Although the servicification level of RCEP countries is slightly lower than that of OECD economies, we do observe a higher foreign servicification level for the RCEP countries. We also find a shift of value-added source from manufacturing activities to services in the manufacturing exports for most RCEP countries, which suggests the rising level of servicification in selected Asian countries. In the next section, we will explore the driving factors of servicification in OECD and RCEP countries. In particular, we will identify the determinants of domestic servicification and foreign servicification with a comparison between the OECD and RCEP countries.

5.3 Empirical Specification

5.3.1 Determinants of Servicification

While some of the unbundling or modularization occurring along the global value chains, servicification may appear by the exigencies of locational dispersion in output and consumption, or by regulatory requirements [Low (2013)]. Moreover, the servicification of manufacturing is seen as a potential opportunity for developing countries to move up in the regional and global

[2]Baldwin and Robert-Nicoud (2014) and Baldwin et al. (2015) defined smile curves as a process that value-added shifted from manufacturing activities towards service value-added activity. In Figure (5.8), we follow their approach to analyze the source of value-added from three sectors. It has shown that most Asian countries have shifted their main source of value-added from manufacturing sectors to service sectors, which is a typical trend of servicification.

value chains[Low (2013)]. Combined with the studies on the motivation of servicification, we identify four possible sources of servicification: (a) reclassification of services[3], (b) strengthening participation in GVCs, (c) motivation to move to the upstream of GVCs, (d) technical and transportation improvement [Baldwin et al. (2015), Low (2013), Lodefalk (2017)].

The reclassification of services has been discussed in the previous analyses regarding the discrepancy between gross trade and GVC trade. Service inputs embodied in manufacturing production were classified as manufacturing exports in gross trade. However, the recent development of the value-added approach makes it possible to decompose the manufacturing exports into value-added terms by sources and thus re-evaluate the role of services in manufacturing. The servicification arising from the reclassification of services mainly blames for statistic errors rather than economic structure changes.

The global value chains (GVCs) have provided an excellent opportunity for the developing countries to deepen their engagement in the global economy. Participating in GVCs specializes countries' production in specific tasks, which strengthens their access to foreign markets. The vertical specialization of GVCs uses a large number of service inputs such as telecommunication, transportation, logistics and R&D services, which link the fragmented production into the global production networks. Concurrently, firms at the upstream position of GVCs tend to produce more services which are bundled with manufacturing products and improve the competitiveness of products by diversification. Countries at the upstream of GVCs tend to be developed economies, which adopt servicification as a potential way of re-industrialization, a strategy to bring the core part of manufacturing industries back to their countries. As a result, the GVC position is also a crucial factor that affects the level of servicification in manufacturing. In addition, the progress in information and telecommunications technology (ICT) dramatically

[3] In traditional trade statistics, all the inputs and outputs of the manufacturing firms were classified as manufacturing activities despite the tasks performed [Baldwin et al. (2015)]. However, when the manufacturing firms start to offshore service tasks, the service content due to misclassification is re-classified as service value added if the offshoring company belongs to service sectors. In this sense, the level of servicification rises without any changes in economic structure. In recent decades, the misclassified part of services could be identified by the international input-output tables, making it possible to re-evaluating the trend of servicification in manufacturing.

improves the tradability of services and promotes service offshoring. It would be much easier for domestic manufacturing firms, especially for the high-end manufacturers, to get access to foreign services. The competitiveness of manufacturing firms would be significantly enhanced with the aid of improved ICT services and transportation services in the international market.

Recent studies have identified institution as another critical factor of servicification [Miroudot and Cadestin (2017)].High-quality service regulations encourage firms to perform service activities, whereas additional rules on services bring extra costs and unnecessary barriers to servicification. In this chapter, we use the indicator of regulation quality as a determinant of servicification to examine the impact of service regulations on servicification of manufacturing. Moreover, the development of services in manufacturing sectors is closely related to the governance of the government. We use the government effectiveness index[4] as another indicator of institutions and examine the impact of the authority effectiveness on servicification.

5.3.2 Data and Empirical Model

In the section, we explore the driving factors of the servicification in manufacturing empirically. As highlighted above, there are five determinants of servicification: reclassification of services, GVC participation, GVC position, ICT improvement, and institutions. The first factor can be eliminated by re-measuring servicification using value-added terms, which traces the real contribution of services in manufacturing industries [5].

The level of servicification is measured as the share of service value-added content in manufacturing exports. The service value-added content in manufacturing sectors has two sources: (a) the domestic service value added ($DSVAshare_{ijt}$) from local companies or local presence of

[4]The government effective index is an indicator of the Worldwide Governance Indicators (WGI) project. It measures the governance of the government, the efficiency of policy implementation, and the level of government control in the economy. A higher government effectiveness index corresponds to a more powerful government where policies are more effectively implemented and the economy is more sufficiently controlled.

[5]The discussion of the reclassification of service value-added activities is given in Appendix C. Though traditional service trade fails to identify the service inputs in manufacturing sectors, we could identify the service value added embodied in manufacturing sectors from international input-output tables and calculate the level of servicification with value-added data. As indicated, we use the share of service value-added content in manufacturing exports as the proxy for servicification of manufacturing.

foreign companies; (b) the foreign service value added ($FSVAshare_{ijt}$) from foreign affiliates of domestic multinational companies or overseas service suppliers. $DSVAshare_{ijt}$ measures the domestic servicification level while $FSVAshare_{ijt}$ representing the level of foreign servicification in domestic production and exports. $FSVAshare_{ijt}$ also estimates the extent of service offshoring in the host country.

The GVC participation index is incorporated in the model to measure the engagement of economies in GVCs at the sectoral level. Following Koopman et al. (2014), we define GVC participation index as the sum of foreign value-added share in exports (backward participation) and the share of domestic value-added in intermediate exports for the third countries (forward participation) [6]. Moreover, GVC position index identifies countries positions in GVCs. Countries with the higher forward participation of GVCs relative to backward participation are referred to upstream countries in GVCs, which have a greater distance to the final use than downstream economies.

We also include other variables such as technological improvement and institutions in the model. Technological development is measured by the share of R&D expenditure in GDP and the number of computer users (per 100 persons). As discussed, the quality of institutions is measured by the government effectiveness index and regulation quality index. Besides, we include the country-specific indicators such as GDP per capita and the share of service workers in total employment to control for country-level characteristics. Additionally, we include the fixed effects to control the effects of the country-, sectoral-, and time-invariant variables such as country size and population. The empirical model is written as follows:

$$DSVAshare_{ijt} = \beta_0 + \beta_1 GVCparti_{ijt} + \beta_2 GVCposition_{ijt} + \boldsymbol{\beta} X_{it} + \sigma_{it} + \theta_{jt} + \epsilon_{ijt} c \quad (5.1)$$

$$FSVAshare_{ijt} = \beta_0 + \beta_1 GVCparti_{ijt} + \beta_2 GVCposition_{ijt} + \boldsymbol{\beta} X_{it} + \sigma_{it} + \theta_{jt} + \epsilon_{ijt} c \quad (5.2)$$

[6] See Koopman et al. (2014) for detail description of GVC participation index and GVC position index.

where σ_{it} andθ_{jt} are the country-time and industry-time specific fixed effects. Table (5.1) provides the description of key variables. The value-added data of GVC indicators comes from OECD TIVA database, which covers 61 economies including OECD countries and other developing economies. There are 14 RCEP countries in the database except for Laos and Myanmar. The value-added data covers 24 sectors with 16 manufacturing sectors and 14 service sectors, ranging from 1995 to 2011 with 5-year intervals[7]. We obtain the country-specific indicators, such as GDP per capita, service labor shares to total employment, R&D expenditure share in GDP and the number of computer users (per 100 persons) from the World Bank database. The institution indicators such as regulation quality and government effectiveness are obtained from the Doing Business database of the World Bank.

Table 5.1: Key Variables Description

Variable	Description	Obs	Mean	Std.	Min	Max
DSVA	Share of domestic services in exports	20,491	46.14	31.89	0.31	97.81
FSVA	Share of foreign services in exports	20,491	8.12	5.49	0.25	35.03
Participation	GVC participation index	20,491	62.27	27.02	0.68	100
Position	GVC position index	20,491	0.67	1.35	-3.7	3.34
SSE	Share of service labor in total employment	20,491	56.79	15.06	12.2	75.4
RDS	R&D share in GDP	20,491	1.84	1.09	0.08	3.74
Computer	Computer user number (per 100 person)	20,491	42.26	33.81	0	83.76
GDP	GDP per capita (unit:1000 USD)	20,491	15.95	14.2	0.47	36.71
GE	Government Effective Index	20,491	0.84	0.78	-0.42	1.94
ReguQ	Regulation Quality Index	20,491	0.64	0.83	-0.44	1.97
Manu	Dummy for manufacturing sector	20,491	0.44	0.5	0	1

5.4 Results

5.4.1 Baseline Results for All Countries

The GVC indicators are important determinants of servicification. Countries with a higher level of participation in GVCs tend to use more offshoring services. Moreover, upstream countries in the GVCs tend to use more service inputs (e.g., design, R&D, finance, etc.) than downstream countries for the production of manufacturing products. However, the regression

[7]The TIVA database (2015) provides value-added data with intervals in the year of 1995, 2000, 2005, 2008, 2009,2010 and 2011.

with the ordinary least squares (OLS) may lead to biased results due to the reverse causality of GVC indicators. Countries with a high level of servicification are more likely to participate and upgrade in GVCs. For example, servicification strengthen countries' competitiveness in the international market, which in turn deepens their engagement in the global value chains. To deal with the possible endogenous problem of GVC indicators, we adopt a five-year lagged GVC indicators as the instruments (IV). We further use the generalized method of moment (GMM) estimation to control for the potential heterogeneity in the model. Table (5.2) shows the empirical results of model (5.1) and (5.2) for the 61 countries using the OLS method with fixed effects and the GMM estimation with IV approach.

The first column of Table (5.2) reports the impact of GVC participation on domestic servicification. The GVC participation has a negative and significant effect on the share of domestic service value added in manufacturing exports (DSVA), suggesting higher participation in the GVCs is associated with less usage of domestic services in manufacturing. Countries with deep participation in GVCs tend to have a high level of international fragmentation of production in GVCs, which enables them to use more foreign intermediates for production. The second column reports the determinants of foreign servicification in GVC activities. The positive coefficient of GVC participation presents that deepening participation in GVCs leads to a significant rise in the share of foreign service value-added in manufacturing exports. These results are robust to the GMM estimations in column (3) and (4).

The GVC position index measures the aggregated upstreamness (distance to the final uses) of countries in the global value chains. The production stages at the upstream of the GVCs tend to be more intensive in knowledge and innovation, which produce components with higher value added[Antràs et al. (2012)]. For example, the upstream tasks (R&D, design, finance, etc.) are hypothesized to create more value than the lower-position tasks (assembling, branding, packaging). Similarly, for manufacturing sectors, the upstream industries (computer, instrument, and electronic equipment) are considered to have a higher value-added than downstream industries (textile, rubber, wood processing). We observe a significantly positive impact of GVC position

Table 5.2: Baseline Results for All Countries

	DSVA (Fixed Effects)	FSVA (Fixed Effects)	DSVA (GMM)	FSVA (GMM)
GVC Participation	-0.171***	0.194***	-0.207***	0.207***
	(0.014)	(0.008)	(0.012)	(0.006)
GVC Position	3.658***	-4.090***	3.703***	-4.113***
	(0.269)	(0.172)	(0.206)	(0.101)
SSE	0.367***	-0.134***	0.370***	-0.128***
	(0.047)	(0.019)	(0.045)	(0.018)
RDS	18.243***	-2.895**	17.781***	-2.648**
	(3.017)	(1.142)	(2.969)	(1.049)
Computer	0.056	0.054***	0.064*	0.057***
	(0.040)	(0.016)	(0.038)	(0.016)
GDP per capita	-0.001***	0.000	-0.001***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Government Effectiveness	-68.803***	18.072***	-66.546***	16.395***
	(12.971)	(4.667)	(12.694)	(4.285)
Regulation Quality	51.997***	-12.324***	50.401***	-11.644***
	(8.987)	(3.341)	(8.882)	(3.059)
Constant	-18.614***	12.093***	29.122***	4.152***
	(5.050)	(2.019)	(3.384)	(1.337)
Global Financial Crisis	Yes	Yes	Yes	Yes
Time × sector Fixed Effect	Yes	Yes	Yes	Yes
Time ×country Fixed Effect	Yes	Yes	Yes	Yes
Observations	11,091	11,091	5082	5082
R^2	0.972	0.892	0.968	0.889

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

on domestic servicification. We also find GVC position affects foreign servicification negatively, suggesting upstream countries in GVCs tend to substitute imported service inputs for domestic services in manufacturing production. The result is robust to the GMM estimation using the lagged 5-year GVC indicators as instruments in column (3) and (4).

