THREE ESSAYS ON THE TRANSFORMATION OF
GLOBAL IT PRODUCTION

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   James Richardson
To my wife, Simona
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Abstract

In the last two decades, the information technology (IT) industry has gone through a fundamental transformation of its organization of international production. This dissertation consists of three essays that address the nature, causes and consequences of this transformation.

The first essay “The Determinants of East Asia’s Information Technology Trade” focuses on the build-up of East Asia’s IT sector and its implications for IT trade in the Asia-Pacific region. East Asia’s expanding role in global IT production is attributed to the decision of multinational firms to vertically fragment their production processes and move labor-intensive production stages to labor-abundant East Asia. To study the impact of international production fragmentation on IT trade in the Asia-Pacific region, a panel regression of modified bilateral IT trade equations is estimated. The estimation results indicate that fragmentation has significantly increased IT trade in the Asia-Pacific region.

The second essay “Modularity and the Organization of International Production” focuses on the co-evolution of vertical outsourcing and horizontal consolidation that has been observed in the IT industry. To account for this phenomenon, I build an industry-equilibrium model in which the boundaries of the firm are endogenous in both the horizontal and vertical dimensions of international production. The concept of modularity is subsequently incorporated into the model. The model not only links the co-evolution to modularity, but also predicts the emergence of de facto input standardization during this process.
The third essay "Assessing the Benefits of Telecommunications Liberalization in Tunisia" focuses on the importance of regulatory reforms on the success of telecommunications liberalization in developing countries. For this purpose, a computational general equilibrium (CGE) model for Tunisia is set up in which the telecommunications sector can form different imperfectly competitive market structures under liberalization. I demonstrate that telecommunications liberalization will be welfare improving if the domestic and foreign telecom providers act competitively, but can be welfare reducing if they form a cartel. The results of this essay strengthen the argument that pro-competitive regulatory reforms need to accompany telecommunications liberalization in developing countries such as Tunisia.
Acknowledgements

During the course of writing this dissertation, I have benefited from discussions and collaboration with a great number of people. First of all, I would like to express my thanks to my dissertation committee members who have been very generous with their time and ideas. They have provided me with many thoughtful comments and astute advice which have greatly benefited my work. I owe special thanks to my chair Denise Konan for her constant inspiration, guidance and encouragement throughout my graduate studies. I am deeply indebted to Byron Gangnes who has not only been my boss for the last three years, but also my mentor and friend. I am very grateful to Theresa Greaney for her careful reading of my work and for many insightful suggestions for its improvement. I wish to highly acknowledge the efforts of my external examiner James Richardson in evaluating the contents of this dissertation. Finally, I extend my deepest appreciation to James Roumasset. Not only have his intellectual creativity and search for fundamentals influenced much of my economic thinking, but he and his wife have provided me with a family in Hawai‘i.

I would like to thank all of the people who read, edited, commented upon and/or critiqued parts of my dissertation. For the second chapter, I am naturally indebted to my co-authors Carl Bonham and Byron Gangnes. We recognize comments that we received at the October 2002 Project Link Meeting in Bologna, Italy and at the February 2003 Conference on New Developments in the Asia Pacific Region at Yokohama National University, Japan. We also want to express gratitude to the University of Hawai‘i New Economy Research Grant program and to the Singapore Management University for financial support.
For the third chapter, I would like to acknowledge comments I received from Dieter Ernst, Meheroo Jussawalla, Timothy Sturgeon, Eiichi Tomiura, Stephen Yeaple, as well as from seminar participants at the University of Hawai‘i at Manoa, the May 2003 Mid-West International Economics Conference at the University of Pittsburgh and the November 2003 Southern Economics Association Conference in San Antonio. For the third chapter, I am indebted to my co-author Denise Konan; and to Jesper Jensen, James Markusen and Thomas Rutherford who have taught me the basics of GAMS/MPSGE modelling.

I am very grateful for the camaraderie of the other students in the program. The enthusiasm, goodwill and intelligence of everyone in my cohort made my years at UH exceptionally rewarding. In particular, Jonghyuk Kim, DoAnne Sanchez, Naotaka Sawada, Tomomi Tanaka, So Umezaki and Yoav Wachsman all provided intellectual support as well as many good times and wonderful memories.

My biggest thanks goes to my family. My parents, Dirk and Hilde, and my brothers, Tobe and Matthias, have encouraged me for as long as I can remember to go through life asking questions. They have been there throughout every challenge in my life, not the least of which was graduate school.

Last but not least, I am forever grateful to my wife Simona. Her presence in my life has made the writing of my dissertation (among other things) all the more enjoyable. She also proof-read my dissertation repeatedly and played a central role in clarifying some of its central concepts. For her love and constant support, I would like to dedicate this dissertation to her.

Honolulu, Hawai‘i
July 6, 2004

Ari Van Assche
Chapter 1

Introduction

1.1 The Transformation of Global IT Production

In the last two decades, the information technology (IT) industry has gone through a fundamental transformation of its organization of production. Prior to the 1980s, the IT industry was dominated by large, vertically integrated firms (e.g., IBM, DEC, Fujitsu and Hitachi) that produced most parts and components within their country boundaries (see Figure 1.1). Since the arrival of the personal computer in the early 1980s, however, the industry has evolved into a horizontally segmented market. The most important IT companies are no longer national firms that design, market and assemble final IT products themselves, but rather global firms that operate within one horizontal slice of the industry's value chain. Dell and Gateway focus on the design and marketing while outsourcing most, if not all, of their components production and assembly. Contract manufacturing firms such as Solectron and Flextronics are the principal companies in the manufacturing and assembly segment. Microsoft is the dominant firm in the operating system segment. Intel is the market leader in the microprocessor sector.

Increasing competition in the wake of the PC revolution has also led to a rapid globalization of the IT industry. Driven by the need to reduce costs, IT firms headquartered in developed countries have moved the production and assembly of labor-intensive IT components to developing countries, primarily in East Asia, to take advantage of low wages.
Vertically Integrated Computer Industry (ca. 1980)

<table>
<thead>
<tr>
<th>Operating system</th>
<th>IBM</th>
<th>DEC</th>
<th>SPERRY-UNIVAC</th>
<th>WANG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chips</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer design</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer assembly</td>
<td></td>
<td></td>
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</table>

Vertically Specialized Computer Industry (present)

<table>
<thead>
<tr>
<th>Operating system</th>
<th>Windows</th>
<th>Mac</th>
<th>Unix</th>
<th>Linux</th>
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<tbody>
<tr>
<td>Chips</td>
<td>Intel</td>
<td>Samsung</td>
<td>Texas Instruments</td>
<td>...</td>
</tr>
<tr>
<td>Computer design</td>
<td>Dell</td>
<td>HP/Compaq</td>
<td>IBM</td>
<td>...</td>
</tr>
<tr>
<td>Computer assembly</td>
<td>Solectron</td>
<td>Sanmina/SCI</td>
<td>Flextronics</td>
<td>...</td>
</tr>
</tbody>
</table>

Figure 1.1: Transformation of the Organization of IT Production
This has gradually turned East Asia into a global IT manufacturing platform, spurring employment and economic growth. East Asia's share of world IT production rose from 6 percent in 1985 to 26 percent in 2000.

Despite the increased dispersion of IT production into selected developing countries, IT use has remained clustered in the developed world. In 2002, the computer and internet penetration rates in low and middle income countries stood at 10 percent of the rates found in the United States (International Telecommunications Union, 2003). This gap in penetration rates between developed and developing countries is generally referred to as the "Global Digital Divide". It is of particular importance since IT use — and not IT production — contributes to total factor productivity growth (Markus Haacker and James Morsink, 2002; Poh-Kam Wong, 2002). The digital divide thus poses a serious challenge to policy makers in developing countries to promote a faster pace of IT adoption. Since the cost, quality and extent of internet access vary with the performance of the telecommunications sector, an important first step for developing countries to bridge the digital divide is to liberalize their telecom sector and allow global telecom networks to compete on the local markets (Menzie D. Chinn and Robert W. Farlie, 2004).

This dissertation uses elements of the theory of global production networks to address the nature, causes and consequences of the IT sector's global transformation from a vertically integrated industry to a horizontally segmented industry. In this chapter, I introduce the theory of global production networks. I illustrate how it can be used to explain trends in global IT production and identify the theory's shortcomings. Subsequently, I provide an overview of the remaining chapters of this dissertation.

1.2 The Theory of Global Production Networks

The theory of global production networks can be used to explain the IT sector's global transformation, since it not only focuses on the cross-border intra-firm relationships between a lead firm and its own affiliates and subsidiaries, but also its arm's length relationships with
its subcontractors, suppliers, service providers, or other firms participating in cooperative relationships (Michael Borrus, Dieter Ernst and Stephan Haggard, 2000). Figure 1.2 provides an overview of the theory of global production networks. The theory indicates that a firm can globalize its intra-firm operations by setting up a subsidiary in the developing South (a) or in other developed countries (b). On the other hand, it can globalize its arm’s length relationships by outsourcing production to a firm in the South (c or e) or in the developed East or West (d).

Trade theory consists of many building blocks for the theory of global production networks. The theory of the multinational firm analyzes under which circumstances a firm sets up a horizontal (a) or vertical subsidiary (b). The literature on vertical outsourcing focuses on the determinants of cross-border vertical outsourcing (c) versus vertical integration (a).

The theory of the multinational firm incorporates elements of industrial organization theory into general-equilibrium trade models to examine location decisions by multinational firms.¹ According to the theory, there are two motives for firms to expand abroad. On the one hand, some firms set up subsidiaries abroad to exploit factor price differences across countries. The economic analysis of this turns on the idea that different parts of the production process have different input requirements and, since input prices vary across countries, it may be profitable to split production, undertaking unskilled labor-intensive activities in labor-abundant countries, for example. Since their production process is fragmented vertically across countries, these multinationals are called vertically integrated. On the other hand, some firms decide to pay an additional fixed cost of setting up a subsidiary to avoid the variable costs of international trade (transportation costs and tariffs). This is especially attractive for a firm when trade costs are high, when commercial presence is required (services trade), when the consumer market is large, and when regulations for setting up subsidiaries are limited. Since these multinationals replicate an identical production

Figure 1.2: Theory of Global Production Networks

(a) Vertical foreign direct investment
(b) Horizontal foreign direct investment
(c) Vertical outsourcing
(d) Horizontal licensing
(e) Co-evolution of vertical outsourcing and horizontal consolidation
process across countries, they are called horizontally integrated.

The theory of vertical outsourcing focuses on the "make-or-buy" decision of the multinational firm by endogenizing the vertical boundaries of the firm.\(^2\) It does so by incorporating elements of transaction cost theory into general-equilibrium trade models. The general conclusion of this literature is that factors typically related to globalization can explain a rise in outsourcing activity. An increase in trade openness, a reduction in trade costs, and a decline in search costs all have been found to induce outsourcing. In addition, the observed sectoral differences in the prevalence of outsourcing have been attributed to a number of sector-specific factors. For example, sectors that are relatively intensive in component production are found to rely more on outsourcing.

The existing theory of global production networks can successfully describe many of the trends in global IT production. The theory of the vertical multinational firm can explain the globalization of IT production and East Asia's transition into a global IT manufacturing base. The theory of vertical outsourcing provides a partial explanation for the IT industry's transformation from a vertically integrated sector to a horizontally segmented industry. Finally, the theory of the horizontal multinational firm illustrates the conditions under which a multinational telecom provider will establish itself in a country to provide telecom services on the local market.

However, the literature also faces at least few shortcomings. A first limitation is that little attention has been paid to the evolution of the supply-base in response to outsourcing. In the outsourcing literature, external firms are implicitly assumed to sell components to at most one final good firm. This assumption is particularly limiting for the analysis of the transformation of global IT production, since there is considerable evidence that vertical outsourcing has co-evolved with horizontal consolidation in some segments of production (relationship e in Figure 2.1). Timothy J. Sturgeon (2002) and Timothy J. Sturgeon and Ji-Ren Lee (2001), for example, document that the recent trend by brand-name electronics

firms to replace in-house manufacturing with outsourced manufacturing has co-evolved with a consolidation of market shares by the five largest firms in the contract manufacturing industry. Similar trends have been found in other IT segments such as semiconductors (Richard N. Langlois and W. Edward Steinmueller, 1999), telecommunications (Feng Li and Jason Whalley, 2002) and operating systems (Timothy Bresnahan, 1999).

A second limitation is that the literature does not address the role of modularity on the organization of global production networks. IT industry specialists have generally attributed the IT sector's transformation to the modular design of the PC system. Prior to the arrival of the PC, electronics companies built computers with a fully closed proprietary architecture, implying a high cost of coordinating interoperability between components. As a result, firms were induced to produce almost all necessary components in-house. The PC, on the other hand, was built with a modular product architecture and open interface standards. Interoperability rules were standardized and publicly known, thus allowing makers of components to independently concentrate their capabilities at a reduced coordination cost. Modularity thus stimulated the IT industry's vertical disintegration.

1.3 Overview of the Chapters

The remaining chapters of this dissertation are organized as follows. Chapter 2 analyzes the nature of the build-up of East Asia's IT sector and its impact of IT trade in the Asia-Pacific region. Chapter 3 investigates the role of modularity on the co-evolution of vertical outsourcing and horizontal consolidation in global IT production. Chapter 4 focuses on the importance of regulatory reform on a developing country's ability to bridge the digital divide through telecom liberalization.

Chapter 2 (The Determinants of East Asia's Information Technology Trade) focuses on the build-up of East Asia's IT sector and its implications for IT trade in the Asia-Pacific region. East Asia's expanding role in global IT production is attributed to the decision of multinational firms headquartered in the developed world to vertically fragment their
production processes and move labor-intensive production stages to labor-abundant East Asia. To study the impact of international production fragmentation on IT trade in the Asia-Pacific region, a panel regression of modified bilateral IT trade equations is estimated. The estimation results indicate that fragmentation has significantly increased IT trade in the Asia-Pacific region.

Chapter 3 (Modularity and the Organization of International Production) focuses on the co-evolution of vertical outsourcing of component production and horizontal consolidation in the component sector that has been observed in the IT industry. To account for this phenomenon, I build an industry-equilibrium model in which the boundaries of the firm are endogenous in both the horizontal and vertical dimensions of international production. The concept of modularity is subsequently incorporated into the model. The model not only links the co-evolution to modularity, but also predicts the emergence of de facto input standardization during this process.

Chapter 4 (Assessing the Benefits of Telecommunications Liberalization in Tunisia) focuses on the importance of regulatory reforms on the success of telecommunications liberalization in developing countries. For this purpose, a computational general equilibrium (CGE) model for Tunisia is set up in which the telecommunications sector can form different imperfectly competitive market structures under liberalization. I demonstrate that telecommunications liberalization will be welfare improving if the domestic and foreign telecom providers act competitively, but can be welfare reducing if they form an international cartel. The results of this study strengthen the argument that pro-competitive regulatory reforms need to accompany telecommunications liberalization in developing countries such as Tunisia.
Chapter 2

The Determinants of East Asia’s Information Technology Trade

2.1 Introduction

Over the past two decades, East Asian economies have become a global manufacturing base for Information Technology (IT) products. East Asia’s growing role in IT production and trade derives from a dramatic change in the IT sector’s organization of international production. Changes in IT technology as well as declines in transportation, communication and other coordination costs have induced U.S. and Japanese multinational enterprises to fragment their production processes and move labor-intensive production stages to East Asia in order to take advantage of its lower factor prices. The changing organization of IT production has altered the nature of IT trade between the United States, Japan and Developing East Asia. It has created international production networks that span across the Asia-Pacific, thus significantly increasing the trade interdependence of the region as a whole.

In this chapter, we study the growth and determinants of IT trade in the Asia-Pacific region with the goal of identifying a robust empirical model of IT trade relationships. We begin in Section 2.2 by reviewing the evolution of East Asian IT trade and patterns of specialization. Then in Section 2.3 we describe the phenomenon of international vertical

9
fragmentation of production and discuss how this process has shaped IT trade and investment relationships for East Asia. In Section 2.4, we turn to empirical trade analysis. In order to account for fragmentation, we alter the standard specification of empirical trade equations. In Section 2.5 we discuss data issues and present preliminary results of a pooled time series-cross section estimation of IT trade equations. In Section 2.6 we conclude.

2.2 East Asia as a Global IT Manufacturing Base

The information technology sector plays an increasingly important role in the world economy.\(^1\) The world share of IT exports in total exports has increased from 4 percent in 1980 to 15 percent in 2000. On average, they have grown 14 percent per year whereas world exports have grown only 6 percent per year.

Over the last two decades, East Asia (Asian NIEs, ASEAN4 and China) has gradually developed into a dominant global manufacturing base of the IT industry, producing IT products primarily destined for developed countries (Jason Dedrick and Kenneth Kraemer, 1998; Nicola J. Lowe and Martin Kenney, 1999; Borrus, Ernst and Haggard, 2000). Production, expenditure and trade data clearly illustrate this trend. While East Asia’s share of world IT production was only 6 percent in 1985, it reached 26 percent in 2000 at a value of 348.6 billion U.S. dollars (slightly less than the United States). Unlike production, however, IT expenditure has remained concentrated in the developed world, with the share of IT expenditure to GDP remaining substantially higher in the U.S., Japan and the EU than in developing East Asia (Table 2.1).

Aggregate trade figures strengthen the assertion that East Asia has evolved into a global IT production base. East Asia’s IT trade in the last two decades has taken off at a rate substantially higher than the rest of the world. Between 1980 and 2000 East Asia’s IT exports and imports grew by 21 and 20 percent a year, respectively, while global IT exports

\(^1\) Throughout this chapter, Information Technology trade data is taken to include merchandise classified in SITC (rev. 2) 75, 76 and 776.
Table 2.1: Developments in Information Technology Production

<table>
<thead>
<tr>
<th>Country</th>
<th>IT Production (Mill)</th>
<th>CAGR (%)</th>
<th>Share of world IT production (%)</th>
<th>IT prod. /GDP (%)</th>
<th>IT expenditure /GDP (%)</th>
</tr>
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<tbody>
<tr>
<td>East Asia (EA)</td>
<td></td>
<td></td>
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<tr>
<td>NIEs</td>
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<td>181,653</td>
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<td>3,680</td>
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<tr>
<td>Singapore</td>
<td>6,501</td>
<td>76,059</td>
<td>14</td>
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<tr>
<td>Taiwan</td>
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<td>47,318</td>
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<td>5,922</td>
<td>50,193</td>
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<td>85,903</td>
<td>17</td>
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<td>Malaysia</td>
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<td>Thailand</td>
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<td>8,083</td>
<td>20</td>
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<tr>
<td>China</td>
<td>5,581</td>
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<tr>
<td>United States</td>
<td>-</td>
<td>385,145</td>
<td></td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td>EU 15 (Excl.)</td>
<td>-</td>
<td>230,272</td>
<td></td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>Japan</td>
<td>89,390</td>
<td>263,451</td>
<td>6</td>
<td>19</td>
<td>19</td>
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<tr>
<td>Total Market</td>
<td>481,708</td>
<td>1,366,369</td>
<td>6</td>
<td>100</td>
<td>100</td>
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Source: IT Expenditure data: World Development Indicators; IT Production: Yearbook of World Electronics Data; GDP: International Financial Indicators.
and imports both grew at an annualized rate of 15 percent. As a result, East Asia's share of world IT exports has risen from 14 percent in 1980 to 40 percent in 2000. East Asia as a whole is now the world's largest exporter for IT-related goods, by far surpassing the United States and Japan (Table 2.2).²

Source and destination market shares of East Asian IT trade provide further insights into the dynamics behind East Asia's IT trade patterns (Table 2.3). Intraregional trade in East Asia has risen substantially over the years, reaching 40 percent of its IT exports and almost 60 percent of its IT imports in 2000. The fact that intra-East Asian trade is more important as a source of imports than a destination of exports indicates a trading pattern in which East Asian economies procure imports within the region and sell exports outside the region. Interregionally, the United States remains East Asia's primary IT destination market. 43 percent of East Asia's interregional IT exports are destined for the U.S., while 29 percent is destined to the European Union and 15 percent is destined to Japan. Japan plays a more important role as a source of IT imports than as a destination of IT exports. Japan's share of East Asia's IT imports is similar to the share of the United States.

