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THE GEOGRAPHY OF MULTINATIONAL PRODUCTION

by

ECE TURGAY-BRETT

Doctoral thesis submitted in partial fulfilment of the requirements

for the award of Doctor of Philosophy degree of Loughborough University

SEPTEMBER 2005

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I have received a great deal of help and support during the production of this thesis. I would like to express my gratitude to Prof. E. J. Pentecost for introducing me to such an interesting field of study and for his helpful guidance and supervision during this project. I also would like to thank my fellow academic staff and research students for their helpful comments and suggestions during departmental research seminars. I am grateful to the Economics Department of Loughborough University for providing the financial support that I needed during my research, and for giving me the opportunity to teach tutorials which I thoroughly enjoyed.

I would like to take this opportunity to thank my husband, Christopher, for his endless love, understanding and motivation which helped immensely towards the completion of this project. With his support, I kept on swimming...
To my dear Christopher...
ABSTRACT

The purpose of this thesis is to contribute to the development of a theoretical model which captures the main firm, sector and location characteristics of multinational firm activity. The knowledge capital model (Markusen and Venables, 1995, 1996) is extended by intra and inter-industry supply linkages to allow multinational firms to be attracted to a country to exploit the agglomeration externalities created by pooling of national or other multinational firms. The main finding through computational general equilibrium (CGE) simulations is that firms show a preference to locate their affiliates in countries with strong supply linkages, as long as the competition among sectors for limited endowments do not increase the factor prices to a level that makes the country disadvantageous. Multinational firms (MNFs) particularly in sectors with high total scale economies, low trade costs and high plant versus firm level scale economies prefer to locate in close proximity to industrial clusters. The propositions obtained from CGE simulations are also tested empirically for manufacturing sector affiliates. The empirical findings provide evidence on the importance of supply linkages in a host economy for attracting MNFs in technology-intensive sectors and that the sub-sectors may vary on the importance they set on finding locations with industrial clusters. In addition to these, the determinants of location decisions of MNFs in Europe and the impact of the European integration policies on multinational production are investigated. The empirical analysis for the potential effects of a regional integration policy reveals that central and peripheral countries may benefit from different aspects of an integration process. Moreover, the intra-region and extra-region foreign direct investment may display different motives for choosing a location for their affiliates. The findings provide support on the hypothesis that intra-EU FDI has become more efficiency seeking, hence, leading to a redistribution of multinational activity within the region.

Keywords: multinational production, foreign direct investment, agglomeration economies, knowledge capital model.
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I. INTRODUCTION

1. Background

The last two decades have witnessed a surge in the magnitude of foreign direct investment (FDI) flows and the importance of multinational firms' (MNFs) output in the composition of world production. Global foreign direct investment inward stock increased by nearly eight-fold in twenty years from $692 billion in 1980 to $6,089 billion in 2000. According to the recent estimates of UNCTAD (2004), there are more than 60,000 MNFs with approximately 900,000 foreign affiliates operating throughout the world. In 2003, MNFs achieved $17.5 trillion worth of affiliate sales including one-third of total world exports. The scale of the growth in FDI flows and stocks could be better established by comparing with some other macroeconomic growth indicators. Table I.1 presents some comparative statistics on the actual value and growth levels of FDI and multinational production with GDP, capital stock and international trade in the world. The differences in the growth rates of these indicators are quite striking. The expansion in current GDP and capital stock (approximately by two-fold) and exports (approximately by three-fold) between 1982 and 2003 have been much slower than the FDI inward stock upsurge (approximately by nine-fold) and the growth of affiliate production (approximately by five-fold) during the same period.

The major reason behind the upsurge in multinational production has been the greater ease of the international flows of goods, services and ideas due to liberalization policies and advances in transport and communication technologies, which have resulted in lower costs of cross border business coordination. Despite the original trend of separating only the production plants from headquarters, in recent years there has been increased fragmentation even in headquarter activities, such as research and development (R&D), software development, call centres/service centres and regional headquarters. All these
developments in the production structure in favour of multinationals raised research interest into why firms choose to fragment activities internationally, why they prefer affiliate production to other modes of international production such as licensing, and finally, where do firms locate each stage of production. As multinational firms can shift location of production globally, their location decisions have important implications for host countries which may suffer from job losses and unemployment due to this shift. Foreign affiliates are estimated to have produced about one-tenth of world GDP in 2002, and to have employed over 54 million employees.

### Table 1.1

| Selected Indicators of FDI and International Production, 1982-2003 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | Value at current prices ($ billion) | Annual growth rate (%) |
| FDI inflows     | 59   | 209  | 560  | 22.9   | 21.5   | 39.7   |
| FDI outflows    | 28   | 242  | 612  | 25.6   | 16.6   | 35.1   |
| FDI inward stock| 796  | 1950 | 8245 | 14.7   | 9.3    | 16.9   |
| FDI outward stock| 590  | 1758 | 8197 | 18.1   | 10.7   | 17.1   |
| Cross border M&A| ..   | 151  | 297  | 25.9   | 24     | 51.5   |
| Sales of foreign affiliates | 2717 | 5660 | 17580* | 16 | 10.2 | 9.7 |
| Gross product of foreign affiliates | 636 | 1454 | 3706* | 17.4 | 6.8 | 8.2 |
| Total assets of foreign affiliates | 2076 | 5883 | 30362 | 18.2 | 13.9 | 20 |
| Exports of foreign affiliates | 717 | 1194 | 3077 | 13.5 | 7.6 | 9.9 |
| Employment of affiliates-thousands | 19232 | 24197 | 54170* | 5.6 | 3.9 | 10.8 |
| GDP in current prices | 11737 | 22588 | 36163 | 10.1 | 5.1 | 1.3 |
| Gross fixed capital formation | 2285 | 4815 | 7294 | 13.4 | 4.2 | 2.4 |
| Royalties and license fee receipts | 9 | 30 | 77* | 21.3 | 14.3 | 7.7 |
| Exp.of goods & non-factor services | 2246 | 4260 | 9228 | 12.7 | 8.7 | 3.6 |

* UNCTAD estimations

Source: UNCTAD, based on its FDI/TNC database (www.unctad.org/fdistatistics) and UNCTAD estimates.

Table 1.2 presents statistics on the significance of manufacturing foreign affiliates in employment, production and R&D expenditure for selected host countries. The table confirms that multinational firm production constitutes a significant share of the national total in many developed and developing countries. For example in Ireland, 48% of labour force is employed by multinational firms, and 86% of value added is produced by MNFs. In other OECD host countries such as Canada, Czech Republic, France, Hungary, Luxembourg, Poland, Sweden and UK the contribution of multinational firms to national turnover levels is over 30%. MNFs also play a significant role in research and
development activities of many countries. In Ireland, MNFs are accounted for approximately 72% of R&D expenditure of the national total. There is a growing empirical literature on the contribution of multinational firms to host economies through employment and positive spillovers, which can promote production efficiency, export competitiveness and technological and managerial capabilities in the host country. Spillovers can take place as a result of transferring assets to their affiliates or non-equity partners through training, or indirectly through increased competition and mobility of trained labour between firms and generate long term and wide spread benefits for the host country (For reviews of relevant literature, see, Griliches (1992) and Blomstrom and Kokko (1998)).

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of employees</th>
<th>Turnover</th>
<th>Value added</th>
<th>R&amp;D expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>22.7</td>
<td>34.5</td>
<td>45.4*</td>
<td>45.4*</td>
</tr>
<tr>
<td>Canada</td>
<td>-</td>
<td>49.9**</td>
<td>-</td>
<td>31.0</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>25.3</td>
<td>39.2</td>
<td>37.9</td>
<td>50.1</td>
</tr>
<tr>
<td>Denmark</td>
<td>10.2*</td>
<td>12*</td>
<td>11.5*</td>
<td>-</td>
</tr>
<tr>
<td>Finland</td>
<td>15.9*</td>
<td>14.4</td>
<td>14.2</td>
<td>11.9</td>
</tr>
<tr>
<td>France</td>
<td>30.1</td>
<td>35.0</td>
<td>34.6</td>
<td>-</td>
</tr>
<tr>
<td>Germany</td>
<td>6.0</td>
<td>9.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hungary</td>
<td>44.5</td>
<td>64.7</td>
<td>54.9</td>
<td>-</td>
</tr>
<tr>
<td>Ireland</td>
<td>48.1</td>
<td>78.2**</td>
<td>85.9</td>
<td>71.9*</td>
</tr>
<tr>
<td>Italy</td>
<td>13.5</td>
<td>22.4*</td>
<td>22.4*</td>
<td>-</td>
</tr>
<tr>
<td>Japan</td>
<td>-</td>
<td>2.5</td>
<td>2.5*</td>
<td>3.9</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>41.4*</td>
<td>52.9*</td>
<td>52.9*</td>
<td>-</td>
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<tr>
<td>Mexico</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Netherlands</td>
<td>18.3</td>
<td>24.4</td>
<td>24.8</td>
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<td>Norway</td>
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<td>Poland</td>
<td>20.9</td>
<td>34.7</td>
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</tr>
<tr>
<td>Portugal</td>
<td>10.1</td>
<td>17.4</td>
<td>15.5</td>
<td>27*</td>
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<tr>
<td>Spain</td>
<td>16.8</td>
<td>29.7</td>
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<tr>
<td>Sweden</td>
<td>29.1</td>
<td>33.4</td>
<td>35.5</td>
<td>35.8</td>
</tr>
<tr>
<td>Turkey</td>
<td>6.4</td>
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<td>UK</td>
<td>20.4*</td>
<td>36.1*</td>
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* 1999 data. ** Gross output data.

Source: OECD Measuring Globalisation database.

Throughout the last decades, the majority of countries reduced or removed barriers in trade and investment flows and introduced various national regulations to support FDI
flows into the country. However, as a result of the fierce competition among host countries, liberalisation policies or fiscal incentives alone are not adequate to attract multinational firms. Moreover, the issue is not only attracting ‘any’ multinational firm, but attracting the right MNFs in the right sector, which will both complement the existing production structure and supply linkages within the country, and contribute to the dynamic comparative advantage of the country by generating positive spillovers and augmenting industrial clusters. In order for the governments to employ the right policies to make the country more attractive, and be able to target the suitable sector multinationals which will benefit the country at best, there is need for better understanding the motives of multinational firms and characteristics of the sectors in which they operate, as well as countries’ own comparative advantages which may comply with these motives. This provides the main motivation for this thesis.

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<tr>
<td>Share in primary sector (%)</td>
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<tr>
<td>Agriculture</td>
</tr>
<tr>
<td>Mining</td>
</tr>
<tr>
<td>Manufacturing (billion $)</td>
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<tr>
<td>Share in manufacturing sector (%)</td>
</tr>
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<td></td>
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<td>Source: UNCTAD</td>
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</table>

The aim of this thesis is, therefore, to contribute to the development of a relevant theoretical model which captures the main firm, sector and location characteristics of multinational activity and fits well with empirical observations. The theoretical and empirical research in the literature (such as Dunning, 1977; Markusen, 2002) suggest that multinational corporations tend to have more sophisticated production technologies and management techniques, and produce differentiated products. Simple data analysis can help to demonstrate some of these characteristics of MNFs mentioned in the literature. First of all, the distribution of foreign direct investment shows large differences across sectors (Table I.3). For example, the capital and technology intensive sectors, such as
chemicals, electrical and electronic equipment and motor vehicles attract a significant share of FDI stock, while low technology sectors such as textile, publishing, rubber and plastic products receive a small share of total FDI. The ascendancy of the service sector in the last decade has also been reflected in the growing share of service sector FDI. Although services typically need to be produced when and where they are consumed, the recent advances in information and communication technologies have made it possible for more services, such as accounting, billing, software development, architectural design and testing, to become tradable. In particular, foreign investment in service sectors such as electricity, water, telecommunications and business services are becoming more prominent. These developments generate new opportunities for a new international division of labour.


Figure I.1 and Figure I.2 provide some further statistical observations on the general MNF characteristics. In order to obtain their ownership advantages (i.e. knowledge capital) and to implement this technology in a foreign country, multinational firms employ more skilled labour and pay higher average wages. Figure I.1 compares relative compensation/employee statistics for domestic firms and foreign affiliates. In all the OECD countries illustrated in the figure, foreign affiliates pay relatively more than their
domestic counterparts. Multinational firms also tend to have higher productivity levels than domestic firms (Figure 1.2), the difference sometimes being quite significant especially in developing countries (i.e. Ireland, Turkey, Hungary and Czech Republic among OECD countries). Another stylized fact on MNFs is that they tend to be large firms and hence international production is fairly concentrated at the firm level. In 2002, 100 largest multinational firms representing less than 0.2% of the total accounted for 14% of sales by foreign affiliates worldwide, 12 % of their assets and 13% of their employment (UNCTAD, 2004).

![Figure 1.2. Gross output per employee of foreign affiliates in the manufacturing sector in 2000: (1):1999, * Turnover per employee data Source: OECD Measuring Globalisation statistics](attachment:figure12.png)

Early theories of multinational production based on industrial organisation and firm theories (i.e. market imperfections hypothesis (Hymer, 1960) and internalisation (Dunning, 1977)) have mainly focused on the reasons for the preference towards multinational production, and successfully linked this phenomenon to the presence of market imperfections and the ownership of a firm-specific advantage (knowledge capital). The main attributes of multinational activity, hence, are the existence of internationally separable and tradable stages of production with different factor intensity requirements in each stage, and the joint input characteristic of the firm-specific advantage. Knowledge capital acts as an offsetting advantage for multinational firms and
enables them to compete in foreign markets against national firms which have better knowledge of the market. The presence of market imperfections, on the other hand, leads to a preference towards internalizing the knowledge capital within the firm rather than licensing. These market imperfections may be as a result of concentrated market structures or high transaction costs such as problems in defining property rights in knowledge or negotiating and enforcing contracts. The extent and pattern of multinational activity is determined by the interaction between the competitive advantages embedded in firms and those embedded in countries, and the way in which firms choose to combine and coordinate these two sets of advantages across national borders. Of the various theories of MNF activity, the ‘eclectic paradigm’ (Dunning, 1977) is the most comprehensive one within which various country, sector and firm specific determinants of multinational activity can be accommodated. Different country characteristics, hence, may be attractive to multinational firms depending on the firm specific factors, the type and range of products produced, and the characteristics of the country of origin. For example, multinational firms may separate headquarter and plant activities to be able to produce in close proximity to consumers abroad and also avoid trade costs involved, or to benefit from international cost differentials. Market-related and efficiency-related factors have been widely discussed in literature, although market-related factors were found to have statistically more significant effects in the empirical studies.

The statistical data on the regional distribution of outward and inward FDI stock provides support on the importance of potential market size considerations of multinationals. For example, in 2000, developed countries made 86% of the direct investment abroad, and received 68% of the total FDI stock (Table 1.4). Hence only 32% of FDI has been invested in developing countries, despite their low factor costs. Besides, out of this amount, most have been received by the relatively rich South-East Asian countries, and Latin America rather than poorer nations. These statistics support the role of high income levels, as well as similarities in endowments on international location of production. The amount of FDI flows among developed nations indicate that that intra-industry FDI is stronger than the North to South flows which mainly depend on the differences in factor costs. Least developed countries, for example, do not even account for 1% of all FDI
inward investment, despite the low levels of wages. However, a combination of potential market size with cheap labour seems to attract MNFs to developing countries which also have an adequate level of skilled labour force. Moreover, in recent years there seem to be an increase in the significance given to the efficiency related factors as a result of trade costs.

<table>
<thead>
<tr>
<th>TABLE I.4. Regional distribution of FDI stocks (% share in total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Developed countries</td>
</tr>
<tr>
<td>EU</td>
</tr>
<tr>
<td>France</td>
</tr>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>Netherlands</td>
</tr>
<tr>
<td>UK</td>
</tr>
<tr>
<td>Other Western Europe</td>
</tr>
<tr>
<td>North America</td>
</tr>
<tr>
<td>Canada</td>
</tr>
<tr>
<td>US</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Other Western Europe</td>
</tr>
<tr>
<td>Developing countries</td>
</tr>
<tr>
<td>Africa</td>
</tr>
<tr>
<td>Latin America &amp; Carib.</td>
</tr>
<tr>
<td>Brazil</td>
</tr>
<tr>
<td>Mexico</td>
</tr>
<tr>
<td>Asia and the Pacific</td>
</tr>
<tr>
<td>China</td>
</tr>
<tr>
<td>Hong Kong</td>
</tr>
<tr>
<td>Singapore</td>
</tr>
<tr>
<td>C&amp;E Europe</td>
</tr>
<tr>
<td>World FDI stock, $ billion</td>
</tr>
</tbody>
</table>

Source: UNCTAD

Table I.5 shows a significant increase in exports to affiliate sales ratio of US multinationals in total manufacturing sector between 1985 and 2000. This indicates that US MNFs have become more likely to produce in a location to benefit from its resources and lower costs rather than only target its market. Despite the general increase in the share of exports in affiliate sales, the manufacturing sub-sectors show great variation. Sectors such as food, cleaning compounds and toiletries have very low shares of export to
affiliate sales ratios, since productions in these sectors are targeted at domestic customers. On the other hand, sectors such as audio, video, communications equipment, electronic components, appliances and transportation equipment have above average export to affiliate sales ratios. These sectors show more vertically integrated structures and efficiency-seeking tendencies in their affiliate location choices. The common characteristics of these sectors are that they employ high technologies and have significant differences in the factor intensities used at each stage of production. Electronic components and audio, video, communication equipment sectors, which show the highest export to affiliate sales ratios, also benefit from low shipment costs based on the weight of products. Appliances and transportation equipment sectors, on the other hand, are also technology-intensive but have higher shipment costs.

<table>
<thead>
<tr>
<th>TABLE I.5. Share of Exports in US Manufacturing Sector Affiliate Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export/total sales (%)</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Total Manufacturing</td>
</tr>
<tr>
<td>Food</td>
</tr>
<tr>
<td>Textile</td>
</tr>
<tr>
<td>Chemicals</td>
</tr>
<tr>
<td>Cleaning comp, toiletries</td>
</tr>
<tr>
<td>Prim..&amp; fabricated metals</td>
</tr>
<tr>
<td>Machinery</td>
</tr>
<tr>
<td>Audio, video, comm.equip.</td>
</tr>
<tr>
<td>Electronic components</td>
</tr>
<tr>
<td>Appliances</td>
</tr>
<tr>
<td>Transportation equip.</td>
</tr>
</tbody>
</table>

Source: US Department of Commerce

Vertical and horizontal natures of MNFs also have links to their concentration tendencies. Food and beverages sector, which mainly target domestic markets and prefers a horizontally integrated production structure, is the most evenly spread amongst host countries, while foreign affiliates in high technology sectors tend to agglomerate in selected locations in the world (Table I.6). For example, approximately 60% of affiliate production in bio-technology sector is located in only three host countries. Owing to the technological advances and competitive pressures of recent years, large MNFs show an
increasing tendency towards disaggregating activities that do not directly contribute to their core ownership-specific activities. This reflects the growing preference for innovation-led flexible production systems, as opposed to cost-reducing mass production systems. Moreover, high overhead costs of production from headquarter activities are threatening firms to limit their product range and innovatory activities. In order to increase their specialization and flexibility, MNFs prefer to outsource some of their production or headquarter activities. Therefore, they pay a special attention to the availability and quality of complementary activities in a host country and are increasingly attracted to industrial clusters which bring benefits through proximity to specialized skills, innovatory capabilities, competitors, suppliers of specialized inputs and institutions. For foreign affiliates local procurement can lower production costs in the host economy. Supply linkages also help with better adaptation of technologies and products to local conditions. The presence of technologically advanced suppliers can provide affiliates with access to external technological and skill resources, and better marketing techniques and distribution channels. These clusters attract efficiency seeking FDI as well as asset seeking FDI preferring the location due to a cluster of skilled labour. Since the formation of industrial clusters may have positive dynamic effects on the competitive advantage of the country, and may even initiate the host country becoming a brand name for a certain sector, these networking tendencies of MNFs have important policy implications. Moreover, the existence of linkages of MNFs with domestic suppliers may prevent MNFs moving to other locations.

<table>
<thead>
<tr>
<th>TABLE I.6. Geographical Concentration of Affiliates*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of industry total</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Top 3 host countries</td>
</tr>
<tr>
<td>Top 5 host countries</td>
</tr>
<tr>
<td>Top 10 host countries</td>
</tr>
<tr>
<td>Top 20 host countries</td>
</tr>
<tr>
<td># affiliates **</td>
</tr>
<tr>
<td># host countries **</td>
</tr>
</tbody>
</table>

* Calculated as the share of the number of foreign affiliates in total foreign affiliates in the world in each sector.  
** Majority owned affiliates only.  
Source: UNCTAD, FDI/TNC database.
As concentration is more likely in technology-intensive sectors, industrial clusters may be expected to form more in developed countries or in developing countries which achieve to attract high technology FDI through their cheap skilled labour force. Table I.7 compares the concentration of US multinational activity in European countries. As large countries should be expected to attract more multinational production, the values are adjusted by comparing the share of each country in US affiliate sales in Europe and the share of country GDP in total European GDP. Countries which have a share greater than one indicate that the country has more affiliate sales relative to its size. US multinationals tend to concentrate their European activities in Belgium, Ireland, Sweden and UK.

<table>
<thead>
<tr>
<th>Country</th>
<th>Share of US affiliate sales in Europe</th>
<th>Share of GDP in Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>0.32</td>
<td>2.15</td>
</tr>
<tr>
<td>Belgium</td>
<td>2.15</td>
<td>1.96</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.24</td>
<td>0.22</td>
</tr>
<tr>
<td>Finland</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>France</td>
<td>0.72</td>
<td>0.77</td>
</tr>
<tr>
<td>Germany</td>
<td>1.11</td>
<td>1.09</td>
</tr>
<tr>
<td>Greece</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Ireland</td>
<td>4.19</td>
<td>4.72</td>
</tr>
<tr>
<td>Italy</td>
<td>0.54</td>
<td>0.56</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>2.94</td>
<td>2.37</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.53</td>
<td>0.44</td>
</tr>
<tr>
<td>Spain</td>
<td>0.90</td>
<td>0.85</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.44</td>
<td>0.35</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.37</td>
<td>0.39</td>
</tr>
<tr>
<td>Turkey</td>
<td>0.03</td>
<td>0.08</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1.76</td>
<td>1.88</td>
</tr>
<tr>
<td>CEE</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hungary</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poland</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: US Department of Commerce and World Bank.
2. Contributions

The theoretical literature of multinational production has focused on the location choices of multinational firms based on international factor cost differentials and market access motives of MNFs. The potential attractiveness of the presence of industrial clusters in a region has not been introduced into the theoretical models of multinational production, although there has been some support in the empirical literature. The principal contribution of this thesis in the literature is to bridge this gap by examining the effects of introducing agglomeration economies into the decision process of multinational firms. Incorporating agglomeration economies into production models facilitates important policy analysis, since a spatial concentration of production, once established, may tend to persist, and small differences in the initial economic conditions of countries may grow over time. The principal contribution has three main elements. First, this thesis introduces agglomeration economies as a location decision factor for multinational firm production in a general equilibrium framework (Chapter IV and Chapter V). The knowledge capital model (Markusen and Venables, 1995) is extended by intra and inter-industry supply linkages to allow multinational firms to be attracted to a country to exploit the agglomeration externalities created by pooling of national or other multinational firms. The model is expected to capture the stylized observation that the sectors with higher scale economies and lower trade costs may expect higher agglomeration. The general equilibrium framework allows for all variables to be determined endogenously in a simulation environment. Hence, the results are expected to reflect the non-linear and non-monotonic structure in real data. Second, an empirical model, which incorporates endowment and sector characteristics of host countries that may potentially affect the choice and level of multinational production, is specified and statistically tested (Chapter VI). The propositions derived from the CGE simulations on the market size, relative factor costs, trade costs and agglomeration economies are incorporated into the specification of this empirical model, and tested empirically for the manufacturing sector using a large bilateral country data set constructed to represent a range of developed and developing home and host country partners. Third, this study also investigates the determinants of location decisions of MNFs in Europe and the impact of the European
integration policies on multinational production (Chapter 7). The propositions from CGE simulations are combined with three components of integration (i.e. membership to EU, the Single Market Programme and currency union) to test the effects of each stage of integration on multinational production in different country groups. The changes in the significance of absolute and relative endowment factors in location decisions and any potential sectoral differences in the investment patterns of multinational firms and whether the integration process had different effects on each sector have also been examined.

The main finding is that when supply linkages are introduced into multinational production models, firms show a preference to locate their affiliates in countries with strong supply linkages, as long as the competition among sectors for limited endowments do not increase the factor prices to a level that makes the country disadvantageous. The CGE simulations mimic a stylized fact of production that industrial clusters tend to occur in sectors with high total scale economies, low trade costs and high plant versus firm level scale economies. Hence, the country and sector characteristics that make vertical multinational firms dominant also support industrial clusters. This finding is in line with the propositions that horizontal multinationals lead to a more dispersed structure in production. The empirical findings of Chapter 6 provides evidence on the importance of supply linkages in a host economy for attracting MNFs in technology-intensive sectors, and Chapter 7 finds further support on that the sub-sectors may not find industrial clusters equally important for their location decisions. The empirical analysis of Chapter 7 for the potential effects of a regional integration policy reveal that central and peripheral countries may benefit from different aspects of an integration process. Moreover, the intra-region (i.e. FDI originating from countries within the integrated region) and extra-region FDI (i.e. FDI originating from countries outside the integrated region) may display different motives for choosing a location for their affiliates. The findings provide support on the hypothesis that intra-EU FDI has become more efficiency seeking, hence, leading to a reallocation of multinational activity within the region.
The plan of this thesis is as follows: The content of the research is set out in Chapter II and Chapter III, which survey the existing literature on the theoretical and recent developments on location of multinational production. These chapters help justify the need for the theoretical and empirical contributions that this research study makes. Chapter IV develops an algebraic general equilibrium model with oligopolistic multinational firms and sectoral linkages. Chapter V presents the findings from the CGE simulations and provides testable propositions. Chapter VI estimates and tests the propositions from the CGE simulations using manufacturing data and a large set of countries. Chapter VII investigates the impact of European integration on the location of multinational production in the region both on sectoral and aggregate levels.
II. THEORIES ON THE GEOGRAPHY OF MULTINATIONAL PRODUCTION: A SURVEY

1. Introduction

The growth in national markets, the willingness of governments to permit foreign ownership and decline in transport costs has led to a surge in foreign direct investment (FDI) and multinational firm activity in the last decades. The purpose of this chapter is to look into the developments in the theoretical literature on multinational production and to identify the potential gaps which need more attention. One question of interest is whether the theoretical propositions currently in the literature already capture the recent developments and changes, and if not whether do they have the potential for further expansion.

A multinational firm (MNF) is a parent company that engages in foreign production through its affiliates located in several countries, exercises direct control over the policies of its affiliates, implements business strategies in production, marketing, finance and staffing that transcend national boundaries. Foreign direct investment (FDI) may be financed through parent company transfer of funds to the new affiliate, borrowing from home-country lenders, borrowing in the host country by the parent company, or any combination of these strategies. Until the 1960s the primary explanation for the international movement of capital has focused on portfolio theory which suggests that capital moves in response to changes in interest rate differentials. There was no separate explanation for foreign direct investment or any other mode of foreign involvement. The main distinctions between FDI and portfolio investment are that FDI is intended to be a longer term investment and is less sensitive to short term fluctuations in an economy, and it involves issues of direct control as resources are transferred internally within firms rather than externally between independent firms. Moreover, in the case of FDI (but not
portfolio investment) it is not simply capital that is transferred but potentially a range of resources (technology, management, marketing skills). Indeed, it is the return on these resources that is of primary concern to FDI, while it is the rate of return on capital that motivates the supply of portfolio investment.

This chapter is organised as follows: Section 2 summarizes the early theories of multinational production in neo-classical theory. Section 3 focuses on the industrial organisation and firm theories, which have provided the basis for further developments in the literature. Section 4 investigates the developments in international trade and general equilibrium approaches, which focus on more mathematical and technical explanations. This section is of importance to this study as the following chapters build on the existing theories of this section.

2. Neo-classical Economic Theories and Multinational Production

Both the classical and neo-classical trade theories are based on perfect factor and product markets and have ruled out foreign direct investment from their models with an explicit assumption of international factor immobility. These two theories, however, show different prospects for incorporation of multinational production into the models, if the factor immobility assumption were relaxed.

The classical trade theory, which focuses on the advantages of the division of labour for countries (or regions) producing and trading according to their comparative advantages, suggests that the main source of comparative advantage is the differentiation between the labour productivity of countries. The theory does not consider the effects of demand differences and relative factor endowments on trade patterns. However, if the assumption of international factor immobility were relaxed, some possible links between trade and investment could be established, since the model assumes differences in technology and production functions, hence leaving room for the presence of ownership advantages. On the other hand, the neo-classical trade theory, which attempted to explain comparative advantages of countries with their factor endowments, assumed that production functions
were the same everywhere with information about technology being freely and instantly available to all countries. The relaxation of immobility of capital would not be sufficient this time for FDI to take place, since none of the countries possess a proprietary knowledge advantage over the other in a world of perfect information availability. When international capital mobility is considered under the neo-classical H-O-S (Heckscher-Ohlin-Samuelson) model, there is no reason to suppose that this transfer would be in the shape of direct investment instead of portfolio investment. Besides, internationally mobile capital and knowledge leads to factor price equalisation and hence cost equalisation between countries. This should leave MNFs indifferent as to where to locate their headquarters or plants.

By relaxing the H-O-S model assumptions, Corden (1985) incorporated the location decisions of MNF into a neo-classical international trade framework. He suggests that when the presence of two immobile factors (i.e. skilled and unskilled labour, or land and labour) are assumed instead of only one (labour), then factor costs will no longer be equalised in all countries under the assumption of internationally mobile capital and knowledge. In this case, MNFs will locate the production of goods that are intensive in skilled labour (unskilled labour) in the countries where skilled labour (unskilled labour) is cheap. When technology is allowed to differ among countries (i.e. due to better infrastructure, political stability etc.), the country with better technology will attract mobile factors, and hence MNFs will tend to locate production of capital and knowledge intensive industries in these countries. The introduction of transport costs or tariffs will encourage MNFs to produce close to the market, while the introduction of increasing returns to scale will encourage firms to locate all production at a single location and supply other markets through exports. When the production function and factor endowments are allowed to change over time (i.e. due to educational system and effort, learning by doing) the corporation will have to reallocate its resources over time. Although Corden’s contribution is helpful in showing how to incorporate location decisions of MNFs into neo-classical framework, it relates the existence of MNFs neither to internalisation nor to existence of imperfect markets and firm-specific advantages.
3. Industrial Organisation and Firm Theories

a. Market Imperfections Hypothesis

The first attempt to distinguish the motivating factors of FDI from traditional trade and finance theory came from Hymer in his doctoral dissertation, which was completed in 1960 (supervised by Kindleberger), but not published until 1976. At the time of his writing the main FDI flow was from US to Western Europe and Canada and was of the horizontal type. Hymer provided an explanation for FDI based on the analysis of the firm and market imperfections. He argued that for firms to produce in a foreign country, where they have to incur additional costs of acclimatising, they must possess some offsetting advantages, which are not shared by local producers. These advantages may be in the form of ‘superior knowledge’ or economies of scale originating from monopolistic or monopsonistic power of the multinational firm. Hymer supported his argument by empirical evidence, especially by reference to Dunning (1958), which showed that US firms possessed superior technology and management skills with regard to US investment in Britain.

The market structure is an assumption of Hymer’s model, and he did not provide any explanation for the origin of monopoly in the first place. On the other hand, he tried to clarify why a monopolistic firm with a firm-specific advantage would choose foreign production rather than licensing the technology to an indigenous firm and hence avoid disadvantages of foreign production. He suggested that market imperfections for knowledge would make licensing unfavourable for the firm. Yet he did not distinguish between different types of market imperfection which may lead to this as concentrated market structure or transaction costs, the latter being due to problems in defining property rights, negotiating, monitoring and enforcing contracts. Even though he mentioned uncertainty and some other factors affecting transaction costs, he failed to relate his discussion explicitly to Coase (1937). Casson (1987) suggests that due to this failure, Hymer could not explain why in certain industries and at certain times, a MNF prevails, while in other industries and at other times an international cartel. For example, cartels
tend to exist in strategic industries which governments oppose to foreign control. MNFs are preferred to cartels when the international political climate is tense (uncertainty, problems in negotiating and enforcing contracts), and when products are heterogeneous (monitoring costs). Enforcing the contracts in cartels is also difficult when the industry has economies of scale, because this will mean closing down of operations in some countries. Kindleberger (1969) also explained FDI by imperfections in goods and factor markets, scale economies and government disruptions.

Another contribution in an industrial organisation framework came from Knickerbocker (1973) who argued that the optimal strategy for firms in an oligopolistic market is to match their rivals move for move. Knickerbocker tested the 'follow the leader' theory on the data of 187 large US based MNFs and found support. The flaw in Knickerbocker’s theory is that he did not state clearly the objectives of the firms and why a chosen strategy (follow the leader) is optimal given this objective. Besides, no explanation of the investment behaviour of the initiating firm is provided.

Theories focusing on market imperfections provide a necessary condition (possession of firm-specific advantage) for multinational production, but they do not account adequately for industry patterns or choice of location. Vernon (1966, 1974) was the first to link location patterns of MNFs and international trade within a monopolistic/oligopolistic market structure. In industries where product innovation is important, products have a limited market life, which depends on the time that it takes for producers to develop a new and superior substitute. During their life span, products pass through various phases, and the characteristics of these phases determine the location decision of their production. During the first phase of the product (new product stage), the manufacturer wants to be closer to the consumer. Since the patent laws protect the innovator and the demand for the product is price inelastic, the innovator faces little or no competition. As the product becomes more recognised, demand from abroad starts and is met by exports. In the next stage (maturing product), as patents expire competition both at home and abroad increases. Demand becomes more price elastic meaning that the producer should cut costs. As both competition from abroad, and the amount demanded by foreign developed
countries rises, the producer prefers to establish a plant abroad where the market is largest and labour costs are relatively lower, in order to reduce tariff, transport and production costs. The last stage of production is the standardisation stage during which price competition is intense and the decisions about where to locate production become more influenced by cost considerations. According to Vernon’s ‘product life cycle theory’ the post-war acceleration of US FDI was a response to either a shorter lag between innovation and standardisation, or to a shift in consumer preferences for standardised products. On the other hand, the theory could not justify the foreign investment which is not export substituting like in food processing industries. Also, it failed to account for the tendency of non-standard products to be produced abroad, and for products to be carefully differentiated to suit the local market. Vernon argued that characteristics specific to certain markets cause firms to become more innovative than rivals outside those markets. However, he does not specify why some firms should be more innovative within a given market. Buckley and Casson (1991) criticise the product life cycle theory for being programmatic rather than dynamic, since the model predicts the sequence in which events occur, but not the rate at which they occur, or the time lag which separates them.