The estimation of the non-GVC factors also shows impressive results. The share of service workers in total employment has a significantly positive impact on the domestic servicification but an opposite effect on the foreign servicification. The results suggest that countries with more service workers would use domestic service inputs instead of foreign services in manufacturing, which reduces the service offshoring of the home country. In this sense, domestic service workers substitute for foreign labor who perform offshoring service tasks, which suggests growth in domestic service labor supply would be crucial for the development of domestic servicification in manufacturing. These results keep robust in columns (3) and (4) with GMM estimation. Moreover, the share of R&D expenditure in GDP has a significantly positive impact on the domestic service content in manufacturing while a significantly negative impact on foreign servicification of the manufacturing. Countries with greater technology improvement tend to use more domestic services instead of foreign services in manufacturing. We also adopt the indicator of number of computer users (per 100 persons) to measure the development of information and communications technology (ICT). The coefficients of ICT are significantly positive in both domestic and foreign servicification, indicating the ICT improvement has accelerated the servicification of manufacturing by increasing the tradability of services across sectors. GDP per capita has a negative marginal impact on the domestic servicification, suggesting high-income countries tend to use less local services. But no significant effect on GDP per capita on the foreign servicification is observed.

The institutional indicators also play essential roles in driving the trend of servicification. The regulatory quality (ReguQ) is given as perceptions of the quality of public services, quality of civil services, and the degree of independence from political pressures. Government effectiveness measures the ability of the government to formulate policies, implement authority and regulate the economy. It is interesting to observe the two institutional variables have different impacts on the level of domestic servicification and foreign servicification. Strengthening government effectiveness reduces domestic service value added in manufacturing, but it improves the share of foreign service content in manufacturing. It suggests that manufacturing firms under the governance of a powerful government tend to seek more foreign service inputs in the production. However, the improvement of regulation quality encourages firms to use more domestic services to replace foreign service inputs in manufacturing production. These results indicate that the high-quality and flexible institutional environment is the premise to maintain a high level of domestic servicification of manufacturing.

5.4.2 Servicification in RCEP Countries

Table (5.2) examines the determinants of servicification for all the sample countries. In this section, we focus on the driving factors of servicification in RCEP countries. Compared to the whole sample, the majority of RCEP countries are developing countries with relatively lower GVC positions, smaller technical advantage, and less stable institutions. Table (5.3) shows the study of the determinants of both domestic servicification and foreign servicification in RCEP countries.

The Asian countries have a lower domestic servicification level but a higher foreign servicification level than the OECD countries. We observe similar impacts of GVC indicators on both domestic and foreign servicification in RCEP countries compared to in the OECD countries. The GVC participation index has a significantly negative effect on the domestic servicification and a positive effect on the foreign servicification for the RCEP countries. Moreover, upstream countries of the GVCs have a higher level of domestic servicification with less use of foreign services inputs in manufacturing. These results are robust both in fixed-effect regression and GMM estimation[8].

[8] Both participation and position variables are robust to different model specifications as given in Table (D.3) of Appendix (C), indicating the omitted variable problem does not lead to severe bias in the estimations.

The share of service labor in total employment has no significant impacts on servicification in the fixed effect regression, whereas its coefficient turns to be significant in the GMM regression. Similar to the results of the full sample, an increase in the share of service labor in total employment improves the level of domestic servicification while declining the level of foreign servicification for RCEP countries. This result highlights the importance of service labor in raising the domestic servicification of manufacturing for the Asian countries. We also observe a positive coefficient of ICT improvement on foreign servicification, which indicates that ICT development reduces the cost of service offshoring, thereby leading to a rising level of foreign servicification in manufacturing. Again, we find countries with high GDP per capita have lower domestic servicification level, but this result is not very robust to the GMM estimation where its coefficient turns to be insignificant.

Similarly, institutional factors have different effects on the domestic and foreign servicification of manufacturing for RCEP countries. It is intriguing to observe that government effectiveness has a negative impact on both domestic servicification and foreign servicification in RCEP countries. It suggests that enhancing the governance of Asian governments hinder the development of servicification in manufacturing. Compared to the positive impact of government effectiveness on foreign servicification in the full sample, the negative coefficient in RCEP countries may be to blame for the close linkages between government and large monopolies or state-owned enterprises (SOEs). These ties hinder the process of marketization in core service sectors, which leads to unnecessary bottlenecks for service sectors as well as servicification of manufacturing in the Asian countries. It was observed that regulation quality has a positive impact on domestic servicification but reduces the share of foreign services value-added activities in manufacturing. The results are consistent with that of full samples, suggesting high-quality regulations help to attain the development of domestic service sectors and increase the level of domestic servicification of manufacturing.

Table 5.3: Baseline Results for RCEP countries

	DSVA (Fixed effect)	FSVA (Fixed effect)	DSVA (GMM)	FSVA (GMM)
GVC Participation	-0.155***	0.228***	-0.145***	0.131***
	(0.036)	(0.013)	(0.019)	(0.010)
GVC Position	3.156***	-6.123***	3.990***	-7.178***
	(0.452)	(0.199)	(0.602)	(0.307)
SSE	0.008	-0.010	0.093**	-0.036**
	(0.015)	(0.006)	(0.037)	(0.015)
RDS	2.099***	0.380	-0.436	0.548
	(0.586)	(0.356)	(0.889)	(0.460)
Computer	0.037**	-0.005	0.031	0.112***
	(0.014)	(0.009)	(0.053)	(0.026)
GDP per capita	-0.192***	0.251***	-0.203	-0.073
	(0.065)	(0.048)	(0.113)	(0.057)
Government Effectiveness	-4.544***	-1.569**	-3.448*	-6.151***
	(1.360)	(0.783)	(1.928)	(1.056)
Regulation Quality	0.441	-2.172***	5.364***	-1.900**
	(0.892)	(0.418)	(1.792)	(0.887)
Constant	40.445***	-0.534	28.433***	5.948***
	(3.328)	(1.955)	(2.882)	(1.046)
Global Financial Crisis	Yes	Yes	Yes	Yes
Time× sector Fixed Effect	Yes	Yes	Yes	Yes
Time× country Fixed Effect	Yes	Yes	Yes	Yes
Observations	468	468	207	207
R^2	0.715	0.908	0.671	0.905

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.4.3 Robustness Check

Baldwin et al. (2015) used the "smile curve" to depict the trend of servicification in Asian countries. As illustrated in Figure (5.8), during the recent period (2005-2011), service activities are the main value-added source of manufacturing production. The "smile curve" provides an alternative approach to examine the existence of servicification in Asian countries. Following Baldwin et al. (2015) [9], we unveil the source of value added in exports and investigates the determinants of servicification using the following empirical model:

$$\Delta ServiceVAshare_{ijt} = \beta_0 + \beta_1 \Delta GVCparticipation_{ijt} + \beta_2 \Delta GVCposition_{ijt} + \gamma \Delta X_{it} + \sigma_{it} + \theta_{jt} + \epsilon_{ijt} \tag{5.3}$$

In contrast to the baseline model, $ServiceVAshare_{ijt}$ refers to the five-year change of the share of service value-added content in gross exports, which covers the service value-added share changes in primary sectors, manufacturing sectors, and service sectors. Similarly, according to the geographical sources of service value added, we denote $\Delta DSVA$ as the changes of domestic service value-added share in exports, which measures the changes of domestic servicification level. We further refer $\Delta FSVA$ as the changes in the share of foreign service value added in exports. $\Delta GVCparticipation_{ijt}$ is the change of GVC participation index. $\Delta GVCposition_{ijt}$ is the change of GVC position index. X_{it} is a vector of control variables which are similar to those of the baseline model. The regression also contains two dummy variables for manufacturing industries and RCEP countries respectively. Our panel data covers 61 countries and 34 sectors with three periods (1995-2000, 2000-2005, and 2005-2010). Table (5.4) reports the estimation results.

[9] Baldwin et al. (2015) first examined the effects of GVC participation changes on the existence of smile curve," while using the fixed effects to control the country-specific and industrial-specific unobserved variables that may cause the omitted variable problem in the estimation. Most coefficients in their analysis are not statistically significant, and the sign of GVC participation is opposite to the expected hypothesis. We improve the model of Baldwin et al. (2015) by including the more control variables to examine the determinants of servicification.

Table 5.4: Robustness check to Servicification with "Smile Curves"

	ΔDSVA			ΔFSVA		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ GVC participation	-0.215***	-0.245***	-0.199***	0.220***	0.216***	0.225***
	(0.015)	(0.014)	(0.017)	(0.010)	(0.011)	(0.011)
Δ GVC position	4.415***	4.896***	4.340***	-4.588***	-4.346***	-4.863***
	(0.258)	(0.293)	(0.299)	(0.202)	(0.231)	(0.237)
SSE	0.028	0.034	0.062*	-0.026**	-0.022**	0.037***
	(0.024)	(0.023)	(0.032)	(0.011)	(0.011)	(0.014)
RDS	-0.520	-0.529	-0.196	0.026	0.024	0.369**
	(0.331)	(0.331)	(0.353)	(0.169)	(0.169)	(0.183)
Computer	0.007	0.005	0.011	-0.007	-0.006	-0.007
	(0.010)	(0.009)	(0.010)	(0.005)	(0.005)	(0.005)
GDP	-0.082	-0.069	-0.100	0.399***	0.397***	0.372***
	(0.059)	(0.059)	(0.062)	(0.037)	(0.038)	(0.039)
Government Effectiveness	-0.318	-0.275	0.556	-1.314***	-1.289***	-1.064***
	(0.479)	(0.477)	(0.546)	(0.261)	(0.260)	(0.281)
Regulation Quality	1.809***	1.748***	1.669***	0.535**	0.510**	1.016***
	(0.470)	(0.475)	(0.517)	(0.262)	(0.255)	(0.279)
Manu×Δpart		0.215***			-0.039	
		(0.063)			(0.026)	
Manu×Δposit		1.114**			-1.442***	
		(0.563)			(0.412)	
Δpart×RCEP			-0.098***			-0.012
			(0.033)			(0.019)
Δposit× RCEP			0.124			-1.328***
			(0.565)			(0.384)
Constant	-1.265	-1.778	-3.804	0.543	0.319	-3.945***
	(1.717)	(1.710)	(2.331)	(0.851)	(0.837)	(1.089)
Global Financial Crisis	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6526	6526	6526	6526	6526	6526

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. We include the interaction between RCEP dummy and the other control variables such as service labor share, R&D share in the model and compare compare the determinants of servicification between OECD and RCEP countries. The details are shown in the Appendix D.