The observed pattern of intensifying interregional production links with the U.S. and Japan and increasing intraregional trade with the developed world is consistent with anecdotal evidence of international production fragmentation and developing IT production networks in East Asia (Dieter Ernst, 2002). As U.S. and Japanese multinationals moved the production of their labor-intensive production stages to East Asia, the region's imports of related intermediate products have grown along with exports to U.S., Japanese and European markets for final assembly or sale. Initially, these intermediate imports were sourced from the home countries of the multinationals. But as production enterprises in developing Asia grew in sophistication, parts and components were increasingly procured from other production sites within the region, thus explaining the rising share of intra-regional trade. East Asia thus has become part of complex Japanese and U.S. IT production networks that

²East Asia's share of exports remains higher than that of the United States even if we exclude intraregional East Asian trade, since nearly two-thirds of East Asia's IT-related exports are interregional (Table 2.3).
Table 2.2: Developments in Information Technology Trade

<table>
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<td>413,818</td>
<td>40</td>
<td>8,953</td>
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<td>288,600</td>
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<td>249,966</td>
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<td>Singapore</td>
<td>2,826</td>
<td>3</td>
<td>76,630</td>
<td>7</td>
<td>1,915</td>
<td>2</td>
<td>50,793</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Taiwan</td>
<td>2,895</td>
<td>4</td>
<td>69,123</td>
<td>7</td>
<td>1,256</td>
<td>2</td>
<td>36,880</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>ASEAN4</td>
<td>1,438</td>
<td>2</td>
<td>109,694</td>
<td>11</td>
<td>2,031</td>
<td>2</td>
<td>66,594</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>Indonesia</td>
<td>102</td>
<td>0</td>
<td>7,631</td>
<td>1</td>
<td>308</td>
<td>0</td>
<td>1,015</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1,252</td>
<td>2</td>
<td>55,759</td>
<td>5</td>
<td>1,006</td>
<td>1</td>
<td>38,077</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>Philippines</td>
<td>71</td>
<td>0</td>
<td>26,798</td>
<td>3</td>
<td>372</td>
<td>0</td>
<td>12,724</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>Thailand</td>
<td>13</td>
<td>0</td>
<td>19,506</td>
<td>2</td>
<td>345</td>
<td>0</td>
<td>14,778</td>
<td>1</td>
<td>47</td>
</tr>
<tr>
<td>China</td>
<td>64</td>
<td>0</td>
<td>46,326</td>
<td>5</td>
<td>573</td>
<td>1</td>
<td>52,009</td>
<td>5</td>
<td>41</td>
</tr>
<tr>
<td>United States</td>
<td>15,961</td>
<td>19</td>
<td>144,100</td>
<td>14</td>
<td>12,610</td>
<td>15</td>
<td>211,701</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>EU 15 (Excl.)</td>
<td>11,367</td>
<td>14</td>
<td>98,661</td>
<td>10</td>
<td>15,965</td>
<td>19</td>
<td>143,213</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Japan</td>
<td>18,057</td>
<td>22</td>
<td>110,857</td>
<td>11</td>
<td>2,043</td>
<td>2</td>
<td>59,533</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Total Market</td>
<td>82,483</td>
<td>100</td>
<td>1,026,321</td>
<td>100</td>
<td>82,483</td>
<td>100</td>
<td>1,026,321</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

Source: Statistics Canada World Trade Database

*"Incl." indicates that the aggregate includes intraregional trade; "Excl." indicates that intraregional trade is excluded.
Table 2.3: The Origins and Destinations of IT Trade

<table>
<thead>
<tr>
<th>Exporting Region</th>
<th>Share of Exports Destined to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>East Asia</td>
</tr>
<tr>
<td>East Asia (Incl.)</td>
<td>20.9</td>
</tr>
<tr>
<td>East Asia (Excl.)</td>
<td>-</td>
</tr>
<tr>
<td>United States</td>
<td>11.2</td>
</tr>
<tr>
<td>EU-15 (Excl.)</td>
<td>11.1</td>
</tr>
<tr>
<td>Japan</td>
<td>18.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Importing Region</th>
<th>Share of Imports Originating from</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>East Asia</td>
</tr>
<tr>
<td>East Asia (Incl.)</td>
<td>26.8</td>
</tr>
<tr>
<td>East Asia (Excl.)</td>
<td>-</td>
</tr>
<tr>
<td>United States</td>
<td>37.5</td>
</tr>
<tr>
<td>EU-15 (Excl.)</td>
<td>15.3</td>
</tr>
<tr>
<td>Japan</td>
<td>25.8</td>
</tr>
</tbody>
</table>

Source: Statistics Canada World Trade Database

span East Asia and the developed world.

An examination of the commodity composition of IT trade provides insight into the factor intensities of the production and trade relationships. By dividing IT-related goods into "IT Parts and Components" and "IT Final Goods", we obtain a rough indication of which regions specialize in the assembly of IT-related final goods and which regions specialize in the production of components of IT-related goods.3 We use revealed comparative advantage (RCA) indices to examine the intensity of IT specialization across the various categories. Measures of export RCA are often used to help assess a country's export specialization. A value that exceeds unity implies that the country has a greater than average share of

3We identify three of the eight three-digit SITC IT sectors as predominantly "Parts and Components" and the remaining five categories as primarily "Final Products". "Parts and Components" comprise SITC 759 (Parts of and accessories suitable for office machines and automatic data processing machines & units), 764 (telecommunication equipment and parts) and 776 (thermionic, cold & photo-cathode valves and tubes). "Final Products" include 751 (office machines), 752 (automatic data processing machines & units), 761 (television receivers), 762 (radio-broadcast receivers) and 763 (grammophones, dictating, sound recorders etc.). This admittedly crude measure is the best one can do with three-digit data.
Table 2.4: East Asian Revealed Comparative Advantage Indices

**Table 2.4a. East Asian RCA Indices: Exports (2000)**

<table>
<thead>
<tr>
<th>Product Group</th>
<th>Total</th>
<th>E.U. 15</th>
<th>U.S.</th>
<th>Japan</th>
<th>East Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Parts and Components</td>
<td>0.98</td>
<td>0.92</td>
<td>0.91</td>
<td>0.96</td>
<td>0.95</td>
</tr>
<tr>
<td>759 - Parts of and accessories suitable for 751-752</td>
<td>0.48</td>
<td>0.35</td>
<td>0.21</td>
<td>0.98</td>
<td>0.82</td>
</tr>
<tr>
<td>764 - Telecommunications equipment and parts</td>
<td>0.7</td>
<td>0.64</td>
<td>0.69</td>
<td>0.83</td>
<td>0.97</td>
</tr>
<tr>
<td>776 - Thermionic, cold &amp; photo-cathode valves, tubes, parts</td>
<td>1.2</td>
<td>1.36</td>
<td>1.21</td>
<td>1.03</td>
<td>0.94</td>
</tr>
<tr>
<td>IT Final Goods</td>
<td>1.05</td>
<td>1.08</td>
<td>1.1</td>
<td>1.04</td>
<td>1.14</td>
</tr>
<tr>
<td>751 - Office machines</td>
<td>1.17</td>
<td>1.13</td>
<td>1.14</td>
<td>1.03</td>
<td>1.2</td>
</tr>
<tr>
<td>752 - Automatic data processing machines &amp; units</td>
<td>0.96</td>
<td>1.04</td>
<td>1.19</td>
<td>0.98</td>
<td>1.02</td>
</tr>
<tr>
<td>761 - Television receivers</td>
<td>0.7</td>
<td>0.42</td>
<td>0.4</td>
<td>1.41</td>
<td>1.03</td>
</tr>
<tr>
<td>762 - Radio-broadcast receivers</td>
<td>1.54</td>
<td>2.12</td>
<td>1.22</td>
<td>1.37</td>
<td>1.61</td>
</tr>
</tbody>
</table>

**Table 2.4b. East Asian RCA Indices: Imports (2000)**

<table>
<thead>
<tr>
<th>Product Group</th>
<th>Total</th>
<th>E.U. 15</th>
<th>U.S.</th>
<th>Japan</th>
<th>East Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Parts and Components</td>
<td>1.26</td>
<td>1.52</td>
<td>1.27</td>
<td>1.15</td>
<td>1.23</td>
</tr>
<tr>
<td>759 - Parts of and accessories suitable for 751-752</td>
<td>0.69</td>
<td>0.68</td>
<td>0.35</td>
<td>0.45</td>
<td>1.18</td>
</tr>
<tr>
<td>764 - Telecommunications equipment and parts</td>
<td>0.65</td>
<td>1.05</td>
<td>0.46</td>
<td>0.57</td>
<td>0.9</td>
</tr>
<tr>
<td>776 - Thermionic, cold &amp; photo-cathode valves, tubes, parts</td>
<td>1.78</td>
<td>2.39</td>
<td>1.74</td>
<td>1.56</td>
<td>1.4</td>
</tr>
<tr>
<td>IT Final Goods</td>
<td>0.65</td>
<td>0.53</td>
<td>0.64</td>
<td>0.68</td>
<td>0.7</td>
</tr>
<tr>
<td>751 - Office machines</td>
<td>1</td>
<td>0.56</td>
<td>0.68</td>
<td>1.02</td>
<td>1.03</td>
</tr>
<tr>
<td>752 - Automatic data processing machines &amp; units</td>
<td>0.45</td>
<td>0.18</td>
<td>0.63</td>
<td>0.46</td>
<td>0.48</td>
</tr>
<tr>
<td>761 - Television receivers</td>
<td>0.27</td>
<td>0.2</td>
<td>0.24</td>
<td>0.43</td>
<td>0.4</td>
</tr>
<tr>
<td>762 - Radio-broadcast receivers</td>
<td>0.33</td>
<td>0.08</td>
<td>0.1</td>
<td>0.18</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Source: Statistics Canada World Trade Database

IT exports in that category. Francis Ng and Alexander Yeats (2001) argue that a similar import RCA index can be used as a reliable predictor of specialization in final product assembly. A country that specializes in the export of final assembly is likely to import more than proportionately parts and components in that sector. It follows that countries with above average import shares for components in a sector are relatively heavily specialized in assembly operation.

The export RCA indices presented in Table 2.4 suggest that East Asia’s IT sector is relatively specialized in the export of final goods and relatively less involved in the export of IT parts and components. The import RCA indices in Table 2.5 indicate that East Asia...
Asia imports proportionately more parts and components in the IT sector than the rest of the world and proportionately fewer final goods. The indices in both tables are consistent with the idea developing East Asia specializes in the labor-intensive assembly of final IT products while the developed world — Japan, the United States and Europe — specialize in the production of components, in particular semiconductors.

2.3 International Production Fragmentation and the Trade-FDI Nexus

In the previous section, we have presented evidence documenting the extent to which East Asia has gradually become a global production platform for labor-intensive IT products. International production fragmentation by American and Japanese IT firms played a major role in building up East Asia’s IT industry. At a moment that East Asia’s electronics sector was virtually non-existent, U.S. and Japanese IT firms established their first affiliates for the sole purpose of export production. As the presence of foreign affiliates in the 1980s mushroomed in the wake of the electronics sector’s increasingly competitive climate and stronger relations were built with non-affiliated host country firms, East Asia was gradually integrated into the worldwide networks of IT production (Lowe and Kenney, 1999; Borrus, Ernst and Haggard, 2000). In this section, we analyze the determinants of international production fragmentation into developing East Asia and its impact on Asia-Pacific trade patterns.

2.3.1 International Production Fragmentation

The theory of fragmentation (Ronald W. Jones and Henryk Kierzkowski, 1990 and 2001) and vertical FDI (Elhanan Helpman 1984, 1985) helps to explain why firms in one country decide to move stages of their production process to another country. If different stages of the production process are separable and have varying factor intensities, then firms in
labor-scarce developed countries have an incentive to relocate the production of their labor-intensive production blocks into low-wage countries. Firms will only do so, however, if the benefits of fragmenting their production process exceed the extra costs of coordinating activities across borders. Such coordination costs include trade and investment barriers, transportation costs, communication costs and governance costs.

A necessary condition for fragmentation is separability of production stages. If it is technically impossible to perform two or more stages in a production process separately, then the activities must remain within a single firm at a single location. Separability was significantly enhanced in the IT sector with the arrival of the modular IBM Personal Computer in the early 1980s (Ernst, 2002). Before the PC, electronics companies generally built computers with a fully closed proprietary architecture. The closed system implied a high cost of coordinating interoperability between components and induced firms to produce almost all necessary components — semiconductors, hardware and operating systems — in-house and principally within one country (Dedrick and Kraemer, 1998; Alfred D. Chandler, 2001). The IBM PC with its modular product architecture permanently altered the structure of production by reducing the cost of coordinating activities across stages. The key feature of the modular system was that the standards of compatibility and interoperability among components were fixed and publicly known (Richard N. Langlois and Paul L. Robertson, 1995). This allowed the makers of components to concentrate their capabilities at a reduced coordination cost and thus to improve their piece of the system independently from others. As a result, separability was enhanced and fragmentation was induced.

The modular structure of the PC also induced fragmentation through another channel. Once the *de facto* standards of interoperability and compatibility were set, barriers to entry into the industry were substantially lowered and thousands of IBM clones and component producers entered into the various niches of the computer business. The resulting competition drove down prices in almost all areas (Langlois and Robertson, 1995). In order to survive in the highly competitive environment, electronics producers were seeking to reduce
production costs by moving labor-intensive production blocks to East Asian (Dedrick and Kraemer, 1998).

The change in industry structure also altered the factor intensities of production stages over time. As a consequence of the falling component prices, labor costs became a bigger share of PC production costs (James Curry and Martin Kenney, 1999). Therefore, more pressure arose to take advantage of lower-cost labor or to improve labor productivity through international fragmentation.

East Asia was initially seen as a favorable place to move labor-intensive IT production blocks for at least few reasons. First, the East Asian countries were known to have not only an abundant supply of low-wage labor but also a large and growing pool of high-skilled engineers. In addition, East Asia had a relatively stable political and macroeconomic environment, conducive to long-term investment projects and business relations (Shahid Yusuf, 2001). Finally, East Asia had already entered the more prosaic consumer electronics industry during the late 1960s (Lowe and Kenney, 1999).

There were a number of favorable factors that further stimulated the fragmentation process into East Asia. First, in the early 1980s, East Asian countries generally changed their policy stance from import substitution to export promotion, thus providing an improved environment for international business linkages. Barriers to trade and investment were reduced, and domestic economic activities such as insurance, banking and transportation were deregulated. These reductions in barriers to trade are particularly conducive toward international production fragmentation because, in a fragmented world, a good needs to cross multiple occasions during the production process (David Hummels, Dana Rapoport and Kei-Mu Yi, 1998).

Second, global transportation costs for distant travel and time-sensitive goods have declined in the last few decades (David Hummels, 2000). The precipitous drop in air shipping prices and the increase in the quality and speed of ocean freighters have significantly reduced the cost of time-sensitive goods. This has benefited the international trade of goods
produced in internationally fragmented production processes were just-in-time linkages are important. At the same time, there has been an important decline in the cost of distant relative to proximate shipping transport, thus providing an extra motivation for trade between East Asia and the United States.

Third, the dramatic reduction in the cost of communication enhanced the coordination, management and monitoring of activities in different locations. In the last few decades, the cost of making phone calls has reduced precipitously; computers have allowed virtually costless means of communication via e-mail and Internet; the use of fax machines has decreased the need for courier services and sped up the communication of important documents. These reductions in communication costs have made it easier for firms to coordinate and monitor production in diverse countries.

2.3.2 The FDI-Trade Nexus

The shift in the IT sector’s organization of production through international fragmentation has had an important impact on the trade structure between the U.S., Japan and East Asian economies. Since FDI is the vehicle through which production stages are generally moved across borders, we can gain important insights into the impact of fragmentation and trade by analyzing the trade-FDI nexus. Over the years, there has been considerable discussion in the trade literature about whether FDI and trade are complements or substitutes (James R. Markusen and Keith E. Maskus, 2001). It is generally acknowledged that the relationship critically depends on the nature of the FDI. The literature distinguishes between horizontal and vertical FDI. FDI designed to serve local markets is often called horizontal FDI, since it typically involves duplicating parts of the production process as additional plants are established to supply different locations. This form of FDI usually substitutes for trade, since parent firms replace exports with local production. In contrast, FDI in search of low-cost inputs is often called vertical FDI since it involves the relocation of a part of the production process in a low-cost location. Vertical FDI is usually trade creating, since
the reallocation of a production block to a host country is likely to induce an increase in imports of intermediate goods from an upstream production stage in the source country and an increase in exports to a downstream production stage in the source country.

Since international production fragmentation occurs in search of low-cost inputs, the associated FDI flows are vertical of nature. As a result, we would expect a positive relationship between FDI inflows into the IT sector and IT trade for Developing East Asian countries. Over the years a number of empirical studies have focused on the question whether aggregate trade and FDI are complements or substitutes in East Asia. Shujiro Urata (2001) uses country-level aggregate trade and investment data and finds that inward FDI stock promotes trade. Keith Head and John Ries (2001) use firm-level data for Japanese manufacturing firms and find a net complementary effect between trade and FDI, with substitution effects occurring for firms that do not export intermediate inputs. Eric Ramstetter (1999, 2002), finally, uses plant-level data and finds that foreign plants have higher trade propensities than local plants in Indonesian, Thai and Singapore manufacturing. In conclusion, there is fairly compelling evidence that inward FDI promotes trade expansion in East Asia's vertically related industries.

2.4 Empirical Trade Equations for IT exports

Following the standard imperfect substitutes trade model, the quantity of IT exports demanded can be expressed as a function of IT income in the destination market, own IT product price, and prices of competing IT products.\footnote{In a multi-country setting, the sign of the bilateral relationship between trade and vertical FDI is ambiguous. An increase in FDI from source country \( i \) into host country \( j \), for example, can induce an increase in total IT exports from host country \( j \), but at the same time reduce its bilateral IT exports to source country \( i \). This will occur if the increase in IT exports directed to the rest of the world more than offsets the reduction in IT exports to the source country \( i \).}

\footnote{This specification derives from the workhorse Armington (1969) model, which views domestic and imported varieties as imperfectly substitutable in consumption. The notation here loosely follows Morris Goldstein and Mohsin Khan (1985). Because we are modeling demand for a specific sub-group of commodities, ideally we would like to include prices of all goods entering the foreign consumption basket. As a practical matter, we do not have reliable time series of prices for IT products, and so restrict our attention to aggregate price deflators, specifically consumer (or overall export) prices.}
where \( X_{i,j} \) is the quantity of IT exports from country \( i \) to country \( j \), \( Y_j \) is country \( j \)'s nominal IT income in units of home currency, \( PX_i \) is the IT export price, \( P_j \) is country \( j \)'s IT price in units of home currency, and \( P_k \) is a vector of IT prices of other competing exporters in units of home currency.

If we assume that demand is homogenous in prices and that foreign consumers choose between country \( i \) goods and a composite of all other countries' goods, we can write (1) as a function of real foreign income and two "real exchange rates" capturing the relative IT prices of home to foreign goods and third country to foreign IT goods.

\[
(2.1) \quad x_{i,j} = f \left( Y_j, PX_i, P_j, P_k \right)
\]

Following standard practice, we estimate this trade model in log-linear form.\(^7\)

\[
(2.2) \quad x_{i,j} = f \left( Y_j, \frac{PX_i}{P_j}, \frac{PO_j}{P_j} \right)
\]

where \( X_{i,j} \) is nominal exports in dollars; \( Y \) is nominal IT income in the importing country; \( \frac{PX_i}{P_j} \) is the "own" relative price expressed in common currency (hereafter, \( RX_{i,j} \)) and \( \frac{PO_j}{P_j} \) is the import-weighted relative price of other exporters to the destination market expressed in common currency (hereafter, \( RPO_{i,j} \)) (see Tamim Bayoumi, 1999). The latter two terms are essentially "real exchange rates" capturing the relative IT prices of home to foreign goods and third country to foreign goods.

Available bilateral trade data are reported in current dollar values for all countries, and there do not exist reliable time series of prices with which to deflate IT exports. We sidestep

\(^{7}\)The choice of the log linear form also imposes extremely strong restrictions on the demand function, by requiring constant elasticities. See Jaime Marquez (1994) for a critique of the assumption of constant elasticities.
this data challenge by assuming that the relative IT price of home to foreign goods equals the relative CPI of home to foreign. This assumption allows us to specify the model in nominal dollar terms.\footnote{William H. Branson (1968) as cited in Goldstein and Khan (1985). But note that the interpretation of price elasticities for exports are different with this specification, since a rise in domestic export prices will raise the value of a given export volume one-for-one. So, at least for a price change originating in the exporting country, value elasticity = volume elasticity + 1.}

\begin{equation}
\ln X_{ij} = \alpha_{ij} + \beta_{ij} \ln Y_j + (1 + \rho_{ij}) \ln RP X_{ij} + \phi_{ij} \ln RPO_{ij} + (1 - \beta_{ij}) \ln P^m
\end{equation}

Again, we have no data on domestic IT prices \(P^m\), but rather include a trend to potentially capture this effect.

As discussed above, there is good reason to think that East Asian exports of IT products will be influenced by the extent of inward foreign direct investment they have received. A model that neglects this determinant of export flows may produce biased estimates of the underlying price and income elasticities. We allow for such influences by appending a term measuring the dollar stock of inward FDI in the source market. Note that because of data limitations, this measure is overall inward FDI without regard to industry or source country.\footnote{Mary Amiti and Katharine Wakelin (2003) caution that regressing trade on lagged FDI continues to result into an endogeneity problem. If one-period lagged FDI is correlated with current FDI, then it will also be serially correlated with exports.}

\begin{equation}
\ln X_{ij} = \alpha_{ij} + \beta_{ij} \ln Y_j + (1 + \rho_{ij}) \ln RP X_{ij} + \phi_{ij} \ln RPO_{ij} + \omega_{ij} \ln FDI_{IN} + (1 - \beta_{ij}) \ln P^m
\end{equation}

The addition of this FDI term may help in identifying demand parameters by proxying for omitted supply influences.\footnote{William Helkie and Peter Hooper (1988) include the capital stock. Bayoumi (1999) and Joseph E. Gagnon (2003) include export-country real GDP as a proxy for supply.}

We would like to estimate a time series model of this export demand behavior. However, the available time series of bilateral IT trade are very limited — the longest series in the
Statistics Canada database run from 1980 to 1999, and price and foreign investment series are also limited. This makes it extremely difficult to estimate model parameters with any precision, or to identify model dynamics. Following Bayoumi (1999), we estimate a panel regression of bilateral trade equations. If model parameters are homogenous across bilateral country pairs, this approach significantly increases the number of data points and precision with which parameters may be estimated.\footnote{An important difference from Bayoumi is that we model the system in levels, rather than growth rates. This preserves long-run information that may be lost in a growth rate specification.}

2.5 Data and Results

We model bilateral trade in information technology products among seven East Asian developing countries—Korea, Malaysia, Indonesia, Thailand, Singapore, the Philippines, and Taiwan—and the U.S., Japan, and the European Union. Data for Hong Kong and China were also collected but the absence of appropriate price deflators and, in the case of China a very short sample period, precludes their inclusion in this analysis.\footnote{For our primary regressions, we have omitted four bilateral flows because of very short samples: Indonesian exports to Korea, the Philippines, and Taiwan, and Philippines exports to Indonesia. We have also interpolated the missing 1989 values for trade between the Philippines and Taiwan.} Bilateral export values in current dollars are taken from the Statistics Canada World Trade Database. (See Appendix A for details.) We define information technology trade as the sum of eight three-digit SITC rev. 2 categories (see footnote 1).