One of the stylised facts for foreign direct investment is the existence of intra-industry FDI. The models based on industrial organisation theory do not rule out the possibility of intra-industry flows, even though the emphasis does not lie on it. Under industrial organisation theory the motivation of both MNFs of different countries is the same which is to exploit the firm-specific advantage they hold due to some market imperfection. Observing the fact that the spread of activities of US based MNFs into Europe had generally preceded the entry of European firms into the US, Graham (1978) proposed that intra-industry FDI may be due to a retaliatory defensive move by the domestic (European) firm. Foreign firms operating unilaterally in a host country enjoy two general advantages over their rivals, which are possession of proprietary intangible asset and the ability to reduce prices without having to do so in their home country. In order to offset these advantages the host country firm enters the foreign firm’s market, and hence threatens the intruder in her home market with the same advantages. Thus the foreign
firm might cease its rivalrous strategy in the domestic market. Although Graham found evidence of a lagged relationship between US FDI in Europe and European FDI in US in industries especially with oligopolistic structures, his regression results do not necessarily indicate causality for 'exchange of threats' hypothesis being the reason for intra-industry FDI. His findings might have suffered from omitted variable bias as he did not use any other variables that might affect the flow of European FDI to US like similar income and development levels.

Other strategic motives for becoming a multinational have also been proposed in the literature. The main strategic motives include increasing market share in the foreign country and entry deterrence. According to Smith (1987) even if cost related motives support concentration of production, a firm may choose to serve the foreign market via affiliates in order to increase its market share in the foreign market. Since the firm avoids transport costs by establishing a plant abroad, it may choose to supply a higher level of output in the affiliate as a result of this advantage and hence increase its market share. Smith also mentions entry deterrence strategy may act as a motive in becoming a multinational production firm. If a firm enters the foreign market before its competitor in the foreign market enters to his, then it may hurt the competitor in its home market and prevent its entry into his home market.

Krugman (1983) examines the existence of vertically integrated multinational in the case of a factor market imperfection: monopsony. Using Perry’s (1978) model, he argues that a monopsonistic downstream firm tends to keep the price of its raw material low, which in turn leads to overseas suppliers (e.g. mining) to produce too little. Hence by integrating backwards, the firm can eliminate the distortion and appropriate the efficiency gain. In this model FDI encourages trade. Although it is sometimes argued that vertically integrated MNFs are essentially created to reduce uncertainty, Krugman’s model shows that it is the monopsony power rather than the uncertainty which lead to vertically integrated multinational firms (Caves, 1996).
The focus in the industrial organisational approach to MNFs has been on firm and industry specific factors, such as economies of scale, product differentiation and better marketing, organisational or management skills to the firm. The existence of market imperfections provides an important basis for MNFs to internalise foreign markets, however this does not mean that MNFs would cease to exist in their absence. Many other explanations are suggested in the literature for the decision of multinational production and investment such as government incentives for foreign firms, belonging to a stronger currency area, maintaining production flexibility, excess managerial capacity etc. Kogut (1983) suggests that characteristics of multinationality, itself, brings the firm a unique ability (firm-specific advantage) to reduce costs of operating in an uncertain world and enable the firm to exploit international distortions in markets or production. Some of the characteristics unique to multinationals are their ability to arbitrage institutional restrictions (i.e. differences in tax system of countries or antitrust provisions, to avoid financial limitations of host countries with their ability to borrow at international markets), the informational externalities captured by the firm in the conduct of international business and the reduction in costs due to joint-input characteristics of some costs.

b. Internalisation and Eclectic Approach

During the 1970s explanations of FDI focused primarily on the firm as a way of understanding the MNF. As early as 1937, Coase, had linked the origins of the firm to the idea that the market is costly and inefficient for undertaking certain transactions. Finding a relevant price, defining obligations of both parties to a contract, the risk involved in accepting such contracts etc. create transaction costs to the firm. The existence of these various costs mean that whenever transactions can be organised and carried on at a lower cost within the firm than through the market, they will be internalised and undertaken within the firm itself. Although the Coase theorem was originally developed to apply to multi-plant indigenous firm, it is equally applied to MNFs. Buckley and Casson (1976) were the first to incorporate these ideas systematically into a theory of MNF. They stated that imperfect markets do not exist only in final product markets, but also for
intermediate products such as semi-processed materials, knowledge incorporated in patents, human capital, managerial and technical skills and so on, which are often specific to firms, but easily transferable between countries. Profit maximising firms facing such imperfections will attempt to internalise the intermediate products within its own organisation. Buckley and Casson noted that these imperfections might arise due to government intervention in the form of tariffs, taxation, exchange rate policies or informational inequalities between buyer and seller of the product. Whilst internalisation brings enhanced market power and a greater ability to control and co-ordinate input and production flows, costs will be incurred from carrying out this co-ordination process. Therefore, a MNF will arise when these benefits exceed the costs of internalisation.

Taking into account the previous contributions, Dunning (1977) proposed an eclectic approach for summarising determinants of FDI, where he tried to encompass every form of FDI and all the modes of foreign involvement as well as the location target which is likely to be preferred. In the eclectic framework FDI is explained with the existence of three advantages, namely, ownership-specific (O), location specific (L), and internalisation (I). The greater the competitive advantage and profits from exploiting these advantages in a foreign location, the more likely the firm would undertake overseas production in preference to alternative modes. Various propositions followed this study discussing the relative importance of owner-specific advantages, location specific advantages and the internalisation concept. Rugman (1980) claimed that internalisation itself is a synthesising explanation of the motives for FDI, therefore the existing theories of FDI, including the eclectic one, were basically sub-sets of a general internalisation theory. He demonstrated his view by examining various important versions of FDI models in the light of internalisation theory. For example oligopolistic markets, which encourage product differentiation, scale economies or other types of firm-specific assets, is one type of market failure that generates externalities, which the firm may internalise. The MNF can save transport costs by setting up a plant overseas rather than relying on exports from the home nation. This spatial cost saving is another firm-specific advantage internalised by the firm, and shows that location approaches to FDI are also a subset of internalisation theory. Casson (1987) argued that the ownership advantage concept in an
O-L-I framework is not necessary for an FDI theory, since a combination of internalisation and location advantage are sufficient to explain multinational activities. This argument may be supported, since ownership advantage is a requirement for internalisation to take place. Hence, the internalisation concept actually encompasses the concept of ownership advantage.

c. Markets and Hierarchies

Williamson (1975) developed an ‘organisational failures’ framework, which provides advantages to hierarchies over markets. Human factors, such as bounded rationality (the limitations of humans to understand complex phenomena) and opportunism (incentive to cheat), interact with environmental factors, such as uncertainty (due to complexity) and the problem of small numbers (which requires discrete rather than continuous solutions), to produce ‘information impactedness’ which is a situation where market signals fail to function. Such limitations of human nature cause market transactions to be inefficient when environmental factors like uncertainty are also present. The main transaction costs are information costs, bargaining costs and enforcement costs. Although Williamson (1975) did not make any serious efforts to extend his analysis to the MNF, except some hints in Williamson (1981), Teece (1981) and Hennart (1982) filled this gap.

Teece (1983) used the internalisation concept to relate both governance (transaction) costs and production costs to the key characteristics of technological complexity and asset specificity. He concluded that the importance of these characteristics within a firm affects the savings from internalisation. Teece (1985) demonstrated a clearer application of transaction costs to the theory of the MNF. In this model, the transaction costs of licensing are increased by many types of contracting costs including opportunism, asset specificity, asymmetries in information and other contingencies. As these costs rise, the MNF will tend to substitute internal market transactions for licensing agreements.

Rugman (1986) indicates that internalisation theorists have also discussed the majority of cases examined by Teece, such as the public good nature of knowledge, buyer
uncertainty problems, problems of contracting under licensing option, risk of dissipation, discrete nature of asset deployment, problems of recontracting, management skills embodied in the firm’s human capital etc. Only they have not phrased these discussions in terms of Williamson’s concepts of opportunism, asset specificity, governance and so on. Casson (1987) also notes that Williamson’s presentation lacks any formal modelling, which specifies precisely the technical structure of the production process and the nature of market environment, which is assumed. However, this theory complements the location and internalisation theory synthesises, therefore putting these together may provide new insights for the theory of FDI.

d. Further Developments

In the literature, there have been a number of attempts to integrate international trade and investment theories to explain location decisions of MNFs. The first systematic attempt to integrate international trade and investment theories under imperfect market structure was Vernon’s product cycle theory (1966, 1974), where market characteristics are the motivating force behind innovations and the international growth of firm. Dunning’s eclectic approach (1977), provided possible links between the decision on the mode of supply to foreign markets, ownership advantages, internalisation and country specific factors.

In addition to Vernon’s product cycle theory and Dunning’s eclectic paradigm, Hirsch (1976) also tried to bring various factors of international trade and investment together. He related the decision between exporting or overseas production to production costs (including physical capital and inputs like labour and raw materials), firm-specific knowhow, cost differential between exporting and domestic marketing (including communication costs with foreign customers, transportation and financial transactions cost and tariffs), cost differential between controlling and co-ordinating foreign and domestic operations (including costs due to foreign languages, laws, taxation systems, labour codes etc. and co-ordinating production, transportation, preparing and maintaining control procedures). Hirsch argues that a firm will choose serving a market via exports or
affiliate production depending on the relevant importance of these factors. For example, when production costs are equal between two countries, a firm will choose to export to the other country market if cost differential between exporting and domestic marketing is less than cost differential between controlling and co-ordinating foreign and domestic operations, otherwise it would prefer to produce in the foreign country. The study emphasizes the importance of existence of a firm-specific asset and the level of trade costs in firm decisions. If the multinational firm does not have any firm-specific advantage then a domestic firm would be more advantageous in production. If there were no trade costs, it would be more profitable to concentrate all production in a single plant in the country with the most favourable production conditions. Although this model underlines the importance of the existence of a firm-specific asset and trade costs, it does not adequately explain the nature of the advantages possessed by the MNFs.

Porter (1996) proposes a new paradigm on international trade and production based on the determinants of national competitive advantage. He broadens the concept of competitive advantage of a nation to be related to not only factor conditions (i.e. labour, skilled labour, infrastructure), but also to market demand factors (i.e. size, growth and composition of market demand), presence or absence of related industries and the structure of firms within the economy. Hence the national competitive advantage of a country emerges from the interaction of these factors with each other. The framework he develops is a dynamic one, as the nature of this interaction tends to change over time. Different factors may play a more essential role in different stages in the development of an industry. The relative importance of these factors may also change within different industries.

Although all these studies linked various firm, sector and country characteristics to explain international trade and production patterns, they need to be put into a formal theoretical framework to facilitate policy analyses.
4. International Trade and General Equilibrium Approaches

The early 1980s witnessed a shift in international trade theories from competitive general equilibrium theories towards an industrial organisation approach. As a result, market structures gained importance in modelling practices. Increasing returns to scale and imperfect competition are incorporated into the models successfully.

a. Factor Proportions Approach

From the industrial organisation standpoint that firm-specific assets associated with marketing, management and R&D can serve product lines without being located in the production plants. Helpman (1984) and Helpman and Krugman (1985) proposed a general equilibrium model of international trade in which multinational production may exist due to the separation of production stages. The model was based on the fact that each stage of production (headquarters, intermediary product, assembly) process required different factor intensities, so that firms could minimise their costs by allocating the location of each stage according to the factor reward differentials of countries. In the absence of transport costs, tariffs and other government distortions such as tax incentives, factor rewards could differ only due to differences in relative factor endowments. Although this assumption of zero transport costs and tariffs simplified the derivation of the model, it also narrowed the scope of the model to include only vertically integrated multinationals, thus excluding demand-pull factors of FDI.

The model consisted of two countries, two internationally immobile factors of production, labour and a general purpose input (i.e. capital) and two sectors. The homogenous good, which required all inputs to be employed in the same location, is produced under constant returns to scale in a competitive market. The differentiated goods are produced under monopolistic competition and increasing returns to scale. A producer of the differentiated product faces plant-specific fixed and variable costs and corporate-specific fixed costs arising from the adoption of the general purpose input into a firm-specific asset. It is assumed that arms length trade of this asset would be an
inferior organisational form to an integrated firm, so that the firm chooses to internalise this advantage. In this model tastes are homothetic and identical and intra-industry trade in the differentiated product is motivated by a taste for variety. There is one-way trade in the homogenous product and the net factor content of trade reflects the relative factor endowments of the countries. When factor endowments are sufficiently similar, factor price equalisation occurs as a result of trade, hence there are no incentives for the formation of MNFs and intra-firm trade. When the difference in factor compositions is extremely large factor prices do not equalise. However in the case of a sufficiently large, but not too large difference, some of the firms in the differentiated sector locate their headquarters in the relatively capital-abundant economy and production in the relatively labour-abundant economy. In a production process with more than two stages, final goods are separated from the headquarters before intermediate products, which are more capital intensive. In the general equilibrium, the ability to geographically separate firms’ activities in the differentiated sector leads to an enlargement of the factor price equalisation set (FPE). When factor price equalisation occurs as a result of the activities of MNFs, the capital-rich country imports the homogenous good and may be a net importer or exporter of finished manufacturing goods, and intermediate goods depending on the difference in relative factor endowments and sizes of countries. This country serves as a base for headquarters activities. In the model inter-industry, intra-industry and intra-firm trade can coexist, although the relation between relative factor endowments and trade are not monotonic.

In the FPE set by trade, there is a negative association between differences in relative factor endowments and the share of intra-industry trade. However, when the difference in factor composition becomes large enough so as to bring about the emergence of MNFs, this relation becomes positive as long as the capital rich country is a net exporter of manufactures. When the difference in relative factor endowments becomes larger so that the capital rich country becomes a net importer of manufactures, the relation turns out to be negative again. Keeping the relative size of countries constant for two stage production, an increase in the difference in factor composition raises the number of MNFs and the number of varieties produced in the home country. Hence larger
differences are associated with a larger share of intra-firm trade. However, this monotonic link is broken when a higher number of production stages are relocated.

The Helpman and the Helpman & Krugman model provide an explanation for one-way direct investment flows between economies with sufficiently large factor composition differences. However, the result of the model, that MNFs do not emerge between countries with similar endowment ratios, is not supported by the evidence of intra-industry FDI among developed countries. By assuming away transport costs and tariffs, the model neglects the importance of demand-pull effects of FDI. Brainard (1993a) points to the differences in the real data and the pure factor proportions model results on relocation decisions and trade patterns. She notes that the total volume of affiliate sales strongly increases with similarities in relative income shares and finds that the variable together with transport costs explains over 40% of the variations in affiliate sales. Also, she illustrates that factor proportions and relative income similarity, rather than differences, better explain variations in intra-industry ratios of multinational sales. Furthermore, the Helpman-Krugman model considers only one-plant multinationals, although many multinationals are multi-plant firms and operate in both countries. More importantly, lack of trade and tariff cost variables limits the usefulness of the model for trade policy analysis.

Factor proportions theory may find some supportive results for individual industries where vertical integration is the main trend. The semi-conductor industry of the US is a good example, where blue prints and key components are designed and produced in the US, and assembly is done by cheap labour in South East Asia and finished goods are shipped back to sales destinations in the US and elsewhere (Yoffie, 1993). Yet, why is South East Asia or particular countries in South East Asia preferred to other cheap labour locations, is not clear according to the model. Moreover, this model does not provide an adequate explanation for the very low levels of FDI from developed countries to the least developed countries, between which the factor endowment ratio differential is significantly high. These results indicate that a pure factor proportions theory is not
sufficient alone to explain the location of multinationals, although it throws light upon vertical multinational activities and trade patterns as a consequence.

Markusen and Zhang (1997) extended the factor proportions model to explain the low levels of direct investment into small and skilled labour scarce countries. The model relies on two major changes to the original approach. The first is that multinational firms actually have minimal skilled labour (i.e. local engineers, technicians, managers, accountants etc) and social infrastructure (i.e. electrical and water supplies, telecommunication, transport links and legal institutions) requirements in the foreign country where they locate their assembly lines. Poor countries lack these requirements and this makes them less attractive for multinational firms, despite their advantage in the form of cheap labour. A second extension of the model is the inclusion of transport costs. Multinationals incur transport costs for the shipment of intermediate products from the home country to the foreign country and the shipment of part (or all) of the final product to sales destinations in the home country. On the other hand, domestic firms face transport costs only for their exports to the foreign country. These changes to the model yield several results that fit the stylised facts and provide links between FDI, endowment ratios and country sizes. The simulation results indicate an inverted U-shaped relationship between the FDI a country receives and its endowment ratio (i.e. labour/skilled labour). The production is only by multinational firms if the foreign country is both large and the relative endowment differences are large. All production is by domestic firms if the foreign country is small and the relative endowment differences are small. Between these cases, there are mixed regimes of multinational and domestic firms operating together. The simulations illustrate that when the foreign country is very scarce in skilled labour and very small, it is not profitable to produce any final goods in that country. When the home country is very small that skilled labour requirements for producing the intermediate good drives skilled labour wages sufficiently high, all production takes place in the foreign country.
b. Proximity versus Concentration

Another group of papers explains the expansion of multinational production in the absence of factor proportion differences and focus on the motivation of multinational firms to access the destination market at the expense of production scale economies at home. In these models, the firms in the differentiated products sector have the option of becoming MNFs by operating plants in both countries or exporting from a single plant in one country. The existence of horizontal MNFs rests on the assumption that they have multi-plant economies of scale. Hence although they incur higher fixed costs per plant (technology transfer costs etc.) than national firms, total fixed costs for a two plant firm are less than double the fixed costs for a single plant firm. Since production occurs in both countries, MNFs are assumed to use local factor markets for the supply of factors of production. MNFs benefit from serving a larger total market without incurring transport costs. Hence, the magnitude of variable transport costs and the size of scale economies at the plant level relative to the firm level determine the locational configuration of production chosen by firms. The predictions of the model are consistent with the observations for intra-industry FDI flow between similar countries and horizontally integrated multinational activities.

Krugman (1983) made an initial proposal of this type of model by allowing for an imperfectly competitive market into trade theory (following the model of Dixit and Stiglitz (1977)) and including the possibility of FDI in addition to trade. The motivation for the existence of MNFs is the presence of high fixed costs in the creation of an advantage, and the joint-input property of this asset, which enables it to be used in many plants without incurring the same cost again. Krugman suggests that higher transport costs encourage FDI, while costs of multinational production due to the difficulty of controlling with a distance or unfamiliarity with language, culture, legal system etc. promote trade. Markusen (1984) provides a simple algebraic proof for economies of multi-plant operation in the presence of a joint input. Horstmann and Markusen (1987) demonstrate that higher competition in the host economy make the relative sizes of firm-specific, plant-specific and transport costs more important for deciding whether to
become multinational or remain as a national firm and export. They conclude that when firm-specific costs and transport costs are large relative to plant-specific cost, it is beneficial to become a MNF.

Other extensions of the model are provided in Horstmann and Markusen (1992) and Brainard (1993a). These models focus on the decision between exporting and producing abroad motivated by market access considerations in the context of two symmetrical countries in their sizes, factor supplies, technologies and demand structures. They explain the existence of multinationals by the trade-off between proximity advantages and scale economies from concentrating production in a single location. Brainard’s general equilibrium framework explains conditions for pure production regimes as well as mixed regimes where national firms coexist with multinational ones in the same industry. The model allows both for the possibility of single and multi-plant configurations for multinationals, as well as multi-level production stages. Multinational production and multi-plant configurations are more likely the higher are returns to scale at the corporate level relative to plant level, the higher are transport costs across markets, the greater is the expenditure on the differentiated products in the foreign market, and the higher is the elasticity of substitution between product varieties. Nevertheless, Brainard (1993b) notes that the equilibrium regime may be different, if multinationals face higher marginal costs in the host economies due to communication and co-ordination costs, and different operating conditions. In addition to this, taxes may distort the location decisions of multinationals by attracting headquarter activities with lower profit taxes and production activities with lower output taxes. Markusen and Venables (1995, 1996) contributes by including the possibility of asymmetries among countries to answer the question of why direct investment is more important among similar countries rather than between countries with endowment composition and size dissimilarities. The general result of their model is the “convergence hypothesis” which means that multinational activities become more important relative to national firms as countries become more similar in size, endowments and technologies. Hence, the equilibrium regime depends not only on trade costs and the relative importance of firm level scale economies over plant level economies, but also to country characteristics (i.e. relative endowments and size). When
there are asymmetries in costs, national firms in the low cost country has an advantage, and their entry reduces the demand for a MNF’s output. Conversely, when costs are similar in the two countries, the demand for multinational production is maximised. The Helpman-Krugman model of zero trade costs and ‘no’ horizontal multinationals emerge as a special case of the general treatment in the model they provide. In this special case of ‘only national firms’, the location of production between countries is determined solely by factor market considerations, as output could be transported without additional cost to supply either market. With positive costs, product market considerations gain importance. They present that a necessary condition for MNFs to exist to be that their savings from trade costs should be sufficiently high relative to the fixed cost disadvantage of operating two plants. In addition to this endowment similarities of countries are important for location decisions, since they provide advantages to horizontal multinationals over national firms.

Further extensions to the proximity-concentration model have enabled the model to capture more of the stylized facts in line with trade and investment trends. The original prediction of this hypothesis on trade is that MNF activity will in part or totally substitute for intra-industry trade. In the extreme case of zero fixed costs or corporate costs approaching to infinity, there will be trade only in ‘invisible’ corporate services and intra-industry multinational production will prevail. For the intermediate range of parameter values, both intra-industry trade in final goods and FDI will exist, the share of exports (multinational production) rising with lower (higher) transport costs and trade barriers, higher (lower) production fixed costs, lower (larger) incremental R&D investments and smaller (larger) world market (Brainard, 1993b). However, as the volume of trade declines as a higher share of world production is undertaken by MNFs, they claim that convergence of country size may not be associated with growing volumes of intra-industry trade as many studies in the literature suggest. Brainard (1993b) argued that with multiple stages of production instead of two, all of which are characterised by different proximity-concentration trade-offs, different results may emerge. If concentration advantages dominate in upstream production activities, while proximity advantage dominate in downstream activities, the intra-industry and intra-firm flows of intermediate
goods replace the intra-industry flows of final goods. Hence, multinational activity becomes complementary to trade in goods as the empirical evidences suggest. Finally, Breuss et al. (2001) incorporates fiscal incentives into the model to identify the effects of structural and cohesion expenditures on horizontal multinational activity. In the model, the structural subsidies are used as a determinant for both trade costs and plant set-up costs. These payments can be used to improve infrastructure facilities and thereby reduce trade costs, or to directly subsidize investments in a specific region. Multinational production is expected to increase, if the host country directs the structural expenditures towards reducing plant set-up costs. If the structural expenditures are used as direct incentives, the results are not monotonic, and the impact of the subsidies depends on the level of transport costs.

c. Unified Treatment of Vertical and Horizontal MNFs

The factor proportions and proximity hypothesis have integrated MNFs into general equilibrium trade models by highlighting different stylised facts of these types of firms. Markusen et al. (1996) attempt incorporating both hypotheses in a unified model by employing the joint-input characteristic of knowledge capital and factor intensity differentials of production stages. In the model, headquarter activities are assumed to incur firm level fixed costs and use only skilled labour. Plant level activities, on the other hand, incur fixed (i.e. for the establishment of a plant) and variable costs (i.e. for the final production stage). While plant level fixed cost is composed of both skilled and unskilled labour, plant level variable cost only uses unskilled labour. All of the factors of production are assumed to be obtained from the sources of the country, where the activity is undertaken. Although both vertical multinational and domestic firms need the same amount of skilled labour in total for their fixed costs, vertical multinationals have the advantage of obtaining the skilled labour required for headquarters activities in the skilled labour abundant country and the unskilled labour required at the plant level in the unskilled labour abundant country. However, they have to pay a penalty for separating the activities, which also prevents the existence of two vertical multinationals headquartered in different countries in the model. A horizontal multinational firm
required more skilled labour than a single plant domestic or a vertical multinational firm, but less than double the amount of domestic firms because of the joint input nature of knowledge capital. In addition to these, due to technology transfer and other costs, multinational firms require more skilled labour in the home country than both types of firms. The assumption that skilled labour requirement at the plant is to be obtained from the host country sources, brings the importance of the development level of host country into the picture. This generates results as in the real world, where the least developed countries do not receive much foreign direct investment due to their low development levels. Another assumption in the model is that domestic firms and vertical multinational firms incur transport costs for exporting their products, measured in unskilled labour terms.

The model captures the characteristics of both horizontally and vertically integrated multinationals. Horizontal multinationals exist when the countries are relatively similar in size and in relative factor endowments. When countries are very similar, the production is done only by horizontal multinationals, and the two other types of firms do not exist. When country sizes or relative endowments slightly differ national and horizontal multinationals coexist. Further differences in relative endowments generate appropriate conditions for vertical multinationals to enter into the market. The simulation results exhibit both non-linear relations and possible interactions between FDI, country sizes, relative endowments and trade costs. For example, when one of the countries is small but skilled labour abundant, headquarters locate in this country, while all production occurs in the large, unskilled labour abundant country. When the unskilled labour abundant country is very small, and the relative endowment difference is very high, then all production and headquarter activities locate in the large and skilled labour abundant country, and hence no multinational activity exist between these countries.

Although the unified knowledge capital model provides non-linear relations between the existence of multinationals and country-specific factors, further simulations with different values for factor intensities of headquarters and plant level activities may be useful to observe the effects of firm level and plant scale economies. Hence, further hypotheses
could be established to test the relationship between R&D, technology transfer cost and FDI. Also, on the theoretical side, endogenising a firm’s technology level (firm-specific asset) may provide useful results. Norback (2001) draws attention to the importance of technology transfer costs and argues that the level of technology transfer costs abroad may lead to contradictory results to those in the literature. In the literature firm-specific assets are generally associated with multinational firms, but he reasons and provides evidence to the effect that high-tech firms are more inclined to export. In his model when transfer costs are small, high-tech firms choose foreign direct investment. At higher transfer costs, on the other hand, high-tech firms choose to export. Therefore, high-tech or R&D intensive firms may gain more by avoiding transport costs of technology rather than avoiding trade costs, since more complex technology demands larger resources for technology transfer. In addition to endogenising firm’s technology, extending the unified model to multi-product stages with the inclusion of an intermediate good sector may affect the results of trade regime as in Brainard (1993b). Moreover, the inclusion of an intermediate sector may help to incorporate agglomeration effect as a determinant of location choice. This type of a model has been offered by Venables (1996) for national firms, where firms prefer to locate close to intermediate products sector, which they use as input for their production. Empirical results on knowledge capital type of general equilibrium models tend to support horizontal models against vertical or unified models. Further empirical analysis with different data sets and variables are required in the literature.

Markusen (1997) has extended the analysis of knowledge capital model to compare the individual and joint effects of trade and investment liberalisation policies. Although the results are not as straightforward as one would prefer this extension is important to analyse the potential effects of recent integration trend at policy level. Four cases are compared by simulations in this study. First one is the case of ‘no liberalisation’ where trade costs are high and multinational production is prohibited. The second case is ‘trade liberalisation’ where trade costs are low and multinationals are prohibited. Third case is ‘investment liberalisation’ where multinationals are allowed for but trade costs are high, and the last case is ‘full liberalisation’ where multinationals are allowed and trade costs
are low. When there is investment liberalisation, a fall in trade costs lead to disappearance of horizontal multinationals, and hence a fall in affiliate production between similar countries. On the other hand this fall in trade costs lead to an increase in affiliate production between countries with significant endowment differences. Thus whether affiliate sales and trade are substitutes or complements is influenced by country characteristics. However, the results on the potential outcome of full liberalisation are indefinite, as they are not the same for high and low trade cost cases. Still, trade and affiliate production tend to be substitutes for similar countries, and potentially are complements for dissimilar countries.

d. Internalisation in General Equilibrium Models

International trade theory works quite well in explaining the location of international production by the MNFs. However, these theories generally focus on the decision of FDI versus exports from the home nation rather than exploring the reasons why internalisation is profitable compared to joint ventures, licensing or other non-equity forms of foreign involvement such as franchising. In fact the switchover from FDI to this second group of foreign involvement is more difficult to handle, since they involve the treatment of often intangible market imperfections, like information asymmetries, contracting and re-contracting costs under bounded rationality, opportunism and so on. For example selling the special knowledge to a foreign firm at its full value will require exposing the knowledge which will cause the parent firm to lose some of its monopoly power. Foreigners eventually learn to produce a good on their own, and learn it faster if the good is produced in their country than if it is imported. Therefore, exporting, licensing and acquiring a subsidiary all generate different incentives for parties during longer periods affecting the choice of production mode.

In trade models, licensing generally is assumed to be a costly modality and is ruled out at the beginning. Ethier (1986) criticises both Markusen (1984) and Helpman (1984) by being primarily concerned to link their treatments of direct investment to the theory of international trade, rather than the O-L-I framework. Therefore, Ethier, instead of taking
internalisation for granted, attempts to incorporate the internalisation decision into a
general equilibrium framework and hence endogenises it. The model is based on specific
factor endowments with a differentiated manufacturing sector, which is composed of
three stages: research, upstream production and downstream production. Research effort
is linked to the public good nature of information and helps to determine the
technological parameter, which in turn determines the level of quality. The public good
nature of information produces an informational asymmetry between the home and
foreign firms, preventing the latter from directly verifying the success or the extent of
home firm’s research effort. This asymmetry brings an intrinsic source of uncertainty
(dispersion for the agents) into the model. According to Ethier, it will be possible to
design an incentive compatible contract, if at least one of the parties is risk neutral, and if
it is feasible for the contract to call for a payment schedule for the foreign firm which
varies across all conceivable states of nature. However, both of these requirements are
demanding, and the latter requires extremely detailed and complex contracts. The
multivariate nature of quality involving the diverse facets of the good’s preparation,
design, delivery and use makes an enforceable contract very difficult. Ethier (1986)
concentrates on the difficulties associated with writing of state-contingent contracts and
concludes that the presence of MNFs is positively related to the size of the dispersion. In
addition to this, similarity in relative factor endowments makes direct investment more
likely and provides a basis for intra-industry trade.

Horstmann and Markusen (1987) construct a model where multinational firms decide
internalisation depending on the concentration in the market. They conclude that the
home country firm will choose to become a multinational when it can credibly pre-empt
all future entry in the host market and become a monopolist. On the other hand, when
more than one plant can operate profitably in the host country, home country firms
cannot pre-empt all future entry and appropriate all of the rents from reduced costs and
competition. Therefore, in this case, the relative sizes of firm, plant-specific costs and
transport costs will be important in the decision as to whether to become multinational or
remain national and export. Horstmann and Markusen show that when firm-specific cost
(R&D) and transport costs are large relative to plant-specific cost, it is better to become a multinational enterprise.

An important contribution to this strand of literature comes from Ethier and Markusen (1996) following the previous study of Ethier (1986), where difficulties in writing complete contracts and informational asymmetry problem involved in knowledge capital causes MNFs emerge instead of licensing. Ethier and Markusen (1996), on the other hand, concentrate on the inability to enforce such contracts, and compare choices of different supply modes to a foreign market (i.e. exporting, licensing, acquiring an affiliate) for more than one period. Using more than one period enables different incentives and outcomes of parties in different periods to be observed. The main assumption of the model is the fact that knowledge of how to produce a new product disseminates gradually. While in the first period only the inventor firm knows how, in the second period any other firms involved in production of the product during the first period (i.e. franchisees, subsidiary employees, licensees) can also produce. As a result, if any of these supply modes is chosen in the first period, some disincentives are required to prevent them from defecting in the second period, otherwise the inventor has to compete with its former partner in the following period. A possible threat to the host firm against defection is that the source firm may have a new partner or export on its own in the second period. After the second period, anyone can produce the good as the knowledge it holds is no longer new. Therefore, a licence agreement only during the second period does not have the risk of defection as the knowledge will be common at the end of the period. Ethier and Markusen (1996) compare the expected earnings of both parties (source and host countries) in both periods under different modes of supply and parameter values, derived in a general equilibrium framework with an endogenous market structure. Supporting the previous literature results, they conclude that the existence of MNFs is more likely when knowledge capital is of medium to high importance to physical capital. The results for the effects of transfer cost, on the other hand, contradict the main findings in the literature. Although high transfer costs make exporting unattractive, they also make two period agreements difficult to sustain. With high trade costs it is easier for the host firm to defect as the threat by the source firm to
export on its own is less credible. Lower wages in the host country than the source country encourage production in the foreign country, as long as wages are not so low to leave no disincentive to subsidiary employees to defect. Higher production costs in the host country makes exporting from the source country a more potent second period threat and reduces the possibility of defecting in the second period.

e. New Economic Geography Approach

The New Trade Theories have explained location choices of multinationals based on cost reduction and market access motives of multinational firms. Differences in factor compositions, sizes of countries and trade costs are the main suggested determinants of FDI inflows into a foreign country. In these models higher plant-level scale economies relative to firm level scale economies promote concentration of production within one plant, while the reverse supports multi-plant multinational firms. The New Trade Theory, which made great advances in putting the O-L-I paradigm into a general equilibrium framework, however, lacks an explanation for one important characteristic observed industrial production patterns. Firms, especially in particular sectors, tend to locate close to each other, sometimes even leading to regional specialisation. Hence, regions or countries with identical initial relative endowment and market potential may attract investment at different levels and sectors. This localisation effect has been a major issue in New Economic Geography, although mainly under national considerations. The agglomeration concept has a good potential to be an explanatory variable for location decisions of multinationals. Multinational firms could be attracted to a country to exploit the agglomeration externalities created by pooling of national or other multinational firms.

The idea of agglomeration economies originates from Marshall (1920). He identified three main resources of agglomeration to be a pooled market for workers with specialised skills, facilitating the development of specialised inputs and services and enabling clustered firms to benefit from localised information spillovers. Weber (1929) puts forward the first explicit definition of agglomeration as “an advantage or cheapening of
production or marketing which results from the fact that production is carried out to some considerable extent at one place”. Hence if location of firms in one region attracts other firms to locate in the same region agglomeration takes place. One point to keep in mind is that although the endowment level and market size attract firms to a certain area, only in the presence of agglomeration externalities does the clustering of firms add to the further attractiveness of the location. Without pecuniary and information externalities, the location will become less attractive due to competition in product and factor markets. Agglomeration economies may accrue from economies of scale from firm’s production, proximity to suppliers, pooled labour market, diffusion of localised knowledge, or urbanisation economies such as highly developed infrastructures or low costs of energy.