The results in Table (5.4) are robust to the baseline model. Column (1) and column (4) suggest that GVC participation is negatively associated with the level of domestic servicification while positively correlated with the foreign servicification level. Countries with broader participation in GVCs tend to use more foreign service inputs for the production of exports. Moreover, moving to the more upstream position in GVCs raises the share of domestic service value added in exports, while declining the share of imported service content in production. The share of service workers in total employment share has no significant effect on domestic servicification but has a negative impact on the level of foreign servicification. Regulation quality has significantly positive effects on both domestic and foreign servicification, suggesting high-quality regulations boosts the servicification of manufacturing. Countries with larger government effectiveness tend to reduce the level of foreign servicification. However, government effectiveness index has no significant impact on domestic servicification.

Column (2) and Column (5) compare the determinants of domestic and foreign servicification in manufacturing and other industries including primary and service sectors. The interaction between manufacturing and GVC participation in Column (2) is significantly positive, but the net effect of GVC participation on domestic servicification for manufacturing sectors is still negative ($-0.245 + 0.215 = -0.03$). The results suggest that deepening GVC participation declines the level of domestic servicification in all sectors, but the impact is smaller in manufacturing than the other sectors. In Column (5), improving GVC participation increases the use of foreign service value-added content in both manufacturing and other industries, but the effect on manufacturing is not significant. We also observe a significant and positive coefficient of GVC position interacted with manufacturing dummy in Column (2), indicating moving to the upstream position of GVCs improves the level of domestic servicification in manufacturing. The negative coefficient of GVC position interacted with manufacturing in Column (5) suggests that upgrading in GVCs reduces the foreign service content in manufacturing sectors. Moreover, the impact is larger for manufacturing sectors than the other industries.

Column (3) and Column (6) of Table (5.4) compare the determinants of the servicification between RCEP countries and OECD countries. The interaction between GVC participation and RCEP dummy in Column (3) is significantly positive, indicating GVC participation lowers the level of domestic servicification and this impact is more significant for RCEP countries than the OECD countries. The coefficient of GVC position interacted RCEP dummy is not significant. However, for OECD countries, having a more upstream position in GVCs improves the share of domestic service value-added in exports. In Column (6), we observe an insignificant effect of GVC participation on the level of foreign servicification for RCEP countries. However, for OECD countries, GVC participation is positively associated with their foreign servicification level. When upgrading to more upstream industries in GVCs, there is a decline in the use of foreign service inputs in exports for both RCEP countries and OECD countries, but the impact is more substantial in OECD countries.

5.5 Conclusion

It is widely recognized that services are playing an indispensable role in international trade and economic growth for both developed and developing countries. The trend of GVCs, also described as the second unbundling of production across borders, changes the production and trade pattern of services. From the perspective of global value chains, services are increasingly adding value to economic activities, particularly in manufacturing sectors, which is termed as the servicification of manufacturing. An emerging branch of literature has explored the new trend of servicification in manufacturing in OECD countries, but few studies focus on that of developing countries. This chapter contributes to the ongoing debate about the servicification of manufacturing in emerging economies, which confirms the rising trend of servicification in Asian countries and examines the driving factors of servicification for selected Asian countries (RCEP countries).

In this chapter, the value-added decomposition technique is used to trace the service value-added content embodied in the global production. We classify servicification into two types:

the domestic servicification in which service value-added origins from domestic service suppliers, and foreign servicification in which service value-added sources from service offshoring. The domestic servicification measures the share of domestic service value-added content in manufacturing exports. The foreign servicification represents the share of foreign service value added in manufacturing exports. We find RCEP countries have a slightly lower level of servicification in manufacturing than OECD countries, but they tend to use more foreign service contents in production than OECD countries. It was also observed that RCEP countries have revealed a comparative advantage in manufacturing and traditional service industries according to the new RCA index based on value-added terms. In most RCEP countries, the value-added source of manufacturing exports has shifted from manufacturing activities to service activities, suggesting a rising level of servicification in Asian countries.

The rising trend of servicification in Asian countries, especially the rise of foreign servicification, has crucial implications for the industrial strategies of countries. The rising level of foreign servicification of manufacturing indicates a higher level of reliance of Asian countries on service offshoring in GVCs, which further highlights the importance of service trade and FDI liberalization for these countries. Eliminating the service trade and investment barriers would facilitate the servicification of manufacturing in Asian countries, which use more foreign service value-added content for the global production at lower costs.

Our empirical model also identifies the role of GVC participation, GVC position, ICT improvement and institutions in driving the trend of servicification. Broader participation in GVCs shifts the demands for service inputs from the domestic market to foreign suppliers. The more countries participate in GVCs, the lower domestic servicification level is. This is because GVCs integrate various stages of production across countries with comparative advantage. Countries with deeper participation integration into GVCs are more specialized and have more access to low-cost offshoring services through GVCs. We also suggest that upgrading the GVC position of countries improves the level of domestic servicification while reducing the use of foreign services in manufacturing. This impact is more significant for OECD countries than RCEP countries. Moreover, the development of ICT reduces service offshoring costs and increases the tradability of services, thus leading to a higher level of foreign servicification in manufacturing.

This study suggests that institutions play a vital role in the process of servicification in manufacturing. For OECD countries, an effective government would significantly reduce the domestic service activities, while increasing the level of foreign servicification. The government effectiveness in RCEP countries, however, is significantly negative for both domestic and foreign service activities. The results indicated that the current governance of Asian governments restrict the use of services in manufacturing and impose extra barriers to service offshoring. Improving regulation quality may be an effective approach to develop the domestic servicification of manufacturing. According to the empirical results, countries with better regulation quality tend to use more domestic services instead of foreign services in manufacturing production. Increasing the share of service workers in total employment is another way to improve domestic servicification according to the research. We find manufacturing firms tend to substitute domestic services for imported service inputs with the increase of domestic service workers. This result has important implications for Asian countries which aim to improve the level of domestic servicification in manufacturing.

Chapter 6

Conclusion

6.1 Concluding Remarks

The rise of global value chains has dramatically reshaped global production patterns and international trade, which creates the scope to derive new insights into trade theories and policy implications relevant to globalization. This thesis focused on three specific questions in GVCs: (a) the role of differences in the cost of human capital in determining the international fragmentation of production across countries and the patterns of bilateral value-added trade, (b) the impacts of participation in GVC activities on wage inequality associated with differences in skills in the workforce within firms, (c) the trend of servicification in Asian countries in manufacturing GVCs.

This study is based on a crucial implication of GVCs that gross trade no longer represents trade in terms of value-added trade. As GVCs span many countries, the rise of GVCs leads to an increasing discrepancy between gross trade and value-added trade. Trade patterns are often analyzed using the gravity model. Its underlying theory is based on value-added concepts, yet the data to which it has been applied is the gross value of trade. The standard gravity model performs poorly in GVCs with the prominent share of intermediates in gross trade [Baldwin et al. (2014)]. To address this problem, we incorporate the global input-output framework into the standard gravity model to derive an approximate model of value-added trade, which involves more than just the source and destination countries. The model further explores the determinants of value-added trade in this setting, which highlights the role of human capital from third countries, through which the domestic value-added is transited en route from the source to the destination in the GVC setting. We propose the prediction that bilateral value-added trade depends not only on the human capital costs of the source and destination countries but also on that of the third countries.

The model was tested in Chapter 3 of the thesis. We observe a polarization effect of human capital (skilled, semi-skilled and unskilled) from the source and destination on their domestic value-added trade. Increasing the unit wage of skilled and unskilled workers of the source and destination country would boost the domestic value-added trade volume between the two countries but improving the rewards of semi-skilled labor declines their bilateral value-added trade. More importantly, we find the human capital of third countries has the anti-polarization impact on the bilateral value-added trade between the source and destination countries, which indicates improving the unit wage of semi-skilled labor from the third country would increase the domestic value-added trade volume between the source and destination countries. These results highlight the complementaries of countries in terms of human capital along the global value chains.

Since value-added trade is directly linked to factor income, in Chapter 4, we explore the impacts of GVC participation and upgrading on the wage inequality of skills within firms. Despite the emerging literature that measures value-added trade across countries and sectors, few studies have examined the value-added trade flows at the firm level. This study addresses the heterogeneity of firms in GVCs by merging the transactional-level data of customs with the firm-level data of enterprises to measure firms participation in firms, namely the ratio of foreign value-added content in exports relative to gross exports (FVAR). We also emphasize the heterogeneity of firms positions in GVCs, as measured by the exporting varieties' upstreamness (or average distance from final use). The findings indicated that only firms with higher profits and larger productivity choose to engage in the global value chains by importing intermediates for the production of exports. Using data for Chinese manufacturing firms, a declining FVAR trend was observed, in which domestic materials are increasingly substituted for imported intermediates, especially for processing firms. Moreover, the findings showed that Chinese manufacturing firms are changing their position in GVCs, moving to upstream sectors that are farther from the final demand. This chapter identifies the implications of these changes for the skill wage premium of firms by incorporating the fair wage hypothesis that firms with better performance tend to pay a higher wage to skilled workers to elicit their efforts. It was observed that GVC participation improves firms' profits and further amplifies the wage inequality between skilled and unskilled labor. Moreover, moving upstream raises firms' wage premiums by increasing the productivity of skilled workers. These results are robust after controlling for the endogeneity.

Servicification of manufacturing represents the increasing use, purchase, production, and exports of services in manufacturing sectors[Lanz et al. (2015)]. The recently released global input-output tables trace service inputs across sectors and countries, which enable the measurement of the service value-added content embodied in manufacturing sectors. Servicification was defined as the share of service value-added content in manufacturing exports and further distinguish service value added by sources. The domestic servicification level measures the share of domestic service value-added in manufacturing exports while foreign servicification level estimates how much foreign service inputs are used in manufacturing exports. In Chapter 5, a comparison of the level of servicification in OECD and RCEP countries (selected Asian countries) was undertaken. The findings showed that the overall servicification level was smaller in RCEP countries than OECD countries, but RCEP countries had a higher level of foreign servicification. It suggests that RCEP countries tend to use more foreign service inputs for the production of exports than OECD countries do. In most RCEP countries, we observe a shift of value added from manufacturing activities to services in manufacturing sectors, which suggests the rising level of servicification of manufacturing in Asian countries. Moreover, this study identified five key factors in driving the domestic and foreign servicification of manufacturing. For both OECD and RCEP countries, deepening participation in GVCs improves the level of foreign servicification while the domestic servicification level declines, but this impact is larger for RCEP countries. Moving upstream in GVCs raises the domestic servicification level while reducing the share of foreign service value added in manufacturing exports. This impact is more significant for OECD countries than RCEP countries. The improvement of information and communication technology (ICT) boosts service offshoring and thus increases the level of foreign servicification in manufacturing. A larger share of domestic service workers in total employment is associated with a higher level of domestic servicification. Lastly, improvement in regulation quality encourages the development of domestic servicification while reducing the level of foreign servicification in both OECD and RCEP countries. However, strengthening the effectiveness of government prompts OECD countries to substitute foreign service inputs for domestic services. Meanwhile, RCEP countries with stronger government effectiveness reduce the service inputs from both domestic market or foreign countries for the production of manufacturing exports.

6.2 Policy Implications

The analysis of GVCs is crucial to understand trade policies and its outcomes on the labor market, industrial development, and economic growth. The fact that gross trade is increasingly unrepresentative for trade in value-added has given rise to new prospects of traditional trade indicators, such as trade balance, trade gains, and trade barriers. For example, the bilateral trade balance would need to be re-estimated because gross trade contains both domestic and foreign value-added contents and leads to an inaccurate picture of trade in value-added. Moreover, trade liberalization favors not only importers but also exporters that use imported intermediates for the production of exports. Similarly, service trade liberalization would be supported by manufacturing firms due to the presence of servicification in manufacturing.