For the destination-market activity variable, we use nominal dollar gross domestic product series from the International Monetary Fund \textit{International Financial Statistics} online database. Arguably it would be better to specify IT export demands as a function of an IT-specific market demand measure, but such data are not readily for most developing economies. Nominal exchange rates are from \textit{International Financial Statistics}. Consumer prices are from The World Bank's \textit{World Development Indicators} Database, 2001.\footnote{The CPI is a potentially poor proxy for relative prices of tradable goods; an alternative version using relative export prices is under construction.} The construction of trade-weighted average relative competitor prices from exchange rates and
Table 2.5: Descriptive Statistics (All Series in Differenced Logarithms)

<table>
<thead>
<tr>
<th></th>
<th>Dollar Exports</th>
<th>Dollar GDP</th>
<th>Bilateral Relative Price, RPX</th>
<th>Relative Competitor Price, RPO</th>
<th>Dollar FDI Inflows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.23</td>
<td>0.07</td>
<td>0.00</td>
<td>0.01</td>
<td>0.13</td>
</tr>
<tr>
<td>Median</td>
<td>0.18</td>
<td>0.09</td>
<td>0.00</td>
<td>0.01</td>
<td>0.12</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.66</td>
<td>0.13</td>
<td>0.12</td>
<td>0.10</td>
<td>0.12</td>
</tr>
<tr>
<td>Observations</td>
<td>1609</td>
<td>1609</td>
<td>1609</td>
<td>1609</td>
<td>1609</td>
</tr>
<tr>
<td>Cross-section range for mean</td>
<td>(-0.085, 0.646)</td>
<td>(0.041, 0.108)</td>
<td>(-0.068, 0.68)</td>
<td>(-0.027, 0.068)</td>
<td>(0.097, 0.176)</td>
</tr>
<tr>
<td>Cross sections</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>86</td>
</tr>
</tbody>
</table>

CPIs is explained in Appendix A. For the European Union, we use an aggregate dollar GDP series from OECD. We construct EU-15 consumer price and exchange rate indices by weighting country series by total trade (aggregate imports plus exports). FDI inflow stock data are from the UNCTAD *Handbook of Statistics On-Line*.

Descriptive statistics for the pooled series are given in Table 2.5. Note that the cross-sectional average rate of growth of IT exports is very high—23 percent for the complete pool—and considerably higher than the rate of growth of nominal dollar output, 7 percent. The average rate of growth of the FDI stock is 13 percent over this two-decade period. There is considerable cross-sectional variation in bilateral export growth rates, ranging from a decline of 8.5 percent (Taiwan exports to Indonesia, which collapsed in dollar terms after 1997) to an average growth rate of nearly 65 percent (Thailand's IT exports to the U.S.).

We would like to estimate the IT trade equations directly, yet many (if not all) of the variables are likely to be non-stationary. In Appendix B we present results of panel unit root tests and conclude that each of the series we study here are in fact I(1) in levels and I(0) in first differences. Given this, one approach would be to estimate each bilateral export equation individually and test for cointegration one by one. However, as is the case for
unit root tests, conventional single equation tests for the null hypothesis of no cointegration tend to have extremely low power and relatively large size distortions. These problems are particularly severe in the presence of moving average errors and in small samples such as ours (Alfred A. Haug, 1993, 1996).

Fortunately, it is possible to address the small sample properties of such tests by combining data on repeated observations over a cross-section of time series. Peter Pedroni (1999) constructs panel cointegration test statistics that have very high power and minimal size distortions while allowing for heterogeneous cointegrating vectors as well as idiosyncratic error dynamics. The cointegrating regression is:

\[
\ln X_{ij,t} = \alpha_{ij} + \delta_{ij} t + \gamma_t + \ln Z_{ij,t} \beta_{ij} + e_{ij,t},
\]

for \( i \neq j = 1, \ldots, N, \ t = 1, \ldots, T, \)

where \( Z_{ij,t} = [Y_{i,t}, RP_{ij}, RPO_{ij}, FDIIN_j]' \) is the vector of right hand side variables. We allow for the possibility of fixed effects, \( a_{ij} \), country specific deterministic trends, \( \delta_{ij} \), and heterogeneous cointegrating vectors, \( \beta_{ij} \). The dataset underlying (2.6) is an unbalanced panel, with the number of usable observations ranges from 13 to 19 across bilateral pairs.

The derivation of the asymptotic distribution for the panel cointegration test statistics require that the errors in (2.6) are cross-sectionally independent. In practice, this condition is likely to be violated and we allow for this possibility by modeling the cross sectional dependency using a common time dummy, \( \gamma_t \). This approach assumes that each cross-sectional error can be decomposed into a shared disturbances and an idiosyncratic disturbance that is independent over the cross-section.

Peter Pedroni (1999, 2000) considers panel (and group mean) statistics which use non-parametric adjustments to address both idiosyncratic serial correlation and endogenous feedback among variables. Table 2.6 shows the results of panel CI tests using the panel and group t- and ADF-statistics.
Table 2.6: Panel Cointegration Tests

<table>
<thead>
<tr>
<th></th>
<th>Panel ADF</th>
<th>Group ADF</th>
<th>Panel t</th>
<th>Group t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted</td>
<td>-9.61</td>
<td>-11.32</td>
<td>-12.15</td>
<td>-14.92</td>
</tr>
<tr>
<td>(\gamma_t = 0)</td>
<td>-7.70</td>
<td>-9.94</td>
<td>-9.36</td>
<td>-9.94</td>
</tr>
<tr>
<td>(\delta_{ij,t} = 0)</td>
<td>-7.33</td>
<td>-9.02</td>
<td>-7.03</td>
<td>-7.68</td>
</tr>
<tr>
<td>(\delta_{ij,t} = \gamma_t = 0)</td>
<td>-4.65</td>
<td>-7.39</td>
<td>-5.67</td>
<td>-7.39</td>
</tr>
</tbody>
</table>

N 85  
T 21  
Max Lag 3

Note: All statistics are significance at or below the 5% level. The test statistics are scaled so that they are distributed as standard normal, N(0,1).

In all regressions, we allow for fixed effects and heterogeneous cointegrating vectors. The first row of results allows for both a common time dummy and individual deterministic trends; the second includes individual deterministic trends; the third row includes only a common time dummy; and the fourth row includes only individual fixed effects. For all tests we reject the null hypothesis of no cointegration at the 5% level.\(^\text{14}\)

Having established the likelihood that a cointegrating relationship exists among the variables, we now turn to estimation of the panel under the maintained assumption of cointegration.

It is well known that ordinary least squares (OLS) estimation of cointegrating regressions result in super consistent estimates with the added benefit of negating the traditional

\(^{14}\text{Based on Monte Carlo simulations reported in Peter Pedroni (1995), we should expect that the group ADF statistic has the best power in samples such as ours with small } T \text{ and moderate } N, \text{ followed by the panel ADF. Pedroni also considers rho and variance-ratio tests. Pedroni (2000) reports Monte Carlo simulations indicating that the panel rho and group rho have power ranging from 0 to 20\% for samples with } T = 20, N = 20. \text{ He finds that the variance-ratio tests consistently produced low power and large size distortions.}\)
problem of endogeneity of regressors.\textsuperscript{15,16} In addition, panel estimation may help to overcome the limits of extremely short available time series for bilateral IT trade, price and foreign investment (the longest time series for the trade data is 1980–1999).

We estimate the pooled specification,

\begin{equation}
\ln X_{ij,t} = \alpha_{ij} + \beta \ln Y_{j,t} + \gamma \ln Rpx_{ij,t} + \delta \ln Rpo_{ij,t} + \omega \ln FDI_{i,t} + \mu_{ij,t}.
\end{equation}

Peter Pedroni (1996) shows that, as for the single equation case, the distribution of the panel OLS estimator of the slope terms in (2.7) is asymptotically biased and dependent on nuisance parameters arising from the serial correlation properties of the data. The asymptotic bias arises due to the endogeneity of the regressors despite the super consistency result.\textsuperscript{17} Only under the overly restrictive assumption that the regressors are strictly exogenous and the serial correlation properties are homogeneous over the cross-section do the OLS estimator or t-statistics have their conventional distributions. Pedroni adapts Peter C.B. Phillips and Bruce E. Hansen’s (1990) fully modified OLS (FMOLS) approach to adjust for both endogeneity and the serial correlation properties of the data. The resulting Panel FMOLS estimators and t-statistics are asymptotically unbiased, free of nuisance parameters, and normally distributed.\textsuperscript{18}

The Panel FMOLS approach imposes few restrictions on the form of (2.7). While we do assume that slope parameters are homogeneous, we allow for heterogeneity via both fixed effects, $\alpha_{ij}$, and idiosyncratic error dynamics. Error dynamics are modeled nonparametrically using the Newey-West estimator with the lag lengths allowed to differ over

\textsuperscript{15}That is, estimates converge to their true values at rate $T$ as opposed to the conventional $\sqrt{T}$ (James H. Stock, 1987).
\textsuperscript{16}In addition to the standard problem of omitted supply side, there are good theoretical reasons to expect trade levels to influence FDI. Investments may be made in response to anticipated trade opportunities, or trade may initially open a market for a firm, which may later have an incentive to move production into the market once scale economies are realized. In addition, common actors, such as per capita income levels, appear to explain both trade and FDI in cross-sectional analyses (Jonathan Eaton and Akiko Tamura, 1995).
\textsuperscript{17}The panel OLS estimator converges to the true value at rate $T\sqrt{N}$ (Pedroni, 1996).
\textsuperscript{18}Unlike, Phillips and Hansen’s (1990) single equation FMOLS, Panel FMOLS estimators are normally distributed due to the averaging of the unit root distributions over the cross-section under the maintained assumption of independent idiosyncratic error processes.
the cross-section. In addition, the non-parametric correction for endogeneity bias is allowed
to differ cross-sectionally. To derive the distribution of the FMOLS estimators, Pedroni
relies on the standard assumption of independence of the cross-sectional errors. This as-
sumption is unlikely to hold in practice due to common shocks. For example, the bursting
of the global tech bubble led to a decline in exports of IT products throughout Asia. This
decline in IT exports is not likely captured by income, relative prices, or FDI. We attempt
to ameliorate this cross-sectional dependency using a common-time dummy.

Based on Monte Carlo studies using samples with time-series dimensions similar to
ours (N = 50, T = 20), Pedroni concludes that the Panel FMOLS estimators “perform
relatively well for the purpose of making inference in cointegrating panels with heterogeneous
dynamics as the cross-section dimension grows large even for panels with relatively short
time series dimensions” (Pedroni, 1996, p. 7; but see his 2000 paper for richer Monte Carlo
results).

Table 2.7 presents our panel FMOLS results.

Table 2.7: Panel FMOLS Regression Results

\[
\ln X_{ij,t} = \alpha_{ij} + \beta \ln Y_{ij,t} + \gamma \ln RPK_{ij,t} + \delta \ln RPO_{ij,t} + \omega \ln FDI_{ij,t} + \mu_{ij,t}. \tag{2.7}
\]

<table>
<thead>
<tr>
<th></th>
<th>All Exporters</th>
<th>All Exporters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Common Time Dummy</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>0.52 (11.6)</td>
<td>2.05 (40.8)</td>
</tr>
<tr>
<td></td>
<td>0.44 (11.34)</td>
<td>2.91 (113.96)</td>
</tr>
<tr>
<td>Importer’s GDP</td>
<td>1.61 (9.19)</td>
<td>1.84 (15.26)</td>
</tr>
<tr>
<td></td>
<td>1.30 (5.24)</td>
<td>2.74 (19.12)</td>
</tr>
<tr>
<td>Relative Competitor Price</td>
<td>-1.58 (-6.15)</td>
<td>-0.5 (0.63)</td>
</tr>
<tr>
<td></td>
<td>-1.16 (-2.69)</td>
<td>-1.13 (5.79)</td>
</tr>
<tr>
<td>Relative Export Price</td>
<td>0.63 (9.76)</td>
<td>0.58 (18.4)</td>
</tr>
<tr>
<td>Exporters’ FDI Inflows</td>
<td>— (—)</td>
<td>— (—)</td>
</tr>
<tr>
<td>N</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>T</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Max Lag</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
In the four columns of the table, we report results both with and without a common
time dummy, and with and without the FDI measure.

Looking first at the columns with a common time dummy, notice that the estimated
elasticities conform with expectations. The income elasticity and competitor price elastic-
ties are positive, and the own relative price elasticity is negative, consistent with trade
theory, and all parameters are significantly different from zero at the 5% level. Note that
the coefficient on "own" relative price is the "value elasticity" and the implied volume elas-
ticity is one unit larger in absolute value, so that there is substantial price responsiveness
of IT exports. (See footnote 8). Relative competitor prices also have substantial effects on
bilateral export flows, with a one percent increase in competitors' prices raising exports by
1.3 percent in the long run.

The magnitude of the estimated income elasticity—0.44 to 0.52—is smaller than we
might have expected for IT products, for which these countries presumably have relatively
high income propensities. The income elasticity rises substantially when the time dummy is
omitted in the rightmost two columns. Here, the income elasticity rise to the 2.1–2.9 range.
In this case the relative export price elasticity becomes much smaller, and insignificantly
different from zero when FDI is included.

We find support for our prediction that exports of IT production are positively related
to FDI inflows into the exporting country. The magnitude of this effect is large, with a 1%
increase in aggregate foreign investment inflows producing a 0.6% increase in IT exports.
Point estimates for parameters other than FDI do not change dramatically when FDI is
included.

The regressions reported above include exports by all 11 countries to all 10 partner
countries. However, it seems likely that because of differences in commodity composition
and differing roles of FDI inflows, the behavior of exports may differ significantly between
developed and developing countries. In ongoing work, we will estimate similar equations
for exports from the 8 East Asian developing economies to the 11 destination markets. We
will also look for differences between IT export equations and those for aggregate exports.

2.6 Conclusion

This chapter uses semi-aggregate data to explore the determinants of East Asia's trade in IT products. In the first part of the chapter, we have provided descriptive evidence that international fragmentation of production processes has played an important role in shaping East Asia's IT trade patterns. In the second half, we have attempted to capture the impact of such fragmentation on the trade patterns by including aggregate FDI inflows as an explanatory variable in IT trade equations. The results support a positive role for FDI, demonstrating the importance of incorporating data on foreign investment patterns in successful empirical modelling of trade flows in the IT sector.

The IT regressions we have reported here are limited to modeling overall IT trade. Since demand for intermediate goods likely depends on different factors than the demand for final goods, separate modeling of components and final goods exports may be instructive. In addition, because of data limitations, we have looked only at overall measures of FDI inflows, without regard to the source country of those inflows. While there are difficulties with bilateral FDI data (see below), some data do exit for U.S. and Japanese source countries. We intend to look at both of these issues in continuing work.

The emergence of East Asia as a global IT supplier has implications for the nature and extent of interdependence among Asian countries and between Asian countries and the U.S. and Europe. We plan further work to embed these empirical IT trade equations within a global econometric model to study these relationships.

However, there are clearly limits to the usefulness of aggregative analysis alone in studying the IT interrelationships among countries. There are several specific areas where access to appropriate firm- or industry-level data would permit important extensions to our research.

One area of difficulty in the current analysis is in determining the end use for goods
in specific bilateral IT flows. In our analysis, we have used 3-digit SITC codes to make a fairly crude division of IT-related goods into "IT Parts and Components" and "IT Final Goods". Ideally, firm- and industry-level data on the sourcing of inputs and the commodity composition of outputs would provide a more accurate division between trade in IT parts and components and IT final goods. This would permit a more detailed analysis of the extent of production networks and allow for a firmer basis for empirical modeling of trade flows.

A second area of difficulty lies in obtaining appropriately detailed FDI data that reflects the nature of international fragmentation. Ideally, we would rely on bilateral FDI data disaggregated to the industry level. Unfortunately, there does not exist a multi-country panel data set on multinational activity at that level of disaggregation (Eric Ramstetter, 2000). Clearly there is a need for development of an internationally consistent set of FDI indicators to support the study of international production fragmentation.

A third area of difficulty is data on relative prices in the IT sector. It is particularly difficult to construct price series for IT exports and imports because of the rapid technological change in semiconductor and computer manufacturing. Because IT-related goods keep improving, the prices charged over time are, in a sense, for different products. Appropriate micro-level data could permit creation of hedonic price indices such as the computer price series created by the U.S. Bureau of Labor Statistics.

Outside the present context, there are a number of aspects of the international fragmentation phenomenon that may be informed by analyses using micro data. One set of issues involves the dynamics of trade in response to fragmentation. As mentioned above, one can expect that international fragmentation initially leads to trade expansion between the source and the host country as the reallocation of a production block to a host country is likely to induce an increase in imports of intermediate goods from an upstream production stage in the source country and an increase in exports to a downstream production stage in the source country. Over time, however, the complementary relationship between
trade and vertical FDI might diminish and even turn negative if domestic or third-country components start to be used instead of source country components. Firm or industry level data on the composition and patterns of imports and exports would help understand the persistence of trade relationships that emerge between home countries, host countries and third countries in production networks.

A more fundamental problem is evaluating the determinants of production fragmentation itself, i.e. the production and investment decisions made by existing firms and new entrants. For this, we would need detailed industry data on factor costs and content, trade and investment barriers and incentives, transportation costs, industry structure characteristics, and other factors. Finally, firm-level information on employment, trade and sourcing practices of firms would inform the larger questions of welfare impacts the fragmentation process on home and host countries.
2.7 Appendix 1: Data Appendix

Trade data are taken from Statistics Canada World Trade Database, which provide bilateral trade flows for all countries and commodities, reported (where available) at the 4-digit SITC (Revision 2) level. Additional details on this data can be found in Robert C. Feenstra, Gordon H. Lipsey and Harry P. Bowen (1997). Trade data are reported on a dollar CIF basis. We define Information Technology (IT) trade as encompassing SITC 75 (Office Machines & Automatic Data Processing Equipment), 76 (Telecommunications & Sound Recording Apparatus) and 776 (Thermionic, Cold & Photo-Cathode Valves, Tubes, Parts).

The countries included in East Asia are the four NIEs (Hong Kong, Korea, Singapore and Taiwan), ASEAN4 (Indonesia, Malaysia, Philippines and Thailand) and China. The developed economies included the U.S., Japan, and EU-15. In the estimation, we do not include Hong Kong and China.

Data on GDP were taken from IMF's International Financial Statistics. EU-15 GDP numbers are estimated by OECD.

CPI data were taken from World Bank, World Development Indicators 2001. For the EU-15, we constructed a European Union weighted average CPI, using national CPI indices weighted by total merchandise trade (exports plus imports) from the Statistics Canada dataset. Exchange rates for this purpose were taken from International Financial Statistics, as described below. We extended the national currency exchange rate series up to 1999 for this purpose.

Nominal exchange rates were taken from IMF, International Financial Statistics (see link above), using the period average rate.

FDI inflow stock data were taken from UNCTAD Handbook of Statistics On-Line.

Following Bayoumi (1999), the relative price of competitors products in each destination market (RPO) were calculated as the import-weighted average of common-currency relative prices:
The exporters' own relative price in the destination market is given by:

\[
RPO_{j,k} = \left( \frac{\sum_{i \neq j}^{N} \frac{P_i}{e_{i,US}} X_{i,k}}{\sum_{i \neq j}^{N} X_{i,k}} \right) \left( \frac{P_k}{e_{k,US}} \right)
\]

The exporters' own relative price in the destination market is given by:

\[
RPX_{j,k} = \frac{P_j}{e_{j,US}} - \frac{P_k}{e_{k,US}}
\]

here \(P_i\) are prices in local currency, \(e_{i,k}\) are local currency per dollar exchange rates, and \(X_{i,k}\) are dollar bilateral exports from country \(i\) to country \(k\).
2.8 Appendix 2: Unit Roots

We present results based on two standard tests for unit roots in panels, the Im, Pesaran and Shin (2003) test and the Levin and Lin (2002) Augmented Dicky Fuller (ADF) test.