The new economic geography literature has introduced endogenous core-periphery patterns into general equilibrium models through mobility of workers (Krugman, 1991a, 1991b) or mobility of firms which prefer proximity to producers of intermediate goods (Venables, 1996). Mobility of some factors between countries may generate differences among regions and hence an industrialised core and a de-industrialised periphery between two initially identical regions. When factors are immobile, as in Krugman (1990), an additional firm in one of the identical regions will increase competition in product and factor markets, and lower profitability. However, when labour migration is allowed among regions, the rise in local varieties and the rise in labour demand due to the additional firm set up will attract more workers into the region. As the labour supply increases local expenditure rises, and factor market competition decreases. This increases the profitability of firms and hence attracts more firms and workers into the region. For this self perpetuating process to start a fall in trade costs may be enough. The stronger the love of variety and the larger the share of manufactures in expenditure, the earlier will agglomeration take place. In the case of immobile labour, a higher elasticity of labour supply from agriculture to manufacturing in a region may also result in agglomeration (Puga 1998). In addition to the linkages through the supply of labour and demand for goods from each other’s workers, firms may also be attracted to a region due to proximity to input suppliers. In these types of models, a country with a large manufacturing sector offers a large market for intermediates, which leads to concentration of intermediates in
that country. This creates a cost advantage for downstream production and attracts manufacturing sector firms further. Agglomeration via input-output linkages without labour mobility is modelled by Krugman and Venables (1995, 1996) and Venables (1996). Agglomeration forces increasingly influence a firm's location decisions as knowledge spillovers and pecuniary externalities gain importance in firm's competitiveness.

While demand linkages, input-output linkages between firms and information externalities promote geographical concentration of production, immobile factors (i.e. land, natural resources), prices of non-tradable goods (e.g. housing) and congestion effects (e.g. traffic, crime) work against agglomeration tendencies (Puga, 1999). Factor accumulation (Baldwin, 1998; Martin and Ottaviano, 1999), historical accidents and expectations (Matsuyama, 1991; Krugman, 1991c) also affect clustering of firms and population in a region. The relative strength of centripetal and centrifugal forces determines the start of this self-perpetuating process. Bringing in this dynamic structure, the new economic geography fills the gap in new trade theory, which assumes the existence of large and small markets without explaining their formation. Hence countries with identical relative factor endowments and market potential may attract investment at different levels and sectors. Models of new economic geography typically exhibit a pattern in which the quantitative behaviour of the model changes abruptly when the quantitative balance of forces passes some threshold level. Therefore, discontinuous changes (i.e. jumps) and multiple equilibria are possible in this framework. The inclusion of agglomeration tendencies brings non-linearity into the model. The self-perpetuating process of agglomeration may start due to a change in the initial conditions of trade costs, expectations, government policies or some historical accident.

Contrary to potential significant effects of agglomeration process, there has been little formal analysis on the effects of agglomeration on location decisions of multinational firms. The theoretical studies which have incorporated multinational firms into new economic geography models have concentrated on the effects of the existence of multinationals on the agglomeration process. For example, Markusen and Venables
(1996) investigate the effects of factor mobility in response to factor price differences with or without the existence of horizontal multinational firms. They find that the international mobility of the factor used intensively in the imperfectly competitive sector may cause a divergence between the production structures of the two economies, whereas full factor mobility may lead to all activity to be agglomerated in one of the locations depending on the initial values of endowments. The presence of multinationals does not eliminate, but reduces the agglomeration tendencies. Ekholm and Forslid (2001) find in a national context that horizontal multi-region firms tend to weaken agglomeration tendencies by narrowing the range of trade costs, which lead to core-periphery outcome. This effect becomes stronger as the degree of multi-plant economies of scale rise. They suggest that the present trend with rapid technological progress may therefore be a force to give rise to a dispersed production structure despite regional integration. However, with vertically integrated firms agglomeration occurs eventually with lower trade costs, although at a more gradual level than the abrupt change of core-periphery model.

There is, however, a growing interest in explaining internationalization of R&D in theoretical and empirical studies. Overseas R&D may be conducted to adapt home-developed technologies to foreign markets or more strategically in order to access local technological expertise abroad and to create new technologies that can be used in all the MNFs' markets. Siotis (1999) develops a symmetric two-firm, two country model where a MNF when serving the foreign market through FDI generates spillovers to local competitors, but will also be able to learn from local rivals. If the technology gap between the firms is large, then advanced firm prefers exports over FDI, while technology laggard firm engages in FDI which allows for technology sourcing. Cadot and Desruelle (1998) suggest a pattern of international specialization in R&D activities according to which firms located in smaller countries do more research, while firms located in larger countries devote more resources to development stage. Ekholm and Hakkala (2003) develop a two country general equilibrium model where firms decide on the locations of R&D and production in a high-tech sector under the assumption that knowledge spillovers and backward linkages act as agglomeration forces. These two agglomeration forces affect the choice of locating R&D and production. Knowledge
spillovers, which may arise as a result of firms learning from each other through cooperation, reverse engineering and turnover of highly specialized labour, are geographically limited in scope. This technological externality creates incentives for firms to locate R&D labs in close proximity to other R&D labs. In the model, a firm deciding to conduct its R&D in a country with a higher number of R&D labs needs to use a smaller amount of skilled labour in order to produce its blueprint. The backward linkages arise from the combination of increasing returns to scale in production and transaction costs, thereby making it beneficial for firms to locate in the larger market. The model is solved for two asymmetric sized countries, the small country being the home country. Although agglomeration economies favour the large country, concentration of both activities in one country increases the price of skilled labour in this country because both production and R&D activities employ skilled labour intensively. The simulations find no specialization at high trade costs, when there are no R&D externalities and countries differ in size but have identical relative endowments. At intermediate trade costs; on the other hand, the home market effect is relatively strong and attracts firms to locate production in the large country. This leads to an increase in the price of skilled labour in this country creating a factor market reason for high-tech firms to locate their R&D activities in the small country. Beyond a certain threshold of R&D externalities, R&D activities tend to become concentrated in one of the countries.

Belderbos, et al. (2005) incorporates location decision of R&D abroad with strategic interactions among competing MNFs and market structure. In equilibrium, the shares of R&D performed abroad depend on the importance of spillovers, the strength of product market competition, the efficiency of intra-firm transfers and whether the firm is a technology leader or a technology laggard (defined in terms of the size of R&D investments). Their results show that greater efficiency of intra-firm transfers leads to a greater reliance on home market R&D by technology leaders if the gap with laggard is sufficiently large. The outcome confirms the results of earlier work on R&D localization in the context of a single MNF's R&D localization decision (Norback, 2001). Laggards, in contrast, perform more R&D abroad in this case, because their home market operations can benefit more from overseas technology sourcing. Greater R&D spillovers have a
similar impact, reducing overseas R&D by leaders due to appropriability concerns, but increasing overseas R&D by laggards due to technology sourcing motive. Overseas R&D, however, does not only provide sourcing opportunities, it may also increase risk of dissipation of R&D results to foreign rivals, in particular when there are fewer possibilities to protect know how and intellectual property. The model suggests that R&D by both leader and laggard tends to agglomerate in the country with the stronger intellectual property rights. On the other hand, greater intensity of product market competition encourages the leading firm to engage in foreign R&D to make use of its technology advantage and to capture a larger share of local market. Laggards, in contrast, are more likely to concentrate R&D at home, to defend their home market position.

More research into the effects of agglomeration economies on location decisions of MNF is needed. The effects of sector linkages, knowledge spillovers and migration need to be integrated with MNF location decisions as well as with current literature of internalisation and industrial economics. In a recent study, Piga and Theotoky (2005) integrate spillovers, location and market structure literatures in a two firm setting by endogenising location-related spillover externality and allowing firms to decide on price, R&D expenditures and location. Their model indicates that the more differentiated the products are the further the firms will locate from each other and the more they will spend on R&D. Their results indicate for a need to re-examination of many previous results obtained in the literature in the absence of location concerns, spillover endogeneity or product differentiation. Extending new economic geography literature to involve both domestic and multinational firms and through endogenising firm and market structures, technology and knowledge spillovers may provide further answers to explain non-monotonic relations observed within actual data.

5. Conclusion

This chapter summarized the developments in the trade and investment literature on the factors motivating multinational activity and their location choices. The recent advances in economic modelling techniques have enabled multinational production to be examined
in a mathematical environment. The main advantages of general equilibrium models are that they allow for extensions and the results can be analysed through simulation exercises. These features make them very important tools for policy analysis.

A number of studies integrated various country, sector and firm characteristics into the general equilibrium models. However, there is still scope for further advances to reflect the comprehensive nature of Dunning's eclectic paradigm and Porter's dynamic comparative advantage concept within these models. One potential area for further progress involves incorporating further sectoral characteristics into these models to capture more of the stylized facts of data on multinational production activity. In recent years, the trend of falling trade costs had an impact on the relative importance of various factors and the way the way variables interact with each other. Falling trade costs and intensified competition makes locations with industrial clusters more attractive to MNFs which want to benefit from lower intermediate input costs, as well as proximity to specialized skills, innovatory capacity and a pool of skilled labour.
III. EMPIRICAL EVIDENCE ON THE LOCATION OF AFFILIATE PRODUCTION

1. Introduction

The major challenge facing the empirical studies on the location of multinational activity involves the non-linear and non-monotonic nature of outcomes from the joint effects of country, sector and firm characteristics. The lack of detailed and extensive data for the related variables also makes econometric modelling of multinational activity quite difficult.

The size of MNF activities could be measured in a variety of ways, although each emphasizes different aspects of these activities and provides different results. As a result of more commonly available data, FDI flows or stocks have been more commonly used to proxy multinational operations. Out of these variables, the stock of FDI is more closely linked to the economic activities of multinational firms than foreign investment flows data. Yet, both of them include only funds transferred from the parent company, and as a result overlooks to the fact that the MNFs may finance their operations by taking up loans in the host economy to fund future expenditures. Therefore, effective FDI flows into the host economy may be low or zero, despite the continuing activities of MNFs in the economy. Some studies have overcome this problem by employing the data on capital expenditures of countries abroad regardless of source of financing of the funds invested instead of FDI data. Potentially better measures of multinational activity are the affiliate related data, such as sales and gross product or value added product levels of affiliates of MNFs in foreign host countries. Although data is scarcer, they are more meaningful indicators in economic terms. Even these measures have their own failures for empirical purposes. For example, capital stock measures rely on historical book values, which can be misleading in inflationary periods. Sales data include the
value of imported inputs which overstates the amount of activity in the host country. Value added production is the best measure of the allocation of production, but is less commonly available. Other potential proxies that may be employed for empirical studies include the number of affiliates, the amount of total and fixed assets of affiliates or employment levels of affiliates.

All of these measures contain information about the country, industry and the firm and hence provide valuable comparisons for the characteristics of MNFs which have chosen a certain location. The important point to remember is that the empirical results will be affected with the choice of measure, since each measure embodies and stresses different aspects of country and firm characteristics. For example, the number of affiliates, the levels of total assets, sales and gross product data in 1998 will reveal Hong Kong and Singapore as the most preferred foreign hosts out of all Asian economies for US multinational investors. On the other hand, the data on the amount of foreign fixed assets a country receives, will register Indonesia as the most favourable affiliate location for US firms, due to its oil resources. Having large populations, China and Malaysia account for the highest affiliate employment levels out of all Asian economies.

Table III.1, presents a summary of recent empirical studies (1990-2004) on the location determinants of the foreign production decision. The table is comprised of studies only which have employed FDI stocks or affiliate related data as their dependent variable. The details of data coverage and methodologies used are illustrated for each study. For direct comparisons from the table the differences in dependent variables should be taken into account. The table also shows the details of significant factors found as determinants of FDI with the proxies used to measure them and coefficient signs. The factors perceived as affecting the firm’s decision to set production abroad are divided into seven main groups. The first two, which are relative factor endowments (or relative factor cost) and market size (or market potential), have been incorporated into theoretical models within a general equilibrium framework, and have received significant amount of empirical attention. The third group is related to the effects of government policies such as corporate tax, fiscal incentives, privatisation, trade liberalization and regional integration policies. Economic growth, development level of
country, cost of borrowing and exchange rates are illustrated under the fourth section as macroeconomic variables. The variables capturing the effects of agglomeration economies, firm (internalisation effect) and industry level factors (plant level scale economies, profitability, competition in the sector etc.) are provided in the following groups. The articles presented in the table are ordered from the most recent study to the least recent one.

2. Empirical Tests on General Equilibrium Models

Among the empirical studies, a recent group tests the general equilibrium models of multinationals incorporated into trade theories following the theoretical developments. Brainard (1993b) and Ekholm (1997, 1998b) compare factor proportions and proximity hypothesis. Ekholm (1997) finds that the income levels of the host and home countries have positive effects individually, while income dissimilarity has a negative effect on the level of affiliate employment of Swedish and US multinationals. Affiliate employment also increases when the home country is relatively more skilled labour intensive and less physical capital intensive. Ekholm (1998b) tests proximity-concentration hypothesis for Swedish multinationals. The dependent variable employed is the share of affiliate sales in total foreign sales. Total foreign sales are defined as the sum of affiliate sales and exports. Because the dependent variable is bounded between zero and one, a logistic specification and non-linear least squares estimation method are used. The results support the proximity versus concentration hypothesis. Firms choose to serve foreign markets via affiliate production if the host market (GDP) is large and concentration advantages (plant-level scale economies) are not significant. A geographical distance between Sweden and the host country reduces the share of affiliate sales in total sales. The model is also estimated by ordinary least squares (OLS) with a correction variable to test for the marginal effects. The results are mainly the same except that distance has a positive and significant effect. This suggests that the negative relation found in the logistic estimation is driven by the effect on the probability of finding any affiliate sales at all. The relative importance of affiliate sales, given that there are such sales, increases with geographical distance instead. This result
is consistent with the view that FDI is more costly for distant and hence different countries, but once the decision to invest is made, this effect is reversed.

Carr, Markusen and Maskus (1998), Markusen and Maskus (1999) and Blonigen et al. (2002) test the fitness of vertical, horizontal and knowledge capital models of multinationals and provide a good opportunity to compare the strength of various specifications. The use of non-linear and interactive terms in these econometric models is an important contribution and the results support their importance for improving the empirical analysis. These non-linear terms also imply that the results are not necessarily the same for all countries, leading to a rich menu of conclusions. Besides, it is always possible to include variables such as fiscal and macroeconomic policies, agglomeration economies into the econometric model to check whether these might capture further relationships among the variables, which are not mentioned in the theoretical model. Such results may be helpful to determine future directions to extend the theory.

Carr, et al. (1998) provides the first attempt to estimate the knowledge capital model. They use the real volume of affiliate sales of US multinationals as their dependent variable and employ both weighted least squares (i.e. to correct for heteroscedasticity on levels), and Tobit procedures (i.e. to account for zero observations in sales). They found for their data that as long as the difference in skilled labour proportions between two countries is low, an increase in the host country’s trade costs raise production by affiliates of parent country firms. The model captures the favourable conditions for horizontal firms through a squared GDP difference variable and trade cost variable. The negative sign and significance of the squared GDP difference term indicate that affiliate sales increase when there is a convergence in country sizes, as long as the initial difference is not too large. Positive trade costs also indicate horizontal multinational activity. Total economic activity (i.e. sum of GDP) also stimulates total affiliate sales. The regression model also captures the activities of vertically integrated multinational firms which take advantage of factor cost differentials between countries through fragmentation of activities. The coefficient of difference in skilled labour variable is positive and significant, indicating that an increase in the parent country’s relative skill labour abundance increases affiliate sales. These results have been interpreted as
support for knowledge capital models, where horizontal and vertical multinationals existed in different country conditions.

However, in a later study Markusen and Maskus (1999) found conflicting results, where the performance of the horizontal model outweighed both vertical and knowledge capital models. Despite the utilisation of the same data set with Carr et al. (1998), they did not find a strong positive role for divergence in relative skilled labour within a slightly different specification. On the contrary, skilled labour difference seems to have negative effect when interacted with effect of total market size. Markusen and Maskus (1999) suggest two possible reasons for these different findings. First, there is some conflict between the assumptions of fixed total endowments in a world of changing level of endowments. Second, using bilateral observations where US is one of the countries in each observation may have generated skewed results by restricting them into a certain range of parameter space, as US is substantially larger than every country in the data set.

In fact, both studies suffered due to misspecification of the endowment difference term as suggested by Blonigen et al. (2002). Using a difference term which may take both positive and negative values in the sample may lead to sign reversals in the pooled coefficient. Blonigen et al. (2002) specified the skill difference and GDP difference terms as absolute values, where variables increase in dissimilarity. The results gave a better overall fit, but did not support the knowledge capital model, since the divergence in relative skilled labour between countries was found to be negatively related with US affiliate sales. Blonigen et al. (2002) also note that the negative effect of endowment divergence is even higher when parent country is already relatively less endowed in skilled labour. The study also revealed some asymmetric results with regards to inbound and outbound data, where relative endowments seemed more important for inbound investment activity. In order to alleviate the problems caused by using a sample where one of the country is in every bilateral pair observation is the US, Blonigen et al. (2002) also tried an alternative sample of FDI activity involving outward investment stock of OECD countries, nevertheless finding similar results confirming the negative relationship between the divergence in relative endowments and FDI activity.
Following the findings of general equilibrium literature, Matha (2001) included factors affecting horizontal and vertical multinationals into his empirical specification. He employed the share of affiliate sales to total foreign sales as the dependent variable for Swedish multinationals. Horizontal and vertical MNFs are distinguished by employing interaction variables which take into account of the extent of vertical integration between parent and its affiliates. Sweden corresponds to the case of a small country which is well endowed with the production factor intensively used in headquarters services, and has a disproportionate share of the largest multinationals in the world in relation to its country size. As a result of home country endowment characteristics, Swedish multinationals are to a significant extent vertically integrated with their affiliates. The results indicate that affiliate production of horizontally integrated MNFs are primarily explained by low-plant level scale economies relative to firm size, large trade costs, large host country size, similarities in per capita income, labour productivity, wages and unit labour costs. Only the coefficient on the R&D intensity did not have the expected sign, and revealed a significant and negative relation with the share of affiliate sales for horizontal multinationals. Norback (2001) points out that this may be related to the fact that the technology transfer from parents to affiliates is not independent of the magnitude of the R&D intensity as commonly assumed in the empirical and theoretical literature and suggests endogenising R&D intensity at firm level. The results provide support for the hypotheses that vertical multinationals geographically fragment production stages in order to exploit differences in factor endowments and that vertically integrated multinationals are promoted by low trade costs. The host country size seems of greater importance for horizontal multinationals.

With the deepening of European integration horizontally integrated multinationals seem to be increasingly deterred by large plant-level economies of scale. Also, supply side considerations have become increasingly important in determining the location of multinational production. These results are consistent with the anticipated effects of increased efficiency and competition inside the EU. Horizontal multinationals are increasingly associated with large trade costs and similarities between countries in technology and human capital levels. Vertically integrated multinationals, on the other hand, are increasingly explained by relative factor endowment differences during the
integration period, while market size effect which was stronger during pre-integration period has lost its importance relatively. These changes indicate that foreign production was taking place in less efficient locations to avoid non-tariff barriers and gain access to individual markets prior to integration.

The sensitivity of results to empirical specifications specifies a need for further empirical studies in the field. Data sets including not only more diversified countries but also industries should be employed, as investment responses may vary considerably by sector. An interesting hypothesis to empirically analyse could be whether there is any sequential entry of vertical and horizontal multinationals into developing countries as is claimed by Zhang (1996). He suggests that as developing countries catch up developed ones in both size and relative endowments, they first attract vertical foreign direct investment and later horizontal foreign direct investment as their markets grow. In addition to this, including variables into empirical specifications which have not been included in theories may also help to determine the direction of future research.

3. Market Demand

A large or a growing market is a signal of the likelihood of profitable investment projects. In empirical studies market size effect is generally proxied by GDP, GDP per capita or value added production. Most studies report robust and supportive results for the importance of market size effect in explaining multinational activity. In some studies a lack of significance (or weak significance) of market variable is explained by the regional integration process where investors target whole integrated region (e.g. EU market) rather than only host country market. However, there is lack of available data to make any distinction between investments destined to serve a host country or other countries via exports, or in other words, a distinction between horizontally and vertically integrated MNFs. While absolute market size variables provide strong support for absolute FDI activity, these variables do not show the same strength in explaining relative investment measures such as FDI per capita, or FDI as a share of GDP.
Blair (1987) and Milner and Pentecost (1996) suggest that for the UK and other countries within the EU, the potential market may be perceived as the whole EU market, rather than just that of the member state in question. Market potential proxied by EU GDP growth, EU (or EC) output level for the industry (Milner and Pentecost, 1996; Barrell and Pain, 1999; Hubert and Pain, 2002) is found to affect outward investment stock of countries positively.

Distance is a commonly employed variable in empirical studies, although the expected sign for this variable is ambiguous. It may capture the effects of dissimilarities in culture and institutions and hence have a negative effect on horizontal multinationals. On the other hand, it may capture the effects of shipping costs, and have a positive effect on horizontal multinationals and a negative effect on vertical multinationals. Similarities between countries have also been proxied by various other variables. Ekholm (1997) reports negative effects of absolute income differences of countries. Holland and Pain (1998) report that FDI inflows into Central Eastern European countries are positively affected by having contiguous borders with the EU countries. Grubert and Mutti (2004) provide evidence on the favourable effects of speaking the same language and having adjacent borders for US multinational activity.

4. Relative Endowment Costs

While most of the empirical studies provide support for the positive effects of a large market, the results on the effects of relative factor costs are ambiguous. Lower labour costs and high unemployment found support for attracting FDI in many studies (Hubert and Pain, 2002; Billington, 1999; Barrell and Pain, 1997, Wheeler and Mody, 1992). Unit factor costs do not seem to have a significant effect on US firms choosing to invest between Germany, France and UK (Devereux and Griffith, 2004). There is also evidence that Swedish multinationals are attracted by the abundance of skilled labour in the countries they invest (Brunerhjelm and Svensson, 1996).

In addition to labour costs, the labour and employer relations also have a significant effect on location decisions. For example, for German companies strikes in the host
country seem to be a repelling force, while same variable is not taken into account by UK multinationals. The labour market reforms of the UK to obtain more flexible labour market institutions increased FDI flows in more labour intensive sectors as well as non-manufacturing sectors (Barrell and Pain, 1997). Pain and Lansbury (1997) also noted that UK has performed poorly in attracting FDI from those sectors where innovations are growing most rapidly.

5. Fiscal policies

National governments try to affect the location of international production activities through the use of fiscal policies or incentives in order to increase externalities in the country which may benefit host country firms. These temporary fiscal policies and incentives may act as strategic instruments benefiting the country for the long term, if there are self reinforcing agglomeration economies in the economy. The main tools employed by governments are tax policies, investment incentives, privatisation, trade liberalization and regional integration policies. However, the final implications of these policies on foreign investment will also depend on the offsetting effects of different factors such as level of infrastructure and agglomeration economies in the country. Empirical estimations need to take all factors into account otherwise sensitivity to certain factors may be misjudged.

Various studies find significant effects of tax levels in a country on the level of foreign investment or activity. Main measures investigated are profit taxes, effective average taxes, and marginal tax rates. Devereux and Griffith (1998) use a nested multinomial logit model to examine the potential effects of effective average tax rate on US multinationals investing in Germany, France or UK. The model is estimated sequentially, first obtaining the estimates of the coefficients from the conditional probability at the lowest level of the decision tree. The sequence is deciding to serve the foreign market, deciding to produce in Europe as against exporting -conditional on having decided to serve the foreign market, choosing of location in Europe (UK, France, Germany) -conditional on having decided to be a multinational. The effective average tax rate plays an important role in the choice of location conditional on the firm having
decided to produce in Europe. However, the effective average tax rate does not play a significant role in the choices between producing abroad in Europe as opposed to either exporting to Europe or not serving the European market at all. Young (1999) provide evidence on that the tax competitiveness of the UK has a significant effect on the total fixed investment expenditure in the UK. Grubert and Mutti (1991, 2004), Hubert and Pain (2002) report a positive effect from tax competitiveness, implying that a rise in the relative effective corporate tax rate in the host location will act to deter inward investment. A similar finding is reported in Billington (1999) for investment flows data.

There is empirical evidence that the degree of openness (lower tariffs) of a country has a negative effect on the location of foreign investment or affiliate activity (Wheeler and Mody, 1992; Grubert and Mutti, 1991; Moden, 1998). This is consistent with the hypothesis related to horizontal multinationals. On the contrary, Grubert and Mutti (2004) report negative effects of tariff levels on US affiliates. Higher tariffs may increase the cost of exported intermediate inputs and discourage multinational activity. Grubert and Mutti (2004) also examine the sensitivity of firms to taxes in different countries. Through the use of various interactive variables they find that less open economies and higher income countries are less sensitive to corporate tax reductions. This may be as a result of the fact that higher income countries provide better infrastructure and agglomeration economies which offsets the negative effects of higher corporate taxes.

Investment incentives given by host governments could be divided into three broad categories such as tax incentives (i.e. preferential tax rates, capital allowances), financial incentives (i.e. government grants, subsidies, loan guarantees, preferential loans, government equity participation in high risk investments), non-financial measures (i.e. provision of subsidised infrastructure such as industrial sites, free trade zones). Based on OECD (1989) and UNCTAD (1998) studies Hubert and Pain (2002) note that there is little evidence that investment incentives are an important determinant of either the scale or the form of foreign investment. However, there is stronger evidence that fiscal incentives and public infrastructure can affect the choice of location within a given country. Breuss et al (2001) analyse the effects of EU structural policy reform on
FDI stocks in EU. The expected impact of structural expenditures depend on whether structural policy is trade cost reducing or fixed investment cost reducing. They find positive effects of structural funds on foreign investment locating in Europe. Except for the ratio of skilled to unskilled labour, all coefficients have the expected signs. Using the empirical results, Breuss et al. simulate the impact of the structural policy reform on real FDI stocks in the EU countries under the assumption that the change occurs within the estimation period and all other influences held constant. With the enlargement of EU and new members, the previous members are expected to receive less structural funds to provide momentum for the integration of new members to the community. The simulations reveal that a reduction in structural funds causes the largest fall in real FDI stocks in Ireland, followed by considerable reductions in Denmark, Belgium-Luxemburg, Austria, Finland and the UK. The least reduction occurs in Germany and Greece. They suggest that the countries may need to take compensating measures to mitigate these negative effects.

Hubert and Pain (2002) report that host government investment share (in GDP) has a small but positive and significant effect in attracting multinational investments. On the contrary, the ratio of ERDF structural funds to GDP seems to have a negative effect on the location decisions of German multinationals (Hubert and Pain, 2002) and French multinationals (Ferrer, 1998). Higher investment in poorer regions assisted by structural fund grants may be necessary to catch-up with more advanced regions but may not be sufficient to offset all the inherent locational disadvantages. Various studies have also suggested that privatisation in the economy may create favourable conditions for multinational investment. The studies which investigate this effect have generally used FDI flows data. Holland and Pain (1998) and Carstensen and Toubal (2004) find transition specific factors such as the level and method of privatisation play an important role in determining the flows of FDI into the Central and Eastern European countries.

There is a growing literature on the effects of EU integration on international production patterns in the region. Many studies provide empirical support for the significance of the Single Market Programme (SMP) effect, where the anticipation of a larger market
size attracts investment into the EU (for US and Japan direct investment in the EU: Aristotelous and Fountas, 1996). Dunning (1997b) provides a review on studies testing the effects of internal market integration on FDI. Studies discussed in detail are UNCTAD (1993), Buigues and Jacquemin (1994), Srinivasan and Mody (1998), Clegg (1995) and Pain and Lansbury (1996). Agarwal (1995) and Pain and Lansbury (1996) refute the hypothesis that intra-EC FDI will fall as a result of deeper economic integration. Most studies in the literature analysing the effects of the EU integration, however, rely on FDI flows data.

One of the main areas of interest have been whether integration has led to investment diversion in the other economies (such as the economies of the European Free Trade Association (EFTA)) and investment creation in EU economies (Baldwin et al., 1995). Brenton et al (1999) investigate whether an increase in the attractiveness of the CEECs to foreign investors has affected the magnitude of FDI going to other European countries. In particular they investigate whether increasing EU integration in the late 1980s, adjustment to the Single Market and the accession of Portugal and Spain had a negative impact upon FDI flows from EU countries going to the three European countries which subsequently joined the EU in 1995, Austria, Finland and Sweden. They found no evidence that integration and FDI in new EU countries significantly reduced FDI flows going to other European countries.

Another area of interest has been on the potential changes in the relative importance of determinants of FDI. Krugman (1997) notes that for many industries, especially high technology ones, transportation costs appear to be increasingly less important. This suggests that US MNFs in these low transport cost industries may well choose to locate in peripheral countries in the EU in order to exploit other locational advantages. Mold (2003) finds no evidence that firms have become more sensitive to factor based differences (e.g. factor costs) between member states and less sensitive to market based changes in the host country. This may be due to the fact that differences between EU countries in terms of income, tastes, culture, and technology continue to be pronounced; hence MNFs may be reluctant to treat the EU as a truly integrated market. Moreover, aggregated data may prevent firm specific tendencies to show up in more concentrated
patterns of affiliate production or FDI. Also, as suggested by Dunning (1997b) the main impact of the SMP may be taking place through its effects on other variables influencing FDI.

6. Other Macroeconomic Variables

Various studies have also investigated the effects of other macroeconomic variables such as economic growth, exchange rate volatility, cost of borrowing, development level and riskiness of host country. Higher economic growth reflects improvement in productivity and development indicators such as education, transport and infrastructure and hence has been employed by many studies to proxy market dynamism, expected future sales and ability to recover investment costs quickly. Lower economic and political risks are associated with a more attractive climate for foreign investors. The significance of economic risk in deterring investment highlights the importance of macroeconomic stability for sustained capital investment. The deterrent effect of political risk underlines the role of host country institutions in providing transparent and predictable investment policies (Lehmann, 1999; Carstensen and Toubal, 2004).

Volatility in the exchange rate may contribute to uncertainty over timing of returns from investment. Countries may prefer to produce in countries whose nominal exchange rates are linked to their own currency. Hence, volatility in exchange rates may be associated with lack of similarity between countries. In addition to this, multinationals may perceive exchange rate volatility as an indication of macroeconomic instability in the host country. The effect of exchange rate volatility may also depend on the relative importance of intermediate inputs to be imported from the parent country, or final products to be exported back to the parent country. All these aspects of exchange rate volatility will have a negative impact on multinational activity. However, MNFs may also perceive exchange rate volatility part of trade cost, and choose to produce abroad instead of exporting, if exchange rate volatility is high. The evidence in the literature on the potential effects of exchange rate volatility is generally weak and contradictory (Cushman, 1985; Aristotelous and Fountas, 1996; Barrel and Pain, 1997; Hubert and Pain, 2002).
Theoretically there is no exact relationship with cost of borrowing in host country and FDI, since multinationals can finance their activities from international capital markets. High interest rates may, however, be an indicator of macroeconomic instability, and hence reduce FDI. The empirical findings on this factor are also ambiguous and weak (Culem, 1988; Mody and Srinivasan, 1998; Devereux and Griffith, 1998; Barrell and Pain, 1999).

7. Agglomeration Economies

Multinational firms could be attracted to a country to exploit the agglomeration externalities created by pooling of national or other multinational firms. Empirical studies have used different proxies to catch this effect, such as quality of infrastructure, the degree of industrialisation, the level of inward FDI (Wheeler and Mody, 1992) the number of national firms in the same sector (Head et al., 1995), and the number of multinationals from the same country in the same sector (Head et al., 1995). Moreover, proximity to other firms producing in the same industry, proximity to final demand, proximity to other firms in the same industry with relatively high R&D are considered to capture agglomeration economies. The relative strength of centrifugal and centripetal forces plays an important role for the level of agglomeration economies in a region. Higher cost of endowments restricts the self reinforcing process of agglomeration economies.

Braunerhjelm and Svensson (1996) find that the existence of local support systems and networks within industries and intra-industry R&D spillovers increases the sales of affiliates. Hubert and Pain (2002) report that German foreign companies prefer relatively large national markets to exploit demand and supply linkages. Additionally they are attracted by high research and development which enables them to benefit from knowledge spillovers from other firms (proxied by the ratio of stock of patents granted to firms resident in the host country to EU stock). The US FDI in Europe (Barrell and Pain, 1999b), seems to be even more driven by agglomeration factors, than German firms, while German multinational companies are primarily driven by their own technological advantages. Devereux and Griffith (1998), Barrell and Pain (1999),

There is a growing interest in understanding location choices for research and development stages of production. A number of studies have examined attractiveness of potential host countries in attracting foreign R&D based on R&D expenditures data by foreign affiliates of MNFs to (Zejan, 1990; Kumar, 1996, 2000; Odagiri & Yasuda 1996; Belderbos, 2001). The studies mainly focus on two major motives for overseas R&D expenditure to be technology exploiting and technology sourcing motives. Firms with own-technology exploiting motives locate their R&D facilities in larger local markets with high per capita income in order to adapt to consumer demands and local tastes better and hence capture a larger market share. On the other hand, MNFs with technology sourcing motives choose countries with an abundance of scientists and engineers and a technological lead in the industry of the investing firm. Technology laggards, in particular, display stronger technology sourcing motives. However, overseas R&D does not only provide sourcing opportunities, it may also increase risk of dissipation of R&D results to foreign rivals, in particular when there are fewer possibilities to protect know how and intellectual property. Lee and Mansfield (1996), and Smarzynska (2004) provide evidence on that MNFs adapt the type of activities located abroad in response to intellectual property rights (IPR) concerns and locate knowledge intensive and higher value added activities in countries with stronger IPR regimes.

8. Firm and Industry Factors

Many studies have found empirical support for the internalisation hypothesis, and hence R&D intensity of firms is associated with multinational production in the literature. For example, the findings of Devereux and Griffith (1998) in a multinomial logit model where firms decide whether to produce abroad or export, support that firms with high plant level fixed costs are less likely to produce abroad, while firms with high intangible assets and relatively high skilled workers are more likely to produce abroad. Grubert and Mutti (2004) also find higher R&D, advertising and labour costs (i.e. more skilled
labour requirement) makes firms more likely to invest abroad, while plant level scale economies (i.e. the ratio of capital expenditure to sales) has a negative impact.

Norback (2001), on the contrary, argues that R&D intensity may be negatively related to multinational production due to cost of technology transfer abroad. R&D firms may prefer to avoid technology transfer costs rather than physical transport costs. Employing the share of foreign sales accounted for by the affiliates as dependent variable, he estimates various specifications by Probit, OLS and 2SLS methods. In these specifications more experience of production abroad is expected to lower technology transfer costs, and hence age of affiliates is used to proxy costs of technology transfer. Irrespective of the specification both the probability and marginal effects show significant and negative effects of R&D intensity of a firm in becoming a multinational. The larger the R&D intensity, the smaller the probability that a firm locates production abroad, and given the production is already established, the smaller is the share of foreign affiliate sales accounted for by the affiliates. Experience (lower technology transfer costs) increases both the probability of investing and production level. The size of a country is also of importance for a firm’s decision to invest abroad, and the level of production afterwards. Differences in relative endowments are not a significant factor for deciding on serving market by local production or exports, but have a significant and positive effect once the affiliates are established.

Planned foreign investments tend to be reduced prior to domestic ones at times of distress. Barrell and Pain (1997) provide evidence for financial factors (i.e. fluctuations in domestic profitability) having an important influence on the timing and scale of foreign direct investment of German companies.