In fact, the indirect effects of third countries, including but not limited to the human capital, ought to be considered in policy analysis. For example, the indirect production linkages with third parties in GVCs would change the consequences of bilateral trade barriers. Imposing a tariff between the source and destination country is likely to affect the value-added trade of the two countries with third countries. On the one hand, the tariff between the source country and destination country would hinder the value-added trade between the source country and third countries which supply intermediates and components to the source country for the production of export products to the destination country. On the other hand, the tariff between source country and destination country may increase the value-added trade between the destination country and the third countries through which the exports of the source country are transited en route. Moreover, trade liberalization between the source country and destination country would create trade to the third countries, which links the source or destination countries via GVCs. As a result, the expansion of GVCs across countries has imposed new insights into trade policies which are required to be interpreted from the value-added perspective.

The pervasiveness of GVCs affects firms' performance and employment structure. In Chapter 4, we conclude that GVC participation of firms is associated with larger wage inequality of skills. We also observe that firms which move upstream in GVCs tend to have wider wage inequality between skilled and unskilled workers. These findings provide a possible explanation for the coexistence of globalization and widening wage inequality of skills in the developing countries. However, although participating and upgrading in GVCs enlarges the wage inequality of skills, they improve firms' profits and productivity by acquiring higher skills. Thus, the appropriate policy response for these results is not to suppress the GVC activities of firms, but to increase the opportunities for unskilled labor to be trained or educated in emerging economies.

Chapter 5 revealed the rising trend of servicification in manufacturing in both OECD countries and emerging economies. This result implies the free movement of service inputs and service professionals would be crucial for manufacturing development, especially in some OECD countries with the strategy of re-industrialization. It was observed that OECD countries had a higher level of servicification in manufacturing than RCEP countries. It suggests that policies related to services would be more important for manufacturing performance in OECD countries. However, the RCEP countries have a higher level of foreign servicification, which indicates service trade liberalization is essential for Asian countries to reap the benefits from

GVCs. It was also found that domestic regulation quality and government effectiveness were of crucial importance for servicification. A high-quality but liberal institutional environment maintains a high level of domestic servicification of manufacturing.

6.3 Future Research

The research using the global input-output framework and value-added trade data to analyze GVCs is relatively new and limited. Except for the topics of this thesis, there are still several possible research dimensions for the future.

Despite the advances in GVC measurement, few studies focus on the theoretical models that interpret the value-added trade patterns and the possible economic consequence of GVCs. As gross trade is increasingly unrepresentative of trade in value-added, many conventional trade models, which were cast in value-added terms but estimated with gross trade data, perform poorly in GVCs [Johnson (2014); Baldwin et al. (2014)]. Several studies have realized the challenge of traditional trade theories in application to GVCs, so they embrace the intermediate trade into the models to describe GVC characteristics in gross trade terms [Bergstrand and Egger (2010); Johnson and Noguera (2012b);Koopman et al. (2012)]. However, these studies did not incorporate the global input-output structure into the models to understand the transformative nature of global production sharing. A more promising approach is to rewrite the whole model in value-added terms where producers use primary factors to produce value-added, and consumers consume value-added from various source countries. In contrast to the studies with intermediate trade, the value-added approach provides a more direct description of the input-output linkages across borders and sectors, but it is rarely used in previous theory studies due to data limitation. With the growing availability of value-added trade data, the value-added approach could be increasingly adopted to develop trade theories and calibrate the parameters.

The value-added trade data changes the perceptions of many trade indicators which were measured in gross trade data. First, the official trade balance is estimated in gross trade terms, which overstates the real trade surplus and deficit between the two countries represented by value-added trade. The value-added view of trade balance has import implications for adjusting bilateral trade policies, which needs deeper analysis in the future. Second, the traditional index of revealed comparative advantage (RCA) derives from the comparison of the export performance of a country in one sector to the export performance of the world in this sector using gross exports data. However, from the GVC perspective, the gross exports contain not only the value-added contribution of the domestic country but also the foreign value-added content from the other countries. Countries with the large volume of exports in one sector may contribute very little value-added to the exports. As a result, the analysis of comparative advantage would be more accurate to use the domestic value-added content embodied in exports in the estimation instead of gross exports [Koopman et al. (2014)]. The new RCA index based on value-added trade would provide a new picture of countries comparative advantage.

Lastly, value-added trade is also critical in estimating the factor content of trade, which was overstated in gross exports with the assumption that export products are produced by the factors of exporting country alone. The factor content of value-added trade enables us to trace the labor and capital that are directly or indirectly embodied in the production of final goods from different sources [Timmer et al. (2014)]. The factor content of value-added trade also provides new data to test the predictions of the Heckscher-Ohlin model[Trefler and Zhu (2010)].

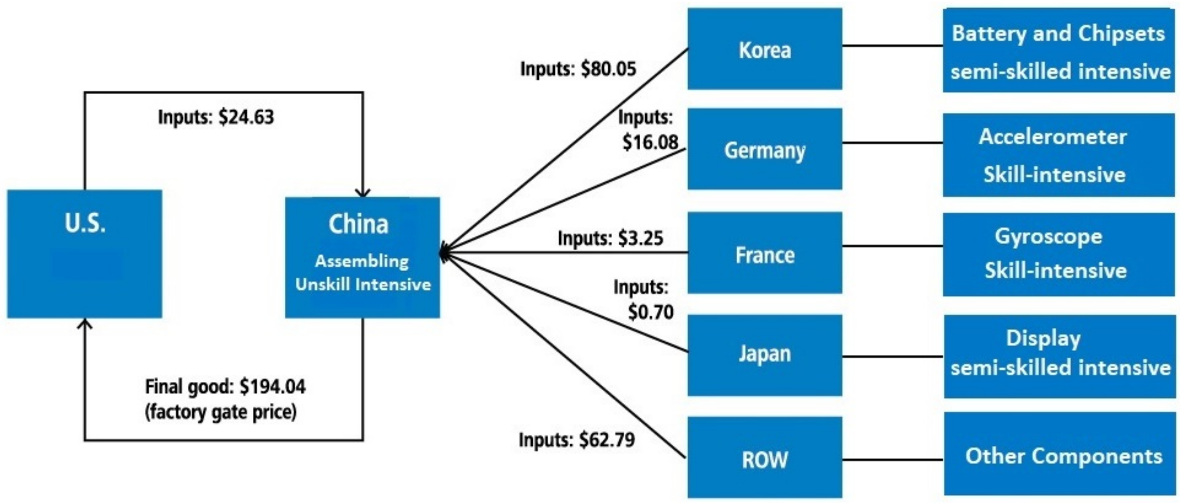
Beyond its implications for trade theories and measurement, the rise of GVCs has imposed new insights into empirical work related to trade policies, economic growth, and labor market. As addressed in Chapter 3, the multi-national production linkages in GVCs has magnified the impacts of bilateral trade policies to the third countries through which the value-added trade is transited en route. For example, trade liberalization between country A and B not only facilitates the trade of the two countries but also boosts trade between country A and C, which provides intermediates and components for the production of exporting products from A to B. Moreover, it may decrease the trade between B and D, through which country As exports are transited but finally consumed in country B. Similar value-added approach could be used in quantifying the impacts of bilateral trade barriers [Koopman et al. (2012)], human capital development, exchange rate fluctuations[Bems and Johnson (2012)] and other economic policies.

In addition, the firm-level value-added trade data provides new measurements on firms GVC activities. Apart from studying the impacts of firms GVC activities on wage inequality in this thesis, new research could focus on the impacts of GVCs on firms productivity, employment, export sophistication, and innovation. Another potential question is a firms choice of an organizational form of GVCs. Even though this question has been addressed by several studies using the property-rights theory [Antras and Helpman (2004), Antràs and Chor (2013)], there are few empirical evidence of firms governance in GVCs. The main reason is that the current firm-level value-added data cannot provide information on the sourcing decisions of firms for different inputs. However, the empirical study of firms organization in GVCs could be an avenue for future research.

Appendix A

Appendices

A Gross Trade versus Value-added Trade: Example of iPhone 4



Us trade balance with	China	Korea	Germany	France	Japan	Rest of world	World Total
Gross	-$169.41	0	0	0	0	0	-$169.41
Value added	-$6.54	-$80.05	-$16.08	-$3.25	-$0.70	-$62.79	-$169.41

Source: This figure explores the difference between value-added trade balance and gross trade balance, which is sourced from Gereffi and Lee (2012). We modified the figure by including the primary exporting variety of intermediates from each country. We also included the type of skills which is intensively used for the production of the intermediates.

Figure A.1: Gross Trade versus Value-added Trade: Example of iPhone 4

Figure (A.1) gives the example of iPhone 4 to show the international fragmentation of production across countries. As the assembling center of iPhone 4, the Chinese manufacturer (Foxconn) imports intermediates and components from Apple suppliers all over the world and assembles them into final goods, which are exported to the United States for sales. For each unit of iPhone 4 that China exports to the United States, there will be a trade deficit of $169.41 in the balance account of payment[1]. The gross trade deficit only accounts for the value of final goods that cross the custom border between China and the U.S. It neglects the value of intermediate inputs imported by China from the third countries (such as Korea, Germany, France, etc.) in Chinese exports. As the direct exporter of the United States, China only obtains $6.54 for exporting one unit of iPhone valued at $194.04. The value-added trade deficit between China and the United States should be $6.54 instead of $169.41. South Korea captures the maximum value-added deficit of exports from China to the United States ($80.05). Moreover, it is the value-added trade instead of gross trade that represents the real impacts of Chinas export shock on the American labor market [Shen and Silva (2018)]. In this sense, the largest impact of US trade deficit on the labor market is not incurred from China, but from South Korea and the other countries which have vertical production linkages with China and United States in GVCs.

Figure (A.1) also shows the types of skills that each country uses to produce the specific components of iPhone 4. We observe that countries perform the tasks which intensively use the skills with comparative advantage in their costs. The international fragmentation of production across countries corresponds to the vertical division of skills based on the specialization of tasks. Different types of skills in different countries complement to produce the final goods in the global supply chains.

[1]The gross import of China from the US is 24.63.*Theexportpriceofoneunitof iPhone4is*194.04. If China exports 1 unit of iPhone 4 to the US, it incurs a $169.41 trade deficit between US and China.

B Skill Classification of WIOD Database by Education

Table B.1: Skill Classification by Education

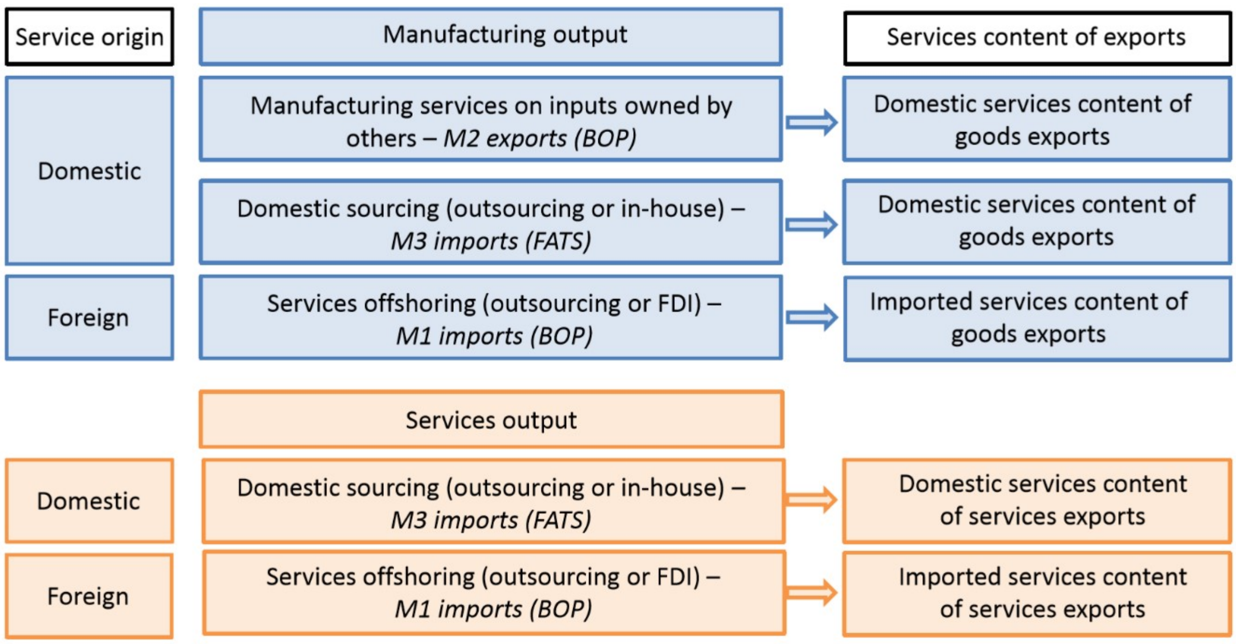
Skills	ISCED Level	1997 ISCED level description
Unskilled labor	1	Primary education or stage of basic education
Unskilled labor	2	Lower secondary or stage of basic education
Semi-skilled labor	3	(Upper) secondary education
Semi-skilled labor	4	Post-secondary non-tertiary education
High-skilled labor	5	First stage of tertiary education
High-skilled labor	6	Second stage of tertiary education

Note: The Classification is based on the International Standard Classification of Education (ISCED).