For the Im Pesarn and Shin (IPS) test, we consider the following standard ADF type regression

\[(2.8) \quad \Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \sum_{j=1}^{p_i} \rho_{ij} \Delta y_{i,t-j} + \epsilon_{i,t},\]

where the null hypothesis of unit roots is

\[H_0 : \beta_i = 0 \quad \text{for all } i,\]

against the alternatives,

\[H_1 : \beta_i < 0, \quad i = 1, 2, \ldots, N_1, \]

\[\beta_i = 0, \quad i = N_1 + 1, \ldots, N.\]

The IPS test, therefore, allows for individual fixed effects and allows \(\beta_i\) to differ over the cross section under the alternative hypothesis. In fact, the IPS test allows for some fraction \((N_1/N)\) of the individual series to have unit roots.

In contrast, the Levin and Lin ADF (LLADF) test imposes homogeneity while still allowing for individual fixed effects.

\[(2.9) \quad \Delta y_{i,t} = \alpha_i + \beta y_{i,t-1} + \sum_{j=1}^{p_i} \rho_{ij} \Delta y_{i,t-j} + \epsilon_{i,t},\]

where the null hypothesis of unit roots is

\[H_0 : \beta = 0\]

against the alternatives,

\[H_1 : \beta < 0,\]
In practice, the IPS test is calculated as the average of individual ADF t-tests, while the LLADF test is an adjusted t-test for the null of a unit root from the panel regression in (2.9). The adjustments to the form of the standard ADF test result in a test statistic with a limiting normal distribution. In both cases, we include a common time dummy in an attempt to ameliorate any cross-sectional dependence that may exist in the errors of the ADF type regression (2.9), or (2.8).

The table below presents results for the tests of the null hypothesis that the logarithm of each series is characterized by a unit root process.

<table>
<thead>
<tr>
<th></th>
<th>IPS</th>
<th>LLADF</th>
<th>T</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>0.06</td>
<td>2.63</td>
<td>21</td>
<td>85</td>
</tr>
<tr>
<td>GDP</td>
<td>-1.73</td>
<td>-0.12</td>
<td>21</td>
<td>85</td>
</tr>
<tr>
<td>Po</td>
<td>-1.00</td>
<td>1.01</td>
<td>21</td>
<td>85</td>
</tr>
<tr>
<td>Px</td>
<td>-1.60</td>
<td>0.40</td>
<td>21</td>
<td>85</td>
</tr>
<tr>
<td>FDI</td>
<td>-4.29</td>
<td>-0.06</td>
<td>21</td>
<td>85</td>
</tr>
</tbody>
</table>

5% critical values: IPS = -2.47, LLADF = -1.64
Note: A bold value indicates significance at or below the 5% level.
Chapter 3

Modularity and the Organization of International Production

3.1 Introduction

The last few decades have seen an unprecedented reorganization of international production. In many industries, production has become increasingly disintegrated as multinational firms have fragmented their production process and set up subsidiaries across borders (Robert C. Feenstra and Gordon H. Hanson, 1996; Jose M. Campa and Linda S. Goldberg, 1997; Robert C. Feenstra, 1998; David Hummels, Jun Ishii and Kei-Mu Yi, 2001). At the same time, the boundaries of the multinational firms have been changing, with cross-border vertical outsourcing (Antràs and Helpman, 2004) and horizontal mergers and acquisitions on the rise (Simon J. Evenett, 2003).

Case studies from a variety of industries have indicated that the trend of vertical outsourcing and horizontal consolidation in international production in some cases might be related. Sturgeon (2002) and Sturgeon and Lee (2001), for example, document that the recent trend by brand-name electronics firms to replace in-house manufacturing with outsourced manufacturing has co-evolved with a consolidation of market shares by the five largest firms in the contract manufacturing industry. Similar trends have been found in other global industries such as semiconductors (Langlois and Steinmueller, 1999), telecommunications (Li and Whalley, 2002), automobiles (Timothy J. Sturgeon and Richard Florida, 2000) and
chemicals (Ashish Arora, Andrea Fosfuri and Alfonso Gambardella, 2001). Indeed, Sturgeon (2002) argues that this trend demonstrates the emergence of a new American model of industrial organization, which he terms modular production networks. In modular industries, lead firms decide to outsource their manufacturing to a small number of contract manufacturing firms because the specialized contract manufacturers are able to exploit both economies of scale and scope by applying the same generic production routines for multiple clients.

The co-evolution of vertical outsourcing and horizontal integration has far-reaching positive and normative implications. Positively, it provides further insights into the trends in international specialization. It suggests that the vertical outsourcing process does not necessarily lead to smaller firms and increased competition. Indeed, if it coincides with horizontal integration in some vertical layers of production, it can actually induce the emergence of large dominant firms with monopoly power. Normatively, the co-evolution thus also has important implications on competition policy (Bresnahan, 1999; Nicholas Economides, 1999).

A detailed review of the existing literature reveals that, to date, no formal theoretical studies have addressed the co-evolution of vertical outsourcing and horizontal integration. The goal of this chapter is to fill this gap by providing a theoretical framework that can explain the co-evolution. In order to do so, I build on two separate streams of literature — international trade and management — that focus on the relative prevalence of vertical integration and outsourcing.

1To my knowledge, there have been no empirical studies that have systematically documented the rise and extent of manufacturing outsourcing. Nonetheless, semi-structured qualitative interviews conducted by researchers at MIT's Industrial Performance Center indicate that this reorganization has primarily occurred in complex assembly sectors such as electronics and motor vehicles.

2PCs and cell phones, for example, are essentially a limited number of standard parts (e.g., resistors, capacitors, and memory chips), which get mounted onto printed circuit boards in different combinations. In assembling these products, contract manufacturing firms can customize products for heterogeneous end users at a relatively low cost.
An emerging international trade literature has studied the impact of market characteristics on the boundaries of the firm by incorporating transaction costs and imperfect competition into industry-equilibrium models. Among them, Denise E. Konan (2000) developed a perfect-contract model with two imperfectly competitive vertical layers of production. In her model, a firm's decision to internationally outsource is determined by the trade-off between the high fixed cost of vertical integration and the high marginal cost of trading at arm's length due to double marginalization. Konan finds that a decrease in market power in the intermediate goods sector reduces the double marginalization cost of arm's length trade and thus induces outsourcing. McLaren (2000) and Grossman and Helpman (2002) focus on the importance of contracts on the organization of international production. In their model, firms face a trade-off between the friction of incomplete contracts in arm's length relationships and excess governance costs in integrated companies. McLaren finds that a "thicker" intermediate good market reduces the hold-up problem that intermediate good firms face and thus induces outsourcing. Grossman and Helpman find that an increase in industry size and a better contracting environment favor outsourcing, but that the impact of competition on the vertical boundaries of the firm is ambiguous.

The management literature has focused more on the role of product characteristics on the organization of production. In particular, a large number of studies have analyzed the link between modularity in product design and the boundaries of the firm. Ron Sanchez and Joseph T. Mahoney (1996) argue that an increase in modularity induces outsourcing, because the standardized component interfaces in a modular product architecture reduce the coordination cost of trading at arm's length. Sturgeon (2002) adds that modularity is even more likely to induce outsourcing if the outsourced production stages face increasing returns. This is because component producers can then move down their average cost curve by applying the same set of standard production routines for various clients. Melissa A. Schilling (2000), finally, links industry standards to modularity. She argues that industry-wide standardization — de facto as well as regulatory — makes the interrelation between
components less specific, thus increasing modularity and providing incentives to firms to outsource.

The goal of this chapter is to explain which market and product characteristics can account for the co-evolution of vertical outsourcing and horizontal integration. For this purpose, I incorporate the concept of modularity into an industry-equilibrium model of international production. The model's predictions help to clarify some of the trends in international specialization, including the roles of modularity and component standardization.

The chapter is organized as follows. Section 3.2 defines modularity and explains how the concept is incorporated into a standard industry-equilibrium model of international production. Section 3.3 then sets up the model by identifying the two basic cost trade-offs that determine the vertical and horizontal boundaries of the firm in industry equilibrium. In the remaining sections, the model is solved and concluding remarks are provided.

3.2 Product Modularity

A final product can be seen as a set of components that interact with one another according to the rules of its product architecture (Karl T. Ulrich, 1995). Product architectures can vary on a continuum from integral to modular (Schilling, 2000; Annabelle Gawer and Michael A. Cusumano, 2002). When a product has an integral architecture, components are specifically adjusted to each other to fully elicit the potential performance of the final product. As a result of this high specificity, replacement of a component by another variety significantly reduces the functionality of the final product. In contrast, components in a modular architecture are designed to interact with each other according to well-defined architectural standards. In this case, input specificity is low and components can be substituted with little loss of functionality as long as their substitutes are compatible with these standards.

An important contribution of this chapter is the incorporation of modularity into an
industry-equilibrium model of international production. To capture input specificity, I follow Grossman and Helpman (2002) by associating each final product with an ideal component. If a component is ideal, then the intermediate good can be used in final good production without a need for spending additional customization costs. However, if the intermediate good is not fully specialized (i.e., not fully compatible), then additional units of labor need to be spent to customize the component to the final good requirements.

I operationalize modularity in the model by allowing the degree of input specificity to vary. I do so by assuming that intermediate and final goods are located on two separate concentric circles. All final goods are symmetrically and uniformly distributed along the circumference of a unit circle. All intermediate goods are arrayed along the circumference of a concentric circle of length $\gamma$, with $\gamma$ ranging from 0 to $\infty$. An intermediate good is ideal for a final good if it lies on the same ray from the origin as the final good. If it does not lie on the same ray, then customization cost $\delta$ arises, where $\delta$ equals the intermediate good circle's arc distance between the intermediary good and the ideal intermediary good. An example is given in Figure 3.1. Four final good firms $X_1$ to $X_4$ are uniformly distributed along the unit length final good circle. The ideal intermediate good for $X_1$ is $Z_1$, the ideal intermediate good for $X_2$ is $Z_2$ and so on. Suppose that final good firm $X_1$ decides to use the non-ideal intermediate good $Z_3$ to produce the final good. In this case, customization cost $\delta$ arises, where $\delta$ equals the arc distance between $Z_1$ and $Z_3$.

While final good producers are uniformly distributed along the circumference of the unit circle, intermediate good producers can choose where to position themselves on the intermediate good circle. As a result, customization costs become endogenous in the model. By assuming that intermediate good producers face economies of scale and can sell their products to at most two final goods firms, the equilibrium customization cost can take on two values. If all intermediate good firms produce ideal components, then the customization

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3 For simplicity, I choose to abstract from additional fixed customization costs that might occur. As such, spending of additional resources for customization is equivalent to a loss in productivity.

4 I assume that intermediate good firms can sell components to at most two final good firms for symmetry.
cost is zero. If all intermediate goods are centered between two ideal inputs, then the customization cost equals $\gamma \frac{\gamma}{2n}$. This situation can constitute an equilibrium if intermediate good producers can exploit economies of scale by producing standardized components.

$$\delta = \begin{cases} 
0 & \text{if all intermediate good firms produce ideal components} \\
\frac{\gamma}{2n} & \text{if all intermediate good firms produce standardized components} 
\end{cases}$$

The condition above implies that the amount of customization costs when standardized components are used depends on two factors: the equilibrium number of final good firms $n$ and the degree of modularity $\gamma$.\footnote{Since our model applies largely to industry or economy-wide phenomena and not to the firm, ignoring the integer problem will not be an important issue here.} An increase in $n$ reduces the equilibrium customization purposes. This assumption permits identifying under which circumstances standardization occurs. However, it does not provide insight into the degree of component standardization.
cost of providing standardized components because the ideal inputs are located closer to one another on the intermediate good circle. A decrease in $\gamma$ reduces the equilibrium customization cost because it reduces the length of the intermediate good circle and thus makes all component varieties closer substitutes to one another. This characteristic is similar to an increase in product modularity and for this reason I proxy the degree of product modularity by $\frac{1}{\gamma}$.

A final question that arises in this setup is which firm faces the burden of customization. In a model without economies of scope, the burden of customization falls on the final good firms (Ari Van Assche, 2003). When intermediate good firms face economies of scope, the burden of customization becomes endogenous. I introduce economies of scope by assuming that intermediate good firms use flexible manufacturing technologies to manufacture differentiated components (B. Curtis Eaton and Nicolas Schmitt, 1994). The essence of this technology is that intermediate good firms have the ability to modify their base product to any other variant by incurring the customization costs themselves. As we shall see, the burden of customization will not only depend on the intermediate and final good firms' relative efficiency of customizing components, but also on other market determinants.

### 3.3 Model Setup

Consider a world with two regions, Home and Foreign, and one industry that produces differentiated consumer goods. The industry in both regions is assumed to be sufficiently small in relation to the rest of the economy, so that the industry can hire as much labor as it wishes at fixed wages. Wages at home $w$ can differ from wages abroad $w^*$. We normalize wages at home to 1 and assume that all fixed cost are always paid in wages at home. The

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6. Take figure 1 as an example. Suppose the intermediate good circle becomes smaller due to an increase in $\gamma$. In that case, the customization cost of using $z_2$ in the production of $x_1$ and $x_2$ reduces.

7. The U.S. Office of Technology Assessment defines flexible manufacturing systems as: A production unit capable of producing a range of discrete products with a minimum of manual intervention.

8. This model applies equally well to a domestic setting where skilled and unskilled laborers face different wages.
production structure in the industry consists of two vertical layers of production that are fragmented across borders. The final good sector $x$ is concentrated at home, while the intermediate good sector $z$ is concentrated abroad.

In the intermediate goods sector $z$, firms face increasing returns to scale and produce differentiated inputs. In the final goods sector $x$, firms compete in a Dixit-Stiglitz monopolistic competition market and produce differentiated final goods. This setup of successive stages of production with increasing returns to scale technologies creates a first cost trade-off that endogenizes the vertical boundaries of the firm in industry equilibrium. If final good firms outsource, they face a high marginal cost due to "double marginalization" (Joseph J. Spengler, 1950) but do not need to pay the fixed cost of setting up an international subsidiary. If the final good firms decide to set up a subsidiary, they internalize the double marginalization distortion, but need to spend the additional fixed cost to set up the subsidiary. The trade-off will determine whether firms will be vertically integrated or will outsource in industry equilibrium.

The assumptions of input specificity and increasing returns to scale in the intermediate good sector create a second cost trade-off that endogenizes the horizontal boundaries of the intermediate good firms under outsourcing. In particular, it determines whether intermediate good firms sell their output to one final good firm or whether they consolidate their market share by providing inputs to multiple final good firms. If intermediate good firms produce ideal components, then no customization costs occur, but the intermediate good firms face a relatively high average cost. If intermediate good firms produce standardized components for two final good firms, then the intermediate good firms are able to move down their average cost curves, but customization costs occur.

Finally, the degree of economies of scope that intermediate good firms face determines which firm faces the burden of customization. As we shall see, the burden of customization does not necessarily fall on the firm that is able to customize intermediate goods at the cheapest rate, but also on other market determinants.
The three cost-tradeoffs allow me to distinguish four production structure regimes (see Figure 3.2). Under Vertical Integration, final good firms set up a subsidiary and produce the intermediate good themselves. Under Ideal Outsourcing, intermediate good firms produce ideal components for final good firms. Under Standardized Outsourcing, intermediate good firms produce standardized components for two final good producers and the burden of customization falls on the final good firms. Under Customized Outsourcing, intermediate good firms produce a base component for two final good firms and face the burden of customization themselves.

![Figure 3.2: Four Production Structures](image)

The equilibrium production structure is determined by a two-step procedure. In step
one, intermediate and final good firms choose from the four production structures to produce consumer goods. In step two, the firms select the profit maximizing price and quantity given the production regime chosen. As usual, the problem is solved through backward induction.\(^9\)

### 3.4 The Model

The final good producers act in a Dixit-Stiglitz monopolistic competition setting. Global consumers spend a constant fraction of their income \(\beta\) on output from the industry. They view the varieties by the industry as symmetrically differentiated and perceive a constant elasticity of substitution \(\sigma\) between every pair of goods. Each consumer maximizes a utility function of the following form:

\[
U = \int_0^n x(i)^{\frac{\sigma-1}{\sigma}} di, \quad 0 < \beta < 1
\]

where \(y(i)\) is consumption of product \(i\) and \(n\) is the measure of final products available on the market. As is well known, these preferences yield the following demand functions for each variety \(i\):

\[
x = Ap_i^{-\sigma}
\]

where

\[
A = \frac{\beta E}{np_i^{1-\sigma}}
\]

As firms are assumed to be symmetric, each firm faces the same demand

\[
x = \frac{\beta E}{np_x}
\]

\(^9\)The full game tree of this model is described in Van Assche (2003)
3.4.1 Vertical Integration

In stage 2, firms maximize their profits given the production structure chosen in stage 1. I start off by assuming that all firms are vertically integrated (VI). In that case, each final good producer chooses to produce the intermediate good \( z \) himself. He naturally chooses to produce the ideal component because he does not want to bear a self-imposed customization cost. The final goods producer thus faces the following profit function:

\[
\pi^VI_x = [p_x(X) - 1 - w^*]x - (F + G_x^*)
\]

where the marginal cost of production includes normalized domestic wages induced during final good production and foreign wages \( w^* \) induced during component production. The fixed cost of VI production includes the fixed cost of setting up a final good firm at home \( F \) and the fixed cost of setting up a subsidiary for component production \( G_x^* \) abroad. Both fixed costs are assumed to be paid in wages at home.

The corresponding first-order condition of optimization provides the standard Dixit-Stiglitz result that the price-marginal-cost mark-up depends only on the elasticity of substitution \( \sigma \):

\[
\hat{p}_x^VI = \left(\frac{\sigma}{\sigma - 1}\right)(1 + w^*)
\]

By plugging the pricing equation (3.6) and the demand function (3.2) into the profit function (3.5), the expected profit function of a vertically integrated firm can be derived:

\[
\hat{\pi}_x^VI = A^VI \sigma^{-\sigma}(\sigma - 1)\sigma^{-1}(1 + w^*)^{1-\sigma} - (F + G_x^*)
\]

The zero-profit condition now allows the determination of the equilibrium number of firms and the level of firm output:
which implies that the number of final good firms is increasing in $\beta E$, decreasing in $\sigma$ and decreasing in fixed costs.

\[ \hat{n}^{VI} = \frac{\sigma^{-1} \beta E}{F + G^*_z} \]

This implies that the scale of firm output is increasing in the ratio of fixed to marginal cost, and increasing in the elasticity of substitution between varieties. Changes in any other demand side parameters such as $\beta$ and $E$ lead to adjustments in industry output via changes in the number of firms only.

### 3.4.2 Outsourcing

Under outsourcing, production of components is outsourced to an external firm. In that case, profits need to be maximized for both the intermediate good firms and the final good firms. I start with the optimization decision for the intermediate good producers. As in Eaton and Schmitt (1994), I assume that intermediate good firms use a flexible manufacturing technology in production which exhibit both economies of scale and economies of scope. They face a fixed cost $G^*_z$ for setting up an intermediate good firm and developing a base product, a constant marginal cost $w^*$ to produce the base product, and an additional marginal cost $w^* \delta_z$ to customize a product for a final good producer. An intermediate good firm thus faces the following general cost structure:

\[ C^O_z = G^*_z + w^*(1 + \delta_z)z \]

with

- $\delta_z = 0$ under Ideal or Standardized Outsourcing
- $\delta_z = \frac{\gamma}{2n}$ under Customized Outsourcing
Under Ideal Outsourcing (IO), \( \delta_z = 0 \) because intermediate good firms produce ideal components for final good firms. Under Standardized Outsourcing (SO), \( \delta_z = 0 \) because the burden of customizing the standardized component falls on the final good firms. Under Customized Outsourcing (CO), \( \delta_z = \frac{1}{2n} \) because the intermediate good firms bear the burden of customizing the standardized components.

The intermediate good producer maximizes the following profit function:

\[
\pi_z^O = [P_z(Z) - w^*(1 + \delta_z)]z - G^*_z
\]

By setting marginal revenue equal to marginal cost:

\[
P_z^O(Z) = \mu_z^O w^*(1 + \delta_z)
\]

with \( \mu_z^O > 1 \)

Note that the markup \( \mu_z^O \) is likely to differ under the three types of outsourcing because of economies of scale. In particular, \( \mu_z^{IO} > \mu_z^{SO} \) and \( \mu_z^{IO} > \mu_z^{CO} \) because under Standardized and Customized Outsourcing, intermediate good firms sell their inputs to two final good firms while under Ideal Outsourcing, they each sell inputs to only one final good firm. As mentioned in section 3, this trade-off between high markup/low customization cost under Ideal Outsourcing and low markup/high customization cost under Standardized and Customized Outsourcing determines the horizontal boundaries of the intermediate good firm in industry equilibrium.

Next, I solve the maximization problem for the final good firm under outsourcing. The final good firm faces the following profit maximization problem:

\[
\pi_x^O = [P_x^O(X) - (1 + r\delta_x) - P_z^O(Z)]x - F
\]
Final good firms face a fixed cost $F$ for setting up a final good firm, a constant marginal cost of 1 to produce the final good, price $P_z$ to purchase input $z$ and a marginal customization cost $r \delta_x$ to customize the input to the final good specifications. $r$ can be seen as the final good firm’s efficiency of customization relative to the intermediate good producer.