9. Conclusion

The empirical literature on the factors affecting affiliate production is growing. There are three major issues that may benefit from further attention. First is the issue of ambiguous results on cost related factors. Although the market-seeking motives of MNFs are successfully captured in empirical studies, the models fail to provide
consistent results on efficiency-related factors, such as relative factor costs, availability of sufficient skilled labour or agglomeration economies. Hence, the literature may benefit from sector level analysis as data coverage and availability increase. The second issue is the influence of regional integration policies on multinational firm location choices. The gradual changes which took place in Europe from the formation of a Common Market to the adoption of a Single Currency create a suitable background to analyse the effects of various stages of regional integration on multinational investment. The third issue which requires further attention is building empirical specifications more closely linked with general equilibrium theories. There is scope for expanding the general equilibrium theories and testing the proposed results empirically.
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<td>Relative factor endowment difference (+)</td>
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<td>Wage difference (-)</td>
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<td>Agglomeration</td>
<td>Internalisation</td>
<td>Industry variables</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>------------------------------------------</td>
<td>-------------</td>
<td>-----------------</td>
<td>-----------------------------</td>
<td>--------------</td>
<td>---------------</td>
<td>----------------</td>
<td>------------------</td>
</tr>
<tr>
<td>19b</td>
<td>(b) US MNF capital expenditure / panel data, 232 obs/ OLS</td>
<td>Average hourly wage (+)</td>
<td>GDP (+)</td>
<td>Economic and political relations with West (+)</td>
<td>Current FDI(+), Infrastructure quality (+) Manuf/GDP(+)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Grubert and Mutti (1991)/ various countries, 1982 /All</td>
<td>Stock of net plant &amp; equipment in majority owned foreign affiliates of US / Cross section</td>
<td>GDP (+) GDP/capita (+)</td>
<td>Tariff on manufacturing (+), Effective tax rate (+)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE III.1 continued...
IV. AGGLOMERATION ECONOMIES AND MULTINATIONAL FIRMS IN A GENERAL EQUILIBRIUM OLIGOPOLY MODEL

1. Introduction

The general equilibrium models of multinational firms have demonstrated various important relationships between country characteristics and the level of affiliate production taking place in that country. Major attributes of these firms and the sectors in which they prevail, have been successfully incorporated into general equilibrium models explaining the reasons behind their existence and some of the conditions they prefer to make investments in. The predominant focus on country characteristics has been on the traditional factors attracting multinationals such as a large domestic market and the presence of natural resources and labour endowments. However, one factor of growing importance, the presence of geographical clusters in economic activity, has been neglected. As distance matters less for many transactions, multinational firms can relocate more functions to obtain an optimal configuration for their production. The intensified competition among multinational companies pushes them towards searching for more efficient international production systems and increases their reliance on external partners such as specialized suppliers and even competitors, in addition to buyers. Hence, multinational firms increasingly try to benefit by locating in countries with good supplier networks, a pool of skilled labour and knowledge producing institutions. Agglomeration economies are important because a spatial concentration of production, once established, may tend to persist, and a small difference in the initial economic size of otherwise equivalent locations may grow over time. This makes the timing of policies as well as the choice of sectors to promote crucial for policy makers.
Agglomeration economies can be described as an advantage of cheapening of production (or R&D, marketing etc) as a result of a considerable amount of production (or headquarter activity) taking place in one region. This means that the location of firms in a region attracts other firms to locate in the same region leading to industrial clusters. The important distinction between agglomeration economies and other factors, which attract firms into a region such as relative endowment levels and market size, is that only in the presence of agglomeration externalities does the clustering of firms adds to the attractiveness of the location. Agglomeration economies only accrue in imperfectly competitive market structures. Otherwise a firm would not have an advantage in concentrating production (or headquarters) activities in a single location, but rather establish a separate facility to serve each market.

Mobility of some production factors is a key factor in the self-perpetuating process of agglomeration. Therefore migration of population according to real wage differentials between regions is a common way incorporating these externalities in a national context. However, there are various restrictions (legal restrictions, language and cultural differences) on immigration of people internationally. Even where the immigration regime is relatively open and there are no language barriers, international migration is far smaller than migration within countries. Without labour mobility one cannot have agglomeration and the cumulative process of geographical concentration in the same way. However a similar process of international specialization can emerge through supply linkages. These linkages create industrial concentration because of self-reinforcing backward and forward linkages (see Fujita et al, 1999). Producers want to choose locations that have good access to large markets and the supplies of goods they require. In addition to the presence of strong supply linkages and/or a pooled labour market, agglomeration economies may also accrue as a result of spillovers from localised knowledge or urbanization economies such as good infrastructure.

The purpose of this chapter is to introduce agglomeration economies as a location decision factor for multinational firm production in a general equilibrium framework. For this purpose the knowledge capital model (Markusen and Venables, 1995, 1996;
Markusen et al., 1996) is expanded by intra and inter-industry supply linkages. Hence, in addition to all other factors multinational firms would be attracted to a country to exploit the agglomeration externalities created by pooling of national or other multinational firms. An oligopolistic market structure is preferred for the sector in which multinational firms are active, since Markusen’s (2002) findings indicate that using a monopolistic competition market structure will abolish total market size effect, a result which is not supported by empirical findings. The end result of agglomeration tendencies of firms depends on the relative strength of forces supporting and limiting concentration. When factors of production are immobile or have restricted mobility, endowment levels will constitute a constraint against agglomeration tendencies of firms. Sectors with more imperfect competition or, in other words, with higher scale economies may expect higher agglomeration. Higher trade costs and hence horizontal structure of firms are expected to discourage concentration, while lower trade costs encourage more concentrated activities.

The plan of the chapter is as follows: Section two provides information on the methodological issues on general equilibrium modelling. Section three presents the assumptions and the derivation of the model and equilibrium effects, while section four gives an insight into the expected outcome using partial equilibrium analysis. Section five discusses the issue of choosing a suitable solver and algorithm for the model.

2. Methodology

A general equilibrium modelling approach will be used throughout the chapter. These models provide an abstraction of the economy which is complex enough to capture a large number of the essential features of it, but simple enough to be tractable. The most valuable properties of these types of models are their transparency in providing a coherent and complete description of the objectives of the agents and of the constraints they face, and their flexibility to represent a wide variety of situations by changing the assumptions about the objectives and constraints of these agents. Using the characteristics of the real economy, this theoretical structure may also be converted into numerical analysis through simulations. For analytical purposes both a partial approach, focusing on
a limited set of factors, and a general equilibrium approach which allows for all endogenous variables to be determined within the model may be utilized. The advancement in computer technologies and modelling techniques has increased the suitability of these models for policy oriented work. The main drawback of computational general equilibrium (CGE) models is the fact that they are rich in economic structure, but deterministic in statistical structure and do not allow for random effects. Econometric studies, on the other hand, are based on simplified economic structure while allowing for richness in statistical specification. The outcomes of CGE analysis could be described as the systematic, not the random, responses of economic variables to exogenous changes.

The steps in building an applied general equilibrium model includes the decision on the number and types of agents in the model, choosing the suitable functional forms to represent the behaviour of each agent, deriving the theoretical model and choosing the parameters and exogenous variables. Some of the important points related with each of these steps will be looked at respectively in the rest of this section.

a. Social Accounting Matrix (SAM)

The first step in generating the model involves deciding the type and number of agents in the model and relating these agents in an economic general equilibrium. The main idea behind the economics of general equilibrium is that demand equals market supplies for all commodities and inputs. This implies that each agent has incomes and expenditures consistent with their budget constraints. Since each agent can only spend what they earn, the value of excess demand (price x volume of excess demand) is identically zero in the economy (Walras Law). Therefore, the fundamental principle of economic accounting is that for every income or receipt there is a corresponding expenditure or outlay. A social accounting matrix (SAM) embodies this fundamental principle recording transactions between accounts in a matrix format. By convention incomes (or receipts) are shown in the rows of the SAM, while expenditures (outlays) are shown in the columns. The benefit of preparing a SAM is that it provides a comprehensive and consistent record of the
interrelationships of an economy at the level of individual production sectors, production factors and public and foreign institutions.

**TABLE IV.1: Social Accounting Matrix**

<table>
<thead>
<tr>
<th><strong>in values</strong></th>
<th><strong>Receipts</strong></th>
<th><strong>Payments</strong></th>
<th><strong>Activities</strong></th>
<th><strong>Commodity</strong></th>
<th><strong>Factor market</strong></th>
<th><strong>Entrepreneur</strong></th>
<th><strong>Household</strong></th>
<th><strong>ROW</strong></th>
<th><strong>TOTAL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Activities</td>
<td>Domestic sales</td>
<td>Intermediate demand</td>
<td>Consumption</td>
<td>Value of fixed cost</td>
<td></td>
<td>factor income</td>
<td>Imports</td>
<td>Factor income</td>
</tr>
<tr>
<td></td>
<td>Commodity market</td>
<td>Exports</td>
<td>Factor income</td>
<td>Household income</td>
<td>FX expenditure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Factor market</td>
<td>Imports</td>
<td>Fixed cost</td>
<td>Household outlays</td>
<td>FX earnings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Entrepreneur revenue</td>
<td>Markup revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Household</td>
<td>Imports</td>
<td>Supply of goods</td>
<td>Factor income payments</td>
<td>Fixed cost</td>
<td>Household outlays</td>
<td>FX earnings</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ROW</td>
<td>Imports</td>
<td>TOTAL expenditure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table IV.1 provides the structure of SAM used in this chapter. The economy is open to international trade but there is no government, savings or investment in the economy for simplicity. The market clearing conditions could easily be observed from the SAM table. In equilibrium foreign exchange earnings of the country must equal foreign exchange spending of the country; consumption of households must equal their total factor incomes; total supply of goods (domestic sales plus imports) must equal total demand in the economy (intermediate product demand by other sectors plus consumer demand). Total expenditure of producers, which is composed of expenditures on intermediate product, variable inputs and fixed inputs must equal their total income earned from domestic and foreign market sales (exports). For the markets to clear fixed costs must equal the mark-up revenue of entrepreneurs.

**b. Choosing Functional Forms**

Unfortunately there are some restrictions on the choice of functional forms best suited to CGE modelling exercises. Ideally, one would like to utilise flexible functional forms where for any data point any set of elasticities could be achieved through an appropriate set of parameter values and hence no prior restrictions are imposed on consumer or
producer behaviour at the base equilibrium. However, in order to be suited to CGE modelling exercises, cost\(^1\) and utility\(^2\) functions need to be globally regular, that is well-behaved everywhere in price space. This is because the computational algorithms employed for finding equilibria typically involve a search path in price space which can contain points lying arbitrarily far from an equilibrium point. Lack of global regularity can thus cause an algorithm to fail even when the function is well-behaved at the benchmark equilibrium.

Lack of global regularity is not crucial for econometric estimation, where the functional forms are used to estimate the local characteristics of technologies and preference orderings from a given set of observations. In CGE analysis, on the contrary, lack of global regularity may be a problem since functional forms are used as a global representation of technologies and preferences. In these models the information available to the modeller is local, and this local information is extrapolated to the full domain of the modelling exercise by specifying utility or production functions that are locally consistent with such information. As a result, the information available to the modeller is typically limited to the calibration point and the true technology or preferences are unknown. In the absence of global information on the technology or preferences, the modeller must adopt explicitly or implicitly certain assumptions concerning the out-of-benchmark characteristics of functions on the basis of local information available (Perroni and Rutherford, 1995a, 1995b). Traditional flexible forms (such as translog, generalized Leontief and normalized quadratic models) do not guarantee global regularity\(^3\), and the functions from the CES (constant elasticity of substitution) family are the suitable ones.

\(^1\) Cost function must be nonnegative, monotonic and concave in prices.

\(^2\) Indirect utility function must be monotonic (positive expenditure share of commodities) and quasi-convex.

\(^3\) Perroni and Rutherford (1995a) compare the global properties of flexible functional forms (such as translog, generalized Leontief and normalized quadratic models) for utility function and describe the cases these models depart from regularity and cause problems. Other studies comparing the global properties of flexible functional forms include Caves and Christensen (1980), Dievert and Wales (1987), Perroni and Rutherford (1995b).
c. **Mixed Complementarity Problem**

The best way of expressing general equilibrium problems is to define the problem in a mixed complementarity problem\(^4\) format (MCP). The complementary problem adds a combinatorial twist to the classic square system of nonlinear equations, thus enabling a broader range of situations to be modeled. In its simplest form the combinatorial problem is to choose from \(2n\) inequalities a subset of \(n\) that will be satisfied as equations. In economics this property could be used to generate a model with different regimes and let the solution determine which ones are active. For example, complementarity allows the choice of only profitable sectors or firms to be active in equilibrium. Formulations of equilibria as a system of equations, on the contrary, do not allow for the model to choose the activities present, but make a priori assumption on this matter.

A mixed complementarity problem\(^5\) is specified by three pieces of data, namely the lower bounds \(l_i\), the upper bounds \(u_i\), and the function \(F(z)\). There will be a \(z\) such that precisely one of the following conditions holds (1):

\[
F_i(z) = 0 \quad \text{and} \quad l_i \leq z_i \leq u_i \\
F_i(z) > 0 \quad \text{and} \quad l_i = z_i \\
F_i(z) < 0 \quad \text{and} \quad z_i = u_i.
\]

\(^4\) Problems of this type occur in many branches of the sciences, including mathematics, engineering, economics, operations research and computer science.

\(^5\) The MCP format encompasses a number of special cases such as a linear system of equations, a non-linear system of equations, a linear complementarity problem, a non-linear complementarity problem, a non-linear program. When a model can be directly expressed as a linear or non-linear program, it is more efficient and reliable to apply a linear or non-linear programming algorithm. MCP is particularly useful for mathematical programs which cannot be processed as optimization problems.
In a more compact form, these conditions can be written as (2):

\[
0 \leq z \perp F(z) \geq 0 \tag{2}
\]

where \( \perp \) signifies that one of the inequalities is satisfied as an equality, so that \( z_i F_i(z) = 0 \).

Walrasian equilibrium to find the price and activity levels can be formulated as a complementarity problem (3):

\[
0 \leq y \perp L(P) \geq 0 \\
0 \leq P \perp S(P, y) \geq 0 \tag{3}
\]

Here, \( S(p, y) \) represents the excess supply function, and \( L(P) \) represents the loss function. Complementarity allows choosing from the activities \( y \) to run (i.e. \( 0 \leq y \)). Only those firms which do not make a loss will be chosen (i.e. \( L(P) = 0 \)). The second set of inequalities state that the price of a commodity can only be positive (i.e. \( 0 \leq P \)) if there is no excess supply (i.e. \( S(P, y) = 0 \)). Similarly, if the excess supply is positive (i.e. \( S(P, y) \geq 0 \)), then the price of the commodity is zero (i.e. \( 0 = P \)), hence no further production takes place. These conditions indeed correspond to the standard exposition of Walras’ law which states that supply equals demand if we assume all prices \( P \) will be positive at a solution.

3. Structure of the Model

a. Assumptions

The model has two countries (denoted by subscripts \( i \) and \( j \)) with open economies, but no government, savings or investments in order to keep analysis simpler. There are two final good sectors \( (X \text{ and } Y) \), two intermediate good sectors \( (X \text{ and } Z) \) and two factors of production (unskilled labour, \( L \), and skilled labour, \( S \)) in the model. Both factors of production are mobile between sectors but not countries.
Sector $X$ produces a homogeneous product under increasing returns to scale by imperfectly competitive Cournot firms. The sector faces fixed costs at both firm-level (arising from R&D), and plant-level. The firm-level fixed costs (or knowledge capital) are skilled-labour intensive relative to the final production and act as joint input reducing the added cost of a second plant. A multinational production structure is possible in this sector since knowledge capital may be fragmented from production. As a result, six different firm types, differentiated by their mode of supply to home and foreign markets, and the location of their headquarters compete in order to operate in this sector. Domestic firms (type-d firms) are headquartered in the home country and supply a foreign market via exports, while horizontal multinational firms (type-h firms) are based in home country make local productions in both countries. Vertical multinationals (type-v firms) are headquartered in the home country supply the foreign country from a plant in that country and export to the home country. These differences endow each type of firm with different strengths and weaknesses or, in other words, different cost structures as a result of which they prefer different country conditions to exist.

Since there are two factors of production in a country, both fixed cost requirements and marginal cost requirements of firms will be measured only in terms of these factors of production (skilled and unskilled-labour). The main difference between these two requirements is that fixed costs are committed a priori to production and are not affected by levels of production. Consequently, level of output relies on factor endowments left over after fixed costs are incurred in terms of factor endowments (skilled and unskilled labour). Firm-level fixed costs (e.g. research and development, further technical activities for implementing the blueprint, and managerial and coordination activities etc.) are more skilled labour intensive than plant-level fixed costs. Therefore, firm level fixed costs are measured in only skilled labour, whereas plant level fixed costs are measured in terms of both skilled and unskilled labour. The fixed cost of implementing a new plant ($G$) is the same for all types of firms, and is measured in terms of unskilled labour. In addition to the unskilled labour required for the implementation of a plant, firms require skilled labour (such as engineers and technicians working at production site, accountants etc) for managerial and coordination activities at the plant level. Domestic firms naturally incur
all costs in the home country, where their headquarters and production are located. On the other hand, internationally fragmented firms as a result have skilled labour requirements not only in the host country where headquarters are located, but in the host country where their affiliate plant is located. They also incur a technology transfer cost for supplying services of the knowledge based asset to a foreign plant. Hence, total fixed costs incurred by vertical MNFs are higher than those of domestic firms headquartered in the same country. Hence, without factor price differences vertical multinationals cannot be advantageous compared to domestic firms. Moreover, two vertical multinationals based in different countries do not co-exist. Horizontal MNFs incur the same amount of fixed costs in the home country as does a domestic firm, but horizontal MNFs also have additional fixed costs incurred in the host foreign country where the second plant is located. To sum up, total skilled labour requirements of a horizontal firm are more than a domestic firm, but due to jointness property of knowledge capital the total skilled labour requirements of a horizontal multinational firm is less than double the skilled labour requirements of a domestic firm.

In addition to skilled and unskilled labour, sector $X$ also requires some intra-industry and inter-industry intermediate products during the production process. Each unit of $X$ requires $\delta_X$ unit of intermediate product $Z$, and $\delta_X$ unit of $X$. This input-output linkage generates agglomeration economies, where the abundance of sector $X$ and sector $Z$ products in a region attract further $X$ sector firms due to lower price level for intermediate products (forward link). Similarly a large sector $X$ implies a larger home market for itself and sector $Z$ firms (backward link). As there is no labour or skilled labour mobility internationally in the model, the level of endowments in countries constitutes a constraint limiting agglomeration tendencies. Additionally as both intermediate products $X$ and $Z$ are skilled labour intensive they compete for skilled labour. This competition also works against agglomeration, strengthening the limiting force of endowments.

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6 A horizontally organised firm benefits from economies of scope due to potential cost savings from joint production of headquarter activities for more than one plant. As knowledge capital is transferable between plants with very little cost, it is less costly for two or more businesses to operate under centralized management than to function independently.
Sector $Y$ is a perfectly competitive final product industry producing a homogenous good under constant returns to scale using both labour and skilled labour. Sector $Z$, on the other hand, is a perfectly competitive intermediate product industry producing a homogenous good under constant returns to scale, using only skilled labour. The price of $Y$ is used as a numeraire ($P_Y=1$) throughout the simulations. One of the crucial assumptions of the model is that firms in the final product sector $X$ and intermediate product sector $Z$ incur transaction costs ($t$) for export sales, while transport costs of sector $Y$ are zero. Transaction costs are measured in terms of unskilled labour. All sectors are assumed to produce homogenous goods internationally in order to keep the model simple, hence the goods are not differentiated by their country of origin.

b. Production, Demand and Equilibrium

This section provides the functions representing the consumers and producers of the model, as well as the market clearing conditions as required by the SAM. There are two constant returns to scale (CRTS) industries ($Y$ and $Z$), one increasing returns to scale (IRTS) industry ($X$) and one consumer to model for each country. The economy is formulated as a mixed complementarity problem, and the variables given on the right hand-side are the associated complementary variables of equations. Only equations for country-$i$ are provided below, but symmetric equations apply to country-$j$. A summary of notation used in the chapter is provided in Table IV.2.

**Production and Factor Demand in Sector $Y$ and Sector $Z$**

Sector $Y$ has a constant returns to scale Cobb-Douglas production function$^8$. It uses both factors of production and is relatively labour intensive. Since the consumers do not

\[ Y_i = A_Y S^\beta L_1^{1-\beta}, \]

where $A_Y$ is the scale (or efficiency) parameter and $\beta$ represents the share of each factor in production.

$^7$ Cobb-Douglas production function has unitary elasticity of substitution. Elasticity of substitution measures the curvature of an isoquant. More specifically, it is the percentage change in factor ratio divided by the percentage change in the technical rate of substitution (slope of an isoquant) at a given output level.
<table>
<thead>
<tr>
<th>Y</th>
<th>homogenous good produced with CRTS, using L and S</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>homogenous high technology product produced with IRTS, using L and S</td>
</tr>
<tr>
<td>Z</td>
<td>homogenous intermediate product produced by CRTS, using only S</td>
</tr>
<tr>
<td>U</td>
<td>utility</td>
</tr>
<tr>
<td>P</td>
<td>price</td>
</tr>
<tr>
<td>Lbar</td>
<td>total unskilled labour endowment</td>
</tr>
<tr>
<td>Sbar</td>
<td>total skilled labour endowment</td>
</tr>
<tr>
<td>L</td>
<td>units of unskilled labour demanded</td>
</tr>
<tr>
<td>S</td>
<td>units of skilled labour demanded</td>
</tr>
<tr>
<td>wL</td>
<td>price of unskilled labour</td>
</tr>
<tr>
<td>ws</td>
<td>price of skilled labour</td>
</tr>
<tr>
<td>M</td>
<td>national income</td>
</tr>
<tr>
<td>c</td>
<td>units of unskilled labour required to produce one unit of value added product</td>
</tr>
<tr>
<td>b</td>
<td>units of skilled labour required to produce one unit of value added product</td>
</tr>
<tr>
<td>t</td>
<td>unit cost of shipping products between countries</td>
</tr>
<tr>
<td>F</td>
<td>units of skilled labour required for fixed costs of a firm producing X</td>
</tr>
<tr>
<td>G</td>
<td>units of unskilled labour required for fixed costs of a firm producing X</td>
</tr>
<tr>
<td>m</td>
<td>mark-up on production of X</td>
</tr>
<tr>
<td>N</td>
<td>number of firms in sector X</td>
</tr>
<tr>
<td>δ</td>
<td>share of intermediate products in final product</td>
</tr>
<tr>
<td>(XT)</td>
<td>total quantity of (X) produced in a country</td>
</tr>
<tr>
<td>(X)DEM</td>
<td>total quantity of (X) demanded in a country</td>
</tr>
<tr>
<td>(X)SUP</td>
<td>total quantity of (X) supplied</td>
</tr>
<tr>
<td>(X)IMP</td>
<td>total quantity of (X) imported</td>
</tr>
<tr>
<td>(X)DD</td>
<td>total quantity of (X) produced for domestic market</td>
</tr>
</tbody>
</table>

**Superscripts**
- d: domestic or national firm (single plant and HQ in the home country)
- h: horizontal multinational (plants in both countries, HQ in the home country)
- v: vertical multinational (single plant in the host and HQ in the home counties)

**Subscripts**
- x,y,z: type of product
- i,j: general references to countries

| X_i^k | output of X produced by the k-type firm headquartered in i and selling in j |
| F_y^k | fixed cost incurred in j by a type k firm headquartered in country i |
| S_y^k | skilled labour demanded in country j by a k type firm headquartered in country i |
| S_{X,i} | total skilled labour demand in country i by sector X |
differentiate between domestic products and imports, and there are no trade costs involved, prices in both countries are equal. Solving for the standard cost minimization problem for sector \( Y \), the unskilled labour (1) and skilled labour (2) input demand functions of the sector are written below.

\[
L_{Y,i} = \frac{Y_i}{A_Y} \left( \frac{w_{S,i}}{w_{L,i}} \right)^\beta \left( \frac{1-\beta}{\beta} \right)^\delta
\]

(1)

\[
S_{Y,i} = \frac{Y_i}{A_Y} \left( \frac{w_{L,i}}{w_{S,i}} \right)^{1-\beta} \left( \frac{\beta}{1-\beta} \right)^{1-\beta}
\]

(2)

In perfectly competitive markets producing under CRTS, representative firms take prices as given and their cost structures determine their output levels at given prices. More formally, this implies that firms maximize their profits when their marginal cost equals price. As an explicit supply function could not be derived for perfectly competitive firms, the zero-profit condition (3) is used instead in order to solve the model. The inequality sign is due to the complementarity nature of the problem. If the total cost (right-hand side) is greater than the total revenue of the firm, then output level will be zero. On the other hand, if total revenue and cost of the firm are equal, then the firm will produce at positive levels.

\[
P_i Y_i \leq w_{L,i} \left( \frac{w_{S,i} (1-\beta)}{\beta} \right)^\beta \frac{Y_i}{A_Y} + w_{S,i} \left( \frac{w_{L,i} \beta}{w_{S,i} (1-\beta)} \right)^{(1-\beta)} \frac{Y_i}{A_Y}
\]

(3)

The intermediate sector \( Z \) also produces under constant returns to scale. It is skilled-labour intensive, since it uses only skilled labour during production while needs unskilled labour only for shipment\(^9\). Below are the input demand functions (4-5) of the sector, where \( Z_{ij} \) represents output of \( Z \) produced in country \( i \) and sold in country \( j \).

\(^9\) The production function for sector \( Z \) is assumed to be: \( Z_i = A_Z S_i \), where \( A_Z \) is the scale parameter.
\[ L_{z,j} = t_z Z_y \quad (4) \]
\[ S_{z,j} = \frac{1}{A_z} (Z_{u,i} + Z_{y,j}) \quad (5) \]

As the product is homogenous internationally, the price of domestic products and imports are equal in a country. Export prices, on the other hand, include trade costs. Because of this pricing difference two cost functions are identified for the Z-sector producing in a country depending on the target market for products. If we define the total Z production in country i \((ZT_i)\) as in (6), then the inequalities (7-8) below provide the zero profit condition in the sector to produce for the domestic market \((Zu)\) and export market \((Z_y)\).

\[ ZT_i = Z_u + Z_y \quad (6) \]
\[ P_{z,j} Z_u \leq w_{s,j} \frac{Z_u}{A_z} \quad Z_u \quad (7) \]
\[ P_{z,j} Z_y \leq w_{s,j} \frac{Z_y}{A_z} + w_{t_z} t_z Z_y \quad Z_y \quad (8) \]

**Production and Factor Demand in Sector X**

Sector X produces a homogenous product under increasing returns to scale, which implies that the firms in the sector face diminishing average cost as their output level rise. In general equilibrium modelling constant average cost function (i.e. CRTS production function) is preferred due to its flexibility and simplicity. One way of introducing IRTS into the model without losing this flexibility is using a fixed cost intercept. In other words it is assumed that a subset of inputs are committed a priori to production and their costs must be covered regardless of the output level, while marginal cost is assumed to be governed by the preferred CRTS production function. The fixed costs may employ the same mix of inputs as the marginal cost, or a different set of inputs. In either case, average cost equals and takes the form of a monotonically declining function with respect to output (9).
In the model, sector $X$ is assumed to have both firm level and plant level scale economies. Since firm level scale economies arise from more skilled labour intensive operations such as R&D, it is incorporated into the model as fixed costs using only skilled labour. Plant level costs are composed of implementation of plant ($G$, measured in unskilled labour), management and coordination activities (measured in skilled labour) and technology transfer cost (only at the foreign plant, measured in skilled labour). Hence the total amount of skilled labour required by an $X$ firm ($F$) is composed of firm level scale economies plus management and coordination activities at the plant level and technology transfer cost at the foreign plant. The product $X$ is produced using not only $S$ and $L$, but also two intermediate products, $X$ and $Z$. Hence, there are both intra-industry and inter-industry linkages in the sector incorporated into the model using a fixed proportions function. The following diagram gives the structure of production.

\[ AC = \frac{FC}{X} + MC \]  \hspace{1cm} (9)
In the first stage skilled and unskilled labour are employed to produce a value added \((VA)\) product under CRTS using a constant elasticity of substitution (CES) function\(^{10}\). The unit requirements of labour \((c_x)\) and skilled labour \((b_x)\) to produce the value added product are given by (10) and (11), respectively.

\[
c_x = \frac{(1 - \gamma)^\sigma w_L^{-\sigma}}{A_x (\gamma^\sigma w_S^{(1-\sigma)} + (1 - \gamma)^\sigma w_L^{(1-\sigma)})^{\sigma/(\sigma - 1)}} \tag{10}
\]

\[
b_x = \frac{\gamma^\sigma w_S^{-\sigma}}{A_x (\gamma^\sigma w_S^{(1-\sigma)} + (1 - \gamma)^\sigma w_L^{(1-\sigma)})^{\sigma/(\sigma - 1)}} \tag{11}
\]

In the second stage, the value added product is combined with intermediate goods using fixed proportions (12).

\[
f(SKL, L, X, Z) = \min\left(\frac{1}{\delta_{VA}}, \frac{1}{\delta_X}X_{INT}, \frac{1}{\delta_Z}Z\right) \tag{12}
\]

Since we know that the firms will not waste any input with a positive price, the firm must operate at a point where \(X = \frac{1}{\delta_{VA}}VA = \frac{1}{\delta_X}X_{INT} = \frac{1}{\delta_Z}Z\). Hence, if the firm wants to

\[\frac{V_A}{w} = \left(\gamma S^\rho + (1 - \gamma)L^\rho\right)^{\sigma/\rho},\]

where \(v\) is one due to constant returns to scale and \(\frac{1}{1 - \rho} = \sigma\) (elasticity of substitution).