C Value-added Decomposition of Service Trade in GVCs

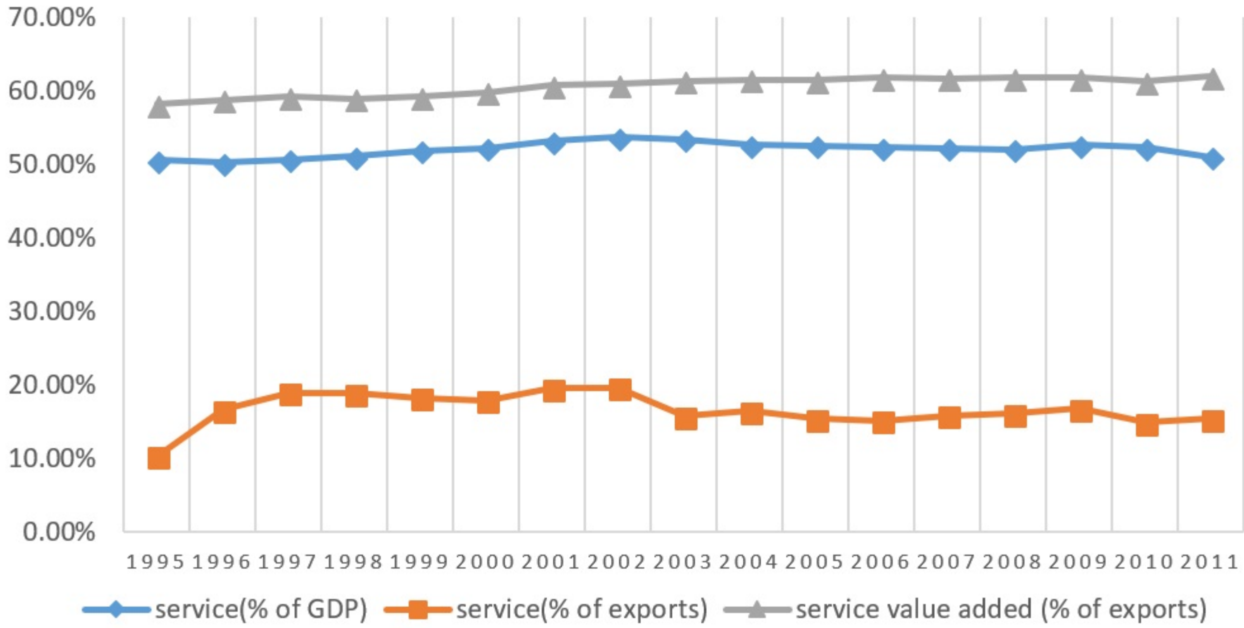
The General Agreement on Trade Services (GATS) defined four modes of international service supply: cross-border supply (mode 1), consumption abroad (mode 2), commercial presence (mode 3) and the presence of natural persons (mode 4). But it failed to capture the services used as intermediate inputs, which widely exist in the global value chains. As Figure C.2 shows, services, originating either from domestic market or foreign countries, could be used as inputs for both manufacturing and service sectors. The domestic supply of services could be either from domestic service companies or local affiliates of foreign companies (Mode 3), constituting the domestic service content of goods. Also, manufacturers also import services overseas, which is called the imported service content of goods. Trade in goods contain the domestic service content and the imported service content. Obviously, the balance of payment account (BOP) only records the service trade that crosses the borders directly, but it fails to recognize indirect trade of services that embodied in goods exports, let alone services content produced by the movement of labour (mode 4) and capital (mode 3).

The international input and output tables create a multinational multi-industry framework that makes it possible to trace the origin of value added in the international trade. In the table, the service value added in exports could be decomposed into the direct export of service



Source: This figure comes from Lanz et al. (2015). BOP is the abbreviation of "the balance of payments" while FATS refers to the Foreign Affiliates Statistics (FATS) framework. The difference between the two statistic framework is BOP could capture the service trade flows across borders while FATS captures the international migration of capital. M1 is the shortage of mode 1 (service cross border supply). M2 represents mode 2 (consumption abroad). M3 denotes mode 3 (commercial presence) and M4 refers to mode 4 (the presence of natural persons).

Figure C.2: Value-added Decomposition of Service Trade in GVCs



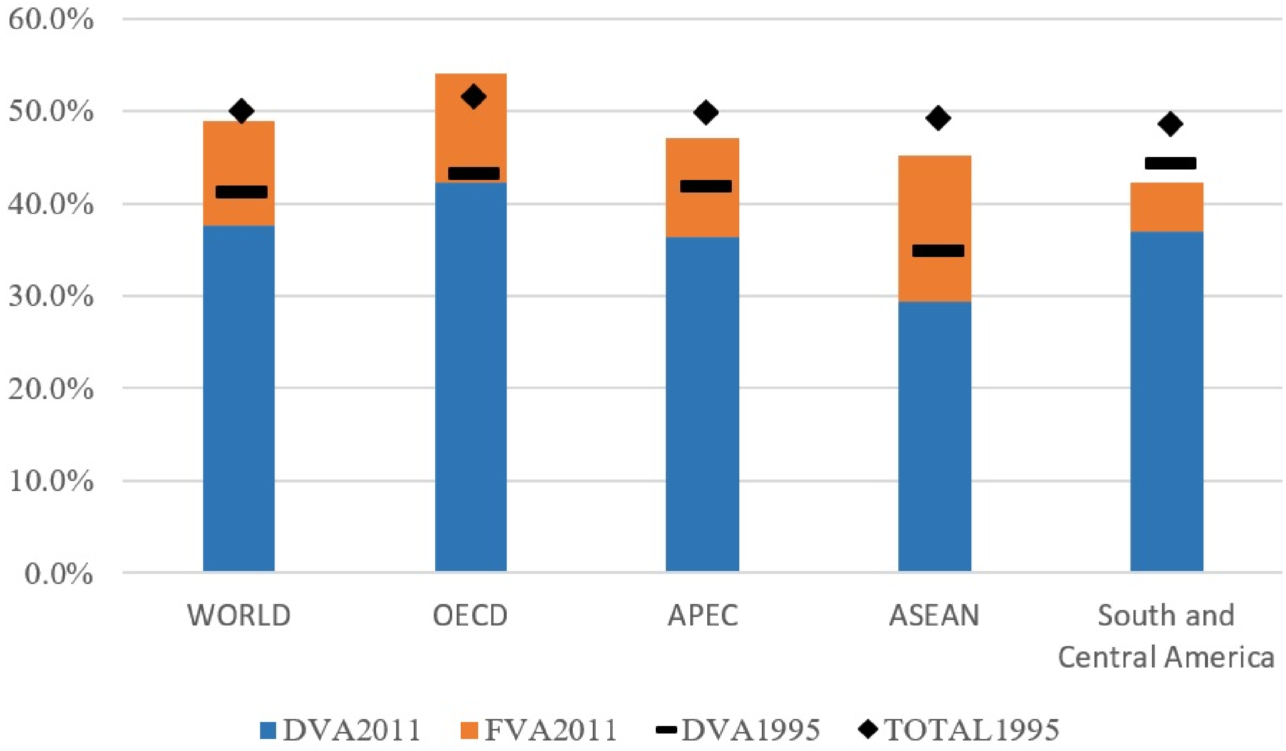
Source: Data from OECD TIVA (2015) database and calculated by the author.

Figure C.3: Share of Service Value-added Content in GDP, Exports and Value-added Trade

and the indirect export of service embodied in goods. Furthermore, service supplied by foreign affiliates (Mode 3) is also classified as the foreign service value added in exports. Recent years have seen an emerging rise in international input and output database such as OECD TIVA database, WIOD database, and JETRO AIIO database. In the paper, we use the OECD TIVA database to estimate the role of services in the global value chains.

Figure C.3 depicts the share of services in gross exports and in value-added trade. It is striking that the share of service value added in GVC exports reaches almost 70% in TIVA database while the share of service trade in total trade being only 20% in the BOP. It indicates that a significant proportion of service content is embodied in the goods trade, which is neglected by the conventional trade measurement. The increasing use of services in the manufacturing sectors is described as the "servicification" of manufacturing, which is also termed as "servicizing" or "manuservice" [Elms and Low (2013)].

Figure C.4 compares the share of service value-added content in total exports by different regions. We observe that the OECD countries have a higher level of servicification than the



Source: Data from OECD TIVA (2015) database and calculated by the author.

Figure C.4: Share of Service Value-added Content in Exports by Regions

developing regions. Services took up 45.2% of the total trade for ASEAN countries in 2011, which is lower than that of OECD countries at 54.1% but is higher than other developing area such as the South and Central America (42.3%). We also observe that the ASEAN countries have the highest level of foreign servicification than the other areas, even the OECD countries.

D Extra Estimation Results

Table (D.2) gives the baseline results of OECD countries. Compared to the RCEP countries in Table (5.3), GVC participation and position have similar impacts on both domestic servicification and foreign servicification in OECD countries. Deeper participation in GVCs tends to reduce the level of domestic servicification while raising the level of foreign servicification in OECD countries. Moreover, increasing the share of service employment in total labour improves the level of foreign servicification, which is different from the effect in the RCEP countries. ICT improvement in terms of computer facilitates both domestic and foreign servicification in the

OECD countries. The government effectiveness only restricts the development of foreign servicification in OECD countries while low regulatory quality harms both domestic and foreign servicification development.