By plugging the pricing equation (3.12) into (3.13):

$$\pi^O_x = [P^O_x(X) - (1 + r \delta_z) - \mu^O_z w^*(1 + \delta_z)]x - F$$

The final good producer’s profit function (3.14) under outsourcing differs from the profit function under vertical integration in two important ways. On the one hand, the final good producer now faces a lower fixed cost than under vertical integration as he does not incur the fixed cost $G_x$ of setting up a subsidiary. On the other hand, the final good producer now faces a higher marginal cost than under vertical integration as he has to pay an extra markup $\mu^O_z$ and potential customization costs $\delta_z$ and $\delta_x$ to purchase the intermediate good.

As mentioned above, this tradeoff determines the vertical boundaries of the firm in this model.

Equation (3.14) also illustrates the distinction between the three types of outsourcing. Under Ideal Outsourcing (IO), the intermediate good firm produces a fully customized base product for the final good firm. In that case, $\delta_z = 0$ and $\delta_x = 0$. Under Customized Outsourcing, the intermediate good firm produces a standardized component to two final good firms and bears the customization cost. In that case, $\delta_z = \delta$ and $\delta_x = 0$. Under Standardized Outsourcing, the intermediate good firm produces a standardized component for two final good firms, while the final good firms bear the customization cost. In that case, $\delta_z = 0$ and $\delta_x = \delta$.

The rest of the analysis is similar to the procedure under vertical integration. If I set the marginal revenue equal to the marginal cost and make use of Dixit-Stiglitz preferences:
By plugging the pricing equation (3.15) and the demand function (3.2) into the profit function (3.13), the expected profit of the final good firm is obtained.

\[
\tilde{p}_x^O = \left(\frac{\sigma}{\sigma - 1}\right) \left(1 + r\delta_x + \mu^O_z w^*(1 + \delta_x)\right)
\]

With free entry, total profits amount to zero. Thus the break-even condition together with (3.3) implies:

\[
\tilde{\pi}_x^O = A^O \sigma^{-\sigma}(\sigma - 1)^{\sigma - 1}(1 + r\delta_x + \mu^O_z w^*(1 + \delta_x))^{1-\sigma} - F
\]

Sales per brand amount to (3.4), or using the price equation and the zero profit condition:

\[
x^O = \frac{F(\sigma - 1)}{1 + r\delta_x + \mu^O_z w^*(1 + \delta_x)}
\]

The determination of the equilibrium number of firms in (3.17) allows me to establish the equilibrium customization cost under Standardized or Customized Outsourcing:

\[
\delta = \frac{\gamma}{2n} = \frac{\gamma \sigma F}{2\beta E}
\]

Equation (3.19) indicates that the customization cost \(\delta\) is positively related to the degree of final good competition \(\sigma\) and to the final good firms’ fixed set up cost \(F\). It is negatively related to the degree of product modularity \(\frac{1}{\gamma}\), and industry demand \(\beta E\).
3.5 Industry Equilibrium Determination

In the previous section, I have solved for the second stage of the model by deriving the profit maximizing price and output in under vertical integration and outsourcing. In this section, I solve the first stage of the model by solving for the equilibrium production structure. This will ultimately allow me to determine the optimal outsourcing strategy for multinational firms. I solve for the equilibrium production structure by using the same approach as Grossman and Helpman (2002): production structure $i$ is the equilibrium production structure if and only if it is unprofitable for firms with another production structure to enter the market. In 3.5.1, I solve for the vertical boundaries of the firm by determining under which conditions Vertical Integration constitutes an industry equilibrium. In 3.5.2, I solve for the horizontal boundaries of the firm in the intermediate good sector by determining under which conditions Ideal Outsourcing constitutes an outsourcing equilibrium. In 3.5.3, I analyze which firm faces the burden of customization by determining under which circumstances Customized Outsourcing is preferred to Standardized Outsourcing.

3.5.1 Vertical Boundaries of the Firm

I start off by focusing on the conditions under which vertical integration is the equilibrium production structure. Vertical integration acts as a stable equilibrium if and only if it is unprofitable for firms to enter with any of the outsourcing production structures. Suppose that a group of firms with an outsourcing production structure attempts to enter a market that is pervasively vertically integrated. In that case, the outsourcing final good firm faces the same equilibrium demand $A^{VI}$ as the other vertically integrated firms with

$$A^{VI} = \sigma^\sigma(\sigma - 1)^{1-\sigma}(F + G_2^*)(1 + w^*)^{\sigma-1}$$

Facing $VI$ demand, the outsourcing final good firm then maximizes profits by setting its price according to (3.15). With this price, the outsourcing final good firm makes sales for:
His operating profits then are:

$$\hat{\pi}_x = A^V I M^O - \sigma = \frac{(\sigma - 1)(F + G^*_z)(1 + w^*)^{\sigma - 1}}{(1 + r\delta_z + \mu^O_z w^*(1 + \delta_z))^{\sigma}}$$

An outsourcing final good firm will decide to stay out of the market if its operating profits are negative. This implies that a sufficient condition for a vertical integration equilibrium is:

$$\hat{\pi}_x = (F + G^*_z)\left(\frac{1 + w^*}{1 + r\delta_z + \mu^O_z w^*(1 + \delta_z)}\right)^{\sigma - 1} - F < 0$$

where $RMC^V I_O$ is the relative marginal cost of vertical integration versus outsourcing and $RFC^V I SO$ is the relative fixed cost of vertical integration versus outsourcing.\(^{10}\)

Equation (3.23) provides the general condition that determines the vertical boundaries of the firm. It states that vertical integration becomes more likely if the marginal cost of vertical integration relative to that of outsourcing decreases, if the fixed cost of vertical integration relative to that of outsourcing goes down, and if the weight of marginal costs relative to fixed costs, measured by scaling factor $\sigma$, goes up. The latter is because vertical integration is the low-marginal cost high-fixed cost production structure.\(^{11}\)

A more detailed analysis of (3.23) also provides the impact of specific market and product determinants of the vertical boundaries of the firm. First, it passes the two basic checks by showing that an increase in the fixed cost of setting up a subsidiary $G^*_z$ induces outsourcing, while an increase in the intermediate good markup $\mu^O_z$ induces vertical integration. Second,
an increase in customization costs $r\delta_x$ and $\delta_z$ induces vertical integration. Third, the impact of competition on the production structure is ambiguous (Grossman and Helpman, 2002). The degree of competition is often measured with the elasticity of substitution $\sigma$. On the one hand, an increase in final good sector competition $\sigma$ induces vertical integration because it increases the weight of relative marginal cost versus relative fixed cost. This is because an increase in $\sigma$ increases the level of output of each firm. On the other hand, an increase in $\sigma$ is likely to also lower the markup on the intermediate good $\mu_z^O$ because intermediate good firms also start producing more, thus moving down their average cost curves. The decrease in the intermediate good markup $\mu_z^O$ favors outsourcing. As a result, the impact of competition on the production structure is ambiguous.

3.5.2 Horizontal Boundaries of the Firm

In this section, I solve for the horizontal boundaries of the firm in the intermediate good sector by determining under which conditions Ideal Outsourcing constitutes an outsourcing equilibrium. Ideal Outsourcing acts as an outsourcing equilibrium if it is unprofitable for firms with another outsourcing production structure to enter the market. Suppose that a group of firms with another outsourcing production structure attempts to enter a market that has pervasive Ideal Outsourcing. In that case, the final good firm faces the same demand $A^{IO}$ as the other Ideal Outsourcing firms with:

\begin{equation}
\bar{A}^{IO} = \sigma^\sigma (\sigma - 1)^{1-\sigma} F(1 + \mu_z^{IO} w^*)^{\sigma-1}
\end{equation}

Facing $IO$ demand, the final good firm then maximizes profits by setting its price according to (3.15). With this price, the final good firm makes sales for:

\begin{equation}
\bar{x}^O = \bar{A}^{IO} \bar{p}_x^{\sigma} = \frac{F(\sigma - 1)(1 + \mu_z^{IO} w^*)^{\sigma-1}}{(1 + r\delta_x + \mu_z^O w^*(1 + \delta_z))^{\sigma}}
\end{equation}

His operating profits then are:
A group of Customized Outsourcing firms and Standardized Outsourcing firms will decide to stay out of the market if its operating profits are negative. This implies that sufficient conditions for an Ideal Outsourcing equilibrium are:

\begin{align*}
&\frac{\mu_{IO} - \mu_{CO}}{\mu_{CO}} \leq \delta = \frac{\gamma F}{2\beta E} \\
&\frac{\mu_{z}^{IO} - \mu_{z}^{SO}}{\mu_{z}^{SO}} \leq \frac{r\delta}{\mu_{z}^{SO} w^*} = \frac{r\gamma F}{2\beta E}
\end{align*}

Equation (3.27) indicates that Customized Outsourcing will not be preferred to Ideal Outsourcing if the customization cost $\delta$ for the intermediate good firm is larger than the percent difference between the the markup under Ideal Outsourcing and the markup under Customized Outsourcing. Equation (3.28) shows that Standardized Outsourcing will not be preferred to Ideal Outsourcing if the customization cost for the final good firm relative to the price of the standardized intermediate good is larger than the percent difference between the the markup under Ideal Outsourcing and the markup under Standardized Outsourcing. Both conditions demonstrate that Ideal Outsourcing will act as a stable equilibrium if economies of scale are low and if customization costs are high. To turn this around, lower customization costs and larger markup reductions due to economies of scale induce horizontal consolidation in the intermediate good sector when outsourcing is prevalent. From (3.19), we also find that an increase in modularity through a reduction in $\gamma$ and an increase in industry demand $\beta E$ both induce horizontal consolidation as it reduces equilibrium customization costs.
3.5.3 Burden of Customization

In this section, I analyze the burden of customization by determining the relative prevalence of Customized Outsourcing versus Standardized Outsourcing. Customized Outsourcing is chosen over Standardized Outsourcing if it is unprofitable for firms with a Standardized Outsourcing production structure to enter a pervasive Customized Outsourcing market. Suppose that a group of firms with a Standardized Outsourcing production structure attempts to enter a market that has pervasive Customized Outsourcing. In that case, the final good firm faces the same demand $A^{CO}$ as the other Customized Outsourcing final good firms:

$$A^{CO} = \sigma^2 (\sigma - 1)^{\frac{1}{\sigma}} F \left( 1 + \mu^I w^* (1 + \frac{\gamma^F}{2\beta E}) \right)^{\frac{\sigma - 1}{\sigma}}$$

Facing CO demand, the SO final good firm then maximizes profits by setting its price according to (3.15). With this price, the final good firm makes sales for:

$$\bar{x}^{SO} = \frac{A^{CO} p_x^{SO} - \sigma}{\sigma} = \frac{F(\sigma - 1)(1 + \mu^I w^* (1 + \frac{\gamma^F}{2\beta E}))^{\frac{\sigma - 1}{\sigma}}}{(1 + \frac{\gamma^F}{2\beta E} + \mu^S w^*)^\sigma}$$

His operating profits then are:

$$\Pi_x^{SO} = F \left[ \frac{1 + \mu^CO w^* (1 + \frac{\gamma^F}{2\beta E})^{\frac{\sigma - 1}{\sigma}}}{1 + \frac{\gamma^F}{2\beta E} + \mu^S w^*} - 1 \right]$$

A group of Standardized Outsourcing firms will decide to stay out of the Customized Outsourcing market if its operating profits are negative. This implies that a sufficient condition for a Customized Outsourcing equilibrium is:

$$\frac{\mu^S - \mu^C}{\mu^C} \geq \frac{\mu^CO w^* \delta - r}{\mu^CO w^* \delta}$$
57

\begin{equation}
\delta = \frac{\sigma F}{2H}
\end{equation}

Customized Outsourcing will be chosen over Standardized Outsourcing if the percent difference in markup between Standardized Outsourcing and Customized Outsourcing is larger than the percent difference between the customization cost for the final good firm and the adjusted customization cost of the intermediate good firm \(\mu_{CO}^* \omega^* \delta\). The implication of this is that the burden of customization does not necessarily fall upon the firm that can customize the intermediate product at the lowest price. Indeed the burden of customization can fall on the final good firm if the intermediate good markup is too high.

### 3.6 Markup Endogenization

Many of the comparative statics in the previous section could not be derived because the intermediate good markup \(\mu\) is endogenous in the model and thus can change when other parameters in the model change. In this section, I explicitly solve for the intermediate good markup by assuming contestable markets in the intermediate goods sector. In 3.6.1, I solve for the intermediate good markup under the three outsourcing equilibria. By plugging these endogenized markup into the industry equilibrium conditions derived in section 2.5, I can then solve for each production structure's market and product determinants. In 3.6.1, I determine the conditions under which Vertical Integration acts as an industry equilibrium. In 3.6.2, I solve for the horizontal boundaries of the firm in the intermediate good sector by determining under which conditions Ideal Outsourcing constitutes an outsourcing equilibrium. In 3.6.3, I analyze which firm faces the burden of customization by determining under which circumstances Customized Outsourcing is preferred to Standardized Outsourcing.

**Ideal Outsourcing**

In an ideal outsourcing equilibrium, the output of the intermediate good firm is identical to the output of the IO final goods firm. As a result:
By combining the pricing equation (3.12) with the output equation (3.33), I can derive the intermediate good firm's profit function. Since I assume that intermediate good firms act in a contestable markets setting, profits can then be set to zero to derive the equilibrium markup condition:

\[
\tilde{\mu}_z^{IO} = \frac{w^*F(\sigma - 1)}{1 + \mu_z^{IO}w^*}
\]

Intermediate good firms will only operate in an Ideal Outsourcing equilibrium if \(F(\sigma - 1) - G_z > 0\). As expected, the markup is unambiguously increasing in the fixed cost of setting up an intermediate good firm \(G_z\). It is decreasing in \(F\) and \(\sigma\) due to the output effect. If the level of output goes up, then the fixed cost is spread over more units of output and the markup declines.

**Standardized and Customized Outsourcing**

In a Standardized and Customized Outsourcing equilibrium, the output of the intermediate good firm is identical to twice the output of the SO final goods firm. As a result:

\[
\tilde{\mu}_z^{SO} = \frac{w^*F(\sigma - 1) + G_z^*}{w^*(F(\sigma - 1) - G_z^*)}
\]

If I plug the pricing equation (3.12) and the output equation (3.35) into the profit function (3.11) and set profits equal to zero due to market contestability, the intermediate good markup becomes:

\[
\tilde{\mu}_z^O = \frac{2w^*F(\sigma - 1)(1 + \delta_z) + G_z^*(1 + r\delta_z)}{w^*(2F(\sigma - 1) - G_z^*)(1 + \delta_z)}
\]
Intermediate good firms will operate in a Standardized or Customized Outsourcing equilibrium if $2F(\sigma - 1) - G_z^* > 0$. The markup is increasing in $G_z^*$ and decreasing in $F$, $\sigma$ and $w^*$. In addition, an increase in customization cost $\delta$ increases the intermediate good markup.

### 3.6.1 Vertical Boundaries of the Firm

Vertical integration acts as a stable equilibrium if and only if it is unprofitable for firms to enter with an IO or SO production structure. By plugging the markup conditions (3.34) and (3.36) into (3.23), I find the two conditions that need to hold for vertical integration to be a stable equilibrium:

\[
(3.37) \quad \left( \frac{F(\sigma - 1) - G_z^*}{F(\sigma - 1)} \right)^{\sigma - 1} \left( \frac{F + G_z^*}{F} \right) \leq 1
\]

and

\[
(3.38) \quad \left( \frac{(1 + w^*)(2F(\sigma - 1) - G_z^*)}{(1 + r\delta_x + w^*(1 + \delta_x))2F(\sigma - 1)} \right)^{\sigma - 1} \left( \frac{F + G_z^*}{F} \right) \leq 1
\]

The two inequalities confirm all the results of section 5.1. It also provides a number of new results. First, an increase in the fixed cost of setting up an intermediate good firm $G_z^*$ induces vertical integration. The reason is that it increases the intermediate good markups $\mu_z$, thus making outsourcing less attractive. Second, an increase in the fixed cost of setting up a final good firm $F$ has an ambiguous effect on the vertical boundaries of the firm. This is because an increase in $F$ on the one hand reduces the relative fixed cost of vertical integration. On the other hand, it increases the output of intermediate good firms, thus reducing their intermediate good markups and increasing the relative marginal cost of vertical integration.

### 3.6.2 Horizontal Boundaries of the Firm

In order to determine the horizontal boundaries of the firm, I once again determine when Ideal Outsourcing is preferred to Standardized and Customized Outsourcing. By plugging
(3.34) and (3.36) into (3.27) and (3.28) and combining the two inequalities, I find that Ideal Outsourcing acts as a stable equilibrium if the following condition holds:

\[
G_z \leq \frac{2F(\sigma - 1)(r\delta_x + w\delta_z)}{1 + w^* + 2(r\delta_x + w\delta_z)}
\]

The condition illustrates that Ideal Outsourcing will act as a stable equilibrium if \( G_z \) is low and if \( F, \sigma, r, \delta \) and \( w^* \) are high. These results reiterate the importance of high economies of scale in the intermediate good sector for horizontal consolidation. It also establishes the interesting point that horizontal consolidation becomes less attractive if output of the final good firm is higher because of a higher \( \sigma \) or \( F \). Finally, Ideal Outsourcing is preferred if the cost of customization is high.

### 3.6.3 Burden of Customization

Customized Outsourcing is chosen over Standardized Outsourcing if it is unprofitable for firms with a Standardized Outsourcing production structure to enter a pervasive Customized Outsourcing market. By plugging (3.36) into (3.32), I find that Customized Outsourcing will be preferred to Standardized Outsourcing if the following condition holds:

\[
\frac{2w^*F(\sigma - 1)}{1 + G_z} \leq r
\]

The burden of customization will fall on the intermediate good firm if \( r \) is high, if \( w^* \), \( F \) and \( \sigma \) are high and if \( G_z \) is low. This illustrates that the burden of customization not only depends on each firm's relative efficiency (determined by \( w^* \) and \( r \)), but also on the intermediate good firm's markup. If \( F \) and \( \sigma \) are low and if \( G_z \) is high, then the intermediate good firm's markup is high and so the cost of Customized Outsourcing increases even if the firms' relative efficiency remains unchanged.
3.7 Conclusion

This chapter develops a theoretical framework to analyze the optimal outsourcing strategy for multinational firms in an industry where external component producers use flexible manufacturing technologies to produce their components. The model contributes to a better understanding of the outsourcing strategies available to multinational enterprises (MNEs) by distinguishing between three types of outsourcing. Under Ideal Outsourcing, intermediate good firms produce ideal components for final good firms. Under Standardized Outsourcing, intermediate good firms produce standardized components for multiple final good producers and the burden of customizing the standardized components falls on the MNE. Under Customized Outsourcing, intermediate good firms produce a base component for multiple final good firms and they face the burden of customization themselves.

The model also provides an explanation why in many globalized industries vertical outsourcing seems to co-evolve with increased horizontal concentration in the contract manufacturing sector. If products are modular and if intermediate good firms can exploit economies of scale, then it can become profitable for a vertically integrated MNE to outsource component production to an intermediate good firm that uses a generic production process (Customized Outsourcing) or produces standardized inputs (Standardized Outsourcing) to multiple final good producers. As such, this chapter links the co-evolution process to the emergence of de facto standardization of inputs and production processes that has been taking place in high technology industries such as electronics, telecommunications, semiconductors and automobiles (Sturgeon, 2002).

Finally, the model provides new insights into which firm faces the burden of customizing standardized inputs. Because component producers have flexible manufacturing technologies, they have the ability to exploit economies of scope by customizing their base component to the requirements of multiple MNE's at limited additional cost. MNE's will only rely on this outsourcing option, however, if the customization cost of component producers is lower
than their own and if the intermediate good firm's markup is not too high. Indeed, it can occur that the final good firm chooses to customize the components itself even though the intermediate good firm is more efficient in doing so.

In summary, the model helps to better appreciate the complexity of trade and investment in a world in which firms choose endogenously their organizational forms. Future extensions to the theoretical model are to allow intermediate good firms to produce standardized components for more than two final good producers, to introduce incomplete contracts and to allow for standards competition.
Chapter 4

Assessing the Benefits of Telecommunications Liberalization to Tunisia

4.1 Introduction

Effective pro-competitive regulation is increasingly recognized to be a crucial factor for successful telecommunications liberalization in developing countries. A growing body of empirical evidence suggests that competition in the telecommunications sector is the most effective agent of improvements in the sector’s performance. For example, Latin American countries that granted monopoly privileges to privatized enterprises saw connections grow at only half the rate observed in Chile, where the government retained the right to issue competing licenses at any time (Björn Wellenius, 1997). In a panel study of 197 countries, Scott J. Wallsten (2002) found that establishing a regulatory authority prior to privatization is significantly and positively correlated with the performance of the telecommunications sector. Carsten Fink, Aaditya Mattoo and Randeep Rathindran (2003) established that, in developing countries, introducing competition after privatizing incumbent operators leads to fewer mainlines per population than if there was a simultaneous introduction of the two policies. Finally, in a study focusing on the Middle East and North Africa (MENA), Aristomene Varoudakis and Carlo Maria Rossotto (2004) found that the poor performance of
these countries' telecommunications sectors was related to their slower pace in opening up to competition. They concluded that, with an effective pro-competitive regulatory environment, telecommunications liberalization in the MENA region holds considerable potential for improving overall economic performance.