A CES function allows for a range of different curvature of isoquants. For example, if the elasticity of substitution equals one, then we would have a Cobb-Douglas production function. If the elasticity of substitution equals zero, then we would have a Leontief production function. Minimizing the standard cost function of \(VA\) with respect to a given level of output provides the standard first order condition:

\[
\frac{w_S}{w_L} = \frac{\gamma}{(1 - \gamma)}\left(\frac{S}{L}\right)^{\sigma - 1}
\]
produce $X$ units of output, it must use $\delta_{i\lambda} X$ units of value added, $\delta_{x} X$ units of intermediate $X$ and $\delta_{z} X$ units of intermediate product $Z$, no matter what the input prices are. Hence the cost function of a firm can be written in the form of (13). The fixed costs which are incorporated into the model to bring about economies of scale are a function of value added product.

$$C = (w_{L} c_{X} + w_{S} b_{X})\delta_{i\lambda} X + P_{X} \delta_{x} X + P_{Z} \delta_{z} X + \text{fixed cost}$$

(13)

The market structure of sector $X$ is oligopoly, where each firm produces a homogenous product, faces downward sloping demand, adjusts output to maximize profits with a common market price while anticipating the output responses of its competitors. In a classic Cournot specification each firm believes that the others will not change their output, and the change in the industry output will coincide with the firm’s own. The pricing rule is that the marginal revenue equals the marginal cost to the firm ($Price(1 - \text{markup}) = \text{Marginal cost}$). In general equilibrium (see SAM table) fixed costs should equal to the mark-up revenue of entrepreneurs. Hence we can write the general equilibrium condition that total revenue of firm equals to the total cost of the firm as (14), and the profit maximization rule that marginal revenue equals to marginal revenue as (15).

$$P_{X} X = (w_{L} c_{X} + w_{S} b_{X})\delta_{i\lambda} X + P_{X} \delta_{x} X + P_{Z} \delta_{z} X + P_{X} \text{mark}\delta_{i\lambda} X$$

(14)

$$P_{X} (1 - \text{mark}\delta_{i\lambda}) = (w_{L} c_{X} + w_{S} b_{X})\delta_{i\lambda} + P_{X} \delta_{x} + P_{Z} \delta_{z}$$

(15)

This basic cost structure is applied to the six possible firm types of the model (one of each type in both countries). The main differences between these firms (domestic firms, vertical multinational firms and horizontal multinational firms) are in their fixed cost requirements and international trade structures. For example, a vertical multinational firm headquartered in country i has skilled labour requirements in both countries. It requires $F_{i}^{Y}$ amount of skilled labour from country i in order to produce the blueprint. In country j it requires skilled labour to implement this blue-print technology in its plant ($F_{j}^{Y}$). The
cost of implementing the blueprint technology abroad is higher than implementing it at home and this additional cost of technology transfer is also embodied in $F_{ij}^Y$. In addition to these, the firm requires some skilled labour at the production level depending on the level of production ($b_XX_{ij}^d$). A vertical multinational headquartered in $i$, on the other hand, requires labour only in the foreign host country where the plant is located. The amount includes a fixed cost ($G$, for building the plant), a variable amount depending on the level of total production ($c_X(X_{ij}^d + X_{ji}^d)$) and cost of shipment of exported products ($t_XX_{ij}^d$). Given the assumptions about the firms the labour and skilled-labour demands of each type of firm headquartered in country $i$ can be summarized as below (16).

$$S_i^d = F_i^d + b_X(X_i^d + X_{ij}^d)$$
$$S_i^h = F_i^h + b_XX_i^h$$
$$S_{ij}^d = F_{ij}^d + b_XX_{ij}^d$$
$$S_{ij}^h = F_{ij}^h + b_XX_{ij}^h$$
$$S_i^v = F_i^v$$
$$S_{ij}^v = F_{ij}^v + b_X(X_{ij}^v + X_{ji}^v)$$

$$L_i^d = G + c_XX_i^d + (c_X + t_X)X_{ij}^d$$
$$L_i^h = G + c_XX_i^h$$
$$L_{ij}^d = G + c_XX_{ij}^d + (c_X + t_X)X_{ji}^d$$

All firms headquartered in country-$i$ have skilled labour requirements from this country, as well as horizontal and vertical multinationals headquartered in country-$j$ but producing in country-$i$. Similarly, domestic firms and horizontal multinationals headquartered in country-$i$ have demand for unskilled labour in this country. Horizontal multinationals and vertical multinationals which are headquartered in country-$j$ also have affiliate plants in country-$i$ and hence require unskilled labour from this country (17-18).

$$S_{X,i} = S_i^d + S_i^h + S_{ij}^h + S_i^v + S_{ij}^v$$
$$L_{X,i} = L_i^d + L_i^h + L_{ij}^h + L_i^v$$

The pricing equations for each type of firm (that marginal revenue equals marginal cost) are given below (19) with their associated complementary variables on the right-hand side. As with sectors $Y$ and $Z$, the consumers do not differentiate between domestic
products and imports of sector $X$, so that the prices of domestic products and imports are equal.

\[
P_{x,j}(1-m_{ij}^d)\delta_{ij} \leq (w_{i,j, c} + w_{i,j, b}) \delta_{ij} + P_{z,j} \delta_{z} + P_{x,j} \delta_{x} \quad X_{ii}^d
\]

\[
P_{x,j}(1-m_{ij}^d)\delta_{ij} \geq (w_{i,j, c} + w_{i,j, b}) \delta_{ij} + P_{z,j} \delta_{z} + P_{x,j} \delta_{x} \quad X_{ii}^d
\]

\[
P_{x,j}(1-m_{ij}^d)\delta_{ij} \leq (w_{i,j, c} + w_{i,j, b}) \delta_{ij} + P_{z,j} \delta_{z} + P_{x,j} \delta_{x} \quad X_{ii}^h
\]

\[
P_{x,j}(1-m_{ij}^d)\delta_{ij} \geq (w_{i,j, c} + w_{i,j, b}) \delta_{ij} + P_{z,j} \delta_{z} + P_{x,j} \delta_{x} \quad X_{ii}^h
\]

\[
P_{x,j}(1-m_{ij}^d)\delta_{ij} \leq (w_{i,j, c} + w_{i,j, b}) \delta_{ij} + P_{z,j} \delta_{z} + P_{x,j} \delta_{x} \quad X_{iy}^d
\]

\[
P_{x,j}(1-m_{ij}^d)\delta_{ij} \geq (w_{i,j, c} + w_{i,j, b}) \delta_{ij} + P_{z,j} \delta_{z} + P_{x,j} \delta_{x} \quad X_{iy}^d
\]

For oligopolistic firms the price cost margin varies parallel to the market share of the firm, and inversely with the market elasticity of demand. In case of a Cobb-Douglas demand, as is in this model, the market elasticity of demand of the product is unity and hence the mark-up rate reduces to the market share of the firm\footnote{Revenue of a Cournot type-k firm serving from j in country i is given by $R_{ij}^k = P_{X_{dem,j}} X_{j}^k$, since prices are a function of consumer demand. Hence the marginal revenue is:}

\[
\frac{\partial R_{ij}^k}{\partial X_{ji}^k} = P_{i} + X_{ji}^k \frac{\partial P_{i}}{\partial X_{X_{ji}^k}} = P_{i} + X_{ji}^k \frac{\partial P_{i}}{\partial X_{X_{ji}^k}} \frac{\partial X_{X_{ji}^k}}{\partial X_{X_{ji}^k}}
\]

\[
= P_{i} + X_{ji}^k \frac{\partial P_{i}}{\partial X_{X_{ji}^k}} \frac{\partial X_{X_{ji}^k}}{\partial X_{X_{ji}^k}}
\]

\[
= P_{i} + X_{ji}^k \frac{\partial P_{i}}{\partial X_{X_{ji}^k}} \frac{\partial X_{X_{ji}^k}}{\partial X_{X_{ji}^k}}
\]

\[
= P_{i} \left( 1 + \frac{X_{ji}^k}{\partial X_{X_{ji}^k}} \frac{\partial P_{i}}{\partial X_{X_{ji}^k}} \frac{\partial X_{X_{ji}^k}}{\partial X_{X_{ji}^k}} \right)
\]

\[
= P_{i} \left( 1 + \frac{X_{ji}^k}{\partial X_{X_{ji}^k}} \frac{\partial P_{i}}{\partial X_{X_{ji}^k}} \frac{\partial X_{X_{ji}^k}}{\partial X_{X_{ji}^k}} \right)
\]

\[
= P_{i} \left( 1 - m_{ij}^k \right)
\]

There is no price differentiation for intermediate product and consumer product. The demand for the intermediate product is not affected by price level. As a result the Marshallian price elasticity of market demand is -1. Cournot conjectures imply that $\frac{\partial X_{X_{ji}^k}}{\partial X_{X_{ji}^k}} = 1$; that is a one unit of increase in a firm's supply
Substituting the mark-up equations into the pricing equations gives expressions for output in terms of price (21).

\[
X^d \geq (\alpha M_j + P_{x,j} \delta_x T_j) \frac{P_{x,j} - [(w_{L,j} c_x + w_{S,j} b_x) \delta_v + P_{z,j} \delta_z + P_{x,j} \delta_x]}{\Delta_v P_{x,j}^2} \\
X^d \geq (\alpha M_j + P_{x,j} \delta_x T_j) \frac{P_{x,j} - [(w_{L,j} c_x + w_{S,j} b_x) \delta_v + P_{z,j} \delta_z + P_{x,j} \delta_x]}{\Delta_v P_{x,j}^2} \\
X^h \geq (\alpha M_j + P_{x,j} \delta_x T_j) \frac{P_{x,j} - [(w_{L,j} c_x + w_{S,j} b_x) \delta_v + P_{z,j} \delta_z + P_{x,j} \delta_x]}{\Delta_v P_{x,j}^2} \\
X^h \geq (\alpha M_j + P_{x,j} \delta_x T_j) \frac{P_{x,j} - [(w_{L,j} c_x + w_{S,j} b_x) \delta_v + P_{z,j} \delta_z + P_{x,j} \delta_x]}{\Delta_v P_{x,j}^2} \\
X^v \geq (\alpha M_j + P_{x,j} \delta_x T_j) \frac{P_{x,j} - [(w_{L,j} c_x + w_{S,j} b_x) \delta_v + P_{z,j} \delta_z + P_{x,j} \delta_x]}{\Delta_v P_{x,j}^2} \\
X^v \geq (\alpha M_j + P_{x,j} \delta_x T_j) \frac{P_{x,j} - [(w_{L,j} c_x + w_{S,j} b_x) \delta_v + P_{z,j} \delta_z + P_{x,j} \delta_x]}{\Delta_v P_{x,j}^2} \\
\text{The zero-profit conditions (free entry and exit) imply that mark-up revenue equals total fixed costs. Adding the zero-profit conditions complete the general equilibrium model (22) by providing the number of firms operating. The number of firms is assumed to be a continuous variable as in monopolistic competition models in the literature.}

\[
P_{x,j} m^d \delta_v X^d_{ij} + P_{x,j} m^d \delta_v X^d_{j} \leq w_{L,j} G + w_{S,j} F^d_{ij} \\
P_{x,j} m^h \delta_v X^h_{ij} + P_{x,j} m^h \delta_v X^h_{j} \leq w_{L,j} G + w_{L,j} G + w_{S,j} F^h_{ij} + w_{S,j} F^h_{j} \\ 
\text{is a one unit increase in market supply. As a result the mark-up rate is reduced to the market share of a firm.}
\]
\[ P_{X,i} m_i^s \delta X_i X_i + P_{X,i} m_i^s \delta X_i X_i \leq w_{L,i} G + w_{S,i} F_i + w_{S,i} F_i \]

Total \( X \) production in country \( i \) (23),

\[ XT_i = XDD_i + XEXP_i, \quad (23) \]

where

\[ XDD_i = N_i^d X_i^d + N_i^h X_i^h + N_j^d X_j^d + N_j^h X_j^h \]
\[ XEXP_i = N_i^d X_i^d + N_j^h X_j^h \]

**Commodity Demand**

In the model there are two types of consumers, a representative household, and sector \( X \), which uses intermediate goods to produce the final product. The representative household consumes two final goods (\( X \) and \( Y \)) and has constant-returns to scale Cobb-Douglas utility function (24). In equilibrium, the sectors make no profits, so the national income of country-\( i \) is as in (25). This income (\( M_i \)) equals budget constraint, hence in the model household income and outlays are in equilibrium. The demand for final goods by the representative consumers of country \( i \) (\( X_{C,i}, Y_{C,i} \)) are hence as follows (26):

\[ U_i = X_{C,i}^{\alpha} Y_{C,i}^{1-\alpha} \quad (24) \]
\[ M_i = w_{L,i} \bar{L}_i + w_{S,i} \bar{S}_i \quad M_i \quad (25) \]
\[ X_{C,i} = \frac{\alpha M_i}{P_{X,i}}, \quad Y_{C,i} = (1-\alpha)M_i \quad (26) \]

Since there is no demand for \( Y \) at the intermediate level, total commodity demand for \( Y \) (\( YDEM_i \)) equals the consumption demand (\( Y_{C,i} \)). On the other hand, total quantity demanded (27) in sector \( X \) (\( XDEM_i \)) is a summation of consumer demand and intermediate demand by producers (\( X_{int,i} \)).
The intermediate sector $Z$ is used only by sector $X$, hence the total quantity of $Z$ demanded is given by equation (28).

\[ Z_{DEM,i} = Z_{int,i} = \delta_Z X T_i \]  

Market clearing

In equilibrium all markets clear. The total supply of endowments ($\tilde{L}$ and $\tilde{S}$) equal the total input requirements by all sectors in the country (29-30).

\[ \tilde{L}_i = L_{T,i} + L_{Z,i} + N_i^d L_{d}^h + N_i^h L_h^h + N_j^h L_{j}^h + N_j^* L_{j}^* \]
\[ \tilde{S}_i = S_{T,i} + S_{Z,i} + N_i^d S_{d}^h + N_i^h S_h^h + N_j^h S_{j}^h + N_j^* S_{j}^* + N_j^* S_{j}^* \]

Similarly the demand and supply in each sector also clear (31-33).

\[ Y_{DEM,i} + Y_{DEM,j} = Y_i + Y_j, \quad P_T \]  
\[ Z_{DEM,i} = Z_{SUP,i} \quad \text{where} \quad Z_{SUP,i} = Z_{ii} + Z_{ji} \quad P_{Z,i} \]  
\[ X_{DEM,i} = X_{SUP,i} \quad \text{where} \quad X_{SUP,i} = X_{DD,i} + X_{IMP,i} \quad P_{X,i} \]

\[ X_{IMP,i} = N_j^d X_{j}^d + N_j^* X_{j}^* \]

According to SAM, individual agents can only spend what they earn. This gives us the accounting identity of Walras Law, which states that when each agent is on its budget constraint, the value of excess demand (price\times volume of excess demand) is identically zero. According to Walrasian equilibrium, on the other hand, demand does not exceed supply, and in equilibrium undesirable goods with excess supply have a zero price. Combination of Walras’s Law with Walrasian equilibrium generates a market clearing condition where the existence of equilibrium in k-1 markets indicate that demand must
equal supply in the kth market as well if $p_{k}>0$. As a result one sector may be dropped from the system. Price of sector $Y$ is used as numeraire (assumed to be one) and the equilibrium condition for this sector is dropped from the system.

4. Insights into the results through partial analysis

All inequality and equality conditions provided need to be solved simultaneously to find the general equilibrium condition. Although it is not possible to find the general equilibrium outcomes without computer simulations, it is possible to make some simple partial analysis where only one variable is changed, and all others are kept constant.

a. Profit Functions

In order to compare the profitability of firms under different conditions, zero profit conditions derived in (22) are re-written more explicitly by substituting the mark-up and output equations with equations given in (20) and (21). Inequalities given in (34a-34c) represent the profit functions domestic, horizontal multination and vertical multinational firms, respectively.

\[
\begin{align*}
(\alpha M_j + P_{X,J}\delta_X T_j) & \left(\frac{P_{X,J} - [(w_{L,j}c_X + w_{S,j}b_X)\delta_Y + P_{Z,J}\delta_Z + P_{X,J}\delta_X]}{\delta_Y P_{X,J}^2}\right) \\
+ (\alpha M_j + P_{X,J}\delta_X T_j) & \left(\frac{P_{X,J} - [(w_{L,j}c_X + w_{S,j}b_X)\delta_Y + w_{L,J}f_X + P_{Z,J}\delta_Z + P_{X,J}\delta_X]}{\delta_Y P_{X,J}^2}\right) \\
\leq w_{L,J}G + w_{S,J}F_j^d & \quad (N_i^d) \tag{34a}
\end{align*}
\]

\[
\begin{align*}
(\alpha M_j + P_{X,J}\delta_X T_j) & \left(\frac{P_{X,J} - [(w_{L,j}c_X + w_{S,j}b_X)\delta_Y + P_{Z,J}\delta_Z + P_{X,J}\delta_X]}{\delta_Y P_{X,J}^2}\right) \\
+ (\alpha M_j + P_{X,J}\delta_X T_j) & \left(\frac{P_{X,J} - [(w_{L,j}c_X + w_{S,j}b_X)\delta_Y + w_{L,J}f_X + P_{Z,J}\delta_Z + P_{X,J}\delta_X]}{\delta_Y P_{X,J}^2}\right) \\
\leq w_{L,J}G + w_{L,J}G + w_{S,J}F_j^h + w_{S,J}F_j^h & \quad (N_i^h) \tag{34b}
\end{align*}
\]
\[
(\alpha M_i + P_{X,i} \delta X_i) \frac{(P_{X,i} - [(w_{L,i} c_x + w_{S,i} b_x) \delta X_i + w_{L,i} f_x + P_{Z,i} \delta z + P_{X,i} \delta x])^2}{\delta X_i P_{X,i}^2} \\
+ (\alpha M_j + P_{X,j} \delta X_j) \frac{(P_{X,j} - [(w_{L,j} c_x + w_{S,j} b_x) \delta X_j + P_{Z,j} \delta z + P_{X,j} \delta x])^2}{\delta X_j P_{X,j}^2} \\
\leq w_{L,i} G + w_{S,j} F^*_{j} + w_{S,j} F^*_{j}
\]

With some simplifications\textsuperscript{12}, the profit functions of all firm types headquartered in country-\textit{i} are presented below with a clearer format (35a-35c).

\[\Pi_i = a_i (\alpha M_i + P_{X,i} \delta X_i) + b_j (\alpha M_j + P_{X,j} \delta X_j) - d_i - e_i \leq 0 \]  
(35a)

\[\Pi_j = b_j (\alpha M_j + P_{X,j} \delta X_j) + a_j (\alpha M_j + P_{X,j} \delta X_j) - d_j - e_j \leq 0 \]  
(35b)

\[\Pi^* = b_j (\alpha M_j + P_{X,j} \delta X_j) + a_j (\alpha M_j + P_{X,j} \delta X_j) - d_j - e_j - f_j \leq 0 \]  
(35c)

\textsuperscript{12} Inequalities represented in (34) could be converted into a simpler more understandable format by assigning new names to a group of variables.

\[a_i = \frac{(P_{X,i} - [(w_{L,i} c_x + w_{S,i} b_x) \delta X_i + P_{Z,i} \delta z + P_{X,i} \delta x])^2}{\delta X_i P_{X,i}^2}, \]

\[b_j = \frac{(P_{X,j} - [(w_{L,j} c_x + w_{S,j} b_x) \delta X_j + w_{L,j} f_x + P_{Z,j} \delta z + P_{X,j} \delta x])^2}{\delta X_j P_{X,j}^2}, \]

plant level fixed costs \quad d_i = w_{L,i} G

firm level fixed costs faced in the base country \quad e_i^k = w_{S,j} F^k_{i}

firm level fixed costs faced in the host country \quad f_j^k = w_{S,j} F^k_{j}

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b. Comparing profitability of firms

By making some assumptions on the initial conditions the profit effects of changes in variables may be observed for each firm type. If the initial conditions in both countries are assumed to be identical, that is both countries have the same income and relative endowment levels, then all commodity and input prices are equal initially (36).

\[ P_{x,i} = P_{x,j}, \quad w_{l,i} = w_{l,j}, \quad w_{s,i} = w_{s,j}, \quad M_i = M_j \]  

(36)

Then in the initial equilibrium following conditions also hold (37).

\[ a_i = a_j > b_i = b_j, \quad d_i = d_j, \quad e_i^k = e_j^k, \quad f_i^k = f_j^k \]  

(37)

These conditions mean that only domestic firms or horizontal multinationals are active initially, since relative wage levels are equal in both countries. Vertical multinational firms cannot compete with domestic firms if there are no wage cost differentials between two countries. Vertical multinationals face higher fixed costs due to separation of activities and technology transfer costs.

Given the initial conditions, an increase in total income of countries (\( \partial M_i = \partial M_j > 0 \)), keeping all prices constant makes multinational production more profitable than single-plant production, since serving a larger market through exports will be more expensive. Therefore, the profit levels of horizontal multinational firms (35b) increase more than the profit levels of domestic (35a) firms (i.e. \( \partial \Pi^h_i = \partial \Pi^h_j > \partial \Pi^d_i = \partial \Pi^d_j \)), since \( a > b \). While an increase in the world income supports horizontal multinationals over domestic firms, a change in the distribution of income in the world (\( \partial M_i = -\partial M_j > 0 \)) gives domestic firms in the country with higher income, an advantage against horizontal multinational firms (\( \partial \Pi^d_i > \partial \Pi^h_i = \partial \Pi^h_j = 0 > \partial \Pi^d_j \)). Higher transport costs (\( \partial t_x > 0 \)) also provide incentives for becoming a horizontal multinational firm rather than a domestic firm which...
serves the foreign market through exports \((\partial \Pi^h = \partial \Pi^i = 0 > \partial \Pi^d = \partial \Pi^f)\). Larger firm level scale economies relative to plant level scale economies \((\partial F = -\partial G > 0)\) supports multi-plant production rather than single plant production, hence gives horizontal multinationals and advantage over domestic firms \((\partial \Pi^h = \partial \Pi^i = 0 > \partial \Pi^d = \partial \Pi^f)\). To sum up, higher total income, higher transport costs, similar income levels between countries and larger firm level scale economies compared to plant level scale economies support horizontal MNFs. Differences in relative wages between countries gives an advantage to vertical multinationals over domestic firms since they can locate headquarters in skilled labour intensive country and production in unskilled labour intensive country.

The partial analyses above are similar to those of Markusen (2002). However, in this model, it is also possible to have an insight on the potential effects of locating in close proximity to intermediate product suppliers. The partial effects of agglomeration economies can be analysed through the changes in the cost of obtaining intermediate products. In the case of intra-sector linkages, a region with a relatively large manufacturing sector \(X\) implies lower costs of production for final goods as a result of savings on intermediates’ transport costs. This constitutes forward linkages. In addition to this a large final good sector provides a large local market for intermediates. This backward linkage results in a larger total expenditure on manufacturing. Firms in the country with larger manufacturing sector become more profitable as a result of lower costs. In the profit functions \((34a-34c)\), an increase in total \(X\) production in a region \((\partial XT > 0)\) make domestic firms producing in this country more profitable compared to domestic firms in the other country. Profit levels of horizontal multinationals headquartered in both countries increase equally as they both produce in both countries, hence they also become more profitable compared to domestic firms producing in the other country. A similar analysis can be done to understand the potential effects of locating close to inter-sector intermediate product suppliers. The variable that will change is within the simplified coefficients of ‘\(a\) and \(b\)’. If country-\(i\) produces more of product \(Z\), the price of this product will be lower in this country due to lack of transport costs. Lower
cost of product Z in country-i \( (\partial P_{z,i} < 0) \) will reduce the costs of firms producing \( X \) in this country. Hence, domestic firms producing in this country and horizontal multinationals headquartered in both countries will benefit from locating in close proximity to intermediate product suppliers.

These analyses only provide some preliminary deductions for the potential effects of each variable on the location decisions of multinationals. As each variable is examined keeping all other variables constant, none of the interaction between variables which normally takes place in a real equilibrium is allowed. Therefore, it is necessary to extend these analyses into numerical simulations to have an insight on the potential effects in a general equilibrium framework. Hence, a solver and suitable algorithm is required to solve the model.

5. Choosing A Mixed Complementarity Problem Solver and Algorithm

Many solution methods based on different theories have been developed to solve non-linear problems. However, due to the inherent mathematical limitations of the solution methods, none of the existing methods assure the optimal convergence of all non-linear problems (NLP). Kao (1998) investigates the performance of various non-linear programming packages on microcomputers from the viewpoints of effectiveness, efficiency, accuracy, and ease of use. The results provide information regarding the suitable package to use under different considerations. The results show that AMPL and GINO have the best ability in solving NLP problems optimally, GAMS is the most efficient package in terms of execution time, GINO has the most accurate solution, and MATLAB needs the least effort in modelling problems. Overall, GAMS and GINO show the best performance regarding all criteria followed by AMPL. All three packages are of modelling language type. The programming languages are used to code the steps and iterative procedures of the algorithm. In contrast, the principal focus of a modelling language is on representing the economic model and not the algorithm for solving it. In modelling language systems it is therefore, possible to separate the model from the
solver. This enables the user to solve the model through different algorithms without any alterations on the model itself (Kendrick and Amman, 1999).

Considering its effectiveness, efficiency, accuracy, and ease of use, GAMS\textsuperscript{13} will be used to solve for the model derived in this chapter. There are two solvers available through GAMS for MCP problems. MILES (a Mixed Inequality and non-Linear Equation Solver) employs a generalized Newton algorithm with a backtracking line search. The solver is originally developed for applied general equilibrium modelling. On the other hand, PATH is a recently developed solver, which employs a ‘global Newton’ method in which the backtracking line search is replaced by a ‘path search’. Although the algorithms share the same rate of convergence near a solution, they may follow different trajectories away from the equilibrium. Since convergence cannot always be guaranteed with either algorithm, it is helpful to have both algorithms available when working with large or difficult problems (Rutherford, 1995a, 1995b).

Billups et al. (1997) compare various computer algorithms for solving large scale MCP which could be interfaced through GAMS. The comparisons for these algorithms are done based on a library of test problems. MILES and PATH are both mature algorithms and suitable for the purposes of this study. The results of Billups et al. illustrate that PATH is not only more efficient than MILES in the solution time required, but also more successful for computing a solution to the problems. PATH algorithm manages to solve 94% and 98% of the problems for large and small models, respectively, while MILES finds a solution for only 83% and 84% of problems for large and small models, respectively.

\textsuperscript{13} More information on GAMS modelling language syntax and resources of information are provided in the Appendix.
6. Conclusions

The aim of the chapter is to generate a theoretical framework in order to analyse the relationship between the multinational production activity and the combined effects of country, sector and firm characteristics. The knowledge capital model (Markusen and Venables, 1995, 1996; Markusen et al., 1996) is extended to include sectoral linkages to allow for analysing the potential effects of agglomeration economies.

The model is presented as a mixed complementarity format with 50 variables to be determined from inequalities and equalities. Due to the complexity of the model, it is not possible to observe the general equilibrium outcomes in an analytical framework. Through partial analyses it is only possible to gain some insight into the potential effects of variables. These simple analyses suggest that higher total income, higher transport costs, similar income levels between countries and larger firm level scale economies compared to plant level scale economies support horizontal MNF production. Differences in relative wages between countries give an advantage to vertical multinationals over domestic firms since they can locate headquarters in skilled labour intensive country and production in unskilled labour intensive country. Firms also benefit from locating in close proximity to the suppliers of intermediate product.

Although these analyses provide some initial deductions on the profitability of different firm structures on different occasions, they fail to provide any exact results of the active regimes where firms may co-exist. The analyses also overlook the non-linear relationships between variables. As a result it is not possible to observe any potentially different effects of small and large changes. In addition to these, the interactions among factors are ignored in partial analyses, since only one variable is allowed to change while all others are kept constant. Therefore, the model needs to be analysed through numerical simulations to have an insight on the potential effects in a general equilibrium framework.
V. CGE SIMULATIONS ON THE LOCATION DECISIONS OF MULTINATIONAL FIRMS

1. Introduction

The partial equilibrium analyses in the last chapter gave a simple initial insight into the potential effects of endowments, trade costs and sector characteristics on the location of multinational production. As only one variable at a time is allowed to change, these analyses lack the interactions among variables which would take place in a real economy. This chapter will take the analyses one step further and allow for all variables to be determined endogenously in a simulation environment. The purpose of the chapter is to solve the general equilibrium model derived in the last chapter in order to obtain testable results for the factors affecting the location of affiliate production. As the model is solved in a general equilibrium framework allowing for all variables to interact each other, the results are expected to reflect the non-linear and non-monotonic structure in real data. Hence, for instance a fall or reduction in trade costs from high levels may not have the same effect as a fall or reduction when the trade costs are already low. Similarly, the changes may show differing results for country pairs with similar or different endowment characteristics, as well as in different sectoral conditions. Being able to reflect this variety of effects is the main benefit of general equilibrium simulations. This allows them to mimic the diversity in a real economy. In this chapter, a special emphasis will be given to the interaction of country effects with sectoral characteristics, stressing the potential effects of changes in sectors with supply linkages.

The first step for carrying out computational general equilibrium analyses involves the process of defining the intercepts, share parameters and behavioural elasticities of the mathematical representation of the economy. These parameters are generally determined through SAM (social accounting matrix) transactions data, which is
constructed from national accounts and other government sources with various adjustments to ensure the existence of equilibrium in all markets. With a large amount of data (such as time series of input-output matrices) statistical estimation techniques may be employed to find parameter values that characterize agents in the artificial economy. The ideal way to estimate the parameters would be to use an econometric approach that takes into account all system-wide constraints. However, this approach is not routinely used by CGE modellers due to data insufficiency and computing resource constraints. In some applied models to estimate simultaneously all of the model parameters using the time series methods would require very large number of observations, or severe identifying restrictions. Therefore, an econometric approach, which is largely developed by Jorgenson (1984), based on estimating sub-systems of a CGE model (demand function, production function etc.) is preferred. Although partitioning the model into sub-models may help to reduce or overcome the problem of data, partitioning does not fully incorporate all the equilibrium restrictions that are emphasized in a general equilibrium model (Shoven and Whalley, 1992). Mansur (1980) notes the difficulty in formulating a maximum likelihood procedure incorporating all equilibrium restrictions. A less formal method used is to extract information from pooled data, or use time series data of cost shares after abstracting them from random influences. Further information on the advances in econometric methods in CGE models could be found in Canova and Ortega (2000).

A more common method for constructing an applied general equilibrium is to calibrate parameters working backwards from the initial SAM to construct economic agents whose transactions duplicate those observed. This is a deterministic procedure, where the main assumption is that the benchmark data is defined as equilibrium. The transactions in the SAM are used to calibrate a model function, calculate a policy parameter or define a model constraint. During the calibration process, values of the relevant elasticities need to be specified by the researcher based on other researches in the literature or even on guess work, since the results in the literature are contradictory and hence not robust. The reason that elasticity values cannot be determined through calibration is that the CES functions, mainly used in CGE studies, have three parameters, but the SAM provides only two pieces of information to work with. This information includes the level of output for given factors and that the isoquant passes
through a specified point with specified slope. Therefore, without the knowledge of elasticities of substitution, it is possible to construct different isoquants consistent with the same data but with different curvatures. Although calibration procedure also has some shortcomings due to its deterministic approach and lack of any statistical testing of the model specification used, it has been used more commonly in CGE analyses than the econometric approach. Additional references and information on various aspects of applied general equilibrium are available in Mansur and Whalley (1984), Waelbroek (1984), Adams and Higgs (1990), Shoven and Whalley (1992), Francois and Reinert (1997).

Before continuing onto the next section, where the benchmark equilibrium and calibration results used in the rest of the chapter are described, there are a few points to mention. For the general equilibrium model being employed, where the source of production is differentiated according to firm types (domestic firms, horizontal and vertical multinational firms), data restrictions do not allow for analysis at the policy level. First of all the available data is not detailed in the firm types. Also, in calibrating a model with scale economies, it is necessary to incorporate some information on the extent of the scale economies that exist. Failure to incorporate high quality information on scale economies may lead to misleading results. However, it is difficult to construct a SAM incorporating this information with the available data. Moreover, many scale based estimates for sectors in the literature are not robust and rely on a small family of engineering studies from 1960s and 1970s. Therefore, an artificial benchmark equilibrium, which replicates the stylized characteristics of multinational firms, will be generated instead. Although this may sound arbitrary, the important point in these analyses is not finding a completely realistic model, but finding a model which will provide an answer to the questions asked. Therefore, it is essential to construct a simple but highly stylized theoretical specification which captures a high number of features of the data. The interest is in examining deviations of the model from a hypothetical equilibrium, not in the actual values of the equilibrium. The simulations in the rest of the study will employ a "what-if" approach and will give an insight into the potential factors affecting the location decisions of multinational firms rather than actual policy effects.
The chapter is organised as follows. First, an artificial SAM will be introduced and the parameter values to be used in the mathematical functions will be calibrated using this benchmark equilibrium. Then counterfactual equilibrium results for different income, relative endowment and trade cost levels will be obtained. After deriving some generalised conclusions from these results, the effects of different firm and sector characteristics such as scale economies, industrial linkages and internalisation will be analysed through various simulations. All simulations reported in this chapter are solved using PATH as a solver, which is suitable for large scale mixed complementarity problems. As mentioned in the last chapter, this solver operates under GAMS (General Algebraic Modelling Systems), which is a software package to solve systems of equations. It should be noted that using MILES as a solver also provided very similar results for most counter-factual equilibria. Only in some cases MILES failed to solve the model while PATH provided a solution. The GAMS code for the general equilibrium model used for simulations is provided in the Appendix.

2. Benchmark Equilibrium and Calibration

The main purpose is to find out under what conditions countries become more desirable hosts for multinational investment. For this purpose, many relative endowment and income level combinations will be examined for different trade costs and sector and firm characteristics. In order to avoid offsetting effects of factors, changes in sector and firm characteristics will be introduced after the basic results on the effects of endowments are obtained. Therefore, initially a benchmark for an economy with X and Y sectors, where sector X uses only skilled labour and labour, but no intermediate input (as in Markusen et al., 1996), is constructed (Table V.1). The model is calibrated to the centre of Edgeworth box where both countries have equal share of endowments, and same level of income. All factor prices are also assumed to equal one. The sector is initially assumed to have high trade costs, high total scale economies and high firm/plant level scale economies. Due to high trade costs and no factor price differentials in this equilibrium only horizontal multinationals are active.

1 More information on GAMS software, documentation on various solvers and introductory tutorials can be found on the following website: www.gams.com.
The fixed cost structures of inactive firms in this equilibrium (i.e. vertical multinationals and domestic firms) are provided in the notes section of Table V.1.

The values chosen in benchmark equilibrium reflect the assumptions of the model. First of all, the model is based on differences between the cost structures of different type of firms. According to the assumptions total fixed cost of horizontal MNFs are less than double the total fixed costs of a domestic firm. In addition to this operating a plant abroad is more costly than operating a plant in home country. Horizontal multinationals operate two plants, one in home and one in host country, while domestic firms and vertical MNFs are both single plant firms. Domestic firms only produce in the home country, and vertical multinationals only produce in the foreign country. For a sector with high total scale economies and high firm/plant level scale economies, horizontal multinational firms are assumed to spend 20 units as fixed cost. They require 12 skilled labour (costing 12 units, as all prices equal 1) in the home country, where headquarter is located. They need 4 units of skilled labour in then foreign country, where one of the plants is located. In addition to these, they require 2 units of unskilled labour in each country to operate the plants.

The notes section of Table V.1 provide additional information regarding the fixed cost requirements of inactive firm types (domestic firms and vertical multinationals) in the benchmark equilibrium. Using the information on the fixed cost requirements of horizontal multinationals and the general assumptions of the model, the cost structures of firms can be obtained in more detail. In order to produce the given amount in the benchmark equilibrium, firms need nine units of skilled labour in the home country for headquarter activities. Additionally, three units of skilled labour are required to operate a plant in the home country. Due to technology transfer costs (one unit of skilled labour), a firm needs four units of skilled labour to operate a plant abroad. Firms also need two units of unskilled labour per plant. To sum up, total fixed cost of horizontal firms are 20 units, vertical multinationals are 15 units, and domestic firms
## Table V.1

### Benchmark Equilibrium: No industrial Linkages

<table>
<thead>
<tr>
<th>in values</th>
<th>Activities</th>
<th>Commodity market</th>
<th>Factor market</th>
<th>Fixed costs</th>
<th>Households</th>
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<tbody>
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<td>100</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

### Notes:
1. The model is calibrated to the centre of Edgeworth Box with high trade costs, so that only horizontal multinationals are active in equilibrium. Sector X is produced only by using skilled and unskilled labour without any intermediate inputs. The sector also has high fixed costs (total scale economies) and high firm/plant level scale economies. Product X and Y has same expenditure share in the incomes of consumers.
2. The parameter values of the model are: \( \alpha = 0.5; \beta = 0.1, A_X = 1.384; \gamma = 0.409, A_X = 1.908, \sigma = 3, \delta_X = 0, \delta_Z = 0, \delta_{VA} = 1 \). The initial values of exogenous variables of the model are: \( L_{bar} = 154, S_{bar} = 46; F_{ij}^d = 4.8, F_{ij}^d = 4.8, F_{ij}^d = 1.6, F_{ij}^d = 3.6, F_{ij}^d = 1.6, G = 0.8; \tau_x = 0.3 \).

### Table Notes:
- The initial values of endogenous variables of the model are: \( N_{ij} = 0, N_{ij} = 2.5, N_{ij} = 0, m_{ij} = 0.2, P_{X_i} = 1.25, X_{ij} = 16, X_{ij} = 16; P_{Y_i} = 100, w_{L_i} = 1, w_{S_i} = 1 \) (all values are symmetric for country-j). Initial total quantity of X produced in country-i is 80.
- Fixed cost structure of inactive firms in the benchmark equilibrium:
  - \( X_i^d = 12, 0, 2, 0, 14 \)
  - \( X_i^e = 9, 4, 0, 2, 15 \)

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are 14 units. Hence the total cost of a horizontal multinational headquartered in country-i is 1.43 times of (less than double) a domestic firm headquartered in country-i. Also, without factor price differentials between two countries a vertical multinational firm cannot compete with domestic firms headquartered in the same country, since a vertical MNF faces higher total fixed costs than a domestic firm.

In a market clearing equilibrium, the total of value of fixed costs should equal total value of mark-up revenue of entrepreneurs. Mark-up rate can be calculated as share of mark-up revenue in total value of value added X production (i.e. 10/50=0.2). This means there are a total of 5 active firms (i.e. 1/0.2=5), half of which (i.e. 2.5) are headquartered in country-i. The initial benchmark price level in sector X (i.e. 1/(1- (1-markup))) is 1.25. This means that in benchmark equilibrium 40 units of X (i.e. 50/1.25=40) is produced by $X^h$ and another 40 units is produced by $X^v$ in country-i. Accordingly the total quantity of X produced in country-i is 80 units, and the value of X production is 100 (i.e. 80×1.25), which equals the total value of demand for X sector products. The total demand is composed of only by consumer demand as there are no intermediate product requirements. All factors of production are assumed to have unitary price level in this initial equilibrium. Price of sector Y is used as numeraire throughout the simulations, and hence all products and factors are measured in relative terms of Y.

The parameters of production functions are calculated using the initial benchmark values of demand for factors of production, their prices and an assumed elasticity of substitution\(^2\). Input shares ($\gamma$) can be calculated using the standard first order condition by minimizing the cost function. Sector Y is produced by a Cobb-Douglas production function, which has a unit elasticity of substitution, while sector X is assumed to have elasticity of substitution which equals 3. After obtaining input share values scale

\(^2\) A CES production function can be defined as follows: $VA = A\left(\gamma S^P + (1-\gamma)L^P\right)^{1/\rho}$, where $\nu$ is one due to constant returns to scale. Minimizing the standard cost function of this value added function with respect to a given level of output produces the standard first order condition as:

$$\frac{w_S}{w_L} = \frac{\gamma}{1-\gamma} \frac{S}{L}^{\rho-1},$$

where elasticity of substitution equals: $\sigma = \frac{1}{1-\rho}$. 