Table D.2: Baseline Results for OECD countries

	DSVA (Fixed Effect)	FSVA (Fixed Effect)	DSVA (GMM)	FSVA (GMM)
GVC participation Index	-0.154***	0.167***	-0.203***	0.182***
	(0.022)	(0.013)	(0.015)	(0.010)
GVC position index	3.803***	-3.912***	3.871***	-4.234***
	(0.458)	(0.322)	(0.299)	(0.187)
SSE	0.009	0.175***	0.031	0.174***
	(0.149)	(0.045)	(0.140)	(0.043)
RDS	-0.943	-0.341	-0.846	-0.425
	(0.732)	(0.278)	(0.689)	(0.261)
Computer	0.436*	0.613***	0.467*	0.609***
	(0.261)	(0.086)	(0.248)	(0.083)
GDP	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Government Effectiveness	3.600	-6.774***	3.794	-7.158***
	(5.231)	(1.948)	(4.881)	(1.853)
Regulatory Quality	-7.751**	-7.322***	-8.764**	-6.788***
	(3.654)	(1.754)	(3.408)	(1.652)
Constant	36.939***	13.339***	38.835***	-26.083***
	(7.889)	(2.602)	(12.878)	(4.193)
Global Financial Crisis	YES	YES	YES	YES
Time× Sector fixed effect	YES	YES	YES	YES
Time × Country Fixed Effect	YES	YES	YES	YES
Observations	5211	5211	2298	2298
R2	-	-	0.977	0.9

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table D.3 provides the interaction details of Table 4. Increasing the share of service labor in employment would reduce the level of foreign servicification for RCEP countries while improving

Table D.3: Robustness check to Servicification with "Smile Curves"

	ΔDSVA			ΔFSVA		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔGVC participation	-0.215***	-0.245***	-0.199***	0.220***	0.216***	0.225***
	(0.015)	(0.014)	(0.017)	(0.010)	(0.011)	(0.011)
ΔGVC position	4.415***	4.896***	4.340***	-4.588***	-4.346***	-4.863***
	(0.258)	(0.293)	(0.299)	(0.202)	(0.231)	(0.237)
SSE	0.028	0.034	0.062*	-0.026**	-0.022**	0.037***
	(0.024)	(0.023)	(0.032)	(0.011)	(0.011)	(0.014)
RDS	-0.520	-0.529	-0.196	0.026	0.024	0.369**
	(0.331)	(0.331)	(0.353)	(0.169)	(0.169)	(0.183)
Computer	0.007	0.005	0.011	-0.007	-0.006	-0.007
	(0.010)	(0.009)	(0.010)	(0.005)	(0.005)	(0.005)
GDP	-0.082	-0.069	-0.100	0.399***	0.397***	0.372***
	(0.059)	(0.059)	(0.062)	(0.037)	(0.038)	(0.039)
government effectiveness	-0.318	-0.275	0.556	-1.314***	-1.289***	-1.064***
	(0.479)	(0.477)	(0.546)	(0.261)	(0.260)	(0.281)
Regulation Quality	1.809***	1.748***	1.669***	0.535**	0.510**	1.016***
	(0.470)	(0.475)	(0.517)	(0.262)	(0.255)	(0.279)
Manufacturing		-0.240			0.000	
		(0.398)			(0.202)	
Manu×Δpart		0.215***			-0.039	
		(0.063)			(0.026)	
Manu×Δposition		1.114**			-1.442***	
		(0.563)			(0.412)	
RCEP			4.072			7.026***
			(2.499)			(1.179)
Δpart×RCEP			-0.098***			-0.012
			(0.033)			(0.019)
Δposit× RCEP			0.124			-1.328***
			(0.565)			(0.384)
SSE× RCEP			-0.057			-0.101***
			(0.046)			(0.019)
RDS ×RCEP			0.792			-0.450
			(0.837)			(0.421)
computer×RCEP			-0.023**			0.011*
			(0.012)			(0.007)
GE×RCEP			-1.318			0.466
			(1.667)			(1.116)
ReguQ×RCEP			0.061			-3.654***
			(1.106)			(0.681)
Constant	-1.265	-1.778	-3.804	0.543	0.319	-3.945***
	(1.717)	(1.710)	(2.331)	(0.851)	(0.837)	(1.089)
Global Financial Crisis	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6526	6526	6526	6526	6526	6526

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

both domestic and foreign servicification level in the OECD countries. Moreover, inadequate regulations of RCEP countries would increase the use of foreign services in production for RCEP countries, while decreasing the use of both domestic and foreign services in production for the OECD countries. The different impacts of regulations on servicification between OECD and RCEP countries mainly lie in the fact that most RCEP countries are lack of the profound institutional environment and enough service workers to guarantee the production of high-quality services. Moreover, we also conclude that the development of ICT increased the level of foreign servicification in RCEP countries with the positive coefficient of ICT interaction.

Bibliography

ADB (2017), "Integrating smes into global value chains: Challenges and policy actions in asias." In *Integrating SMEs into Global Value Chains: Challenges and Policy Actions in Asias*, 1–12, Springer.

Ahmad, Nadim, Sonia Araujo, Alessia Lo Turco, and Daniela Maggioni (2013), "Using trade microdata to improve trade in value-added measures: Proof of concept using turkish data." *Trade in Value Added*, 21.

Akerlof, George A (1982), "Labor contracts as partial gift exchange." *The quarterly journal of economics*, 97, 543–569.

Akerlof, George A and Janet L Yellen (1990), "The fair wage-effort hypothesis and unemployment." *The Quarterly Journal of Economics*, 105, 255–283.

Alexander, Patrick D (2016), "Comparative advantage and multi-stage production."

Alfaro, Laura, Davin Chor, Pol Antras, and Paola Conconi (2017), "Internalizing global value chains: A firm-level analysis."

Allen, Treb and Costas Arkolakis (2014), "Trade and the topography of the spatial economy." *The Quarterly Journal of Economics*, 129, 1085–1140.

Amador, João and Sónia Cabral (2014), "Global value chains: Surveying drivers and measures."

Amiti, Mary and Lisa Cameron (2012), "Trade liberalization and the wage skill premium: Evidence from indonesia." *Journal of International Economics*, 87, 277–287.

Amiti, Mary and Donald R Davis (2011), “Trade, firms, and wages: Theory and evidence.” *The Review of economic studies*, 79, 1–36.

Amiti, Mary and Shang-Jin Wei (2005), *Service offshoring, productivity, and employment: Evidence from the United States.* 5-238, International Monetary Fund.

Amiti, Mary and Shang-Jin Wei (2009), “Service offshoring and productivity: Evidence from the us.” *The World Economy*, 32, 203–220.

Anderson, James E (1979), “A theoretical foundation for the gravity equation.” *The American Economic Review*, 69, 106–116.

Anderson, James E (2011), “The gravity model.” *Annu. Rev. Econ.*, 3, 133–160.

Anderson, James E and Eric Van Wincoop (2003), “Gravity with gravitas: a solution to the border puzzle.” *the American Economic Review*, 93, 170–192.

Anderson, James E and Eric Van Wincoop (2004), “Trade costs.” *Journal of Economic literature*, 42, 691–751.

Antonietti, Roberto and Davide Antonioli (2011), “The impact of production offshoring on the skill composition of manufacturing firms: evidence from italy.” *International Review of Applied Economics*, 25, 87–105.

Antràs, Pol and Davin Chor (2013), “Organizing the global value chain.” *Econometrica*, 81, 2127–2204.

Antras, Pol and Davin Chor (2018), “On the measurement of upstreamness and downstreamness in global value chains.” Technical report, National Bureau of Economic Research.

Antràs, Pol, Davin Chor, Thibault Fally, and Russell Hillberry (2012), “Measuring the upstreamness of production and trade flows.” *The American Economic Review*, 102, 412–416.

Antras, Pol and Elhanan Helpman (2004), “Global sourcing.” *Journal of Political Economy*, 112, 552–580.

Anukoonwattaka, Witada, Marco Scagliusi, and Mia Mikic (2015), "Servicification and industrial exports from asia and the pacific."

Arellano, Manuel and Stephen Bond (1988), *Dynamic Panel Data Estimation Using PPD: A Guide for Users*. Institute for Fiscal Studies London.

Arkolakis, Costas, Arnaud Costinot, and Andrés Rodríguez-Clare (2012), "New trade models, same old gains?" *The American Economic Review*, 102, 94–130.

Arnold, Jens M, Beata S Javorcik, and Aaditya Mattoo (2011), "Does services liberalization benefit manufacturing firms?: Evidence from the czech republic." *Journal of International Economics*, 85, 136–146.

Arnold, Jens Matthias, Beata Javorcik, Molly Lipscomb, and Aaditya Mattoo (2016), "Services reform and manufacturing performance: Evidence from india." *The Economic Journal*, 126, 1–39.

Autor (2013), "The" task approach" to labor markets: an overview." Technical report, National Bureau of Economic Research.

Autor, David and David Dorn (2013), "The growth of low-skill service jobs and the polarization of the us labor market." *The American Economic Review*, 103, 1553–1597.

Autor, David, Lawrence F Katz, and Melissa S Kearney (2006), "The polarization of the us labor market." Technical report, National Bureau of Economic Research.

Autor, Mark G, Duggan (2003), "The skill content of recent technological change: An exploration." *The Quarterly Journal of Economics*, 157–205.

Baldwin, John Russel, Beiling Yan, et al. (2014), *Global value chains and the productivity of Canadian manufacturing firms*. Statistics Canada= Statistique Canada.

Baldwin, Richard (2011), "Trade and industrialisation after globalisation's 2nd unbundling: How building and joining a supply chain are different and why it matters." Technical report, National Bureau of Economic Research.

Baldwin, Richard (2013), "Misthinking globalisation." In *Keynote Lecture at the 21st International Input–Output Conference.*

Baldwin, Richard, Rikard Forslid, and Tadashi Ito (2015), "Unveiling the evolving sources of value added in exports." *Draft, February.*

Baldwin, Richard and Frédéric Robert-Nicoud (2014), "Trade-in-goods and trade-in-tasks: An integrating framework." *Journal of International Economics*, 92, 51–62.

Baldwin, Richard and Daria Taglioni (2011), "Gravity chains: Estimating bilateral trade flows when parts and components trade is important." Technical report, National Bureau of Economic Research.

Baldwin, Richard and Anthony J Venables (2013), "Spiders and snakes: offshoring and agglomeration in the global economy." *Journal of International Economics*, 90, 245–254.

Banga, Rashmi (2013), "Measuring value in global value chains." *UNCTAD Background Paper. Geneva: United Nations (http://unctad. org/en/PublicationsLibrary/ecidc2013misc1_bp8. pdf).*

Barro, Robert J (1991), "A cross-country study of growth, saving, and government." In *National saving and economic performance*, 271–304, University of Chicago Press.

Barro, Robert J and Jong-Wha Lee (1993), "International comparisons of educational attainment." *Journal of monetary economics*, 32, 363–394.

Bas, Maria (2014), "Does services liberalization affect manufacturing firms? export performance? evidence from india." *Journal of Comparative Economics*, 42, 569–589.

Baumgarten, Daniel, Ingo Geishecker, and Holger Görg (2013), "Offshoring, tasks, and the skill-wage pattern." *European Economic Review*, 61, 132–152.

Becker, Sascha O, Karolina Ekholm, and Marc-Andreas Muendler (2013), "Offshoring and the onshore composition of tasks and skills." *Journal of International Economics*, 90, 91–106.

Becker, Sascha O and Marc-Andreas Muendler (2015), "Trade and tasks: an exploration over three decades in germany." *Economic Policy*, 30, 589–641.

Bems, Rudolfs and Robert C Johnson (2012), "Value-added exchange rates." Technical report, National Bureau of Economic Research.

Bergstrand, Jeffrey H (1985), "The gravity equation in international trade: some microeconomic foundations and empirical evidence." *The review of economics and statistics*, 474–481.

Bergstrand, Jeffrey H, Peter Egger, and Mario Larch (2013), "Gravity redux: Estimation of gravity-equation coefficients, elasticities of substitution, and general equilibrium comparative statics under asymmetric bilateral trade costs." *Journal of International Economics*, 89, 110–121.

Bergstrand, JH and P Egger (2010), "A general equilibrium theory for estimating gravity equations of bilateral fdi, final goods trade, and intermediate trade flows." *The Gravity Model in International Trade*, 29–70.

Bernard, Andrew B, J Bradford Jensen, Stephen J Redding, and Peter K Schott (2012), "The empirics of firm heterogeneity and international trade." *Annu. Rev. Econ.*, 4, 283–313.

Bernard, Andrew B, Valerie Smeets, and Frederic Warzynski (2017), "Rethinking deindustrialization." *Economic Policy*, 32, 5–38.