Regulation is particularly important in the telecommunications sector because of several reasons. Like most services, barriers to the provision of telecom primarily operate through entry barriers to local markets, rules of conduct, and rules of competition (John Whalley, 2003). All these barriers are determined or influenced by the existing regulatory environment. There are also a number of unique characteristics of the telecommunications sector that emphasize the importance of regulation. Since strong network effects are prevalent in telecom, increased market access does not necessarily increase competition in the sector (Jean-Jacques Laffont and Jean Tirole, 2001). In order to provide services to local customers, market entrants need to interconnect with the local network of the incumbent operator. Since the terms of interconnection need to be negotiated between the two firms, this provides the incumbent with the power to erect barriers to entry. In particular, it can erode the competitiveness of new market entrants by charging excessively high interconnection fees or even by entirely prohibiting the foreign entrant from interconnecting with its network.\footnote{For example, AT&T refused to interconnect independent local telecommunications companies to its long distance network, unless they became part of the Bell System, which essentially meant unless they were acquired. Carl Shapiro and Hal R. Varian (1998) discuss some other historical examples.} In addition, the incumbent can induce legitimate collusion with the new entrants by setting appropriate interconnection fees (Michael Carter and Julian Wright, 1999).

Reflecting the importance of effective regulation as a safeguard for competition, a major achievement of the 1997 WTO Agreement on Basic Telecommunications Services was the creation of the "Reference Paper" on pro-competitive regulatory principles in the telecommunications sector (Peter Cowhey and Mikhail M. Klimenko, 2001).\footnote{The WTO Agreement on Basic Telecommunications Services is an annex to the Fourth Protocol of the General Agreement on Trade and Services (GATS). It commits participating countries to open their telecommunications services markets. Tunisia is one of the 69 countries that signed onto the WTO Agreement on Basic Telecommunications. It was one of the 8 countries that did not sign onto the Reference Paper.} The Reference Paper
represents the regulatory component of the basic telecommunications agreement. It provides a set of common principles for a regulatory framework that countries should follow to support the transition of the telecommunications sector to a competitive marketplace and to guarantee effective market access and foreign investment commitments. Among these principles, a regulator is required to be separate from, and not accountable to, any supplier of basic telecommunications services. Interconnection are expected to be inter alia on non-discriminatory, transparent and reasonable terms, conditions and rates. The other Reference Paper principles provide for competition safeguards, greater transparency and requires the creation of dispute resolution mechanisms.3

Attempts have been made in recent years to quantify the effects of telecommunications liberalization in a computable general equilibrium (CGE) framework (e.g., George Verikios and Xiao-Guang Zhang, 2004; Jesper Jensen, Thomas F. Rutherford and David G. Tarr, 2003). However, none of these studies have explicitly addressed the importance of market structure and the regulatory environment. The problem lies in the way that barriers to telecom trade are incorporated into the CGE framework (Whalley, 2003). As in most CGE studies on service trade liberalization, barriers to telecom trade are first converted into their tariff equivalents by estimating the price-cost margins in the telecom sector. Telecommunications liberalization is then modelled as the partial or complete removal of these tariff-equivalent telecom barriers. Throughout the liberalization process, however, the market structure in the services sector remain unchanged.

This study uses a CGE model to provide a quantitative analysis of the importance of regulation and market structure on the success of partial telecommunications liberalization in Tunisia. For this purpose, we incorporate a telecommunications sector with an imperfectly competitive market structure into the CGE framework that Denise E. Konan and

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3The Reference Paper deals with six regulatory principles including competitive safeguards, interconnection, universal service, licensing, allocation and use of scarce resource and creation of independent regulator. Once a country adopts the Reference Paper, the principles become binding commitments and enforceable through dispute settlement under WTO. A summary of the six principles can be found in appendix 1.
Keith E. Maskus (2002) have built for Tunisia. We assume that in the benchmark a domestic incumbent monopolizes the telecommunications industry. In the counterfactuals, the Tunisian government liberalizes its telecommunications sector by providing a license to a single foreign telecom provider. If regulations can enforce competition between the domestic and foreign firm, then the telecommunications market structure turns into a Cournot duopoly. If regulations are weak, then the domestic and the foreign firm can form a cartel.

The chapter is organized as follows. Section 4.2 provides an overview of Tunisia's telecommunications sector. Section 4.3 explains the setup of the CGE model and the specific nature of the telecommunications sector in the model. Section 4.4 summarizes the benchmark data used. Section 4.5 provides the results and section 4.6 concludes.

4.2 Overview of Tunisia's Telecom Industry

Tunisia represents a good case study to investigate the impact of regulation and market structure on the success of telecom liberalization in developing countries. Reforms in its telecommunications industry have lagged behind those in countries with similar income levels, and the resulting absence of competition has limited the growth of both fixed and mobile networks. For these reasons, telecom liberalization holds a considerable potential for improving not only Tunisia's sectoral performance, but also its overall economic performance.

The Tunisian telecommunications market has long been characterized by the monopoly of Tunisie Telecom and the extensive role of the government as policy-maker, regulator and operator in the sector. Tunisie Telecom, also known as "Office National des Télécommunications" continues to be a 100% state owned company with a national monopoly on fixed telephony services and on the provision of internet infrastructure. Until recently, Tunisie Telecom also had a monopoly on the mobile telephony through its subsidiary Tunisie Mobile.

Like most developing countries, the Tunisian government initially was reluctant to open
the telecommunication sector to private and foreign investment. Since the mid-1990s, however, the government has initiated a cautious program of telecommunications liberalization. In 1997, it was one of the 56 signees of the World Trade Organization Agreement of Basic Telecommunications Services, thus committing itself to gradually liberalizing its telecommunications sector. In accordance to the Agreement, Tunisia committed to permitting telex and data transmission competition from 1999, mobile telephone and paging, frame relay, and teleconferencing from 2000, and local telephone competition in 2003. For all services, however, foreign ownership was capped at 49%, and foreign ownership of Tunisie Telecom was only permitted to 10% beginning in 2002. Tunisia was one of the few signees, however, that did not commit to pro-competitive regulatory reforms by signing on to the Reference Paper.

In January 2001, Tunisia enacted a new Communications Code (Law n. 2001-1), which would regulate the telecommunications sector. The law enabled the opening-up of the market to private companies by introducing a licensing regime for the supply of telecommunications services and networks. In addition, the Code created two regulatory agencies: the National Instance of Telecommunications (NIT) and the National Agency for Frequency (NAF). The NIT is in charge of the regulation of the telecommunications sector and the NAF is in charge of spectrum management. The Code falls short of setting up an independent regulatory agency, though, since significant lawful capacities are left to the Ministry of Communications Technologies with regard to licence awarding, dispute settlements and application of sanctions.

In March 2002, Tunisia awarded a second mobile phone license to Orascom Telecom.4 Orascom launched its services in December 2002 under the brand name of Tunisiana. The entry of a second mobile phone operator on the market is expected to increase mobile penetration dramatically. For example, the consulting firm Arab Advisors projected the mobile phone market to increase almost nine fold by 2006, reaching a penetration rate of 43

4The Egyptian consortium paid U.S.$454 million for the license.
percent, or 4.4 million subscribers (Carlo Maria Rossotto, Khalid Sekkat and Aristomene Varoudakis, 2003).

![Telecommunications Liberalization Index (1999)](image)

Source: Varoudakis and Rossotto (2004)

Figure 4.1: Telecommunications Liberalization Index (1999)

Notwithstanding recent reforms, Tunisia's telecommunications sector remains one of the least advanced among developing countries in terms of market liberalization. As is illustrated in figure 4.1, Tunisia's telecommunications liberalization index in 1999 was below the average of the worst-performing developing region in the world, that is, the MENA region. In addition, although Tunisia has stepped up its pace of reforms in the past five years, its liberalization index continues to fall far short of the average ratings achieved by developing countries with similar levels of GDP per capita (Varoudakis and Rossotto, 2004).

The telecommunications liberalization index was constructed by Varoudakis and Rossotto (2004). It takes into account and measures degrees of liberalization according to: (1) degree of effective competition; (2) openness to FDI in telecommunications, and (3) pro-competitive regulation and independence of regulatory body.
Tunisia's lack of telecom liberalization has led to an underperforming telecom sector. Tunisia's fixed line penetration rate was similar to Lower Middle-Income Countries between 1980 and the early 1990s (see figure 4.2). From then onwards, however, as other developing countries with similar income started to liberalize their telecom sector, Tunisia lagged behind. In addition, the mobile phone penetration rate in Tunisia has continuously remained below that of other Lower Middle-Income Countries.

As Tunisia ranks low in the scale of telecom liberalization and telecom performance, opening up markets to competition thus has the potential to generate significant benefits in terms of telecom sector development and overall economic growth.
4.3 Model Structure

We employ what is, in most respects, a standard CGE model of a small open economy for Tunisia (Konan and Maskus, 2002). The nesting structure of the model is presented in figure 4.3, and the full list of model equations can be found in Appendix 3. Our contribution lies in the way we incorporate the telecommunication sector's market structure in the model. We assume that commercial presence is required for telecom providers to produce domestic services for Tunisian customers. Domestic regulations in the benchmark render the telecom sector's market structure imperfectly competitive. The telecommunications sector can adopt different market structures in the counterfactual scenarios depending on the regulatory reforms embraced during telecom liberalization. This setup allows us to analyze the impact of market structure and regulatory reforms on the success of telecom liberalization in Tunisia.

In the model, commercial presence is required for firms to provide domestic telecom services to Tunisian customers. For this purpose, we assume that cross-border trade in telecommunications cannot substitute for domestic telecommunications services (Zhang and Verikios, 2004). Thus the values for the Armington elasticities are set zero for communication services. The implication of this assumption is that foreign firms need to obtain a license from the Tunisian telecom regulator in order to operate in the Tunisian market and provide domestic services.

The telecommunications sector is assumed to be imperfectly competitive. In the baseline scenario, it consists of a domestic monopoly. In the counterfactual scenarios, the telecommunications sector is liberalized and one foreign firm is allowed to enter the market. Since domestic and foreign firms provide differentiated products, we choose total telecom output \( Z \) to be a CES function of composite telecom services provided by the domestic provider \( Z_D \) and the multinational telecom provider \( Z_M \).

\footnote{The Armington elasticities are also set to zero for the other producer services Finance, Insurance and Business Services.}
Figure 4.3: Nesting Structure of CGE Model for Tunisia
The elasticity of substitution between the domestic and foreign provider is $\sigma = \frac{1}{1-\epsilon}$. We require that $\sigma$ exceeds unity.

Under telecom liberalization, a foreign firm is allowed to enter the telecom sector and compete with the domestic monopoly. The firms can thus form two separate market structures depending on their interaction. Under international Cournot duopoly, the incumbent and the foreign firm strategically compete in quantities. Under international cartel, the two firms collude. For the telecom providers, the major difference between the various market structures is the Lerner markup conditions that they implement. The main contribution of this chapter is the derivation of each firm's markup rule under each market structure.

As Anders Hoffmann (2003) illustrates, deriving the optimal Lerner markup condition in a general equilibrium setting is not trivial since each firm faces more than one buyer and the buyers often have different elasticities of demand. In other CGE studies that incorporate imperfect competition, this problem is often avoided by focusing on large group monopolistic competition since in that case the elasticity of demand for each buyer is identical and fixed. As is illustrated in Appendix 2, Hoffmann (2003) shows that the general equilibrium Lerner markup condition is a weighted average of the elasticities of demand for the different buyers:

\[
(4.1) \quad Z = (Z_D^* + Z_M^*)^\frac{1}{\epsilon} 
\]

The elasticity of substitution between the domestic and foreign provider is $\sigma = \frac{1}{1-\epsilon}$. We require that $\sigma$ exceeds unity.

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\[
(4.2) \quad p_i \left[ 1 - \frac{1}{\phi_i \theta_i} + \frac{1}{\sum_j \phi_{ij} \theta_{ij}} \right] = c_i 
\]

where $\phi_j$ is the elasticity of demand for buyer $j$ and $\theta_{ij}$ is the share of the total quantity sold to buyer $j$. The elasticity of demand for the $N$ producer's good is, therefore, a weighted average of the elasticities of demand for the different buyers. In Appendix 2, we derive the general equilibrium Lerner markup conditions for the three market structures (monopoly, duopoly and cartel). They can be summarized into one generalized Lerner markup condition:
\[ \frac{p_{xj} - c_j(w, r)}{p_{xj}} = \frac{1}{\sigma} \left[ \frac{\theta_u}{1 + (\sigma - 1)s_i} + \sum_i \frac{\theta_{yi\rho}}{(1 - s_j)\rho + \sigma(s_{vai})s_j} \right]^{-1} \]

where \( p_{xj} \) is the price of telecom services from provider \( j \), \( c_j \) is the marginal cost of provider \( j \), \( s_j \) is the market share of telecom provider \( j \) in the telecom market. \( s_{vai} \) is the share of value added in combined value added and producer services. \( \sigma \) is the elasticity of substitution between domestic telecom services and foreign telecom services. \( \rho \) is the elasticity of substitution between value added and producer services. As is explained in Appendix 2, the Lerner markup condition for each firm under international Cournot duopoly equals the generalized Lerner markup condition. Under domestic monopoly, the Lerner markup condition for the domestic firm is the generalized Lerner markup condition with \( s_d = 1 \). Under international cartel, both the domestic and the foreign firm treat \( s_j = 1 \).

There are two distinctions between the domestic incumbent and the foreign entrant. On the one hand, the foreign entrant might be more efficient than the domestic incumbent. We represent this by assuming that the foreign firm in some scenarios has a lower marginal cost \( c_i \) than the domestic firm. On the other hand, the foreign entrant might shift its profits abroad rather than to the domestic representative agent.

It is important to note that liberalization does not, in our model, generate endogenous changes in FDI flows. Rather, the scenarios involve changes in ownership and market structure in ways that may improve efficiency and alters the distribution of rents. This assumption reflects the fact that in several service sectors there is no foreign participation (that is, FDI) in the benchmark equilibrium. In that context it is impossible to determine what the impact of liberalization would be on “marginal” FDI flows, which would not be meaningful. This assumption also permits us to retain a fixed aggregate capital stock in the model, rather than engaging in dynamic simulations of endogenous investment and capital allocation. In this context, the estimates of welfare changes from liberalization of establishment rules are likely to be understated relative to full long-run gains.\(^7\)

\(^7\)Timothy J. Kehoe (2003) discusses the importance of incorporating changes in trade and investment flows.
Similar to Jesper Jensen, Thomas F. Rutherford and David Tarr (2003b), we assume that telecom services are part of a select group of producer services that can have a significant impact on the productivity of value added.\(^8\) We introduce this idea by modelling composite producer services \(PS\) as an imperfect substitute to value added.

\[
PS_i = \min \left[ \frac{x_{1i}}{b_{1i}}, \ldots, \frac{x_{m-1,i}}{b_{m-1,i}}, \frac{Z_i}{b_{z_i}} \right]
\]

\[
V_i = \left( (L_{i}^{\alpha_{i}}K_{i}^{\beta_{i}})^{\gamma} + PS_i^{\gamma} \right)^{\frac{1}{\gamma}}
\]

The elasticity of substitution between value added and producer services is \(\rho = \frac{1}{1-\gamma}\). As we shall see in the next section, \(\rho\) is endogenous in the model.

We assume that production of all sectors, except for telecom, is characterized by constant returns to scale and perfect competition, implying that prices equal marginal costs of output in these sectors. In all sectors, production functions are approximated with Leontief technologies using composite intermediate inputs \(x_{ji}\) for all sectors except for producer services \(j = 1, \ldots, n\), and the CES combination of real value added and composite producer services \(V_i\) mentioned above.

\[
Y_i = \min \left[ \frac{x_{1i}}{a_{1i}}, \ldots, \frac{x_{ni}}{a_{ni}}, \frac{V_i}{a_{VA_i}} \right]
\]

Intermediate inputs and final goods are differentiated by country of origin according to the Armington assumption, so that export and import prices differ across regions. The three trading regions are the European Union (EU), the Arab League countries, and the

\(^8\) In our model, producer services are: telecommunication services, financial services, insurance, and business services.
rest of the world (ROW). In each sector, demand for domestically produced and imported goods is represented by a CES function, and intermediate imports are also differentiated across regional sources of supply in a CES structure. Similarly, Tunisian industries supply regionally differentiated goods to both domestic and foreign markets (exports). Production follows a nested two-stage constant elasticity of transformation (CET) function. Total output is first calculated as the sum of domestic supply and total exports, with the latter then being allocated across the same destination regions according to a sub-CET function. Capital and labor are assumed to be freely mobile across sectors, implying that our simulations pertain to long-run outcomes of liberalization.

A representative consumer maximizes a nested CES utility function with a corresponding multi-staged budget constraint. In the first stage, the consumer decides how much to spend on goods from each sector, given the budget constraint. Income elasticities across sectors are set at unity as given by a Cobb-Douglas (CD) utility nest. In the second nest, the consumer determines domestic and aggregate import expenditures in each sector according to a CES function. Then given a budget for imports, the consumer selects purchases of imports from each region. These latter functions also characterize the split between government consumption and investment spending on domestic and imported goods and services. The representative consumer receives income from primary factors (labor and capital), net transfers from the government, the current-account deficit, and any net economic rents that domestic and foreign firms transfer to them.

Two standard closure rules are imposed: the savings-investment balance and a fixed current account balance. The savings-investment balance is based on the assumption that the capital stock is exogenously fixed at the benchmark level. This stock is financed through forced consumer savings that acts as a direct (lump-sum) tax. The interest rate (an index price of the composite capital stock) is endogenous and determined by factor demand conditions. The current-account is defined as the sum of the merchandise trade balance, the services balance, net foreign worker remittances, and (negative) net payments on foreign
capital. We assume that foreign reserves will be held constant so that the current account will be just offset by (the negative of) the capital account. The current-account balance itself is held constant in real terms throughout the simulations. Income from foreign remittances less foreign capital payments enters as an exogenous addition to the representative agent's income. To hold the current account balance fixed while international prices are constant requires a balancing item. This is accomplished by means of a change in the home "real exchange rate," which refers implicitly to a change in the home price index (generated by changes in price of home-produced goods) sufficient to sustain a constant current-account balance as import and export volumes change.

The government budget deficit is a deduction in available income for the representative agent, constituting a transfer to government consumption. The deficit is held fixed during our simulations.

4.4 Benchmark Data

The data for the model consist of a Social Accounting Matrix (SAM), estimates of the price-cost margin in the telecommunications sector and of other parameters such as import and export trade flows by region, sectoral tax and tariff rates, and elasticities of substitution and transformation. The core input-output model is the 1995 table provided on a diskette by the Institut National de la Statistique (INS). The 56 sector table was combined with the INS Les Comptes de la Nation (1998) report and then assembled into a consistent set of relationships between intermediate demand, final demand and value-added to produce the SAM.

In order to have valid estimates of the Lerner markup in the telecommunications sector, it would be necessary to estimate the impact of telecom barriers on price markups.9 Unfortunately, these estimates are not available for Tunisia. By relying on industry studies

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9Christopher Findlay and Tony Warren (2000) suggest computing the pro-competitive impacts using price-cost margins (or "net interest margins").
Table 4.1: Sector Codes and Descriptions

<table>
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<tr>
<th>Aggregate Sectors</th>
<th>Code</th>
<th>Sectors</th>
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in Tunisia and extensive discussions with Tunisian industry experts, country economists
and government officials and on studies by Jamel Zarrouk (2000) and Konan and Maskus
(2002), we have been able to estimate an approximate monopoly markup of 20% in Tunisia’s
telecom sector.

We allow for the possibility that the foreign telecom provider is more efficient than
the domestic incumbent in providing telecommunications services. If this is the case, we
assume that the foreign firm faces a marginal cost that is 10% lower than that of the
domestic incumbent.

Because we explicitly derive the Lerner markup condition for the domestic monopolist
in the benchmark, the elasticity of substitution between value added and producer services
$\rho$ is endogenous in the model. From (4.3), $\rho$ becomes:

\begin{equation}
\rho = \left[1 - \frac{MK}{MK} \right] \left[ \sum_i \frac{\theta_{yi}}{s_{V,Ai}} \right]^{-1}
\end{equation}

The implication of this result is that the elasticity of substitution between value added and
producer services equals 4.3 in the benchmark.