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parameters \((A)\) can be calculated using these values. Hence the parameters can be calculated using the following formulas:

\[ y = \frac{w_g S^\gamma}{w_g S^\gamma + w_k L^\gamma}, \]  

\[ A = \frac{\frac{X}{\left(\beta S^\sigma + (1 - \beta)L^\sigma\right)^\frac{\sigma}{\sigma - 1}}} \]

The last parameter required for the model is share of each product in consumption. In the benchmark, it is assumed that consumers spend their income equally on \(X\) and \(Y\) products \((\alpha=0.5)\).

By changing the parameter values (exogenous values) of this initial model (Table V.1), counterfactual equilibria for different relative endowment, income and trade cost levels may be calculated through simulations. However, in order to examine the effects of a change in the relative importance of firm/plant level scale economies on the regime, slight changes in the benchmark equilibrium are required. Table V.2 presents the new benchmark equilibrium for a sector with high trade costs, high total scale economies and low firm/plant level scale economies. Firm level skilled labour requirement are dropped to 5 from 9, and plant level labour requirements are doubled from two units to four while plant level skilled labour requirements are unchanged. Since the total fixed costs are kept the same as before, initial mark-up and price levels are not affected. All parameter values and unit of output produced are identical to the previous benchmark. Only initial endowment levels are adjusted to make sure the initial benchmark factor price levels equal one in both countries, while producing the same quantity of value added output (a total of 80 units of \(X\) produced in country-\(i\) by \(X_{ii}^h\) and \(X_{ih}^h\)). Table V.3 provides a benchmark for an economy with high trade costs, low total scale economies and high firm/plant level scale economies. Total fixed costs are half of the initial benchmark. This means initial mark-up and price level are lower, and the number of active firms is higher. Hence, the competition in the sector is more intense as entry costs are lower. All parameter values and the units of output produced
are the same as the first benchmark, although initial endowment levels are adjusted to ensure unit factor costs.

Table V.4 and Table V.5 present the benchmark equilibrium for sectors with inter and intra sector linkages, respectively. The parameters for the share of intermediate products in production could be obtained by dividing the total quantity of intermediate input used to total quantity of $X$ produced (3-5).

$$\delta_{VA} = \frac{VA}{X}$$ (3)

$$\delta_{X} = \frac{X_{INT}}{X}$$ (4)

$$\delta_{Z} = \frac{Z}{X}$$ (5)

In order to keep the models comparable, same parameter values of production functions and consumption are employed. Quantity of $X$ produced at the initial benchmark equilibrium is also identical to all previous benchmark values.

When the general equilibrium model is solved using the parameter values obtained through calibration, the initial results should mimic benchmark values. This constitutes an important checking point for the validity of the model. If the model solved fails to replicate the initial benchmark values, then there must be some mistake either during the derivation of the mathematical model (that it is not compatible with the assumptions) or during its transfer to a solver. Moreover, providing the initial equilibrium results of endogenous variables is important to aid the solver during simulations.
### TABLE V.2

**Benchmark Equilibrium: Low scale economies**

<table>
<thead>
<tr>
<th>Activities</th>
<th>Commodity market</th>
<th>Factor market</th>
<th>Fixed costs</th>
<th>Households</th>
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</table>

Notes: The model is calibrated to the centre of Edgeworth Box with high trade costs, so that only horizontal multinationals are active in equilibrium. Sector X is produced only by using skilled and unskilled labour without any intermediate inputs. The sector also has low fixed costs (total scale economies) and high firm/plant level scale economies. Product X and Y has same expenditure share in the incomes of consumers. The parameter values of the model are: \( \alpha = 0.5; \beta = 0.1, A_Y = 1.384; \gamma = 0.409, A_X = 1.908, \sigma = 3, \delta_X = 0, \delta_Z = 0 \delta_V A = 1. \) The initial values of exogenous variables of the model are: \( L_{bar} = 143, S_{bar} = 37; F_{ij}^d = 1.333, F_{ij}^d = 0, F_{ij}^b = 1.333, F_{ij}^b = 0.444, F_{ij}^r = 1.0, F_{ij}^r = 0.444, G = 0.222; \tau_X = 0.3. \) The initial values of endogenous variables of the model are: \( N_{ij}^d = 0, N_{ij}^b = 4.5, N_{ij}^r = 0, m_i = 0.111, P_{Xj} = 1.125, X_{ij}^b = 8.8889, X_{ij}^b = 8.8889; PY = 1, Y = 90; wL_i = 1, wS_i = 1(all values are symmetric for country-j). Initial total quantity of X produced in country-i is 80.
TABLE V.3
Benchmark Equilibrium: Low firm/plant level scale economies
in values
Households

Notes: The model is calibrated to the centre of Edge worth Box with high trade costs, so that only horizontal multinationals are active in equilibrium. Sector X is produced only by
using skilled and unskilled labour without any intermediate inputs. The sector also has high fixed costs (total scale economies) and Iow frrmJplant level scale economies. Product X
and Y has same expenditure share in the incomes of consumers. The parameter values of the model are: a = 0.5; P= 0.1, Ay =1.384; Y= 0.409, Ax = 1.908, a =3, Ox = 0, Oz = 0 OVA
= 1. The initial values of exogenous variablesd of the model are: ~bar = 158, Sibar = 42; Fjjd = 3.2, Fi/= 0, Fjjh = 3.2,
= 1.6, F/ = 2, Fi/ = 1.6, G = 1.6; tx = 0.3. The initial values
h
V
of endogenous variables ofthe model are: Ni = 0, Ni = 2.5, N j = 0, mjh = 0.2, PXj= 1.25, xl = 16, Xijh = 16; PY=I, Yj=100; wLj=l,wSj=1 (all values are symmetric for country-j).
Initial total quantity of X produced in country-i is 80.

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114


TABLE V.4
Benchmark Equilibrium: Inter-industry linkages

<table>
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<th>in values</th>
<th>Activities</th>
<th>Commodity market</th>
<th>Factor market</th>
<th>Fixed costs</th>
<th>Households</th>
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Notes: The model is calibrated to the centre of Edgeworth Box with high trade costs, so that only horizontal multinationals are active in equilibrium. Sector X is produced only by using skilled and unskilled labour and intermediate input Z. The sector also has high fixed costs (total scale economies) and high firm/plant level scale economies. Product X and Y has same expenditure share in the incomes of consumers. Initially Z is allowed to be produced in both countries. The parameter values of the model are: $\alpha = 0.5; \beta = 0.1; \lambda = 1.384; \gamma = 0.409, \omega = 1.908, \delta_X = 0, \delta_Z = 0.114 \delta_{VA} = 0.909; A_Z = 1, tz = 0.3$. The initial values of exogenous variables of the model are: $L_{bar} = 163, S_{bar} = 57; F_{ii} = 4.8, F_{ij} = 0, F_{ik} = 4.8, F_{ik} = 1.6, F_{ij} = 3.6, F_{ij} = 1.6, G = 0.8; tx = 0.3$. The initial values of endogenous variables of the model are: $N_{i}^{a} = 0, N_{j}^{b} = 2.5, N_{i}^{x} = 0, m_{i}^{h} = 0, m_{j}^{h} = 0.2, PX_{i} = 1.25, X_{ii}^{h} = 17.6, X_{ij}^{h} = 17.6; PY = 1, Y_j = 110; \omega L = 1, o S = 1$. After obtaining the parameter values using this symmetric equilibrium, the model is resolved for an asymmetric version where sector Z is allowed to be produced only in country-i.
### Table V.5

**Benchmark Equilibrium: Intra-industry linkages**

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**Notes:** The model is calibrated to the centre of Edgeworth Box with high trade costs, so that only horizontal multinationals are active in equilibrium. Sector X is produced by using skilled and unskilled labour and intra-industry (X) intermediate inputs. The sector also has high fixed costs (total scale economies) and high firm/plant level scale economies. Product X and Y has same expenditure share in the incomes of consumers. The parameter values of the model are: $\alpha = 0.5$, $\beta = 0.1$, $\gamma = 1.384$, $\sigma = 0.409$, $\delta X = 1.908$, $\delta = 0.167$, $\delta Z = 0$, $\delta_{YA} = 0.833$. The initial values of exogenous variables of the model are: $L \text{bar} = 154$, $S \text{bar} = 46$; $F_{ii} = 4.8$, $F_{ij} = 0$, $F_{ii} = 4.8$, $F_{ij} = 1.6$, $F_{ii} = 3.6$, $F_{ij} = 1.6$, $G = 0.8$, $\Gamma = 0.3$. The initial values of endogenous variables of the model are: $N_{ij}^d = 0$, $N_{ij}^h = 2.5$, $N_{ij}^v = 0$, $m_i^h = 0.2$, $PX_i = 1.25$, $X_{ii}^h = 19.2$, $X_{ij}^h = 19.2$; $PY = 1$, $Y_i = 100$; $w_{Li} = 1$, $w_{Sl} = 1$ (all values are symmetric for country-j).
3. Computational General Equilibrium Analysis

The purpose of the following CGE analysis is to observe the deviations from the benchmark equilibrium brought about by new parameter (exogenous) values. The effects of income, relative endowments, trade costs and sectoral characteristics are of interest. New parameter values for different variables will be introduced only after the main attributes of the previous effect is clarified. Therefore, the analysis will start from the first benchmark equilibrium with given sectoral characteristics and allowing for changes only in endowments and later in trade costs. The significance of the sectoral characteristics will be investigated afterwards. The main concern is to find the effects of changes on active firm types in equilibrium (i.e. to find out which conditions are more desirable for each type of firm) and the level of affiliate activity (i.e. to find out which conditions support higher volume of affiliate production).

a) Country-specific factors and trade costs

In order to find out the potential effects of the relative size and endowments of countries for attracting multinational firms, the model is solved for 361 different combinations of relative endowments by altering the distribution of world endowment by 5-percent steps. This enables to analyse all possible country pairs that may have trading or multinational production links. The results of simulations are presented in an Edgeworth-Box, where country-i is measured from the southwest corner and country-j from the northeast corner. The axes are the shares of the countries in total world endowment of skilled and unskilled labour endowment.

Figure V.1 is a summary of the distribution of active firms for different endowment levels of countries for a sector with high trade costs (shipment requires 0.30 units of labour per quantity exported), no supply linkages, high scale economies and high firm to plant level fixed costs. Before interpreting the simulations results, the relative endowment and income combinations within the Edgeworth box need to be clarified.

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Parameters used in the simulations are:
\[ \alpha = 0.5, \beta_r = 0.1, \beta_T = 1.384, \beta_{X,V4} = 0.409, \delta_X = 1.908, \delta_Z = 0, \delta_Z = 0 \]
The benchmark equilibrium (as given in Table V.1) is realized in the centre box, where both countries share total world endowments and hence income equally. Along the southwest-northeast (SW-NE) diagonal the two countries have identical relative endowments but differ in size. Above this diagonal, country-i is comparatively advantageous in skilled labour, and below this diagonal comparatively advantageous in unskilled labour intensive products. In each cell endowment allocation changes according to the values on axes, while income is determined endogenously depending both on quantity and prices of endowments of the country. The income distribution of country-i is given Figure V.2 for each endowment combination. As illustrated in the figure, the income share of country-i gets larger as the country’s share of both endowments increase (i.e. towards the right of the figure). The boxes are shaded according to similarity of income shares. The relative sizes of countries differ extremely towards the south-west and north-east corners, while countries tend to have more similar incomes towards the middle of the figure. The line in the middle, which is slightly sloped to left, is the ‘equal income’ axis and incomes of countries differ parallel to this axis as they depart further.

The results (Figure V.1) illustrate that for high trade costs horizontal multinationals dominate towards the centre of Edgeworth Box. Analysing Figure V.1 in conjunction with Figure V.2, indicate that horizontal firms prefer to function between countries with similar or only moderately different incomes. They also prefer relative endowment differences between country pairs to be low. For country pairs with similar income but significantly different relative endowments or countries with significantly different income but similar relative endowments horizontal firms and domestic firms tend to compete. Domestic firms, on the other hand, are the only active firms when the relatively labour endowed country is very small (i.e. first row on the Edgeworth-box). The rest of the country pairs have mixed regimes of all three firm types. Vertical multinationals become active in production when countries differ significantly both in their relative endowments and sizes, or differ extremely in their sizes.
Figure V.1 Equilibrium Regimes (high scale economies, high trade costs, no sectoral linkages): Parameters used in the simulations are: $a=0.5$, $b=0.1$, $A_Y=1.384$; $\beta_{YVA}=0.409$, $A_X=1.908$, $\delta_X=0$, $\delta_Z=0$; $t_X=0.3$.

Figure V.2 Income shares of countries: Assumptions are the same as in previous figure. Values in boxes show the % share of country-i income in total income.
The full set of active firm types is given in Figure V.3. The numbers in each cell represent the location of headquarters of active firm types (i.e. 1 for horizontal multinational firms, 2 for vertical multinational firms, 3 for domestic firms). For example, in the south-west corner of the box, where country-i has 5% of both world endowments and hence income, and country j has 95% income, vertical multinationals headquartered in country-i and domestic firms headquartered in country j are active (20.300). Since vertical firms headquartered in country-i produce in j, all production, in this box, takes place in country-j. In the middle of the graph, where both countries are equal in endowments and income, horizontal MNFs headquartered in each country are active (1.001), and hence production takes place in both countries. When country-i has 50% of unskilled labour endowments and 60% of skilled labour endowments, only horizontal firms headquartered in country-i are active (1.000). The horizontal MNF produces in both countries, in domestic plants in country-i and affiliate plants in country-j. Therefore although there is X sector production in both countries, affiliate production takes place only in country-j.

Figure V.3 also provides an answer to the question of the links between endowments of a country and the volume of affiliate production. In addition to showing active firms in equilibrium, each cell illustrates the total level of affiliate sales taking place. The cells have been shaded according to the level of production. From the graph, it may be observed that total affiliate sales are none or at very low levels when one country-is extremely scarce in skilled-labour, and very small (i.e. in the first row and the last row of Edgeworth-Box). There are two darkly shaded sections in the figure where affiliate sales are at their highest levels. These sections correspond to when relative endowments and sizes of countries are significantly different, and the country which is comparatively advantageous in skilled-labour intensive products is smaller in size than the labour intensive country. Hence, total multinational production reaches its highest level when one country is small, skilled-labour intensive and labour scarce, and the other country is large, labour intensive and abundant in both endowments. These country characteristic are compatible with vertical MNF activity.

4 Total affiliate production (or total affiliate sales) of country-iequals the value of output of plants in country-i owned by horizontal or vertical multinationals headquartered in country-j. Total affiliate production is the sum of affiliate production taking place in each country.
Figure V.3  Equilibrium Regimes and Affiliate Production: Assumptions are the same as in Figure-I. Values in boxes show active firms headquartered in either country at the given endowment shares. When countries are exactly the same in their endowments (each country have 50% of skilled and unskilled labour), only horizontal firms headquartered in both countries are active (1.001). This means that there is affiliate production in both countries. When country-I owns 15% of skilled labour and 5% of labour, vertical firms headquartered in country-i and domestic firms headquartered in country-j are active (20.300). This means that all production takes place in country-j.
On the SW-NE diagonal where relative endowments are equal, affiliate sales are low for large income differences (i.e. corners of the Edgeworth box), but keep rising towards the middle of the graph as income differences disappear. Therefore, similarities in income levels seem to encourage overall multinational production. Multinational production seems to be quite high in general between countries with moderately different incomes and relative endowments. The active firm type under these conditions is horizontal multinational firms.

Figure V.4 illustrates the same equilibrium results only for when there is positive affiliate production in country-i. It is more obvious from this figure that when a country is advantageous in labour endowment to it is more likely that it will attract multinational production. Although it is advantageous to be labour-intensive, still this does not mean that a county attracts more affiliate production as it only gets more and more labour intensive. Affiliate production tends to increase towards the right of the box. In this part of the box country-i is not only more labour intensive, but also has a larger income (or market potential). Accordingly, it may be sensible to conclude that countries with cheap labour plus a large market are attractive to multinational investors. There is also an increase in affiliate sales as the labour intensive country gets more abundant in skilled labour. This is due to skilled labour requirements of multinationals in the host country such as engineers, technicians, accountants etc. One thing clear from these figures is that the link between multinational production and country endowments is not a monotonic link which can be summarized easily.

b) Trade costs

In the analyses to follow, trade costs are assumed to measure all costs of doing business at a distance such as lack of face to face contact, more complex and expensive communication and information gathering, different languages, legal system, product standards, cultures and existence of shipping costs and tariffs. Recent years have witnessed lower international trade cost levels, with the advancements in technology, a trend for trade liberalization and regional integration, all of which resulted in lower shipping costs and tariffs as well as convergence in tastes, cultures and product standards. Examining the individual and joint effects of trade costs (with
Figure V.4 Equilibrium Regimes and Affiliate Production in Country-i: Assumptions are the same as in Figure I. Values in boxes show active firms headquartered in either country at the given endowment shares. Only boxes where there is affiliate production in country-i are filled in.
other country and sector characteristics) is essential to project future developments in international production. A major difference between the cost structures of horizontal and vertical multinationals and domestic firms is the trade costs they face. Horizontal MNFs avoid these costs by producing in both markets. Therefore, the first expected outcome of lower trade costs on firm types is that horizontal MNFs become less profitable as there is less benefit from tariff jumping and there are two plants to run. On the contrary, single plant firms which rely on serving the other market through exports gain advantage as a result of lower trade costs.

Figure V.5 gives an idea on the potential changes in the equilibrium production structure as a result of changing trade costs. Figure V.5a delivers the simulation results for high trade costs, and hence is identical to Figure V.1. Figure V.5b, on the other hand, shows that for low-medium level trade costs. The number of country pairs, where only horizontal multinational firms operates drops considerably, while more single plant firms (vertical MNFs and domestic firms) become active. Figure V.5c present the simulation results for low trade costs, where domestic firms become dominant for similar income and endowment countries (towards the middle of Edgeworth-Box). For low trade costs affiliate activity continues only between countries with significant differences in income and/or relative endowments. Although not illustrated in graphs, for very low levels of trade costs vertical MNFs may also lose advantage compared to domestic firms, if relative factor cost between countries is not significant enough to cover the transfer cost of vertical MNFs to operate a plant in a foreign country.

The affiliate production levels for each country pair at different trade costs are provided in a 3-D setting in Figure V.6. The results linked to country endowment effects are similar to those of before, the figures showing the same saddle like look that is affiliate production increasing towards the middle of Edgeworth-Box as a result of similarity between countries, which supports horizontal multinational production, and reaching a maximum level for large labour intensive countries with abundant skilled labour. The interactive effect of trade costs with endowments is observable through comparisons of the three figures (Figure V.6a-Figure IV.6c) utilizing different trade cost levels. With lower trade costs, horizontal multinational production
Figure V.5 Effects of trade costs on equilibrium regimes: a) High trade costs, $t_x=0.30$; b) Low-medium trade costs, $t_x=0.15$; c) Low trade costs, $t_x=0.10$. 

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Figure V.6  Effects of trade costs on total volume of affiliate production:

a) High trade costs, \( tx=0.30 \);

b) Low-medium trade costs, \( tx=0.15 \);

c) Low trade costs, \( tx=0.10 \)
loses its appeal and affiliate production drops between similar countries, while affiliate production by vertical MNFs continues. At very low trade costs, horizontal multinational production between similar countries is completely replaced by domestic production.

The outcomes from the simulations draw attention to a potential rise in vertical multinational structures as a result of falling trade costs globally. Especially within closer regions, which experience more convergence in standards, and tastes rather than only falling trade barriers, there may be a shift towards single plant production to benefit from scale economies and low costs of exporting.

c) Results on Country Characteristics and Trade costs

The results obtained embody many non-linear and non-monotonic relationships. Therefore, it is not possible to generalise the results, and hence say, for instance that lower trade costs decreases/or increases affiliate production. Instead the effects of the changes have to be analysed interactively with other factors, and have to be classified to a group of characteristics jointly. For the purposes of obtaining more clear and testable results, the results presented in 3-D graphs will be reduced into some 2-D analyses to identify common characteristics of individual boxes.

The first question of interest is the effects of a change in home and host country trade costs. Previous simulations employed symmetric trade cost levels for both countries. Therefore, in the following simulations parent and host country trade costs will be differentiated. It is assumed that country-i increases its custom duties to discourage imports, while country-j maintains the same level. The changes in the volume of affiliate production in country-i are shown in Figure V.7a, for when trade cost in country-i is increased from 0.15 to 0.30, while the trade cost in country-j is still 0.30. The change is positive for all country pairs. An increase in host country trade costs encourages affiliate production by supporting further horizontal multinational production. The rise in the trade costs do not discourage vertical MNF plants either, since their exports back to the home country are not affected from this rise. As a result, the increase is the largest in the middle of the graph for countries with
relatively similar income. On the other hand, if host country trade cost is unaltered and home country trade cost has increased, only vertical MNFs operating in this country are affected. The effect on the volume to affiliate production is negative, as it is more costly for vertical multinational firms to export to home country (Figure V.7b).

**Proposition 1:** Trade cost levels of the host country effect the volume of affiliate production positively by supporting horizontal multinational activity which benefit from tariff jumping.

**Proposition 2:** Home country trade costs have a negative impact on the affiliate production of vertical multinationals. This means when the home country is small and relatively skilled labour endowed, a fall in trade cost of the home country will cause an increase in the host country affiliate production.

Considering these propositions regarding the individual effects of home and host country trade costs, it is possible to infer the potential effects of a simultaneous change in trade costs of both countries. For example, when countries reduce their tariffs mutually (i.e. as a result of a trade agreement or regional integration agreement), the intra-regional FDI (or FDI between country pairs with a trade agreement) is expected to be more of vertical type and less of horizontal type. Horizontal multinational activity loses its appeal as a result of lower host country trade costs, and vertical multinational activity will ascend due to lower home country trade costs.

The next question is what the impact of higher total world income is on international production. Statistics on affiliate production point to a positive link between these variables. Therefore, it is important that the model replicates this trend. Figure V.7c shows the difference in the volume of affiliate production in country-i, when total world income is approximately 40% higher. The difference is positive for all country pairs, indicating that both vertical and horizontal multinationals will benefit from this. Figure V.8 and Figure V.9 examine the effects of world income in more detail, illustrating both the equilibrium regimes and the volume of affiliate production for
Figure V.7 Change in the total volume of affiliate production in country-i:

a) Trade cost of host country-i is raised to 0.30 from 0.15, while trade cost of parent country-j is kept unchanged at 0.30.

b) Trade cost of host country-i is kept unchanged at 0.30, while trade cost of parent country-j is increased from 0.15 to 0.30.

c) Total world income is increased by 43%.
Figure V.8 Equilibrium regimes: a) High total world income, medium trade costs, $t_x=0.20$; b) 30% lower total world income, medium trade cost, $t_x=0.20$.

Figure V.9 Total volume of affiliate production a) High total world income, medium trade costs, $t_x=0.20$; b) 30% lower total world income, medium trade cost, $t_x=0.20$. 
two different world income levels. The distribution of equilibrium regimes among country pairs does not show large differences for different world income levels. Higher total income seems to only slightly favour horizontal multinational production, while lower total income slightly favours single plant production. The effects of total income are more obvious on the total volume of affiliate production. A 30% decrease in total world income leading to lower total affiliate production in the world (Figure V.9).

**Proposition 3:** Higher total income encourages more affiliate production in each country.

The following analysis will summarize the simulation results for specific groups of countries. Choosing specific country groups, such as equal income, allows for changing other country characteristics, such as relative endowments in a controlled manner. According to international production statistics, multinational activity has been highest between high income countries throughout decades. Among these countries total income has been high, and differences between incomes and relative endowments have been relatively low. Figures V.10a summarizes the results for equal income countries. In this simulation, countries are assumed to share world endowment of labour equally, while their shares of skilled labour endowment differ. For example, when the share of skilled labour endowment of country-i is 0.5, relative endowments become equal as countries already have equal shares of labour. To the right of point 0.5 on the horizontal axis, country-i is more skilled labour intensive, and to the left more unskilled labour intensive. Hence the potential effects of relative endowment changes may be observed through this simulation. Figures V.10a presents the volume of total affiliate production for different trade cost levels. Except when the trade cost becomes very low, total affiliate sales between equal income countries are highest when relative endowments are equal or similar.

Figures V.10b investigates potential effects of market size changes on multinational production. The simulations solve the general equilibrium model for 19 cases, each of which represent increasing shares of country-i income in total, keeping relative endowments of countries identical. As has been mentioned before, countries have
Figure V.10 a) Effects of relative endowments and trade costs on total affiliate production
b) Effects of market size and trade costs on total affiliate production
c) Effects of market size and trade costs on total horizontal affiliate production
identical relative endowments on the SW-NE axis, while the income share of country-i increases again from SW corner to NE corner. Hence, the simulations include the country pairs on this axis, allowing for income distribution to change. The results suggest that total affiliate production increases as countries have more similar incomes (i.e. towards the middle of the graph). In this section of the figure, only horizontal multinationals are active. At lower trade costs smaller size differences are tolerated by horizontal multinationals, the spread of the figure narrowing down. The negative effects of lower trade costs on horizontal multinationals may also be observed from Figure V.10c. At low trade costs there is no horizontal firm activity in the graph.

In Figure V.10b, there is also a rise of multinational activity at significant size differences (i.e. towards the right and left ends of the figure). This activity comes from vertical multinational firms which benefit from operating a plant in the larger country with abundant endowments. This section of the graph is more sensitive to trade cost changes, and benefits from reductions in trade costs as it exports to the home country at a lower cost.

Proposition 4: Similar income and relative endowments yield higher total affiliate production in the world at higher trade costs.

Proposition 5: Affiliate production in a country increases when the host country is large, and trade costs are lower.

These propositions are compatible with the stylized country characteristics multinational firms prefer to operate in. Table I.4 have presented the distribution of FDI stocks in the world, revealing a preference towards high income developed countries. Even among the developing countries, the countries which are preferred for multinational production are the ones with relatively high incomes and development levels.

The analyses up to this point have mainly looked into the effects of changes on total affiliate production. However, it may be useful to separate individual country results.
Figure V.11a and Figure V.11b illustrate affiliate production in country-i, affiliate production in country-j as well as total affiliate production for high and low-medium trade costs. The results suggest that affiliate production in a country is higher when the parent country is slightly larger than the host country.

**Proposition 6:** Affiliate production in a country increases when parent country is larger than the host country but when the difference is not extreme.

It is also evident from the figures that multinational activity is negligible when the country is very small. This finding is parallel to the insignificant amounts of affiliate activity in less developed countries (LDCs). The small domestic markets and low skilled-labour endowments of these countries make them unattractive locations despite their low labour costs.

**Proposition 7:** If a country is very small, it does not attract multinational production at any trade cost.

Figure V.12a presents similar analyses for equal income countries at high trade costs. The results suggest that affiliate production in a host country reaches its peak, when the countries are similar, but host country is slightly more labour intensive. Before generalising this result, a case with different country sizes needs to be checked. Figure V.12b gives the results of solving the general equilibrium model for two countries when one country owns approximately 80% of world income. The horizontal axis shows the share of skilled labour owned by country-i. This represents the abundance of skilled labour in the country as well as the relative endowment levels since country-i owns 80% of world labour endowments. When country-i also owns 80% of skilled labour, relative endowments of countries are equal. To the left of point 0.80 on the horizontal axis, country-i is labour intensive, and to the right skilled labour intensive. Affiliate production in country-i is at its maximum when the country is both labour intensive and abundant in skilled labour, and it drops if the country is skilled labour intensive or scarce in skilled labour.
Figure V.11  Total affiliate production and affiliate production by country
a) High trade costs, tx=0.30
b) Low-medium trade costs, tx=0.15
Figure V.12  Effects of relative endowments on host country affiliate production

a) Equal income countries at high trade cost, \( t_x=0.30 \)
b) Large versus small country at high trade costs, \( t_x=0.30 \)

Figure V.13  The joint effects of comparative advantage in labour and market size
Proposition 8: Affiliate production in a country increases when the country is both labour-intensive and abundant in skilled labour.

The next figure (Figure V.13) illustrates the volume of affiliate sales on row nine of the Edgeworth-Box where countries have equal shares of skilled labour. Towards the right of the horizontal axis both the labour share intensity and income share of country-i increases. Hence the graph shows the joint impact of income and relative endowments. Affiliate production in country-i tends to increase as the country becomes more labour intensive and has a greater market potential. In the simulations provided, both horizontal multinationals and vertical multinationals produce in the country as the country becomes larger and both endowments become abundant.

Proposition 9: Affiliate production in a country increases as the country becomes more labour intensive and has a greater market potential.

These propositions on trade costs and country characteristics can be interpreted jointly to deduce the potential effects of regional integration on multinational activity, such as the EU. A regional fall in trade costs may have different impacts on intra-regional FDI and extra-regional FDI. A fall in trade costs of home and host country provides support for more vertical multinational firms and deters horizontal multinational investment. Hence relative size and input cost differences will gain importance in the location decisions of multinationals. As a result of the shift towards efficiency-seeking multinationals from market-seeking multinationals, some countries may gain and some may lose investors during the integration process. Hence, the distribution of multinational activity within the region will be affected. Within the region, large countries with relatively cheap labour and abundant skilled-labour are expected to attract larger amounts of FDI. The regional integration is expected to have a different impact on multinational investors from countries outside the region. As the host country trade costs are not changed towards extra-regional countries, the impact on FDI from extra-regional countries will not be due to trade cost changes. Rather, the effect will be as a result of a growth in market potential, since when a firm invests in any country within the region it will be able to serve all other regional countries without any tariffs. Therefore, the region can be thought of as one large country
receiving multinational investment from countries outside the region as a result of its market potential. If the integrated region increases trade barriers against countries outside the region, then a tariff-jumping incentive will emerge for investors from extra-region countries. The increase in trade costs against extra-regional investors may be as a result of a choice by the domestic market as they prefer to trade with companies within the region rather than export from outside. This preferential treatment may act as a barrier against exporters into the region. Hence, in order to keep their market share, they may switch to multinational production rather than exporting.

d) Sector and firm-specific factors

This section analyses the differences on the location decisions of firms from different sectors, that is with different scale economies, industrial linkages and government policies (such as taxes).

Figure V.14a illustrates the active firms in equilibrium at high trade costs for all relative endowment and income combinations as in Figure V.5a. However, this time (Figure V.14) the sector has a lower ratio of firm/plant level scale economies (i.e. using benchmark in Table V.3). The distribution of equilibrium regimes in the Edgeworth-Box is similar to previous results, since horizontal MNF are active for similar income and relative endowment countries, while vertical multinationals become active with dissimilarities in income and relative endowments. The main difference at same trade cost levels is that horizontal MNFs are active for a significantly smaller number of country combinations. On the other hand, vertical MNFs become active at even moderate differences. These results suggest that the strength of firm level and plant level scale economies in a sector has an impact on active firm types in equilibrium. When firm level scale economies are high, multi-plant production structure and hence horizontal multinationals are supported. On the contrary, high plant level scale economies encourage single plant firm structures, and hence vertical multinationals and domestic firms.
Figure V.14  Low firm/plant level scale economies same level total scale economies
a) High trade costs (tx=0.30)    b) Medium trade costs (tx=0.20)
c) Low-medium trade costs (tx=0.15)
Figure V.14b and Figure V.14c illustrates the equilibrium regimes for lower trade costs for the same sector. The general effect of trade cost is the same as in Figure V.5, and horizontal multinationals lose advantage against single plant firms, which now can export at lower costs while benefiting from scale economies. Yet, in Figure V.14, the equilibrium regimes change towards single plant firms more swiftly than in Figure V.5. The equilibrium regimes at low F/G scale economies seem to be more sensitive to trade cost changes. At lower trade costs horizontal MNF structure is replaced with vertical MNFs and domestic firms for a larger set of country pairs.

Figure IV.15a illustrates the affiliate production levels between equal income and equal relative endowment countries, respectively, for a sector with low F/G scale economies. Total scale economies are, however, the same as before. The results are not different to those of a sector with high F/G fixed costs. Hence, the total affiliate production reaches a maximum when countries are similar. Although not explicitly shown on the graph affiliate production in country-i reaches a maximum when the country is relatively labour-intensive and slightly smaller than the parent country. However, as illustrated in Figure V.14, the relative importance of firm versus plant level scale economies has an impact on the sensitivity of production regime to changes in trade cost levels. Figure V.15a also support that for a sector with lower F/G fixed costs, the decline in horizontal affiliate production is much larger at lower trade costs compared to a sector with higher F/G fixed costs.

Similar results can be deducted from Figure V.15b, where relative endowments are identical, and only the relative sizes of countries change. With lower trade costs, affiliate production between similar countries (i.e. where horizontal affiliate production is dominant) decreases more than for a sector with higher F/G ratio. The sectors with lower F/G seem, however, to be more suitable for affiliate activity between countries with moderate to large size differences, where vertical multinationals start gaining advantage against horizontal multinationals. Relatively high plant level scale economies generate a tendency towards single plant firms.

Figure IV.5a and Figure IV.14a represent high trade costs (tx=0.30), and Figure IV.5b and Figure IV.c represent low-medium trade costs (tx=0.15).
Figure V.15  Low firm/plant level scale economies (total scale economies are the same as initial benchmark) a) Effects of relative endowments and trade costs on total affiliate production b) Effects of market size and trade costs on total affiliate production

Figure V.16  Low firm/plant level scale same level economies (total scale economies are the same as initial benchmark): The joint effects of comparative advantage in labour and market size
The result in Figure V.16 also supports the view that vertical MNFs may become active for much smaller country size and relative endowment differences. However, this time for very large country differences domestic firm production is also active and competes with other firm types.

**Proposition 10:** Higher F/G supports multi-plant production, and lower F/G supports single-plant production. For single plant sectors trade cost changes have a larger impact on the amount of affiliate production.

Figure V.17 illustrates affiliate production at high trade costs for sectors with different levels of total scale economies. Lower total scale economies indicate that the sector is more competitive and entry barriers are low. Figure V.17a replicates the results for a sector with high scale economies using the initial benchmark equilibrium in Table V.1. Figure V.17b provides the results when total scale economies are 50% lower. The benchmark equilibrium for this simulation is provided in Table V.2. There is a clear reduction in the total affiliate production for the sector with lower total scale economies. The difference is highlighted as the total scale economies are reduced further in Figure V.17c. The difference between the figures supports the fact that multinational production is more compatible with higher total scale economies, or in other words, imperfect competition. This result is compatible with the statistics on multinational production. Table I.3 have presented the sectoral distribution of inward FDI stocks indicating that the capital and technology intensive sectors such as chemicals, electrical and electronic equipment and motor vehicles attract a significant share of world FDI, while low technology sectors such as textile, publishing, rubber and plastic products constitute a small share of total world FDI stock.