Beverelli, Cosimo, Matteo Fiorini, and Bernard Hoekman (2017), "Services trade policy and manufacturing productivity: The role of institutions." *Journal of International Economics*, 104, 166–182.

Boddin, Dominik and Philipp Henze (2014), "International trade and the servitization of manufacturing: Evidence from german micro data." *ETSG, Münich, Germany.*

Brandt, Loren, Johannes Van Biesebroeck, and Yifan Zhang (2014), "Challenges of working with the chinese nbs firm-level data." *China Economic Review*, 30, 339–352.

Cai, Hongbin and Qiao Liu (2009), "Competition and corporate tax avoidance: Evidence from chinese industrial firms." *The Economic Journal*, 119, 764–795.

Caliendo, Lorenzo and Fernando Parro (2014), "Estimates of the trade and welfare effects of nafta." *The Review of Economic Studies*, rdu035.

Chen, Bo, Miaojie Yu, and Zhihao Yu (2017), "Measured skill premia and input trade liberalization: Evidence from chinese firms." *Journal of International Economics*, 109, 31–42.

Chen, Xikang, Leonard K Cheng, Kwok-Chiu Fung, Lawrence J Lau, Yun-Wing Sung, Kunfu Zhu, Cuihong Yang, Jiansuo Pei, and Yuwan Duan (2012), "Domestic value added and employment generated by chinese exports: A quantitative estimation." *China Economic Review*, 23, 850–864.

Choi, Changkyu (2010), "The effect of the internet on service trade." *Economics Letters*, 109, 102–104.

Chor, Davin (2010), "Unpacking sources of comparative advantage: A quantitative approach." *Journal of International Economics*, 82, 152–167.

Contractor, Farok J, Vikas Kumar, Sumit K Kundu, and Torben Pedersen (2010), "Reconceptualizing the firm in a world of outsourcing and offshoring: The organizational and geographical relocation of high-value company functions." *Journal of Management Studies*, 47, 1417–1433.

Costinot, Arnaud and Andres Rodriguez-Clare (2013), "Trade theory with numbers: Quantifying the consequences of globalization." Technical report, National Bureau of Economic Research.

Crino, Rosario (2010), "Service offshoring and white-collar employment." *The Review of Economic Studies*, 77, 595–632.

Crino, Rosario (2012), "Service offshoring and the skill composition of labour demand." *Oxford Bulletin of Economics and Statistics*, 74, 20–57.

Criscuolo, Chiara and Luis Garicano (2010), "Offshoring and wage inequality: Using occupational licensing as a shifter of offshoring costs." *The American Economic Review*, 100, 439–443.

Crozet, Matthieu, Emmanuel Milet, et al. (2014), "The servitization of french manufacturing firms." Technical report.

Danthine, Jean-Pierre and André Kurmann (2004), "Fair wages in a new keynesian model of the business cycle." *Review of Economic Dynamics*, 7, 107–142.

Dauth, Wolfgang, Sebastian Findeisen, and Jens Suedekum (2017), "Trade and manufacturing jobs in germany." *American Economic Review*, 107, 337–42.

De Backer, Koen and Sébastien Miroudot (2014), "Mapping global value chains." *OECD Trade Policy Papers*.

Dean, Judith M, Kwok Chiu Fung, and Zhi Wang (2011), "Measuring vertical specialization: The case of china." *Review of International Economics*, 19, 609–625.

Dietzenbacher, Erik and Isidoro Romero (2007), "Production chains in an interregional framework: identification by means of average propagation lengths." *International Regional Science Review*, 30, 362–383.

Eaton, Jonathan and Samuel Kortum (2002), "Technology, geography, and trade." *Econometrica*, 70, 1741–1779.

Ebenstein, Avraham, Ann Harrison, Margaret McMillan, and Shannon Phillips (2014), "Estimating the impact of trade and offshoring on american workers using the current population surveys." *Review of Economics and Statistics*, 96, 581–595.

Egger, Hartmut, Peter Egger, and Udo Kreickemeier (2013), "Trade, wages, and profits." *European Economic Review*, 64, 332–350.

Egger, Hartmut and Udo Kreickemeier (2009), "Firm heterogeneity and the labor market effects of trade liberalization." *International Economic Review*, 50, 187–216.

Egger, Hartmut, Udo Kreickemeier, and Jens Wrona (2015), "Offshoring domestic jobs." *Journal of International Economics*, 97, 112–125.

Egger, Hartmut, Kreickemeier Udo, and Wrona Jens (2016), "Offshoring, firm selection, and job polarisation in general equilibrium."

Elms, Deborah K and Patrick Low (2013), *Global value chains in a changing world*. World Trade Organization Geneva.

Fally, Thibault (2012), "Production staging: measurement and facts." *Boulder, Colorado, University of Colorado Boulder, May*, 155–168.

Feenstra, Robert and Gordon Hanson (2001), "Global production sharing and rising inequality: A survey of trade and wages." Technical report, National Bureau of Economic Research.

Feenstra, Robert C (1998), "Integration of trade and disintegration of production in the global economy." *Journal of economic Perspectives*, 12, 31–50.

Feenstra, Robert C (2010), *Offshoring in the global economy: microeconomic structure and macroeconomic implications*. mit Press.

Feenstra, Robert C and Gordon H Hanson (1996), "Globalization, outsourcing, and wage inequality." Technical report, National Bureau of Economic Research.

Feenstra, Robert C and Gordon H Hanson (1999), "The impact of outsourcing and high-technology capital on wages: estimates for the united states, 1979–1990." *The Quarterly Journal of Economics*, 114, 907–940.

Feenstra, Robert C and Gordon H Hanson (2000), "Aggregation bias in the factor content of trade: evidence from us manufacturing." *American Economic Review*, 90, 155–160.

Feenstra, Robert C and Chang Hong (2010), "China's exports and employment." In *China's growing role in world trade*, 167–199, University of Chicago Press.

Feenstra, Robert C, Zhiyuan Li, and Miaojie Yu (2014), "Exports and credit constraints under incomplete information: Theory and evidence from china." *Review of Economics and Statistics*, 96, 729–744.

Fernandez-Stark, Karina, Penny Bamber, and Gary Gereffi (2011), "The offshore services global value chain." *Skills for Upgrading: Workforce Development and Global Value Chains in Developing Countries. Center for Globalization, Governance and Competitiveness, Duke University*, 132–189.

Fujita, Masahisa and Jacques-François Thisse (2006), "Globalization and the evolution of the supply chain: who gains and who loses?" *International Economic Review*, 47, 811–836.

Galiani, Sebastian and Pablo Sanguinetti (2003), "The impact of trade liberalization on wage inequality: evidence from argentina." *Journal of development Economics*, 72, 497–513.

Geishecker, Ingo and Holger Görg (2008), "Winners and losers: A micro-level analysis of international outsourcing and wages." *Canadian Journal of Economics/Revue canadienne d'économique*, 41, 243–270.

Gereffi, Gary (2015), "Global value chains, development and emerging economies." *Global Value Chains, Development and Emerging Economies.*

Gereffi, Gary and Karina Fernandez-Stark (2010), "The offshore services industry: a global value chain approach." *Durham: Center on Globalization Governance and Competitiveness-Duke University. Commisioned by CORFO.*

Gereffi, Gary and Karina Fernandez-Stark (2011), "Global value chain analysis: a primer." *Center on Globalization, Governance & Competitiveness (CGGC), Duke University, North Carolina, USA.*

Gereffi, Gary and Joonkoo Lee (2012), "Why the world suddenly cares about global supply chains." *Journal of supply chain management*, 48, 24–32.

Globerman, Steven (2011), "Global value chains: Economic and policy issues."

Goldberg, Pinelopi Koujianou and Nina Pavcnik (2007), "Distributional effects of globalization in developing countries." *Journal of economic Literature*, 45, 39–82.

Goos, Maarten, Alan Manning, and Anna Salomons (2009), "Job polarization in europe." *The American Economic Review*, 99, 58–63.

Goos, Maarten, Alan Manning, and Anna Salomons (2014), "Explaining job polarization: Routine-biased technological change and offshoring." *American Economic Review*, 104, 2509–26.

Grossman, Gene M and Esteban Rossi-Hansberg (2008), "Trading tasks: A simple theory of offshoring." *American Economic Review*, 98, 1978–97.

Grossman, Gene M and Esteban Rossi-Hansberg (2012), "Task trade between similar countries." *Econometrica*, 80, 593–629.

Harrison, Ann and Margaret McMillan (2011), "Offshoring jobs? multinationals and us manufacturing employment." *Review of Economics and Statistics*, 93, 857–875.

Heckman, James J (1979), "Sample selection bias as a specification error." *Econometrica*.

Helg, Rodolfo and Lucia Tajoli (2005), "Patterns of international fragmentation of production and the relative demand for labor." *The North American Journal of Economics and Finance*, 16, 233–254.

Helpman, Elhanan (1984), "A simple theory of international trade with multinational corporations." *Journal of political economy*, 92, 451–471.

Helpman, Elhanan (2016), "Globalization and wage inequality." Technical report, National Bureau of Economic Research.

Helpman, Elhanan, Oleg Itskhoki, and Stephen Redding (2010), "Inequality and unemployment in a global economy." *Econometrica*, 78, 1239–1283.

Helpman, Elhanan, Marc Melitz, and Yona Rubinstein (2008), "Estimating trade flows: Trading partners and trading volumes." Technical Report 2.

Heuser, Cecilia and Aaditya Mattoo (2017), "Services trade and global value chains."

Hijzen, Alexander (2007), "International outsourcing, technological change, and wage inequality." *Review of International Economics*, 15, 188–205.

Hijzen, Alexander and Paul Swaim (2007), "Does offshoring reduce industry employment?" *National Institute Economic Review*, 201, 86–96.

Ho, Lok Sang, Xiangdong Wei, and Wai Chung Wong (2005), "The effect of outward processing trade on wage inequality: the hong kong case." *Journal of International Economics*, 67, 241–257.

Hoekman, Bernard and Ben Shepherd (2017), "Services productivity, trade policy and manufacturing exports." *The World Economy*, 40, 499–516.

Hsieh, Chang-Tai and Keong T Woo (2005), "The impact of outsourcing to china on hong kong's labor market." *American Economic Review*, 95, 1673–1687.

Hummels, David, Jun Ishii, and Kei-Mu Yi (2001), "The nature and growth of vertical specialization in world trade." *Journal of international Economics*, 54, 75–96.

Hummels, David, Rasmus Jørgensen, Jakob Munch, and Chong Xiang (2014), "The wage effects of offshoring: Evidence from danish matched worker-firm data." *American Economic Review*, 104, 1597–1629.

Hummels, David, Jakob R Munch, and Chong Xiang (2016), "Offshoring and labor markets." Technical report, National Bureau of Economic Research.

INOMATA, SATOSHI (2017), "Analytical frameworks for global value chains: An overview."

Jiang, Xiao (2015), "Employment effects of trade in intermediate and final goods: An empirical assessment." *International Labour Review*, 154, 147–164.

Johnson, Robert C (2014), "Five facts about value-added exports and implications for macroeconomics and trade research." *The Journal of Economic Perspectives*, 28, 119–142.

Johnson, Robert C (2017), "Measuring global value chains." Technical report, National Bureau of Economic Research.

Johnson, Robert C and Guillermo Noguera (2012a), "Accounting for intermediates: Production sharing and trade in value added." *Journal of international Economics*, 86, 224–236.

Johnson, Robert C and Guillermo Noguera (2012b), "Fragmentation and trade in value added over four decades." Technical report, National Bureau of Economic Research.

Ju, Jiandong and Xinding Yu (2015), "Productivity, profitability, production and export structures along the value chain in china." *Journal of Comparative Economics*, 43, 33–54.