Welfare results in CGE models are highly sensitive to the assumptions on trade elas­
ticities (Hertel et al., 2004). The data required to estimate the relevant trade elasticities
for the Tunisian market are not available. Therefore, we make standard assumptions about
their values. In particular, benchmark trade elasticities are drawn from Thomas F. Ruther­
ford, Elisabet E. Rutstrom and David G. Tarr (1995) and Denise E. Konan and Keith E.
Maskus (2000, 2002). The various trade elasticities are 2.0 for substitution between domes­
tic and imported goods, 5.0 for substitution among regional imports and for transformation
between domestic output and exports, and 8.0 for transformation among regional export
destinations. For the reasons mentioned above, we also assume that the trade elasticities
are 0.5 for services and 0 for producer services.
Table 4.2: Telecom Liberalization Scenarios

<table>
<thead>
<tr>
<th></th>
<th>Efficiency Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Profit Shifting</td>
<td></td>
</tr>
<tr>
<td>Pro-Competitive</td>
<td>yes</td>
</tr>
<tr>
<td>Effect</td>
<td>no</td>
</tr>
</tbody>
</table>

No Profit Shifting

<table>
<thead>
<tr>
<th></th>
<th>Efficiency Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Profit Shifting</td>
<td></td>
</tr>
<tr>
<td>Pro-Competitive</td>
<td>yes</td>
</tr>
<tr>
<td>Effect</td>
<td>no</td>
</tr>
</tbody>
</table>

4.5 Estimation Results

In this section, we present the results of the analysis of telecom liberalization in Tunisia. The telecom liberalization scenarios considered can be categorized according to three effects: a pro-competitive effect, a profit-shifting effect and an efficiency effect (Table 4.2). First, since duopoly is a more competitive market structure than cartel, we indicate that a pro-competitive effect occurs under international duopoly (DUO) but not under cartel (CAR). Second, a profit shifting effect occurs if the rents generated by the foreign entrant are shifted abroad (subscript F), but not if the rents are transferred to the domestic representative agent (subscript D). Finally, if the foreign firm is relatively more efficient than the domestic firm, we indicate that an efficiency effect occurs (superscript A for asymmetry). If both the domestic and foreign firms are equally efficient, no efficiency effect occurs, and we represent this with superscript S (for symmetry).

As it can be expected, the welfare gain of telecommunications liberalization is the highest under DUO_A (Table 3.4). Under this best-case scenario, a more efficient foreign firm
Table 4.3: Macro-Economic Impact of Telecom Liberalization

<table>
<thead>
<tr>
<th>Macroeconomic Indicators&lt;sup&gt;a&lt;/sup&gt;</th>
<th>BMK</th>
<th>DUO&lt;sup&gt;b&lt;/sup&gt;</th>
<th>DUO&lt;sup&gt;c&lt;/sup&gt;</th>
<th>DUO&lt;sup&gt;d&lt;/sup&gt;</th>
<th>DUO&lt;sup&gt;e&lt;/sup&gt;</th>
<th>CAR&lt;sup&gt;a&lt;/sup&gt;</th>
<th>CAR&lt;sup&gt;b&lt;/sup&gt;</th>
<th>CAR&lt;sup&gt;c&lt;/sup&gt;</th>
<th>CAR&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household welfare (EV)</td>
<td>-</td>
<td>1.71</td>
<td>0.95</td>
<td>1.09</td>
<td>0.56</td>
<td>0.84</td>
<td>0.25</td>
<td>0.37</td>
<td>-0.15</td>
</tr>
<tr>
<td>Output, real</td>
<td>-</td>
<td>1.03</td>
<td>0.58</td>
<td>0.99</td>
<td>0.55</td>
<td>0.52</td>
<td>0.16</td>
<td>0.49</td>
<td>0.13</td>
</tr>
<tr>
<td>Consumer price index</td>
<td>-</td>
<td>-1.09</td>
<td>-0.24</td>
<td>-1.45</td>
<td>-0.42</td>
<td>-0.77</td>
<td>-0.19</td>
<td>-0.90</td>
<td>-0.19</td>
</tr>
</tbody>
</table>

| Aggregate Trade<sup>a</sup>        |     |                |                |                |                |                |                |                |                |
| Real exchange rate                 | -   | -2.59E-09      | 1.03E-11       | 3.52E-06       | 1.16E-05       | -5.38E-07      | -1.50E-07      | 8.43E-07       | 2.95E-06       |
| Aggregate exports                  | -   | 8.48           | 4.73           | 8.48           | 4.73           | 2.77           | 0.74           | 2.77           | 0.74           |
| Aggregate imports                  | -   | 2.88           | 1.70           | 2.88           | 1.70           | 1.10           | 0.31           | 1.10           | 0.31           |

| Return to Mobile Factors<sup>a</sup> |     |                |                |                |                |                |                |                |                |
| Capital                            | -   | 0.86           | 0.54           | 0.86           | 0.54           | 0.32           | 0.09           | 0.32           | 0.09           |
| Labor                              | -   | 0.86           | 0.52           | 0.86           | 0.52           | 0.27           | 0.07           | 0.27           | 0.07           |

| Output Share<sup>b</sup>          |     |                |                |                |                |                |                |                |                |
| Agriculture                        | 19.06 | 18.10          | 18.50          | 18.10          | 18.50          | 18.77          | 18.99          | 18.77          | 18.99          |
| Manufacturing                      | 32.07 | 32.65          | 32.38          | 32.65          | 32.38          | 32.24          | 32.11          | 32.24          | 32.11          |
| Mining & Utilities                 | 6.89  | 6.70           | 6.78           | 6.70           | 6.78           | 6.83           | 6.87           | 6.83           | 6.87           |
| Services                           | 41.98 | 42.55          | 42.34          | 42.55          | 42.34          | 42.16          | 42.03          | 42.16          | 42.03          |
| Services excl. producer services   | 37.53 | 36.31          | 36.83          | 36.31          | 36.83          | 37.14          | 37.43          | 37.14          | 37.43          |
| Producer services excl. telecom    | 3.50  | 3.49           | 3.50           | 3.49           | 3.50           | 3.50           | 3.50           | 3.50           | 3.50           |
| Telecom                            | 0.95  | 2.75           | 2.01           | 2.75           | 2.01           | 1.53           | 1.11           | 1.53           | 1.11           |

<sup>a</sup> % change from BMK
<sup>b</sup> % share of real output
strategically competes in quantities with the domestic incumbent and transfers its profits to the domestic representative agent. As a result, the welfare-improving efficiency and pro-competitive effects are present. In addition, the welfare-reducing profit shifting effect does not occur. In this case, household welfare (measured as Hicksian equivalent variation) is estimated to improve by 1.71 percent while real output increases by 1.03 percent. The economic growth is primarily export-led, with aggregate exports expanding 8.48 percent. The benefits accrue equally to capital and labor, with returns to both increasing by 0.86 percent. Resources are primarily moved into telecommunications and manufacturing. The share of the economy in telecom increases from 1 percent in the benchmark to 2.8 percent, while the share of manufacturing increases from 32.1 to 32.7 percent. The increase in manufacturing is largely driven by a 15.5 percent growth of the clothing industry (see Appendix 4). Economic activity in agriculture, petroleum and mining, and non-producer services, on the other hand, decline.

Under the worst-case scenario, \( CAR_p^S \), an equally efficient foreign firm colludes with the domestic incumbent and shifts its profits abroad. As a result, there are no welfare-improving pro-competitive or efficiency effects, while the welfare-reducing profit shifting effect occurs. In this case, household welfare is estimated to worsen 0.15 percent while real output increases by 0.13 percent. The economic growth remains export-led, with aggregate exports expanding 0.74 percent. Despite the drop in welfare, real returns to mobile factors increase. Capital gains disproportionately, with the rate of return of capital increasing by 0.09 percent and wages increasing 0.07 percent. Resources continue to be moved into telecommunications and manufacturing. The share of the economy in telecom increases from 1 percent in the benchmark to 1.1 percent, while the share of manufacturing increases insignificantly. The increase in manufacturing is largely driven by a 1.3 percent growth of the clothing industry (see Appendix 4). Economic activity in agriculture, petroleum and mining, and non-producer services, on the other hand, decline.
Under the alternative scenarios, changes in the macro-indicators are in the same direction as in the best-case scenario, but their magnitudes differ. If the profit shifting effect occurs (i.e., the foreign firm shifts profits abroad), then the resulting real income loss of the representative agent leads to a smaller welfare gain than when profits are retained. Aggregate trade, sectoral output shares and the returns to mobile factors, on the other hand, remain virtually unchanged. In the absence of efficiency and/or pro-competitive effects, the magnitude of the changes in all the macro-indicators are dampened when compared to the scenarios where they are present. Welfare, output, exports and returns to mobile factors see smaller gains, while sectoral output shares see smaller changes.

It is useful to further decompose the total welfare gains into the pro-competitive effect, the efficiency effect and the profit shifting effect. This can be done for each scenario by measuring the change in the total welfare gain if an effect is removed (Table 4.4). Consider the first column of Table 4.4 ($DUO^A_0$) as an example. As discussed earlier, under this best-case scenario the welfare gain is 1.7 percent and both pro-competitive and efficiency effects are present, while there is no profit-shifting effect. The contribution of the pro-competitive effect to welfare can be calculated by subtracting the welfare gain under $CAR^A_0$ from that under $DUO^A_0$, which amounts to 0.89 percent.\(^{10}\) Similarly, the efficiency effect is calculated to be $\%\Delta W(DUO^A_0 - DUO^S_D) = 0.76\%$. Similar calculations are made for the other scenarios in Table 4.4. If we subtract the sum of the three effects from the total effect under each scenario, we find positive residual effects of varying magnitudes. This residual effect can be attributed to two separate factors. On the one hand, since there is imperfect substitutability between domestic and foreign telecom services, there is an additional love-of-variety effect that affects welfare positively in each scenario. Since the residual effect is a constant 0.25 percent in all scenarios where maximum one effect is present, we estimate the love-of-variety effect to contribute 0.25 percent to welfare under each scenario. On the other hand, there are interaction effects present. An interaction between the efficiency effect and

\(^{10}\%\Delta W(DUO^A_0 - CAR^L_0)$
the profit-shifting effect leads to an additional increase in welfare (DUOFA and CARFA).
The interaction between the pro-competitive effect and the efficiency effect has a negative
impact on welfare, implying that either type of reform alone will produce some gains that
overlap those of the other effect (DUODA).

Sensitivity analysis of the size of the foreign firm's efficiency advantage provides further
evidence of an interaction between the efficiency effect and the profit shifting effect. As
illustrated in Figure 4.4, the welfare loss of profit shifting under duopoly increases as the
efficiency advantage of the foreign firm increases. The reason is that a larger efficiency
advantage leads to an increase in the foreign firm's market share and profits. Profit shifting
thus leads to a larger welfare loss since it induces a larger real income loss to the domestic
represent agent.

4.6 Conclusion

This chapter uses a CGE model of Tunisia's economy to analyze the importance of reg­
ulatory reforms on the success of telecom liberalization in developing countries. For this
purpose, we have assumed that Tunisia's liberalized telecommunications sector can take on
different imperfectly competitive market structures depending on the regulatory environ­
ment. If pro-competitive regulatory reforms are realized, the domestic incumbent and the
foreign entrant strategically compete. If no pro-competitive reforms are implemented, the
two firms collude.

Our results suggest that pro-competitive regulatory reform needs to precede or accom­
pany telecom liberalization. According to our conservative estimates, the potential welfare
implications of telecom liberalization are clearly positive if competition can be guaranteed
between the two firms. Welfare (measured as equivalent variation) and GDP are both esti­
mated to increase more than 0.5 percent, and the welfare gains can increase to 1.7 percent
if foreign firms are more efficient and do not shift their profits abroad. In contrast, telecom
liberalization can be welfare deteriorating if the two firms collude and the foreign firm shifts
Table 4.4: Decomposition of welfare effects

<table>
<thead>
<tr>
<th></th>
<th>DUO_d</th>
<th>DUO_F</th>
<th>DUO_f</th>
<th>CAR_d</th>
<th>CAR_F</th>
<th>CAR_f</th>
<th>CAR_F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total effect</td>
<td>1.71</td>
<td>0.95</td>
<td>1.09</td>
<td>0.56</td>
<td>0.84</td>
<td>0.25</td>
<td>0.37</td>
</tr>
<tr>
<td>Pro-competitive effect</td>
<td>0.89</td>
<td>0.70</td>
<td>0.72</td>
<td>0.71</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Efficiency effect</td>
<td>0.76</td>
<td>-</td>
<td>0.53</td>
<td>-</td>
<td>0.59</td>
<td>-</td>
<td>0.52</td>
</tr>
<tr>
<td>Profit-shifting effect</td>
<td>-</td>
<td>-</td>
<td>-0.62</td>
<td>-0.39</td>
<td>-</td>
<td>-</td>
<td>-0.47</td>
</tr>
<tr>
<td>Residual effect</td>
<td>0.06</td>
<td>0.25</td>
<td>0.46</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.32</td>
</tr>
<tr>
<td>Love-of-variety effect</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Interaction effect</td>
<td>-0.19</td>
<td>-</td>
<td>0.21</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Figure 4.4: Interaction between Profit-Shifting Effect and Efficiency Effect under Duopoly
its profits abroad. Our results thus call for Tunisia to step up its pro-competitive regulatory reforms while liberalizing its telecom sector.

The uncertainty surrounding the estimated monopoly markup in the telecom sector, the efficiency advantage of foreign telecom providers and the amount of profit shifting deserve further exploration, since improved estimates are critical for a more accurate determination of the magnitude of the potential impacts of telecom liberalization. It is important to note that cautious assumptions were made here about the existing distortions and the potential competitive effects and efficiency improvements with liberalization. It may be that a dramatic reform effort might bring even greater gains than those reported here.
4.7 Appendix 1: Summary of the WTO Reference Paper

The following is a summary of the major features of the WTO Reference Paper (Cowhey and Klimenko, 1999).

1. It creates obligations for governments concerning their regulation of “major suppliers” of telecommunications services. A major supplier controls “essential facilities” for the public network that “cannot feasibly be economically or technically substituted in order to provide a service.” Thus, the paper focuses on regulatory treatment of the dominant incumbent carrier.

2. Governments must take measures to assure that major suppliers do not engage in anti-competitive practices, such as anti-competitive cross-subsidies, use of information obtained from competitors, or withholding timely technical information needed by competitors.

3. Governments will assure interconnection with a major supplier for competitors at any technically feasible point in the networks. The terms, conditions, and quality must be non-discriminatory (no less favorable to the competitor than the operating company of the major supplier). Interconnection must be timely and done at “cost-oriented rates that are transparent, reasonable, having regard to economic feasibility, and sufficiently unbundled so that the supplier need not pay for network components or facilities that it does not require for the service to be provided.” The terms for interconnection must be publicly available and enforceable on a timely basis.

4. Governments may maintain policy measures designed to achieve universal service. However, they must be administered in ways that are transparent, nondiscriminatory and competitively neutral. They should not be more burdensome than necessary to achieve the specific goal for universal service.
5. The regulatory body is separate from the operators and must employ procedures that assure impartiality in regard to all market participants.

6. Governments will use procedures for the allocation and use of scarce resources, including frequencies, that are timely, objective, transparent and nondiscriminatory.
4.8 Appendix 2: Deriving the Lerner Markup Conditions

In our CGE model, the imperfectly competitive telecommunications sector sells its services at the same price to different buyers. It sells its services as an input to all the sectors in the economy and also sells its services as a final good to consumers. Hoffmann (2003) illustrates that in this case, the optimal markup for the telecom providers depends on the demand elasticity for all the different buyers. In this appendix, we will first replicate Hoffmann (2003) to illustrate that the optimal markup condition for telecommunications providers is a weighted average of the demand elasticities for the different buyers. Subsequently, we will derive the optimal markup conditions for each firm under the various market structures. Finally, we will derive a generalized markup condition for each firm that encompasses the various market structures.

4.8.1 Hoffmann Lerner Markup Condition

Hoffmann (2003) uses three equations to derive the general equilibrium Lerner markup condition when a firm faces different buyers. First, the following arbitrage condition needs to hold for firm $z$:

\[
\frac{\partial p_z}{\partial z_i} dz_i = \frac{\partial p_z}{\partial z_j} dz_j
\]

(A-1)

In equation (A-1), $z_i$ represents the amount of telecommunications services allocated to sector $i$. By converting the partials to inverse price elasticities and rearranging:

\[
dz_i = \frac{\phi_i z_i}{\phi_j z_j} dz_j
\]

(A-2) where $\phi_i = -\frac{\partial z_i}{\partial p_z} z_i$. If we sum (A-2) over all uses $i$:

\[
\sum_i dz_i = \sum_i \frac{\phi_i z_i}{\phi_j z_j} dz_j
\]

(A-3)
A second necessary equation states that changes in a firm’s total telecom supply $z$ equals the sum of the changes in the supply to all the buyers:

\[(A-4)\quad dz = \sum_i dz_i\]

By combining (A-3) and (A-4):

\[(A-5)\quad dz_j = \left[\frac{\phi_j z_j}{\sum_i \phi_i z_i}\right] dz\]

A final equation is the total derivative of the profit equation for firm $z$:

\[(A-6)\quad (p_z - c) \sum_i dz_i + \sum_i z_i \frac{\partial p_z}{\partial z_i} dz_i = 0\]

If we incorporate (A-4) and (A-5) into (A-7):

\[(A-7)\quad (p_z - c) dz - p_z \frac{\sum_i z_i}{\sum_i \phi_i z_i} dz = 0\]

This leads us to Hoffmann’s Lerner markup condition:

\[(A-8)\quad p_z \left[1 - \frac{1}{\sum_i \phi_i \theta_i}\right] = c\]

where $\theta_i = \frac{z_i}{\sum_i z_i}$. It can be useful to distinguish the usage of telecom services as a final good from the other usages since the derivation of the demand elasticity will be different:

\[(A-9)\quad p_z \left[1 - \frac{1}{\phi_u \theta_u + \sum_i \phi_i \theta_i}\right] = c\]

where $\phi_u$ equals the consumers’ demand elasticity for firm $z$’s telecom services; $\theta_u$ equals the share of firm $z$’s telecom services that is sold to consumers; $\phi_i$ equals the demand elasticity for firm $z$’s telecom services by sector $i$ and $\theta_i$ equals the share of firm $z$’s total telecom services that is sold to sector $i$. 
4.8.2 Derivation the Lerner Markup Condition

The demand elasticities that a telecom provider faces will depend on the market structure that it is operating in. In this section, we derive the demand elasticities that each firm faces from the various buyers under the various market structures. We first derive the elasticity of demand for intermediate good users under each market structure. Then we derive the elasticity of demand for final demand. Third, we combine the individual demand elasticities to derive the Lerner markup condition for each service provider under each market structure. Finally, we determine the generalized Lerner markup condition.

4.8.3 Demand Elasticity for Intermediate Inputs

To determine a firm’s demand elasticity for each sector under each market structure, we need to first derive the price for telecom service in each market structure. Let $p_{yi}$ denote the domestic price of final good output $Y_i$ in sector $i$ and $p_{zj}$ denote the price received by telecom provider $j$. Note that $p_{zj}$ does not differ from sector to sector since we assume that there is no price discrimination. Since final $Y_i$ production is assumed perfectly competitive in our model, $p_{zj}$ is the value of the marginal product of $z_j$ in producing $Y_i$. The price of telecom service $p_{zj}$ can thus be derived from the chain rule:

$$p_{zj} = p_{yi} \frac{\partial Y_i}{\partial z_{ij}} = p_{yi} \frac{\partial Y_i}{\partial Z_{ij}} \frac{\partial Z_{ij}}{\partial z_{ij}}$$

From (3.6) and (3.8), we know that output for each sector $Y_i$ and composite producer services $PS_i$ are Leontief. As a result, the cost share of $V_i$ in the production of $Y_i$ is $a_{VAi}$ and the cost share of $Z$ in the production of $PS_i$ is $b_{zi}$. Therefore,

$$Y_i = \frac{V_i}{a_{VAi}}$$

$$PS_i = \frac{Z_i}{b_{zi}}$$
By plugging (A-12) and (3.7) into (A-11):

\[
Y_i = \frac{\left(\frac{L_i^{\alpha_i}K_i^{\beta_i}Z_i^{1-\gamma}}{b_{zi}}\right)_{\gamma}^{1-\gamma}}{a_{V,Ai}}
\]  

(A-13)

From (A-13), we can derive \(\frac{\partial Y_i}{\partial Z_i}\):

\[
\frac{\partial Y_i}{\partial Z_i} = \frac{1}{a_{V,Ai}b_{zi}} \left[ (L_i^{\alpha_i}K_i^{\beta_i})^{\gamma} + \left(\frac{Z_i}{b_{zi}}\right)^{\gamma} \right] \frac{\gamma}{1-\gamma} \left(\frac{Z_i}{b_{zi}}\right)^{-1}
\]  

(A-14)

This equation will be common to all the different market structures. For the further derivation of (A-10), we need to investigate each market structure separately.