**Proposition 11:** Multinational activity is more pronounced for sectors with higher total scale economies.
Figure V.17  Effects of total scale economies on the volume of affiliate production

a) High total scale economies  b) Medium total scale economies

c) Low total scale economies
e) Industrial linkages and agglomeration

Another potential factor which may have an impact on the location decisions of multinational firms is the potential benefits through proximity to suppliers. Depending on the sectoral linkages in the production structure, proximity to an intermediate sector may be rather important for a firm to reduce its costs, for which otherwise it would have to rely on imports at higher prices. This section will look into the potential effects of sectoral linkages and agglomeration economies on multinational production activity. The main purpose is to investigate whether just the existence of other firms attract further affiliate production into a region. Hence the effects of other factors such as market potential need to be separated from the agglomeration effect which leads to a spatial concentration of production.

Previous studies have shown that horizontal multinational firms actually tend to weaken agglomeration tendencies of firms (Markusen and Venables, 1996; Ekholm and Forslid, 2001). Nevertheless, agglomeration may occur eventually with vertical multinationals at lower trade costs. Yet, this is expected to happen at a more gradual level than the abrupt changes as in core-periphery models (Ekholm and Forslid, 2001). In addition to the potential existence of horizontal multinational firms, immobile factors of production also act as centrifugal forces limiting concentration of activity in a region.

As the partial equilibrium results suggest firms prefer to be in close proximity to intermediate input producers and reduce their costs. First, the presence inter-sectoral supply linkages between firms will be analysed. In this case, in addition to the factors of production (i.e. unskilled-labour and skilled labour), sector $X$ also requires intermediate input $Z$ produced by another sector. The initial (symmetric) benchmark for this case is provided in Table V.4. However, as both $Z$ and $X$ are skilled labour intensive sectors coexistence of these sectors in a country means higher competition and hence higher prices for skilled labour. This effect will work against agglomeration in equilibrium. Due to the offsetting effects of centrifugal forces, it is not easy to observe the potential impact of the existence of inter-sector linkages in a symmetric environment.
Therefore, an extreme case is chosen in which the intermediate sector-Z is only active in country-i. Figure V.18 illustrates affiliate production activity in and Edgeworth-Box setting for two different sectors, one with low inter-sectoral linkages (Figure V.18a) and one with higher inter-sector linkages (Figure V.18b). In both graphs, affiliate production in sector $X$ is active in country-j for low income levels of country-i which already accommodates sector Z. As country-i becomes larger, it becomes available to accommodate both sectors simultaneously. The asymmetric appearance in the graphs illustrate that affiliate production is active in country-i for a higher number of country pairs. Hence, affiliate production in sector $X$ is more likely to locate in country-i to be in close proximity to intermediate product sector Z.

**Proposition 12:** Affiliate production prefers to locate in a region where intermediate inputs are cheaper, as long as competition for factors of production by all sectors do not make the location disadvantageous.

Intra-industry linkages create self reinforcing agglomeration of production. The locational patterns of firms depending on country characteristics are the same as before. The only difference is that producers of $X$ benefit from being close to other sector $X$ producers. Therefore, countries with high $X$ production are expected to attract further $X$ production. As higher income should be expected to attract more production due to market size, this effect is eliminated by using adjusted results as the ratio of volume of production to income.

Figure V.19 shows the ratio of volume of total production (i.e. domestic and multinational firm production) to income for country-i. A ratio of one indicates that all demand by consumers is provided by production in the country by domestic firms or affiliates. At the benchmark equilibrium (equal income and endowment countries) when the ratio is 1.20 both consumer demand and intermediate product demand by $X$ sector is supplied by production in the country. When the ratio is higher than this, country $X$ accommodates more than the total demand (consumer demand + intermediate product demand) in the country. Figure V.19 suggests that when country-i is very large, production of $X$ concentrates in the country. This effect becomes more prominent at low trade costs.
Figure V.18  Inter industry linkages: Asymmetric countries, intermediate sector produced only in country-\(i\).  
\(a\) weak linkages  
\(b\) strong linkages

Figure V.19  Ratio of volume of total production to income for country-\(i\)
This concentration tendency, however, is not only due to the market potential of this country, but also to benefits from plant scale economies and agglomeration economies. In order to separate the individual effect of agglomeration economies, two sectors, one without intra-industry linkages and one with intra-sector linkages are simulated (Figure V.20). From high to low trade costs both sectors agglomerate, producing more than the total demand in the country, when the country is very large. At very low costs, however, there is an increasing gap between the ratios of these two sectors, indicating the extra agglomeration effect born from intra-sector linkages. Higher production of $X$ in a country attracts further sector $X$ production due to low prices of intermediate sector product. To sum up, sector $X$ tends to concentrate in the larger country not only due to its market potential, but also to benefit from both scale economies and existence of intra-sector linkages. This process of clustering is triggered by low trade costs.

Figure V.21 looks into two sectors both having intra-industry linkages, but one with high scale economies and one with low scale economies. The sector with higher scale economies tends to show more agglomeration tendencies at large income levels in country-i for high to low trade cost levels. This tendency, however, disappears for very low trade costs (i.e. at very low trade costs, both graphs become adjacent), as the effects of intra-sector linkages become more dominant, and as result both sectors show similar concentration tendencies.

The simulations above looked into the agglomeration tendencies in total production (i.e. domestic and multinational firm production). The subsequent analysis will focus on the effects of agglomeration economies on only multinational production and the behaviours of MNFs in sectors with and without intra-industry sector linkages will be compared. Other than their differences in supply linkages, the sectors that are compared next have identical characteristics in terms of total scale economies or relative firm versus plant-level scale economies. The following figures provide the simulation results for the volume of affiliate production. In order to account for the total country size differences in simulation benchmark equilibriums (i.e. due to the presence of an intermediate sector in one sector, and not in the other), volume of total affiliate production is divided by the total income.
Figure V.20 Intra industry linkages and trade costs

a) High trade costs 

b) Medium trade costs 

c) Low trade costs
Figure V.21 Intra industry linkages and scale economies
a) High trade costs   b) Medium trade costs   c) Low trade costs
Figure V.22 illustrates that affiliate production also tends to concentrate in large countries. For the regions where horizontal multinationals are dominant, the difference between the two lines is mainly due to intermediate demand. Hence there are not any agglomeration economies attracting further production into the area. This result is in line with the propositions in the literature that horizontal MNFs tend to weaken concentration within regions. On the other hand, as size differences between countries increase and single plant firms gain advantage, the difference between the lines is much higher than the level of intermediate demand generates. The difference emerging between two sectors at high host country income levels is born by intra-sector linkages and triggered by the presence of plant-level scale economies and lower trade costs.

As Figure V.23 presents, affiliate production in sectors with higher scale economies are more likely to agglomerate than sectors with low total scale economies. This result of the model replicates a stylized fact on multinational production. Raw statistics (Table I.7) show that multinational firms are geographically most concentrated in high technology sectors such as semiconductors and bio-technology. These sectors also have very high export ratios as a result of low shipment costs, and show less dependency on regional factors such as culture or tastes. These characteristics make such sectors suitable for vertical multinational firm activity as well as geographical concentration. Other sectors such as motor vehicles or appliances, which are produced at a medium-high technology level, also show some tendency towards concentration in some regions, although to a lesser extent than high technology sectors. Moreover, these sectors face higher shipment costs as a result of the weight of the products. Low technology sectors, on the other hand, are geographically the most dispersed ones.

Proposition 13: Affiliate production in sectors with high scale economies, low trade costs and high supply linkages tend to agglomerate in countries with industrial clusters.
Figure V.22 Intra industry linkages, trade costs and affiliate production

- a) High trade costs
- b) Medium trade costs
- c) Low trade costs
Figure V.23 Intra industry linkages, scale economies and affiliate production
a) High trade costs     b) Medium trade costs     c) Low trade costs
4. Conclusions

This chapter has provided various testable propositions for the potential effects of country, sector and firm characteristics on the factors affecting the location of affiliate production. The propositions are deduced from general equilibrium simulations allowing country endowment levels, sectoral characteristics (i.e. scale economies) and trade costs to interact with each other. The simulations are successful in capturing the diversity in real data through non-monotonic and non-linear results. The main contribution of the chapter is the incorporation of supply linkages into the knowledge capital model through which further characteristics of multinational firms are captured in a general equilibrium environment. This allows for a better observation on the sources of sectoral differences in multinational activities in conjunction with host country’s comparative advantages and hence better policy decisions to benefit the host country. Promoting sectors which will interact with the existing supplier network within the country may contribute to the dynamic comparative advantage of the country in the long term. The formation of industrial clusters in an economy may trigger a process as a result of which initially similar countries may end up with different sizes and comparative advantages.

The simulations replicate various stylized characteristics of multinational production such as compatibility with high total scale economies. Higher firm level scale economies tend to encourage horizontal multinational production while higher plant level scale economies promote vertical multinational production. The simulation results suggest that similar income and relative endowments yield higher total affiliate production at higher trade costs attracting tariff jumping horizontal multinational firms. Multinational firms also prefer countries with higher market potential, cheap labour and abundant skilled labour. Affiliate production favours locations where intermediate inputs are cheaper, as long as competition for factors of production by all sectors do not make the location disadvantageous. Locating close to intermediate sectors may result in agglomeration economies in high technology sectors at low trade costs and hence further attraction of firms into the country. The findings on the effects of supply linkages are important, since MNFs in some sectors show an increasing tendency for locating in close proximity to clusters of related firms. The findings are
also not confined to only manufacturing sectors with intermediate input demand. More and more MNFs choose to contract their whole production systems, or headquarter activities such as call centres and concentrating on their core activities. Consequently, having a strong supplier network within the country is becoming an important factor for attracting multinationals into the country.

The knowledge capital model has further potential to be extended in future research. For policy analysis one extension may be to introduce trade costs into the agricultural sector (sector Y). Although this will not change the main essence of 'what if' type experiments performed here, one potential result is that the range of parameters where agglomeration occurs may be reduced. This is due to the fact that agricultural trade costs work against agglomeration, since a location with concentrated manufacturing sector will have to import these products which have higher prices as a result of trade costs. Another extension may be to allow factors of production to move in response to international factor price differences, and hence allow for skilled and unskilled labour mobility between countries. The model may also be expanded to incorporate agglomeration externalities through the knowledge production function allowing for locational spillovers to reduce the cost of subsequent innovations in a region where headquarters locate.

Having obtained various propositions on the location choices of multinational firms, the next step is to perform statistical analysis and empirical tests on the suitability of the model to data.
VI. TESTING THE MODEL OF AFFILIATE PRODUCTION
IN MANUFACTURING SECTOR

1. Introduction

Chapter V has provided various testable propositions for the potential effects of country, sector and firm characteristics on the locational determinants of affiliate production. Allowing for interactions among variables in a general equilibrium framework, the diversity in real data has been captured. In this chapter, the propositions concluded from these computational general equilibrium (CGE) simulations are tested empirically on manufacturing sector. For this purpose a large bilateral country data set is constructed to represent a range of developed and developing home and host country partners. This large data set helps to test the locational characteristics both horizontally and vertically-integrated multinational firms (MNFs) may find attractive. The main challenge for finding a good empirical representation of the model is due to the presence of non-linear and non-monotonic effects of variables suggested in the CGE simulations. These characteristics require a non-linear empirical specification with various interaction terms. The main contribution of this chapter is specifying, estimating and testing an empirical model, which incorporates endowment characteristics as well as sectoral differences which potentially affects the choice and level of multinational production. Detailed analyses are carried out in order to choose a correct specification and estimation method for the model.

The plan of this chapter is as follows: Section 2 explains the specification of the model in association with the CGE results. Section 3 gives details on the construction of the data set and alternative variables, while Section 4 provides the preliminary OLS estimation results. The problems in the model are dealt with and various remedies to improve the
performance are suggested in Section 5. Section 6 discusses the final estimation results and section 7 concludes.

2. Model Specification

The computational general equilibrium simulations in Chapter V demonstrated the resource-seeking (e.g. human resources), market-seeking (e.g., host country market) and efficiency-seeking (e.g. factor cost differentials, agglomeration economies) motives of multinational firms. Depending to their motivations, multinational firms may choose horizontally or vertically integrated production structures. The main difficulty for capturing all these motivations for different firm structures is that one country or firm characteristic which supports one type of multinational production may have adverse effects on the other. For example, the simulations suggest that host and home country trade costs have different effects on horizontally and vertically integrated MNFs. The trade cost levels of the host country have a positive impact on the volume of affiliate production of horizontally integrated MNFs which benefit from tariff jumping, and no effect on vertical MNFs. Home country trade costs, on the other hand, have a diverse impact on the affiliate production of vertically integrated multinationals. This means that when vertical MNFs are active, a fall in trade cost of the home country will cause an increase in the host country affiliate production.

The CGE simulations also demonstrated that the volume of production (sales) is likely to be higher when the total market potential is larger. A higher level of total income of home and host countries supports both the horizontally and vertically integrated multinational production. Total horizontal affiliate production reaches a maximum when two countries are assumed to have similar income levels and relative endowment structures. As these firms duplicate roughly the same activities in both countries, they benefit from similarities between the home and host countries such as similar income levels, endowment structures and tastes. At the individual country level horizontal affiliate production in a host country is highest when the parent country is slightly larger than the host, but when the size difference is not extreme. This inverse U-shape relation
between parent country size and affiliate sales needs to be represented in estimated equations. Vertically integrated MNFs, on the other hand, become more advantageous when the parent country is small and skilled labour intensive, while the host economy provides a large market potential and cheap labour. Hence, they benefit from separating the production activities with different factor intensities and locating them into countries according to relative factor costs.

One of the most striking results of the simulations is that the countries, which jointly offer a large market and cheap labour in addition to adequate levels of skilled labour are the most attractive ones for affiliate production. In this combination of relative endowment and income levels, vertical and horizontal multinationals tend to co-exist. Although MNFs prefer low unskilled labour wages in the host country, they still do have some skilled labour requirements in the host country (i.e. technicians, accountants etc.). For this reason, the skilled labour ratio in the total labour force is also an important factor for attracting multinationals into a host country. Another important factor is the clustering of firms and production in a host economy. Agglomeration economies tend to occur in sectors with higher scale economies. Hence, an interaction term, composed of the scale economies in the sector and the size of manufacturing (or all production) in the host country, may help to capture the agglomeration effect in the econometric model.

Given these results, the following equation (1) has been proposed for estimation purposes, where \( \text{AFFSALE} \) is the real volume of production (or sales) by affiliates in country-\( j \), of parent firm in country-\( i \):

\[
\text{AFFSALE} = \beta_0 + \beta_1 \text{TOTINCOME} + \beta_2 \text{PINCOMESH} + \beta_3 \text{PINCOMESH}^2 + \beta_4 (\text{HINCOMESH} \times \text{COMPSKL}) + \beta_5 \text{HSKLRATIO} \\
+ \beta_6 (\text{SCALE} \times \text{HINCOMESH}) + \beta_7 \text{HTRADEC} + \beta_8 \text{PTRADEC} + \varepsilon
\]  

(1)

In the specification given the initial letters \( p \) and \( h \) represent parent (home) and host countries, respectively. TOTINCOME is the total level of income of home and host country. INCOMESH represent the income share of a country in the TOTINCOME. COMPSKL represent the comparative advantage of a country in skilled labour. SKLRATIO is the ratio of skilled labour in the total labour force, SCALE is the scale economies in the sector, TRADEC is the level of trade cost.
In the specification above, the coefficient of total income of home and host countries \((\beta_1)\) is expected to be positive. This coefficient tests the proposition that higher total income supports higher affiliate activity (i.e. proposition 3 of Chapter V). The inverse-U shape relation between parent county size and affiliate sales is captured with the second and third independent variables (i.e. propositions 4-7 of Chapter V). A positive coefficient for the income share of parent country \((\beta_2)\) and a negative coefficient for the squared version of the same variable \((\beta_3)\) are expected. The squared income share of the parent country is included in order to penalize high differences in income levels. The joint effect of the host country income share and the comparative advantage in skilled labour \((\beta_4)\) is expected to be negative, since large market potential and relatively cheap unskilled-labour seem to attract potential multinational investors rather than cheap skilled labour (i.e. proposition 9 of Chapter V). The skilled labour ratio variable tests the significance MNFs give to abundance of skilled labour in the countries they choose to invest (i.e. proposition 8 of Chapter V). The coefficient of this variable is \((\beta_5)\) is expected to be positive. The next variable measures the joint effect of scale economies and income share of host country. The findings of last chapter indicate that MNFs of technology or capital-intensive sectors benefit from locating in close proximity to industrial clusters. The coefficient of this variable \((\beta_6)\) is anticipated to be positive. In this interactive agglomeration term, the level of scale economies in the sector is represented by the overall scale economies of the parent country. The reason for this is the fact that the more technology intensive the production in the parent country, the more likely they are to invest abroad in technology intensive products. Finally, the coefficient of host country trade cost \((\beta_7)\) is expected to be positive, while the coefficient of home (parent) country \((\beta_8)\) is expected to be negative.

3. Data

Most empirical studies tend to use FDI flows or stocks to proxy multinational activity in a country. However, multinational FDI flows or stocks include only funds transferred from the parent company, and as a result overlooks to the fact that the MNFs may finance their operations by taking up loans in the host economy to fund future expenditures. In
that case effective FDI flows into the host economy may be low or zero, despite the continuing activities of MNFs in the economy. Some studies have overcome this problem by employing the data on capital expenditures of countries abroad regardless of source of financing of the funds invested. In this chapter, the affiliate sales (or production) data is used to capture the multinational activity in an economy. Although the data is scarcer, this variable is more meaningful in economic terms.

Figure VI.1 Full data coverage of country pairs

Until recently, the only internationally available information on foreign investment was on capital stocks and flows collected for balance of payments statistics. The OECD now also collects and reports data on the performance of foreign affiliates of the OECD countries. The majority of data is based on inward investments, although a few countries (i.e. USA, Germany, Italy) also provide information on their outward investment performance. One of the performance measures reported is the volume of turnover (or production for some countries) of affiliates, and this will be used as the dependent variable (AFFSALE) in this study. The data enables to arrange it according to parent and host country pairs over a period of 1985-1999. However, not all countries report the volume of affiliate turnover (or production) every year and especially before 1992 the majority of home and host countries reported are developed countries. Two data sets are
constructed, one \textit{(AFFSALEZ)} with turnover data including sales reported as zero (missing values are left as missing values), and one \textit{(AFFSALE)} with only positive volume of sales (no zero values). The original data set with zero values included has 44 home and host countries (Figure VI.1)\textsuperscript{2}. However due to unavailable data for other variables (skilled labour share and R&D share in GDP, in particular) only 30 home and 44 host countries have been covered in the regressions to be estimated. All turnover and production data are in million USD converted from local currency by using average exchange rates and deflated by the US wholesale price index.

In order to represent relative incomes or market potential of countries real GDP data measured in billions of 1995 constant US dollars are used. Share of parent (host) country GDP is calculated as parent (host) country GDP divided by the summation of home and host country real GDP levels. As an alternative measure of income, real GDP per capita, which takes income allocation differences into account, was also used. The data on GDP and exchange rates are obtained from the World Development Indicators, 2003.

Parallel to CGE simulations, relative endowments are represented by skilled and unskilled labour shares. Data on the share of skilled labour is obtained from ILO (SEGREGAT data), which reports the ratio of workers in each occupational category. According to ISCO68 methodology, occupational categories 0/1 (professional, technical workers) and 2 (administrative workers) fall under the category of skilled labour. There have been two problems with this data set, however. First, labour data by occupational classifications has not been reported every year by every country. Therefore, in cases where some annual figures were missing period averages for each country are used to fill in the missing observations, with the assumption that skilled and unskilled labour share do not change dramatically between two consecutive years. The second problem has been

\textsuperscript{2} The following countries have data on affiliate sales (or production) for various years as host or parent countries: Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Croatia, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, India, Ireland, Italy, Japan, Korea, Luxemburg, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Romania, Russia, Singapore, Spain, Slovak Republic, Slovenia, Sweden, Switzerland, Thailand, Turkey, Ukraine, UK, US. Some country pairs have zero affiliate sales. There is no data available for Bulgaria, Croatia, Ukraine, India, Philippines, Thailand, Chile, Hong Kong, Brazil, and Luxembourg as (home) parent countries.
caused by a change in methodology for collecting occupational data. In this new classification occupational categories 1 (legislators, senior officials and managers), 2 (professionals) and 3 (technicians and associate professionals) fall under the category of skilled labour. Most countries have switched to ISCO88, but at different times. Moreover, not all countries have adjusted their previous figures according to this new reporting system. Therefore, for these countries an adjustment is made to report all data in ISCO88, again with the assumption that the share of skilled labour in total labour force does not change much in two consecutive years. The variable $HSKL\text{RATIO}$ is computed as the ratio of skilled labour divided by the total labour force. The comparative advantage index of the host country ($H\text{COMP}_\text{SKL}$) is constructed as the ratio of skilled labour divided by the ratio of unskilled labour of the host country divided by the equivalent ratio for parent country. Hence, a higher $H\text{COMP}_\text{SKL}$ ratio indicates a higher comparative advantage in skilled labour for the host country.

As suggested by Braconier et al. (2003), an alternative measure of income ($SIZE$) has also been constructed using endowment levels of home and host countries. This measure is directly mapped to the Edgeworth box presentations of the previous chapter and the size of a country is calculated by the length of a ray from the origin to its endowment point using the law of Pythagoras. Hence, the size of a country is equal to the squared root of the summation of squared skilled and unskilled labour shares of the country in total world endowment$^3$.

In the CGE model, scale economies are assumed to be the result of fixed costs of skilled labour in the headquarters located in the home country. In order to represent the technology intensity of the parent country, the ratio of general expenditure on research and development ($GERD$) in GDP is used. The data is obtained from World Development Indicators, 2003. As an alternative measure of scale economies, the number of scientists

$$SIZE = \sqrt{SKL\text{SHARE}^2 + L\text{SHARE}^2},$$

where $SKL\text{SHARE}$ and $L\text{SHARE}$ represent skilled and unskilled labour shares of a country, respectively. $SKL\text{SHARE}$ ($L\text{SHARE}$) is calculated as skilled (unskilled) labour endowment of a country divided by the total labour endowment of home and host country partners.
and engineers per million has also been tried in the regressions. This data set, however, is much shorter than GERD and does not extend to years prior to 1990.

The most difficult variable to construct has been the trade cost measure, as there is no direct measure available to cover the extent of information used in the CGE assumptions. As a result, more than one variable is used simultaneously to cover different aspects of the required information. The first measure is the trade cost index (TRADEC), constructed as one minus the share of foreign trade in GDP. The assumption used is that the more open a country is the lower the trade costs will be. This index represents the more policy controllable aspect of trade cost. Higher host country trade cost is expected to attract horizontal investment aiming to jump over the tariff barrier. On the other hand, higher home country trade costs tend to discourage vertical multinational firms which produce in a foreign country and export back to home country. Accordingly, the variable HTRADEC is expected to have a positive sign, while PTRADEC is expected to have a negative sign. As a second measure of trade cost, the distance between the capital cities of home and host country pairs (as crow flies) is included to the model. The coefficient of DISTANCE is expected to have a negative sign since dissimilarities between two countries increase parallel to distance. However, this variable also proxies transport (shipment) costs between countries, and according to our simulation results high transport costs tend to encourage horizontal multinational investment. Therefore, a quadratic version of this variable, DISTANCE$^2$, is also included in order to capture this potential effect and is expected to have a positive coefficient. In addition to these variables, a dummy variable (SIMILAR) is included to capture the effects of similarities such as language, culture and tastes. The dummy variable takes the value one if the country pairs share a border or if they have the same official language. The coefficient of this variable is expected to be positive.

The estimations also include dummy variables in order to capture country fixed effects. Rather than using a dummy variable for each country pair (i.e. for example, capturing fixed effects of UK affiliates in the USA separately from those of UK affiliates in Germany), only individual parent and host country dummies are utilised to capture cross
section effects. For example, HUSA, represents a dummy variable which takes value one when USA is a host county and zero otherwise. Similarly, PUSA, represents another dummy variable which takes value one when USA is a parent country, and zero otherwise.

4. Preliminary OLS Regression results

Various models using the alternative variables mentioned above are estimated using Ordinary Least squares (OLS) for two different data sets of affiliate sales (AFFSALEZ and AFFSALE). In the estimations all the alternative variables suggested in the previous section had the correct coefficient signs and in all cases the addition of fixed host and home country effects provided a better fit based on the $R^2$ and F statistics. The results for AFFSALE and AFFSALEZ with and without fixed country effects are reported in Table VI.1.

The coefficients of all variables have the correct signs and are significantly different from zero in all model specifications. The results, therefore, show support for the potential agglomeration effect in addition to endowment and trade cost effects. In industries with higher scale economies, agglomeration of firms seems to generate further attraction for multinational investment. The home and host country fixed effects are jointly significant and improve the fitness of the model, yet, the explanatory power of the model is still only 56%. Moreover, these results are valid only if the standard regression assumptions are satisfied. The properties of least squares estimators and the statistical analysis are based on the assumptions that the relationship between the dependent variable and the regressors is linear, the errors are independently and identically distributed normal random variables each with mean zero and a common variance, $\sigma^2$. Therefore, the model residuals need to be examined before commenting on the overall performance of the model.
TABLE VI.1a
Description of Variables and Expected Signs

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description of Variable</th>
<th>Expected sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFFSALE</td>
<td>Real volume of production (or sales) by affiliates of parent country-j in host country-i. All turnover and production data are in million USD converted from local currency by using average exchange rates and deflated by the US wholesale price index.</td>
<td>Dependent variable</td>
</tr>
<tr>
<td>GDPSUM</td>
<td>Sum of home and host country real GDP data measured in billions of 1995 constant US dollars. The data on GDP and exchange rates are obtained from the World Development Indicators, 2003.</td>
<td>(+)</td>
</tr>
<tr>
<td>PGDPSh</td>
<td>Share of parent country GDP, calculated as parent country real GDP divided by the sum of home and host country real GDP levels.</td>
<td>(+)</td>
</tr>
<tr>
<td>PGDPSh²</td>
<td>This variable aims to capture dissimilarities in sizes of home and host countries.</td>
<td>(-)</td>
</tr>
<tr>
<td>HGDPSH</td>
<td>Share of host country GDP, calculated as host country real GDP divided by the sum of home and host country real GDP levels.</td>
<td>(+)</td>
</tr>
<tr>
<td>HSKLRATIO</td>
<td>The ratio of skilled labour in host country divided by the total labour force of that country. Data on the share of skilled labour is obtained from ILO (SEGREGAT data), which reports the ratio of workers in each occupational category. The variable aims to capture skilled labour availability in host country.</td>
<td>(+)</td>
</tr>
<tr>
<td>HCOMPSKL</td>
<td>The comparative advantage index of the host country constructed as the ratio of skilled labour to unskilled labour ratio of the host country divided by the equivalent ratio for parent country. Hence, a higher HCOMPSKL ratio indicates a higher comparative advantage in skilled labour for the host country. In order to represent the technology intensity of the parent country, the ratio of general expenditure on research and development (GERD) in GDP is used. The data is obtained from World Development Indicators, 2003. The more technology intensive a parent country, the more likely it is that affiliates of firms from this country will be involved in technology-intensive sectors abroad.</td>
<td>(-)</td>
</tr>
<tr>
<td>PGERD</td>
<td>Host country trade cost constructed as one minus the share of foreign trade in GDP. The assumption used is that the more open a country is the lower the trade costs will be. This index represents the more policy controllable aspect of trade cost.</td>
<td>(+)</td>
</tr>
<tr>
<td>HTRADEC</td>
<td>Parent country trade cost, constructed as above.</td>
<td>(-)</td>
</tr>
<tr>
<td>PTTRADEC</td>
<td>A dummy variable included to capture the effects of similarities such as language, culture and tastes, takes the value one if the country pairs share a border or if they have the same official language.</td>
<td>(+)</td>
</tr>
<tr>
<td>SIMILAR</td>
<td>The distance between the capital cities of home and host country pairs (as crow flies). Dissimilarities between two countries increase parallel to distance.</td>
<td>(-)</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>Dissimilarities between two countries increase parallel to distance.</td>
<td>(+)</td>
</tr>
<tr>
<td>DISTANCE²</td>
<td>Squared DISTANCE variable. Proxies transport (shipment) costs between countries.</td>
<td>(+)</td>
</tr>
</tbody>
</table>
# TABLE VI.1b
## Preliminary OLS Estimation Results

<table>
<thead>
<tr>
<th>Method</th>
<th>OLS</th>
<th>OLS with Fixed Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable</td>
<td>OLSSALEZ</td>
<td>OLSSALE</td>
</tr>
<tr>
<td>GDPSUM</td>
<td>4.69 (14.76)</td>
<td>5.50 (15.10)</td>
</tr>
<tr>
<td>PGDPSh</td>
<td>61111 (10.60)</td>
<td>87553 (10.36)</td>
</tr>
<tr>
<td>PGDPSh^2</td>
<td>-59010 (-9.85)</td>
<td>-75436 (-9.57)</td>
</tr>
<tr>
<td>HGDPSh*HCOMPskl</td>
<td>-1577 (-5.47)</td>
<td>-1859 (-3.74)</td>
</tr>
<tr>
<td>HSKLRATIO</td>
<td>16394 (5.12)</td>
<td>15886 (4.25)</td>
</tr>
<tr>
<td>PGERD*HGDPSh</td>
<td>1662 (3.37)</td>
<td>4385 (6.11)</td>
</tr>
<tr>
<td>HTRADEC</td>
<td>345 (3.22)</td>
<td>498 (2.80)</td>
</tr>
<tr>
<td>PTRADEC</td>
<td>4.11 (0.027)</td>
<td>39.14 (0.21)</td>
</tr>
<tr>
<td>SIMILAR</td>
<td>7346 (5.31)</td>
<td>9420 (6.35)</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>-3.17 (-7.48)</td>
<td>-3.40 (-5.94)</td>
</tr>
<tr>
<td>DISTANCE^2</td>
<td>0.0002 (5.23)</td>
<td>0.00018 (3.10)</td>
</tr>
<tr>
<td>C</td>
<td>-81285 (-2.63)</td>
<td>-132790 (-3.18)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th># observations</th>
<th>2121</th>
<th>1654</th>
<th>2121</th>
<th>1654</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.435</td>
<td>0.462</td>
<td>0.532</td>
<td>0.561</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-23174</td>
<td>-18200</td>
<td>-22952</td>
<td>-18010</td>
</tr>
<tr>
<td>AIC</td>
<td>21.86</td>
<td>22.02</td>
<td>21.69</td>
<td>21.84</td>
</tr>
<tr>
<td>SBC</td>
<td>21.90</td>
<td>22.07</td>
<td>21.84</td>
<td>22.03</td>
</tr>
<tr>
<td>F-stat</td>
<td>126.7</td>
<td>110.5</td>
<td>44.1</td>
<td>38.8</td>
</tr>
<tr>
<td>Prob.(F-stat)</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>DW</td>
<td>1.910</td>
<td>2.096</td>
<td>2.095</td>
<td>2.30</td>
</tr>
</tbody>
</table>

Notes: 1. AFFSALEZ is the volume of real turnover including zero observations, while AFFSALE includes only positive observations. The first letters, P and H in the regressors denote parent, and host countries, respectively. All variable definitions are on Table VI.1a. 2. All models are estimated using White heteroscedasticity consistent standard errors and covariances. The figures reported in parenthesis are t-statistics. 3. Fixed effect specifications include home and host country dummies.
The Durbin-Watson statistic of our model is close to 2, and does not indicate a significant autocorrelation problem. However, the White statistic\(^4\) is significant \([\text{Obs}^*R^2 = 458, \text{Prob}(0.0000)]\), and hence the model residuals do not have an homogenous variance. When heteroscedasticity is present OLS estimation places more weight on the observations with large error variances than those with smaller error variances. Because of this implicit weighting, OLS parameter estimators are unbiased and consistent, but not efficient: i.e., the variances of the estimated parameters are not the minimum variances. In addition the estimated variances of the estimated parameters will be biased estimators of the true variance of the estimated parameters. If these biased estimates are used statistical tests and confidence intervals will be incorrect.

\[ \text{Figure VI.2} \quad \text{Standardized residuals versus OLS fitted values: Under standard assumptions the standard residuals should be uncorrelated with the fitted values.} \]

\( ^4 \) White's test is a test of the null hypothesis of no heteroscedasticity against heteroscedasticity of some unknown general form. The test statistic is computed by an auxiliary regression, where we regress the squared residuals on all possible (non-redundant) cross products of the regressors. The White statistic is computed as the number of observations times the centred \(R^2\) from the test regression, and is asymptotically distributed as a \(\chi^2\) distribution with degrees of freedom equal to the number of slope coefficients (excluding the constant) in the test regression.
The regression results reported in Table VI.1 are with White heteroscedasticity consistent standard errors to provide unbiased estimates for variances of the coefficient estimators. However, the least squares estimators are still inefficient, even if the variances of the parameter estimates are correctly determined.

Residual analysis is an effective way to detect the problems in a model. Figure VI.2 is a scatter plot of the standardized residuals\(^5\) versus the fitted values of the estimated OLS model with fixed effects using dependent variable \textit{AFFSALE}. Under the standard assumptions, the standardized residuals should be uncorrelated with the fitted values; therefore, this residual plot should be a random scatter of points around zero mean. However, in Figure VI.2, the standardized residuals are scattered around a clear curve, and hence the model is not sustained by the data. Also the variation around the mean tends to increase for higher values of fitted variable, illustrating the existence of a non-constant variance.

\(^5\) Standardized residual is defined as \( e^* = \frac{e_i}{\sqrt{\text{MSE}}} \), where \( e_i \) is the residual, and MSE (error mean square) is an estimate of the variance of the error terms.
The residual series of the OLS regression do not seem to possess a normal distribution either. When normality does not hold, the inference procedures are approximate, which means that the level of a test or confidence interval may not be as the normal theory says. However, when the sample size is reasonably large relative to the number of regression coefficients (as is in this model), the inference procedures for regression coefficients are generally quite accurate (the accuracy increases with the sample size).

Figure VI.3 provides the summary statistics of the residuals of the same model. The series tend to exhibit a high peak around the mean and possess long tails, indicating too many small and large values compared to a normal distribution. The non-normality of the residuals could also be observed from the normal probability plot of standardized residuals (Figure VI.4), where the ordered standardized residuals are plotted against the so-called normal scores. The normal scores are what we would expect to obtain if a sample of size n is taken from a normal distribution.

If the residuals are normally distributed, the ordered residuals should be approximately the same as the ordered normal scores. Under the normality assumption this plot should resemble a (nearly) straight line with an intercept of zero and a slope of one (these are the
mean and the standard deviation of the standardized residuals, respectively. The
standardized residuals clearly deviate from the expected normal levels, with some
extreme positive residuals (outliers). A more in-depth analysis of the series indicates that
the positive outliers tend to occur when both the home and host countries are highly
developed countries. Hence, when the US is the home country and Canada, Germany or
UK are the host counties (for largest outliers), or the US is the host country and Japan or
UK are the home countries (for largest outliers). The model does not seem to capture
affiliate production tendencies for highly developed country pairs.