Kasahara, Hiroyuki, Yawen Liang, and Joel Rodrigue (2016), "Does importing intermediates increase the demand for skilled workers? plant-level evidence from indonesia." *Journal of International Economics*, 102, 242–261.

Kee, Hiau Looi and Heiwai Tang (2016), "Domestic value added in exports: Theory and firm evidence from china." *American Economic Review*, 106, 1402–36.

Kelle, Markus (2013), "Crossing industry borders: German manufacturers as services exporters." *The World Economy*, 36, 1494–1515.

Kelle, Markus and Jörn Kleinert (2010), "German firms in service trade." *Applied Economics Quarterly*, 56, 51–71.

Kizu, Takaaki, Stefan Kühn, Christian Viegelahn, et al. (2016), *Linking jobs in global supply chains to demand*. ILO.

Koopman, Robert, Zhi Wang, and Shang-Jin Wei (2012), "Estimating domestic content in exports when processing trade is pervasive." *Journal of development economics*, 99, 178–189.

Koopman, Robert, Zhi Wang, and Shang-Jin Wei (2014), "Tracing value-added and double counting in gross exports." *The American Economic Review*, 104, 459–494.

Lanz, Rainer, Andreas Maurer, et al. (2015), *Services and global value chains: Some evidence on servicification of manufacturing and services networks*. World Trade Organization, Economic Research and Statistics Division.

Lenzen, Manfred, Daniel Moran, Keiichiro Kanemoto, and Arne Geschke (2013), "Building eora: a global multi-region input–output database at high country and sector resolution." *Economic Systems Research*, 25, 20–49.

Li, Shantong and Zhaoyuan Xu (2008), "The trend of regional income disparity in the people's republic of china."

Liu, Runjuan and Daniel Trefler (2011), "A sorted tale of globalization: White collar jobs and the rise of service offshoring." Technical report, National Bureau of Economic Research.

Lodefalk, M (2010), "Servicification of swedish manufacturing." *Kommerskollegium 2010*, 1.

Lodefalk, Magnus (2014), "The role of services for manufacturing firm exports." *Review of World Economics*, 150, 59–82.

Lodefalk, Magnus (2017), "Servicification of firms and trade policy implications." *World Trade Review*, 16, 59–83.

Los, Bart, Erik Dietzenbacher, Robert Stehrer, MP Timmer, and Gaaitzen de Vries (2012), "Trade performance in internationally fragmented production networks: Concepts and measures." *World Input Output Database-WIOD Working Paper.*

Los, Bart, Marcel P Timmer, and Gaaitzen J Vries (2015), "How global are global value chains? a new approach to measure international fragmentation." *Journal of Regional Science*, 55, 66–92.

Low, Patrick (2013), "The role of services in global value chains." *Global value chains in a changing world (Hong Kong, China*, 61–81.

Ma, Hong, Zhi Wang, and Kunfu Zhu (2015), "Domestic content in china's exports and its distribution by firm ownership." *Journal of Comparative Economics*, 43, 3–18.

Mariasingham, Joseph (2014), "Adb multi-region input-output database: Sources and methods." Technical report.

Marin, Dalia (2006), "A new international division of labor in europe: Outsourcing and offshoring to eastern europe." *Journal of the European Economic Association*, 4, 612–622.

Mastrogiacomo, Luca, Federico Barravecchia, and Fiorenzo Franceschini (2017), "A general overview of manufacturing servitization in italy." *Procedia CIRP*, 64, 121–126.

Melitz, Marc J (2003), "The impact of trade on intra-industry reallocations and aggregate industry productivity." *Econometrica*, 71, 1695–1725.

Meng, Bo, Yaxiong Zhang, and Satoshi Inomata (2013), "Compilation and applications of ide-jetro's international input–output tables." *Economic Systems Research*, 25, 122–142.

Milberg, William and Deborah Winkler (2013), *Outsourcing economics: global value chains in capitalist development*. Cambridge University Press.

Miller, Ronald E and Umed Temurshoev (2017), "Output upstreamness and input downstreamness of industries/countries in world production." *International Regional Science Review*, 40, 443–475.

Mion, Giordano and Linke Zhu (2013), "Import competition from and offshoring to china: A curse or blessing for firms?" *Journal of International Economics*, 89, 202–215.

Miroudot, C. Cadestin, S. (2017), "Services in global value chains: From inputs to value-creating activities." *OECD Trade Policy Papers*, No. 197.

Miroudot, Sbastien and Charles Cadestin (2017), "Services in global value chains: From inputs to value-creating activities." Technical report, OECD Report.

Miroudot, Sébastien, Rainer Lanz, and Alexandros Ragoussis (2009), "Trade in intermediate goods and services."

Mitra, Devashish and Priya Ranjan (2010), "Offshoring and unemployment: The role of search frictions labor mobility." *Journal of International Economics*, 81, 219–229.

Morris, Mike and Cornelia Staritz (2017), "Industrial upgrading and development in lesotho's apparel industry: global value chains, foreign direct investment, and market diversification." *Oxford Development Studies*, 45, 303–320.

Mulligan, Casey B and Xavier Sala-i Martin (1995), "Measuring aggregate human capital." Technical report, National Bureau of Economic Research.

Nehru, Vikram, Eric Swanson, Ashutosh Dubey, et al. (1993), "A new database on human capital stock: Sources, methodology and results." Technical report, The World Bank.

Noguera, Guillermo (2012), "Trade costs and gravity for gross and value added trade." *Job Market Paper, Columbia University*.

Nordås, Hildegunn Kyvik (2010), "Trade in goods and services: Two sides of the same coin?" *Economic Modelling*, 27, 496–506.

Nordås, Hildegunn Kyvik and Yunhee Kim (2013), "The role of services for competitiveness in manufacturing."

OECD (2014), "Challenges, opportunities, and implications for policy." In *Report prepared for submission to the G20 Trade Ministers Meeting Sydney, Australia*, volume 19.

OECD (2017), "Oecd skills outlook 2017." *OECD Report*.

OECD-WTO (2012), "Trade in value-added: concepts, methodologies and challenges."

Oldenski, Lindsay (2014), "Offshoring and the polarization of the us labor market." *Industrial & Labor Relations Review*, 67, 734–761.

Olley, G Steven and Ariel Pakes (1992), "The dynamics of productivity in the telecommunications equipment industry." Technical report, National Bureau of Economic Research.

Ottaviano, Gianmarco IP, Giovanni Peri, and Greg C Wright (2013), "Immigration, offshoring, and american jobs." *American Economic Review*, 103, 1925–59.

Petrin, Amil and James Levinsohn (2012), "Measuring aggregate productivity growth using plant-level data." *The RAND Journal of Economics*, 43, 705–725.

Pilat, Dirk and Anita Wölfl (2005), "Measuring the interaction between manufacturing and services."

Puzzello, Laura (2012), "A proportionality assumption and measurement biases in the factor content of trade." *Journal of International Economics*, 87, 105–111.

Rahman, Mohammad Masudur and Laila Arjuman Ara (2015), "Tpp, ttip and rcep: implications for south asian economies." *South Asia Economic Journal*, 16, 27–45.

Ranjan, Priya (2013), "Offshoring, unemployment, and wages: The role of labor market institutions." *Journal of International Economics*, 89, 172–186.

Roodman, David et al. (2009), "How to do xtabond2: An introduction to difference and system gmm in stata." *Stata Journal*, 9, 86–136.

Schwörer, Tillmann (2011), "Offshoring and productivity: Evidence for the western european manufacturing sector."

Sethupathy, Guru (2013), "Offshoring, wages, and employment: Theory and evidence." *European Economic Review*, 62, 73–97.

Shen, Leilei and Peri Silva (2018), "Value-added exports and us local labor markets: Does china really matter?" *European Economic Review*, 101, 479–504.

Shepotylo, Oleksandr and Volodymyr Vakhitov (2015), "Services liberalization and productivity of manufacturing firms." *Economics of Transition*, 23, 1–44.

Silva, JMC Santos and Silvana Tenreyro (2006), "The log of gravity." *The Review of Economics and statistics*, 88, 641–658.

Silva, João and Silvana Tenreyro (2011), "Poisson: Some convergence issues." *Working Paper*.

Stadler, Konstantin, Richard Wood, Tatyana Bulavskaya, Carl-Johan Södersten, Moana Simas, Sarah Schmidt, Arkaitz Usubiaga, José Acosta-Fernández, Jeroen Kuenen, Martin Bruckner, et al. (2017), "Exiobase 3: Developing a time series of detailed environmentally extended multi-regional input-output tables." *Journal of Industrial Ecology*.

Stehrer, Robert, Neil Foster, and Gaaitzen de Vries (2010), "Value added and factors in trade: A comprehensive approach." *Dynamics*, 67, 40.

Stephenson, S and J Drake-Brockman (2014), "The services trade dimension of global value chains: Policy implications for commonwealth developing countries and small states." *Commonwealth Trade Policy Discussion Papers*, 4.

Timmer, Marcel P, Erik Dietzenbacher, Bart Los, Robert Stehrer, and Gaaitzen J Vries (2015), "An illustrated user guide to the world input–output database: the case of global automotive production." *Review of International Economics*, 23, 575–605.

Timmer, Marcel P, Abdul Azeez Erumban, Bart Los, Robert Stehrer, and Gaaitzen J de Vries (2014), "Slicing up global value chains." *The Journal of Economic Perspectives*, 28, 99–118.

Trefler, Daniel and Susan Chun Zhu (2010), "The structure of factor content predictions." *Journal of International Economics*, 82, 195–207.

UNCTAD (2015), *Key Statistics and Trends in International Trade 2015*. United Nation Conference on Trade and Development Report.

Upward, Richard, Zheng Wang, and Jinghai Zheng (2013), "Weighing china's export basket: The domestic content and technology intensity of chinese exports." *Journal of Comparative Economics*, 41, 527–543.

Vandermerwe, Sandra and Juan Rada (1988), "Servitization of business: adding value by adding services." *European management journal*, 6, 314–324.

Verhoogen, Eric A (2008), "Trade, quality upgrading, and wage inequality in the mexican manufacturing sector." *The Quarterly Journal of Economics*, 123, 489–530.

Vries, Gaaitzen J de, Robert Stehrer, Bart Los, Abdul Azeez Erumban, Marcel Timmer, et al. (2014), "Slicing up global value chains." *Journal of Economic Perspectives*, 28, 99–118.

Wagner, Joachim (2011), "Offshoring and firm performance: self-selection, effects on performance, or both?" *Review of World Economics*, 147, 217–247.

Wang, Zhi, Shang-Jin Wei, Xinding Yu, and Kunfu Zhu (2017), "Characterizing global value chains: Production length and upstreamness." Technical report, National Bureau of Economic Research.

Wang, Zhi, Shang-Jin Wei, and Kunfu Zhu (2013), "Quantifying international production sharing at the bilateral and sector levels." Technical report, National Bureau of Economic Research.

Windmeijer, Frank (2005), "A finite sample correction for the variance of linear efficient two-step gmm estimators." *Journal of Econometrics*, 1, 25–51.

Wooldridge, Jeffrey M (2008), "Instrumental variables estimation of the average treatment effect in the correlated random coefficient model." In *Modelling and evaluating treatment effects in econometrics*, 93–116, Emerald Group Publishing Limited.

WTO (2016), "International trade statistics 2016." *WTO Trade Report*.

Yi, Kei-Mu (2003), "Can vertical specialization explain the growth of world trade?" *Journal of political Economy*, 111, 52–102.

Yu, Miaojie (2015), "Processing trade, tariff reductions and firm productivity: evidence from chinese firms." *The Economic Journal*, 125, 943–988.

Zhu, Susan Chun and Daniel Trefler (2005), "Trade and inequality in developing countries: a general equilibrium analysis." *Journal of international Economics*, 65, 21–48.