**Domestic Monopoly**

Under a domestic monopoly, the government solely gives a license to a domestic telecom provider. As a result, equation (4.1) simplifies to:

\[
Z_i = Z_{id} = z_{id}
\]  

(A-15)

Consequently:

\[
\frac{\partial Z_i}{\partial Z_{id}} = \frac{\partial Z_{id}}{\partial z_{id}} = 1
\]  

(A-16)

If we incorporate (A-14) and (A-16) into (A-10), the price for the domestic monopolist thus is:

\[
p_{zd} = \frac{p_{zi}}{a_{V,Ai}b_{zi}} \left[ (L_i^{\alpha_i}K_i^{\beta_i})^{\gamma} + \left(\frac{Z_i}{b_{zi}}\right)^{\gamma} \right] \frac{\gamma}{1-\gamma} \left(\frac{Z_i}{b_{zi}}\right)^{-1}
\]  

(A-17)

With the price function, we can now derive the perceived elasticity of demand from each sector that uses telecom as an input:
For modelling purposes, it is important to derive the market share of value added $s_{VA}$. For this, we rely on the cost minimization problem for $V$:

\[
\Lambda = p_{va} V A + p_{ba} P S + \lambda \left( V - (VA^\gamma + PS^\gamma)^{\frac{1}{\gamma}} \right)
\]

If we solve for this:

\[
s_{VA} = \frac{p_{va}^{1-\rho}}{p_{va}^{1-\rho} + p_{pa}^{1-\rho}}
\]

**International Cournot Duopoly**

Under international Cournot duopoly, the regulator gives a license to one domestic and one foreign provider and the two providers compete strategically in quantities. This implies that equation (4.1) simplifies to:

\[
(\text{A-21}) \quad Z = (z_{id}^e + z_{im}^e)^{\frac{1}{\epsilon}}
\]

As a result,

\[
(\text{A-22}) \quad \frac{\partial Z_i}{\partial Z_{ij}} = (z_{id}^e + z_{im}^e)^{\frac{1-\epsilon}{\epsilon}} z_{ij}^{\epsilon-1}
\]

\[
(\text{A-23}) \quad \frac{\partial Z_{ij}}{\partial z_{ij}} = 1
\]
If we incorporate (A-14), (A-22) and (A-23) into (A-10), the price for each duopolist thus is:

\[
p_{xj} = \frac{p_{yi}}{a_{yA}b_{zi}} \left[ (L_{i}^{a} K_{i}^{b})^{\gamma} + \left( \frac{Z_{i}}{b_{zi}} \right)^{\gamma-1} \left( \frac{Z_{i}}{b_{zi}} \right) \right]^{\frac{1-\gamma}{\gamma}} \left( z_{id}^{e} + z_{im}^{e} \right)^{\frac{1-\gamma}{\gamma}} z_{ij}^{e-1}
\]

Under Cournot competition, each firm assumes that a change in its output will leave the other firm's output unchanged. As a result, each firm j's perceived inverse price elasticity for each intermediate use i is:

\[
\phi_{yi} = \frac{1}{\sigma} (1 - s_{j}) + \frac{1}{\rho} s_{vai} s_{j}
\]

where market share for firm j equals \( s_{j} = \frac{z_{j}^{e}}{z_{d}^{e} + z_{m}^{e}} \).

For modelling purposes, it is important to derive the market share of the domestic firm \( s_{d} \). For this, we rely on the cost minimization problem for \( Z \):

\[
\Lambda = p_{zd} z_{d} + p_{zm} z_{m} + \lambda \left( Z - (z_{d}^{e} + z_{m}^{e})^{\frac{1}{\gamma}} \right)
\]

The first order conditions lead to the following demand functions for the inputs \( z_{d} \) and \( z_{f} \):

\[
z_{j} = Z p_{j}^{1-\sigma} \left( \sum_{i} p_{i}^{1-\sigma} \right)^{\frac{1}{\sigma-1}}
\]

We can now plug the input demand functions in the cost minimization problem and set \( Z = 1 \) to derive \( P_{z} \):

\[
P_{z} = \frac{I_{Z}}{Z} = \frac{1}{\left( \sum_{i} p_{i}^{1-\sigma} \right)^{\frac{1}{\sigma-1}}}
\]

This implies that the input demand functions are:
This implies that:

\[
\text{(A-30)} \quad s_j = \frac{p_{zj}^{1-\sigma}}{p_{zd}^{1-\sigma} + p_{zm}^{1-\sigma}}
\]

**International Cartel**

Under an international cartel, the regulator provides a license to a domestic and a foreign telecom provider, but both providers collude. To determine the Lerner markup conditions when the domestic and the foreign telecommunications providers form a cartel, we assume that both firms set the same price \( p_{zd} = p_{zm} \). Since there is a constant elasticity of substitution between both telecom services, this implies that both firms also provide the same amount of telecommunication services, i.e. \( z_d = z_m \). From (4.1), the production function for \( Z \) thus becomes:

\[
\text{(A-31)} \quad Z_i = 2^{\frac{1}{\gamma}} z_i
\]

where \( z_i = z_{id} = z_{im} \)

\[
\text{(A-32)} \quad \frac{\partial Z_i}{\partial z_i} = 2^{\frac{1}{\gamma}}
\]

If we incorporate (A-14) and (A-32) into (A-10), the price for the domestic and foreign firm thus equals:

\[
\text{(A-33)} \quad p_z = \frac{p_{yi} y_i}{\alpha V_A i b_{zi}} \left[ (L_i^0 K_i^0)^{\gamma} \left( \frac{Z_i}{b_{zi}} \right)^{\frac{1-\gamma}{\gamma}} \left( \frac{Z_i}{b_{zi}} \right)^{\gamma-1} (z_{id}^\varepsilon z_{im}^\varepsilon) \right]^{\frac{1-\varepsilon}{\varepsilon}} x_{ij}^{1-\varepsilon} 2^{\frac{1}{\gamma}}
\]
The perceived inverse elasticity of demand from each firm that uses telecom as an input is:

\[
\frac{1}{\phi_i} = -\frac{\partial p_z}{\partial z_i} \frac{z_i}{p_z} = \frac{s_{VAi}}{\rho}
\]

4.8.4 Demand Elasticity for Final Demand

Preferences of the representative consumer are represented by a Cobb-Douglas utility function.

\[
U(C) = \sum_h \kappa_h \log(Y_h^C) + \kappa_z \log(Z^C)
\]

It is a well-established result that the demand elasticity for each final (composite) good is equal to 1.

**Domestic monopoly**

In a domestic monopoly,

\[
Z_c = Z_{cd} = z_{cd}
\]

As such, the final demand elasticity for the domestic monopolist is 1.

**International Cournot Duopoly**

In a Cournot duopoly,

\[
Z = (z_{id} + z_{im})^{\frac{1}{i}}
\]

As is derived in Keith Head and Thierry Mayer (1999), this leads to the following final demand elasticity:
(A-38) \[ \frac{1}{\phi_{ui}} = \frac{1}{\sigma} \left( 1 + (\sigma - 1)s_i \right) \]

**International Cartel**

In an international Cartel, both firms treat final demand elasticity as 1.

### 4.8.5 Generalized Lerner Markup Condition

If we import all the individual demand elasticities into the Hoffmann Lerner markup condition (A-9), we find the general equilibrium markup condition for each firm under each market structure. The general equilibrium Lerner markup condition can be represented by an encompassing condition that holds for all market structures:

(A-39) \[ \frac{p_{sj} - c_j(w, r)}{p_{sj}} = \frac{1}{\sigma} \left[ \frac{\theta_u}{1 + (\sigma - 1)s_i} + \sum_i \frac{\theta_{yi} \rho}{(1 - s_j) \rho + \sigma(s_{vai}) s_j} \right]^{-1} \]

Under international duopoly, the encompassing general equilibrium Lerner markup condition holds for each firm, with \( s_j = \frac{p_{sj}^{1-\sigma}}{p_{sd}^{1-\sigma} + p_{pm}^{1-\sigma}} \). Under domestic monopoly, \( s_d = 1 \). Under international cartel, both firms treat \( s_j = 1 \).
4.9 Appendix 3: Full Description of the CGE Model

Final output in sector \( i \), \( Y_i \), is produced according to a nested Leontief-CES production function of intermediate inputs, \( x_{ji} \) for sectors \( j = 1, ..., n \) and the composite value added function \( V_i \).

\[
Y_i = \min \left[ \frac{x_{1i}}{a_{1i}}, ..., \frac{x_{ni}}{a_{ni}}, \frac{V_i}{a_{VA}} \right]
\]  

(B-1)

Composite value added, \( V_i \), is a CES nest of value added \( L_i^{\alpha_i}K_i^{\beta_i} \) and producer services \( PS_i \).

\[
V_i = \left[ (L_i^{\alpha_i}K_i^{\beta_i})^\gamma + PS_i^{\gamma} \right]^{1/\gamma}
\]  

(B-2)

Composite producer services, \( PS_i \), are produced according to a Leontief production function. They consist of telecommunication services, commercial services, construction services, transportation services, financial services, insurance, business services, property rent and leasing, repair services and education and health services.

\[
PS_i = \min \left[ \frac{x_{1i}}{b_{1i}}, ..., \frac{x_{m-1,i}}{b_{m-1,i}}, \frac{Z_i}{b_{zs}} \right]
\]  

(B-3)

Telecommunications services, \( Z \), is comprised of telecom services provided by the domestic incumbent \( Z_D \) and telecom services provided by the multinational market entrant \( Z_M \).

\[
Z = (Z_D^\ell + Z_M^\ell)\ell
\]  

(B-4)

In export sectors, the production for the domestic market \( D_i \) is distinguished from that for export \( EX_i \) according to a two-tier nested constant elasticity of transformation (CET) frontier.
The second-tier CET-nest aggregates total exports, \( X_i \), from exports by destination, \( EX_{ri} \), indexed by \( r \) (EU, MENA, and ROW).

\[
Y_i = \left[ \delta_{Di}D_i^{\xi_i} + \delta_{EX_i}EX_i^{\xi_i} \right]^{\xi_i} 
\]

Intermediate good, \( Z_{ji} \), and final demand, \( C_j \), in sector \( j \) is differentiated by country of origin. Domestic output \( D_{ji} \) and \( D_{jc} \), and region \( r \) imports, \( IM_{rji} \) and \( IM_{rjc} \) are aggregated in the following nested Armington CES functions.

\[
EX_i = \left[ \sum_r \eta_{ri}EX_{rj}^{\xi_i} \right]^{\xi_i} 
\]

\[
x_{ji} = \left[ \lambda_{Di}D_{ji}^{\xi_j} + \lambda_{IM_{ji}}IM_{ji}^{\xi_j} \right]^{\xi_j} 
\]

\[
C_j = \left[ \nu_{Di}D_{jc}^{\xi_j} + \nu_{IM_{jC}}IM_{jC}^{\xi_j} \right]^{\xi_j} 
\]

where composite intermediate and final imports, respectively, \( IM_{ji} \) and \( IM_{jC} \), are given by the following:

\[
IM_{ji} = \left[ \sum_r \omega_{jr}IM_{jir}^{\psi_i} \right]^{\psi_i} 
\]

\[
IM_{jC} = \left[ \sum_r \omega_{jr}IM_{jC_r}^{\psi_i} \right]^{\psi_i} 
\]

In all sectors except for the telecommunications sector, firms face constant returns to scale and behave competitively, implying that prices, \( P_j \), equal marginal cost, \( C_j \), for output within
sector $j$. The domestic policy environment is reflected by government revenue producing tariffs on sector $j$ imports from region $r$, $t_{jr}$ and a tax on primary input value added, $\tau_j$

\[ (B-11) \quad c_j Y_j = \sum_j p_j D_{ji} + \sum_j (1 + t_{jr}) p_{jm}^r M_{jm} + (w_K K_i + w_L L_i) \]

In the imperfectly competitive telecom sector, the domestic and foreign firm face the following Lerner markup condition:

\[ (B-12) \quad \frac{p_{zj} - c_j}{p_{zj}} = \frac{1}{\sigma} \left[ \frac{\theta_u}{1 + (\sigma - 1)s_i} + \sum_i \frac{\theta_p \rho}{(1 - s_j) + \sigma(s_{vai})s_j} \right]^{-1} \]

In the model, private household expenditures are determined by a representative agent with a multi-nested CES utility function. This allows the agent to make separable multi-staged budget decisions. In the top-tier budgeting decision the income elasticity is assumed to be unity with a Cobb-Douglas nested utility function:

\[ (B-13) \quad U = \Pi_i C_i^{b_i} \quad \text{with} \quad \sum_i b_i = 1 \]

The second budgeting stage involves the consumer deciding how much to spend on domestic versus imported commodities, which is determined in equations (B-7)-(B-10).

Private households receive income generated by returns to endowments of labor, $\tilde{E}_L$, and other value added, $\tilde{E}_K$. Households receive monopoly rent transfers from the domestic telecom incumbent $\pi_D Z_D$ and under some scenarios from the multinational telecom provider $\pi_M Z_M$. Households support a government budget deficit, $D$, and engage in savings through exogenously fixed investment instruments, $I_i$.

\[ (B-14) \quad \sum_i \tilde{p}_i C_i = w_K \tilde{E}_K + w_L \tilde{E}_L - \sum_i p_i I_i^t - \sum_i \tilde{p}_i^{IF} I_i^F - r^F K^F - D + \pi_D Z_D + \pi_M Z_M \]
The model simplifies the treatment of government and intertemporal decisions. The government is assumed to spend based on a fixed real income, with preferences reflecting those of households. A lump-sum tax adjusts endogenously in response to policy shocks to maintain a revenue-neutral government budget.

\[(B-15) \sum_i p^C_i G_i = D + \sum_i \tau V_i p^C_i V_i + \sum_i \sum_r t_{ir} p^m_{ir} (IM_{iCr} + IM_{iFr})\]

Similarly, real private investment in each sector, \(I_i\), is exogenously fixed at the benchmark level.

As noted above, import and export prices are exogenous following the small-economy assumption. The real current account balance, \(B\), is exogenously given at international prices and is assumed to be exogenous. That is, the volume of trade adjusts endogenously to ensure a constant real current account. The balance of payments conditions also holds.

\[(B-16) B = \sum_i \sum_r p^e_{ir} EX_{ri} - \sum_j \sum_r p^m_{ir} IM^j_{ri} - \sum_i \sum_r p^m_{ir} IM^C_{ri}\]

\[(B-17) 0 = \sum_r \sum_i \frac{1}{e} (p^m_{ir} IM_{ri} - p^e_{ir} EX_{ri} - w^F_{LR} L^F - r^F K^F - \pi_M Z_M)\]

It is important to note that key identities hold as the optimizing behavior of agents assures that income will equal expenditures. Market clearance is achieved in each goods market, each factor market and the total supply value in the economy is balanced.

\[(B-18) S_i = \sum_j a_{ji} Y_j + G_i + I^F_i + I^l_i + C_i\]

\[(B-19) \sum_i K_i = \bar{E}_K; \quad \sum_i L_i = \bar{E}_L\]
In this Arrow-Debreu type model, Walras' law is satisfied and, given a numeraire, a unique set of real prices is determined in each scenario. (A full list of all identities can be found in Denise E. Konan (2003).)
Table 4.5: List of Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>$B$</td>
<td>Current-account balance</td>
</tr>
<tr>
<td>$c_i$</td>
<td>Index of marginal cost of production</td>
</tr>
<tr>
<td>$C_i$</td>
<td>Private consumption</td>
</tr>
<tr>
<td>$D$</td>
<td>Government budget deficit</td>
</tr>
<tr>
<td>$D_{ij}$</td>
<td>Domestic sales in sector $i$ used by $j$</td>
</tr>
<tr>
<td>$e$</td>
<td>Real exchange rate (price index for foreign exchange)</td>
</tr>
<tr>
<td>$EX_{ir}$</td>
<td>Exports in sector $i$ to region $r$</td>
</tr>
<tr>
<td>$G_i$</td>
<td>Public consumption</td>
</tr>
<tr>
<td>$I_i^F$, $I_i^L$</td>
<td>Fixed capital formation and inventory</td>
</tr>
<tr>
<td>$IM_{ijr}$</td>
<td>Imports in sector $i$ from region $r$ used in $j$</td>
</tr>
<tr>
<td>$K_F$</td>
<td>Net payments on foreign capital holdings</td>
</tr>
<tr>
<td>$K_i$</td>
<td>Non-labor (capital) inputs</td>
</tr>
<tr>
<td>$L_i$</td>
<td>Domestic labor inputs</td>
</tr>
<tr>
<td>$p_i$</td>
<td>Domestic producer price index</td>
</tr>
<tr>
<td>$p_i^j$</td>
<td>Price index of domestic goods used by $j$</td>
</tr>
<tr>
<td>$p_{ir}$</td>
<td>Producer price index for goods exported to region $r$</td>
</tr>
<tr>
<td>$p_{ijr}$</td>
<td>Domestic price index for imports in sector $i$ from region $r$ used in $j$</td>
</tr>
<tr>
<td>$\bar{p}_i$</td>
<td>Composite price index for total domestic supply</td>
</tr>
<tr>
<td>$\bar{p}_{ij}$</td>
<td>Composite price index (weighted average of home and imported prices)</td>
</tr>
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<td>$PS_i$</td>
<td>Producer services</td>
</tr>
<tr>
<td>$S_i$</td>
<td>Supply on domestic market</td>
</tr>
<tr>
<td>$U$</td>
<td>Utility of representative consumer</td>
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<tr>
<td>$V_i$</td>
<td>Value added</td>
</tr>
<tr>
<td>$w_K$, $w_L$</td>
<td>Factor price indexes</td>
</tr>
<tr>
<td>$x_{ij}$</td>
<td>Composite intermediate input of $j$ into $i$</td>
</tr>
<tr>
<td>$Y_i$</td>
<td>Output of good $i$</td>
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<tr>
<td>$Z_D$</td>
<td>Telecom services provided by domestic incumbent</td>
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<tr>
<td>$Z_M$</td>
<td>Telecom services provided by foreign entrant</td>
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<tr>
<td>$\theta_i$</td>
<td>Share of total telecom services used by $i$</td>
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<tr>
<td>$\rho$</td>
<td>Elasticity of substitution between value added and producer services</td>
</tr>
<tr>
<td>$\tau_{V,i}$</td>
<td>Endogenous tax rate on value added</td>
</tr>
<tr>
<td>$\phi_i$</td>
<td>Elasticity of demand for telecom user $i$</td>
</tr>
</tbody>
</table>
Table 4.6: List of Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_i )</td>
<td>Labor share of value added in sector ( i )</td>
</tr>
<tr>
<td>( \beta_i )</td>
<td>Non-labor share of value added</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>Transformation elasticity between domestic and exported output</td>
</tr>
<tr>
<td>( \epsilon )</td>
<td>Transformation elasticity on exports between regions</td>
</tr>
<tr>
<td>( \zeta_i )</td>
<td>Transformation elasticity on exports between regions</td>
</tr>
<tr>
<td>( \lambda_i )</td>
<td>Service resource-using barriers on output (( \lambda_i = 0 ) for non-service sectors)</td>
</tr>
<tr>
<td>( \mu_j )</td>
<td>Substitution elasticity between domestic and imported intermediates</td>
</tr>
<tr>
<td>( \xi_j )</td>
<td>Substitution elasticity between domestic and imported consumption</td>
</tr>
<tr>
<td>( \pi_i )</td>
<td>Telecom rents for service provider ( i )</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>Elasticity of substitution between domestic and foreign telecom services</td>
</tr>
<tr>
<td>( \psi_i )</td>
<td>Armington elasticity on imports between regions</td>
</tr>
<tr>
<td>( \tilde{E}_K, \tilde{E}_L )</td>
<td>Endowments of capital and labor</td>
</tr>
<tr>
<td>( p_{i,r}^{in} )</td>
<td>Price of imports from region ( r )</td>
</tr>
<tr>
<td>( p_{i,r}^{ex} )</td>
<td>Price of exports to region ( r )</td>
</tr>
<tr>
<td>( r^F )</td>
<td>Price of foreign capital payments</td>
</tr>
<tr>
<td>( t_{ir} )</td>
<td>Tariff rate on imports from region ( r ) (( t_{ri} = 0 ) for service sectors)</td>
</tr>
<tr>
<td>( u_i )</td>
<td>Resource-using services border barriers (( u_i = 0 ) for non-service sectors)</td>
</tr>
</tbody>
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### 4.10 Appendix 4: Sectoral Impact Table

Table 4.7: Impact of Telecom Liberalization on Sectoral Output

<table>
<thead>
<tr>
<th>Sector</th>
<th>DUO$_B$</th>
<th>DUO$_D$</th>
<th>DUO$_S$</th>
<th>CAR$_B$</th>
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Chapter 5

Conclusion and Directions for Further Research

This dissertation addresses the nature, causes and consequences of the IT sector's global transformation from a vertically integrated industry to a horizontally segmented sector. In Chapter 1, I provide an overview of the theory of global production networks and indicate that the existing literature faces a number of shortcomings. The remaining chapters apply the theory of global production networks and address some of its limitations. In Chapter 2, East Asia's expanding role in global IT production and trade is attributed to international production fragmentation. In Chapter 3, the co-evolution of vertical outsourcing and horizontal integration is linked to the modularization of IT products and the emergence of de facto input standardization. Chapter 4 illustrates the importance of regulatory reform on a developing country's ability to bridge the digital divide through telecom liberalization.

Three directions for future research need to be considered. First, the trade literature has paid little attention to the location of break points in the production process. Most studies treat the boundaries between production stages as exogenously given.\footnote{Trade studies generally divide the production process into an intermediate good stage and a final good stage.} This can be a limiting assumption since a firm's choice of break points often is as much a managerial decision as it is an attribute of the technology itself (Ashish Arora, Andrea Fosfuri and Alfonso Gambardella, 2001). As a result, it might have significant implications for the

Second, the literature has generally treated the degree of competition within and between layers of production as exogenous. This is a limiting assumption since it is well-established that the transformation of global IT production was accompanied by a significant change in the degree of competition within and between layers of IT production. Market power is no longer in the hands of assemblers such as IBM and Toshiba, but has shifted to new market leaders such as Microsoft and Intel. These firms have the common characteristic that they own key technical specifications that have been accepted as de facto product standards in the market (Michael Borrus, 2000).

Third, more research needs to be conducted on the relationship between the organization of a global production network, innovation and economic growth. On a micro level, a key question that needs to be addressed is whether outsourcing hampers or facilitates a lead firm's ability to innovate. On a macro level, a deeper understanding is needed of the circumstances under which a global production network creates knowledge spillovers to the rest of the economy (Dieter Ernst, 2003).
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