![Figure VI.5: Dependent variable (AFFSALE) versus OLS fitted values: The curvilinear relation indicates that the data is not sustained by a linear regression.](image)

Thus the model fails to provide residuals compatible with standard regression
assumptions. Furthermore, a scatter plot of the response variable against fitted values
shows a non-linear trend (Figure VI.5) questioning the suitability of a linear estimation
method for this data set. Transformation of the response variable is a common method to
linearize a curvilinear regression relation (simultaneous transformations on one or more
of the predictors may also be needed for a better fit). Only after achieving a linear
regression relation, may the problems of heteroscedasticity and non-normality be subject
to further investigation. The problems of unequal error variances and non-normality of
the error terms frequently appear together, and it is a better practice to first remedy the heteroscedasticity problem, and then if still necessary deal with non-normality of residuals. Since the transformation of a response variable also changes the shape and the spread of the distribution of this variable, the problems of unequal variance and non-normality of distribution of error terms are also likely to be eliminated or reduced as a result of a response variable transformation. If not, weighted least squares estimation may be required.

The next section provides some analysis to decide how the dependent variable should be transformed, if at all, in order to achieve a model more compatible with the statistical assumptions. The decision on the transformations will be made using numerical (Box-Cox approach) and graphical approaches in collaboration. Each potential transformation will be compared using various goodness of fit, heteroscedasticity and normality performance criterion. At the end, residual and response plots of these transformations will be compared to support the final choice of transformation or a group of potential transformations. After the response variable transformation has been selected, non-linearities in the predictor variables will also be checked using Box-Tidwell transformations. This will help to decide whether we need higher order predictor variables instead of the linear ones in order to achieve a better fit. If the response transformations do not eliminate the heteroscedasticity problem, weighted least squares estimation (WLS) method may be considered.

5. Remedial Measures

a. Variable Transformations to Achieve Linearity

Cook and Weisberg (1994 a,b) have suggested using an inverse response plot (a scatter plot of $\hat{Y}$ against $Y$, where $Y$ is the dependent variable and $\hat{Y}$ is the fitted values of the dependent variable), and fitting a curve to the plot to estimate the appropriate value for $\lambda$. As with many graphical methods, however, the inverse response plot may be more valuable as a device for suggesting that a transformation is needed, rather than providing
a clear signal as to the form of the appropriate transformation. In order to obtain the
inverse response plot the axis should be reversed in Figure VI.5. This provides a
monotonically increasing figure. Curves obtained using power transformations of \( (Y) \) for
\( 0 < \lambda < 1 \) seems to provide a better fit to the plot than non-transformed \( (Y) \), and the best fit
seems to occur around \( 0.3 < \lambda < 0.4 \). Box-Tidwell\(^6\) approach may also be used to estimate
the appropriate transformations, with \( Y \) playing the role of regressor to be transformed.
The Box-Cox transformation approach is one of the most widely used transformations.
Transformations suggested by this numerical method and the graphical inverse response
plot method need not always agree. The inverse fitted value plot chooses transformations
to linearize the response function, while the Box-Cox method tries to make the errors in
the transformed scale as close to normally distributed as possible. As originally presented
by Box and Cox (1964), the objective is to transfer \( Y \) to \( Y^\lambda \) in such a way that the
transformed \( Y \) is a linear function of the regressors, with approximate normality for \( Y^\lambda \)
and a constant variance. The Box-Cox family of transformations is generally presented in
textbooks as (2) below. When we use a model with an intercept, we may simply use \( Y^\lambda \)
in place of \( (Y^\lambda - 1) / \lambda \).

\[
Y^\lambda = \begin{cases} 
(Y^\lambda - 1) / \lambda & \lambda \neq 0 \\
\log(Y) & \lambda = 0
\end{cases}
\]  

\(^6\) Box and Tidwell (1962) provided a method to detect the need for a non-linear term instead of the
corresponding linear term. With the Box-Tidwell procedure one assumes that:
\[
E(Y) = \beta_0 + \beta_1 X^t
\]

where \( X^t \) is the transformed \( X \), with \( X^t = \begin{cases} 
\ln(X) & \alpha = 0 \\
X^\alpha & \alpha \neq 0
\end{cases} \)

Expanding \( E(Y) \) in a Taylor series and employing the chain rule for derivatives produces
\[
E(Y) = \beta_0 + \beta_1 X + \gamma [X \ln(X)]
\]
where \( \gamma = (\alpha - 1) \beta_1 \).

In order to find the estimate of the appropriate transformation, \( \alpha \), we need to obtain \( \hat{\beta}_1^* \) by estimating (1),
and obtain \( \hat{Y} \) by estimating (2), both by using OLS technique. Then solve for \( \alpha \) using equation (3).

\[
Y = \beta_0 + \beta_1^* X \\
y = \beta_0 + \beta_1 X + \gamma X \ln(X) \\
\alpha = \frac{\hat{Y}}{\hat{\beta}_1} + 1
\]
After transforming the response variable for a range of possible values of \( \lambda \), the transformation best suits the needs of the model should be selected by regressing the transformed variable on the model predictors, and evaluating the performance of each model using parametric and non-parametric indicators. Various power transformations of the dependent variable (affiliate sales) ranging between -2 to +2 have been tested, and the performance indicators for each transformation have been reported in Table VI.2. Next, some explanations for these performance criteria will be provided.

The standard approach for choosing the appropriate \( \lambda \), explained in Draper and Smith (1981), is to compute (3) for a range of possible values of \( \lambda \), and then select the one that maximizes \( L(\lambda) \).

\[
L(\lambda) = -\frac{1}{2} n \log \left( \frac{SSE}{n} \right) + (\lambda - 1) \sum \log(Y)
\] (3)

One disadvantage of this method is that the transformed dependent variable is assumed to have a normal distribution, and if the transformed dependent variable is not at least approximately normally distributed, then the selection of \( \lambda \) could be undermined. Since this cannot be guaranteed in this model, this selection method should be viewed as of secondary importance. Also the choice will not guarantee approximate normality in the transformed variable.

Therefore, in addition to this standard approach, some non-parametric measures which do not depend on the assumption of normality will be reported. These measures also allow the performance on normality to be checked. This approach has been suggested and illustrated in Ryan (1997). The first point to keep in mind is that whenever the dependent variable is transformed, the proper form of \( R^2 \) should be used to check whether the transformation has been beneficial for obtaining a better fit. This point has been emphasized by Kvalseth (1985) and Scott and Wild (1991). The former suggests using the form (4),
\[ R_{\text{raw}}^2 = 1 - \frac{\sum (Y - \hat{Y}_{\text{raw}})^2}{\sum (Y - \bar{Y})^2} \]  

(4)

where \( \hat{Y}_{\text{raw}} \) is the predicted value of \( Y \) converted back to the original scale. However, the downside of this statistic is that the value of \( R_{\text{raw}}^2 \) may be negative, especially when a predicted value on the transformed scale is very close to zero, and as result it 'blows up' when transformed back to the original (raw) scale. Ryan (1997) suggests using, \( r^2_{\lambda, \hat{Y}_{\text{raw}}} \), the square of the correlation between the response values and the predicted values obtained after converting back to the original (raw) scale. There will usually be close agreement between the two statistics for good models, though. Goodness of fit measures for models with transformed variables is reported under columns 2-4 in Table VI.2.

In addition to the goodness of fit measures, the homoscedasticity and normality assumptions will be checked by three indicators each. The performance of transformations on normality will be inspected roughly by computing the correlation between the scaled residuals and their normalized values after transformation, in addition to the classic Jarque-Bera statistics\(^7\). The skewness statistic will also be reported for each \( \lambda \) value in order to observe whether the non-normality problem sources mainly from non-symmetry or kurtosis. First measure of homoscedasticity reported is the White test. As a second measure, \( (r_{\text{H1}}) \), the correlation between the squared standardized residuals and \( \log(\hat{Y}) \) will be presented. The third measure is to observe whether there is any linear relationship between the standard deviation and a power of the mean response. Hence, the correlation between the log of the absolute value of the residuals and \( \log(\hat{Y}) \) will be reported\(^8\).

---

\(^7\) Jarque-Bera is a commonly used test statistic for testing whether the series is normally distributed. The test statistic measures the difference of the kurtosis and skewness of the series with those from the normal distribution. The statistic is computed as \( JB = \frac{n-k}{6} \left( S^2 + \frac{1}{4} (K-3)^2 \right) \), where \( S \) is skewness, \( K \) is kurtosis and \( k \) represents the number of estimated coefficients used to create the series. Under the null hypothesis of normal distribution, the JB statistic is distributed as \( X^2 \) with two degrees of freedom. The reported probability is the probability that a JB statistic exceeds (in absolute value) the observed value under the null (a small probability leads to the null hypothesis of a normal distribution).

\(^8\) This measure has been suggested by Carroll and Ruppert 1988, and Ryan, 1997.
Using some graphical evaluation methods might help further which dependent variable to use in the estimations. Figure VI.6 scatter plots transformed dependent variables against their fitted values. The transformed dependent variables for $0 \leq \lambda \leq 0.2$ have approximately linear relationships with their fitted values, and hence linear regression estimation methods are appropriate to apply on these models. Standardized residual plots also support these transformations. A fitted lowess $^9$ curve of order two is shown on each graph. For $0 \leq \lambda \leq 0.2$, the plots are scattered around mean zero, while for $\lambda \geq 0.3$ standardized residuals are still correlated with fitted values. None of the graphs, however, seem to have a constant standard variation function. Especially in the first two graphs (a. $\lambda=0$, b. $\lambda=0.1$), it is clearly evident that the variability of residuals is much larger for low levels of fitted values.

According to Table VI.2, power transformations ranging between $0-0.5$ generate an improvement in fitness of the model, increasing the $r^2_{Y,Y_{raw}}$ from $0.58$ to over $0.71$. Particularly, the transformations of $Y^{0.1}$, $Y^{0.2}$ seem to fit the model quite well. Nevertheless neither the homoscedasticity nor normality conditions are met in any of the transformations. To sum up, the Box-Cox transformations have been useful to achieve linearization of the model, but have not been sufficient to mimic the standard regression assumptions. Weighted least squares estimation technique is still required to obtain the efficient estimates and this is the subject of the next section. It should also be noted that replacing the linear predictor variables with power transformed ones (according to Box-Tidwell transformation choices) did not provide any improvements on goodness of fit, and therefore the tests are not reported here. As a result the models only with response variable transformations will be considered for further improvements.

$^9$ The lowess method is a nonparametric method to obtain a smoothed curve by fitting successive linear regression functions in local neighbourhoods. It does not provide an analytical expression for the functional form of the regression relationship, but suggests the shape of the regression curve. Higher order polynomials can also be utilized with this method. The name lowess stands for locally weighted regression scatter plot smoothing.
### TABLE VI.2
Box-Cox Transformations

<table>
<thead>
<tr>
<th>λ</th>
<th>$R^2_{raw}$</th>
<th>$r^2_{Y,Yraw}$</th>
<th>LL</th>
<th>skewness</th>
<th>JB (p-value)</th>
<th>$r_{e,en}$ (p-value)</th>
<th>White (p-value)</th>
<th>$r_{H1}$ (p-value)</th>
<th>$r_{H2}$ (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.1</td>
<td>negative</td>
<td>0.33</td>
<td>-20178</td>
<td>1.29</td>
<td>3546 (0.0000)</td>
<td>0.921</td>
<td>415 (0.0000)</td>
<td>-0.435</td>
<td>-0.318</td>
</tr>
<tr>
<td>0.0</td>
<td>0.31</td>
<td>0.71</td>
<td>-14061</td>
<td>-0.51</td>
<td>845 (0.0000)</td>
<td>0.945</td>
<td>415 (0.0000)</td>
<td>-0.346</td>
<td>-0.308</td>
</tr>
<tr>
<td>0.1</td>
<td>0.84</td>
<td>0.83</td>
<td>-9823</td>
<td>0.01</td>
<td>179 (0.0000)</td>
<td>0.960</td>
<td>336 (0.0000)</td>
<td>-0.235</td>
<td>-0.194</td>
</tr>
<tr>
<td>0.2</td>
<td>0.80</td>
<td>0.85</td>
<td>-10773</td>
<td>0.25</td>
<td>61 (0.0000)</td>
<td>0.970</td>
<td>271 (0.0000)</td>
<td>-0.021</td>
<td>-0.014</td>
</tr>
<tr>
<td>0.3</td>
<td>0.76</td>
<td>0.84</td>
<td>-11470</td>
<td>0.40</td>
<td>92 (0.0000)</td>
<td>0.968</td>
<td>372 (0.0000)</td>
<td>0.173</td>
<td>0.115</td>
</tr>
<tr>
<td>0.4</td>
<td>0.72</td>
<td>0.81</td>
<td>-12124</td>
<td>0.65</td>
<td>346 (0.0000)</td>
<td>0.957</td>
<td>502 (0.0000)</td>
<td>0.260</td>
<td>0.148</td>
</tr>
<tr>
<td>0.5</td>
<td>0.70</td>
<td>0.78</td>
<td>-12756</td>
<td>0.99</td>
<td>1153 (0.0000)</td>
<td>0.942</td>
<td>546 (0.0000)</td>
<td>0.327</td>
<td>0.219</td>
</tr>
<tr>
<td>1.0</td>
<td>0.59</td>
<td>0.58</td>
<td>-15663</td>
<td>2.95</td>
<td>26441 (0.0000)</td>
<td>0.864</td>
<td>458 (0.0000)</td>
<td>0.270</td>
<td>0.657</td>
</tr>
</tbody>
</table>
## TABLE VI.3
OLS Estimation with Transformed Dependent Variables

<table>
<thead>
<tr>
<th>Method</th>
<th>OLS with Fixed Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable</td>
<td>AFFSALE</td>
</tr>
<tr>
<td>GDPSUM</td>
<td>7.87 (7.98)</td>
</tr>
<tr>
<td>PGDPSh</td>
<td>101869 (9.75)</td>
</tr>
<tr>
<td>PGDPSh²</td>
<td>-72807 (-8.87)</td>
</tr>
<tr>
<td>HDPSH*HCOMP²</td>
<td>-2298 (-2.85)</td>
</tr>
<tr>
<td>HSgRATIO</td>
<td>20754 (2.16)</td>
</tr>
<tr>
<td>RCERD*HGDPSH</td>
<td>9152 (5.66)</td>
</tr>
<tr>
<td>HTRADEC</td>
<td>432 (2.32)</td>
</tr>
<tr>
<td>PTRADEC</td>
<td>-1684 (-5.90)</td>
</tr>
<tr>
<td>SIMILAR</td>
<td>5226 (3.51)</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>-6.14 (-4.94)</td>
</tr>
<tr>
<td>DISTANCE²</td>
<td>0.00037 (3.02)</td>
</tr>
<tr>
<td>C</td>
<td>222012 (3.59)</td>
</tr>
</tbody>
</table>

# observations | 1654 | 1654 | 1654 | 1654

$R^2_{raw}$ | 0.576 | 0.31 | 0.84 | 0.80

Skewness | 2.955 | -0.51 | 0.01 | 0.25
Kurtosis | 21.67 | 6.34 | 4.61 | 3.79

Jarque-Bera | 26441 (0.0000) | 845 (0.0000) | 179 (0.0000) | 61 (0.0000)

White | 458 (0.0000) | 415 (0.0000) | 336 (0.0000) | 271 (0.0000)

Notes: 1. The first letters, P and H in the regressors denote parent, and host counties, respectively. All variable definitions are presented on Table VI.1a. 2. All models are estimated using White heteroscedasticity consistent standard errors and covariances. The figures reported in parenthesis are t-statistics. $R^2_{raw}$ is computed on the original scale. The figures reported in parenthesis for JB and White statistics are the probability values that the JB and White statistics exceed the observed value under the null-a small value leads to the rejection of null hypothesis of normal distribution or homoscedasticity. 3. Fixed effect specifications include home and host country dummies.
Figure VI.6  Dependent variable versus OLS fitted values: The graphs show the scatter plots of transformed dependent variables on fitted values where (a) $\lambda=0$, (b) 0.1, (c) 0.2, (d) 0.3, respectively. Transformations ranging between $0<\lambda<0.2$ have resulted in approximately linear models, and hence linear regression estimation techniques are now appropriate to use for these particular transformations.
Figure VI. 7. Standardized residuals versus OLS fitted values: Comparing these figures to Figure VI.2, it is possible to observe that the transformations, $0 \leq \lambda \leq 0.2$, have achieved a constant mean around zero, but have failed to achieve a constant standard deviation. (a),(b) For the logarithmic transformation and $\lambda=0.1$, the standardized residuals are scattered around mean zero, with increasing variation for lower fitted values. c) For $\lambda=0.2$, the standardized residuals have an approximate mean of zero, although some outliers affect this tendency for low and high fitted values. The tendency of heteroscedasticity is less obvious. d) For $\lambda=0.3$, the residuals do not have a constant mean. The model is not sustained by the data.
b. Dealing with heteroscedasticity and non-normality

Although approximate linearity has been attained via response transformations, the problems of significant heteroscedasticity and non-normality persist. Since an appropriate model for linear estimations is attained, weighted least squares (WLS) method\textsuperscript{10} can be used to reduce or eliminate unequal variances of the error terms.

If we have the following simple linear model (5)

$$ Y_i = \beta_0 + \beta_1 X_i + u_i \quad (5) $$

and it is known that

$$ E(u_i^2) = \sigma_i^2 w_i^2 \quad (6) $$

then we can divide through by $w_i$ and use OLS on the transformed model\textsuperscript{11}

$$ \frac{Y_i}{w_i} = \beta_0 \frac{1}{w_i} + \beta_1 \frac{X_i}{w_i} + v_i \quad (7) $$

where

$$ E(v_i^2) = E(u_i/w_i)^2 = \sigma_i^2 \quad (8) $$

Of course, in practice $w_i$ (weights) will be unknown, but we can get some idea of its form by running various auxiliary regressions\textsuperscript{12}. The squared residuals, $e_i^2$, are an estimator of $\sigma_i^2$, and the absolute residual $|e_i|$ is an estimator of the standard deviation $\sigma_i$. Therefore, it

---

\textsuperscript{10} Information of WLS estimation may be found in most econometrics textbooks, such as Kutner et al. (2004), Pindyck and Rubinfeld (1998).

\textsuperscript{11} It is important to note that if there is an intercept in the original equation, there will not be one in the transformed equation: $Y/w$ is regressed on $1/w$ and $X/w$ alone, and the estimate of the slope coefficient on the regressor $1/w$ is the estimate of the intercept.

\textsuperscript{12} Additional information regarding the modelling of $\sigma$ or $\sigma^2$ could be found in Carroll and Ruppert (1988) and Davidian and Carroll (1987).
is possible to estimate the variance function describing the relation of $\sigma_i^2$ to relevant predictor variables by first fitting the regression model using unweighted least squares and then regressing the squared residuals (absolute residuals) against the appropriate predictor variables. One possibility is to regress squared residuals against all possible (non-redundant) cross products of regressors (i.e. as in White test). Regressions using the absolute residuals in the second stage are called Glejser tests, and it is advisable to use this approach especially if there are outliers in the data, because regressing absolute residuals is less affected by outliers than regressing squared residuals. After the variance function or the standard deviation is estimated, the fitted values from this function are used to obtain the estimated weights.

Another simple commonly used model is a power of the mean model in which $\sigma_i$ is modelled as (9), where $\sigma$ is the constant of proportionality.

$$\sigma_i = \sigma(\mu_i)^\theta \tag{9}$$

With this model the $\sigma_i$ (and hence $\sigma_i^2$) are thought to vary as the mean varies. If we take the logarithm of each side, we then have a simple linear regression model. Specifically, we obtain (10).

$$\log(\sigma_i) = \log(\sigma) + \Theta \log(\mu_i) \tag{10}$$

Hence after substituting appropriate estimators for $\sigma_i$ and $\mu_i$, which would be obtained from the OLS fit using $Y$ as the dependent variable, the weights would be obtained from the predicted values from the logarithmic model. $\log(|e_i|)$ can be regarded as a substitute for $\log(\sigma_i)$, and $\hat{Y}_i$ as a substitute for $\mu_i$. Thus by regressing $\log(|e_i|)$ against $\log(\hat{Y}_i)$ it is possible to see if a strong relationship is indicated. The predicted values for $\sigma_i$ would then be used as weights. Whichever approach is used in estimating the variance, it is likely that iteratively reweighted least squares (IRLS) will be necessary. Often one or two more iterations are sufficient to stabilize the estimated regression coefficients.
Table VI.4 reports the performance measures of the transformed dependent variable when the model is estimated with weighted least squares technique. The normality and homoscedasticity measures reported are based on weighted residuals. All three methods for obtaining weights mentioned above are used to estimate the weights to remove heteroscedasticity in each transformation. For most of the estimated weights, one or two iterations have been sufficient for estimated regression coefficients to converge. Only the non-transformed ($\lambda=1$) model required four iterations to converge while using the Glejser adjustment method. All heteroscedasticity adjusted WLS models resulted in better normality and homoscedasticity statistics. Glejser method (using $|e|$ to estimate weights) provided the best results in all transformations in particular outperformed all other methods, and removed heteroscedasticity in all cases. Especially for the logarithmic case the White statistic provides a very strong support against the existence of any heteroscedasticity.

Weighted residuals reported in Table VI.4 show less non-normality tendencies compared to their non-weighted versions. Although the Jarque-Bera statistic still rejects the existence of normal distribution in all cases at 5% significance level, and the correlation measures of normality are still lower than preferred, there is improvement in the symmetry of the residuals. Response transformations of $\lambda=0.1$ and 0.2, in particular tend to have a symmetric residual distribution for the weighted models. This indicates that most of the non-normality comes from high kurtosis, and possibly from outliers (or from long tails). Despite the improvements in all cases, we should note that the transformations of $\lambda\geq0.3$ still show significant non-normality even after the removal of heteroscedasticity.

The improvements achieved could be observed by comparing the graphs in Figure VI.8 with the previous ones. If the model is correct, then in a plot of residuals versus fitted values (or predictors or a combination of predictors) the residual mean function and the residual variance functions should be approximately constant. All standardized residual plots in Figure VI.8 seem to be a random scatter of points around mean zero, indicating an appropriate mean function and removal of heteroscedasticity. However, the models still seem to suffer from some outlier values. The effects of these outlier values could be
observed better from the normal probability plots. The standardized residuals of the logarithmic model (Figure V.8a) deviate from expected normal values especially for larger absolute values. The other two transformations seem to be approximately normally distributed both having only three significantly large outliers. The outliers are not the same and do not seem to be as a result an apparent error such as typing.

Table VI.4 also reports the goodness of fit measures at the original scale. Hence, first the fitted values are computed using the weighted estimates of coefficients (as mentioned by Willett and Singer (1988)), and then these fitted values are transformed back to their original scales. Removing heteroscedasticity has improved the fitness of models for $\lambda=0$ and 0.1 considerably, while the goodness of fit has remained approximately the same for $\lambda=0.2$. Nevertheless, the goodness of fit at the original scale worsened with the WLS estimation for transformations where $\lambda\geq0.3$.

To sum up, the WLS estimation method has been successful to remove the problem of heteroscedasticity, and hence outperformed the OLS estimation method. Weighted least squares estimation on the transformed variable, AFFSALE$^{0.1}$, provides the best fit and the residuals meet all standard assumptions. The logarithmic transformation also provides a good fit, and strongly rejects the existence of any heteroscedasticity. However, the residuals do not seem to be normally distributed. Since the data set is large, the effects of outliers should not affect the estimations significantly. Therefore, if the outliers are not influential as a result of the large data set the logarithmic transformation may be preferred. The reason for this preference is that the logarithmic transformation provides ease of coefficient interpretation. Next section checks whether the estimation results could be improved further upon by deleting outliers.
<table>
<thead>
<tr>
<th>( \lambda )</th>
<th>Weighted Least Squares</th>
<th>Goodness of Fit</th>
<th>Measures for Normality</th>
<th>Measures for Homoscedasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda )</td>
<td>( \beta_2 )</td>
<td>( \beta_Y, Y_{\text{raw}} )</td>
<td>skewness</td>
<td>( \text{JB} )</td>
</tr>
<tr>
<td>0</td>
<td>non-weighted</td>
<td>0.31</td>
<td>0.71</td>
<td>-0.51</td>
</tr>
<tr>
<td></td>
<td>( r^2 )</td>
<td>0.89</td>
<td>0.89</td>
<td>-0.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.83</td>
<td>0.87</td>
<td>-0.39</td>
</tr>
<tr>
<td></td>
<td>( \log r )</td>
<td>0.87</td>
<td>0.87</td>
<td>-0.50</td>
</tr>
<tr>
<td>0.1</td>
<td>non-weighted</td>
<td>0.84</td>
<td>0.83</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>( r^2 )</td>
<td>0.85</td>
<td>0.85</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.88</td>
<td>0.88</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>( \log r )</td>
<td>0.88</td>
<td>0.88</td>
<td>-0.16</td>
</tr>
<tr>
<td>0.2</td>
<td>non-weighted</td>
<td>0.80</td>
<td>0.85</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>( r^2 )</td>
<td>0.81</td>
<td>0.84</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.81</td>
<td>0.84</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>( \log r )</td>
<td>0.81</td>
<td>0.86</td>
<td>0.17</td>
</tr>
<tr>
<td>0.3</td>
<td>non-weighted</td>
<td>0.76</td>
<td>0.84</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>( \log r )</td>
<td>0.68</td>
<td>0.80</td>
<td>0.25</td>
</tr>
<tr>
<td>1.0</td>
<td>non-weighted</td>
<td>0.59</td>
<td>0.58</td>
<td>2.95</td>
</tr>
<tr>
<td></td>
<td>( \log r )</td>
<td>-0.05</td>
<td>0.12</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Figure V.8. *Standardized residuals versus WLS fitted values: In all graphs standardized residuals are randomly scattered around mean zero.

**Normal probability plot of standardized residuals:** (a) The residuals are not normally distributed.
(b), (c) The residuals are approximately normally distributed except some outliers.
c. Iteratively Re-weighted Robust Least Squares Regression

In the graphical representations above it has been demonstrated that outlying values effect the distribution of residuals. Ordinary Least Squares (OLS) method is susceptible to existence of outliers, resulting sometimes in a seriously distorted fitted model for the remaining cases. The outliers in the transformed models above are not as a result of a clear error (such as typing etc.), therefore a robust regression procedure in order to dampen the influence of outlying cases will be utilized in an effort to provide a better fit to the majority of cases. Iteratively re-weighted least squares (IRLS) used in the previous section may also be used to provide robust regressions. Instead of using weights based on the error variances, IRLS robust regression uses weights based on how far outlying a case is, as measured by the residual for that case. Outlying cases that have large residuals are given smaller weights, and the weights are revised at each iteration, until the estimation process stabilizes. The stabilization point can be decided by observing whether the weights change relatively little, whether the estimated regression coefficients change very little, or whether the fitted values change relatively little.

Table VI.5 reports the performance measures for WLS estimations where the largest residuals after the removal of heteroscedasticity are given zero weights. This means these values will not be used in the estimation of parameters. For the models (b) and (c), removal of only three observations each have been adequate to achieve approximately normally distributed residuals. Moreover, the White homoscedasticity measures have also improved in both cases, rejecting the existence of heteroscedasticity stronger. For the logarithmic case 1% of the observations (17 observations) are weighted at zero for the estimations. As a result, the model also shows a much clearer tendency of normality with improved symmetry (Figure VI.9).
### TABLE VI.5
Iteratively Re-Weighted Least Squares

<table>
<thead>
<tr>
<th>λ</th>
<th>weights</th>
<th>( R^2 )</th>
<th>( r^2_{Y,Y_{raw}} )</th>
<th>skewness</th>
<th>JB</th>
<th>( r_{e,em} )</th>
<th>White</th>
<th>( t_{H1} )</th>
<th>( t_{H2} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(</td>
<td>r</td>
<td>)</td>
<td>0.83</td>
<td>0.87</td>
<td>-0.39</td>
<td>64 (0.0000)</td>
<td>0.970</td>
<td>29 (0.9999)</td>
</tr>
<tr>
<td></td>
<td>Outlier adj.</td>
<td>0.83</td>
<td>0.87</td>
<td>-0.20</td>
<td>12 (0.0025)</td>
<td>0.979</td>
<td>45 (0.9677)</td>
<td>-0.06</td>
<td>-0.07</td>
</tr>
<tr>
<td>0.1</td>
<td>(</td>
<td>r</td>
<td>)</td>
<td>0.88</td>
<td>0.88</td>
<td>0.05</td>
<td>16 (0.0003)</td>
<td>0.973</td>
<td>63 (0.4902)</td>
</tr>
<tr>
<td></td>
<td>Outlier adj.</td>
<td>0.88</td>
<td>0.88</td>
<td>-0.05</td>
<td>3 (0.2267)</td>
<td>0.980</td>
<td>55 (0.7813)</td>
<td>-0.061</td>
<td>-0.073</td>
</tr>
<tr>
<td>0.2</td>
<td>(</td>
<td>r</td>
<td>)</td>
<td>0.81</td>
<td>0.84</td>
<td>0.05</td>
<td>47 (0.0000)</td>
<td>0.971</td>
<td>68 (0.3268)</td>
</tr>
<tr>
<td></td>
<td>Outlier adj.</td>
<td>0.80</td>
<td>0.84</td>
<td>0.03</td>
<td>8 (0.0164)</td>
<td>0.981</td>
<td>47 (0.9369)</td>
<td>-0.032</td>
<td>0.014</td>
</tr>
</tbody>
</table>
Figure VI.9. (a) 17 outlier values (1% of total data set) are given zero weights for estimations. The residuals are now approximately normally distributed. (b), (c) 3 outlier values are given zero weight in each case. The residuals are approximately normally distributed.
6. Results

The WLS and IRLS robust regression estimation results are presented on Table VI.6 and Table VI.7, respectively. The coefficient estimates are very close in both estimations, since as a result of the large data set employed the effects of outliers have not been large enough to change the estimates significantly.

The results of the model are encouraging. All the coefficients of the model have the expected signs and are significant. Thus, the propositions of the previous chapter are supported with empirical evidence. The model supports the importance of market-related factors for MNF production, since all three variables (GDPSUM, PGDPSh, PGDPSH²) are statistically significant. The GDPSUM variable captures the market size effect for both host country (target market for horizontal MNFs) and parent country (target market for vertical MNFs). The PGDPSh and PGDPSH² variables, on the other hand, reveal that MNFs tend to originate from higher income countries, and prefer to locate in countries with incomes not very different to that of the parent country. In addition to these variables, a positively signed host country trade cost variable and a negatively signed distance variable captures the market-seeking motives of horizontally integrated MNFs. The results also provides support on the importance of cost-related factors for MNFs. Cheap labour (i.e. comparative disadvantage of host country in skilled-labour) is an important determinant of location choice as long as the country also provides a good market potential. Availability of skilled-labour in the host country is another concern for location decisions. These two findings also explain why countries with cheap labour but not sufficient skilled-labour or a large market potential do not attract significant amounts of FDI. In addition, in the technologically intensive sectors, agglomeration tendencies of firms tend to make that country more attractive to potential new investors.
TABLE VI.6
WLS Estimation with Transformed Dependent Variables

<table>
<thead>
<tr>
<th>Method</th>
<th>WLS with Fixed Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable</td>
<td>Log(AFFSALE)</td>
</tr>
<tr>
<td>GDPSUM</td>
<td>0.0004 (14.16)</td>
</tr>
<tr>
<td>PGDPSH</td>
<td>3.0 (7.65)</td>
</tr>
<tr>
<td>PGDPSH^2</td>
<td>-2.52 (-8.61)</td>
</tr>
<tr>
<td>HGDPSH*HCOMPskl</td>
<td>-0.23 (-5.13)</td>
</tr>
<tr>
<td>HSKLRATIO</td>
<td>5.95 (9.36)</td>
</tr>
<tr>
<td>PGERD*HGDPSH</td>
<td>0.73 (8.54)</td>
</tr>
<tr>
<td>HITRADEC</td>
<td>0.06 (4.13)</td>
</tr>
<tr>
<td>PTRADEC</td>
<td>-0.16 (-6.28)</td>
</tr>
<tr>
<td>SIMILAR</td>
<td>0.55 (13.08)</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>-0.0003 (-13.49)</td>
</tr>
<tr>
<td>DISTANCE^2</td>
<td>3.07E-08 (7.52)</td>
</tr>
<tr>
<td>C</td>
<td>20.9 (3.23)</td>
</tr>
</tbody>
</table>

| # observations             | 1654             | 1654               | 1654               |
| \text{R}^2_\text{raw}     | 0.83             | 0.88               | 0.81               |
| Skewness                   | -0.39            | 0.05               | 0.05               |
| Kurtosis                   | 3.54             | 3.47               | 3.81               |
| Jarque-Bera                | 64 (0.0000)      | 16 (0.0003)        | 47 (0.0000)        |

| White                      | 29 (0.9999)      | 63 (0.4902)        | 68 (0.3268)        |

Notes: 1. The first letters, P and H in the regressors denote parent, and host countries, respectively. All variable definitions are presented on Table VI.1a. 2. All models are estimated using White heteroscedasticity consistent standard errors and covariances. The figures reported in parenthesis are t-statistics. \( \text{R}^2_\text{raw} \) is computed on the original scale. The residual statistics are based on the weighted residuals. The figures reported in parenthesis for JB and White statistics are the probability values that the JB and White statistics exceed the observed value under the null-a small value leads to the rejection of null hypothesis of normal distribution or homoscedasticity. 3. Fixed effect specifications include home and host country dummies. 4. In each estimation, the weights are obtained by using Glejser method (i.e. regressing the absolute residuals against all possible (non-redundant) cross products of regressors (i.e. as in White test). Maximum two iterations have been required to remove heteroscedasticity.
TABLE VI.7
IRLS Robust Regression Estimation

<table>
<thead>
<tr>
<th>Method</th>
<th>Robust Regression with Fixed Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Log(AFFSALE)</td>
</tr>
<tr>
<td>GDPSUM</td>
<td>0.0004 (18.03)</td>
</tr>
<tr>
<td>PGDPSh</td>
<td>3.16 (8.47)</td>
</tr>
<tr>
<td>PGDPSh$^2$</td>
<td>-2.56 (-9.37)</td>
</tr>
<tr>
<td>HGDPSh*HGCMP$^\text{skl}$</td>
<td>-0.22 (-5.12)</td>
</tr>
<tr>
<td>HSCLRATIO</td>
<td>5.29 (9.32)</td>
</tr>
<tr>
<td>PGERD*HGDPSh</td>
<td>0.78 (9.61)</td>
</tr>
<tr>
<td>HTRADEC</td>
<td>0.05 (3.85)</td>
</tr>
<tr>
<td>PTRADEC</td>
<td>-0.17 (-7.30)</td>
</tr>
<tr>
<td>SIMILAR</td>
<td>0.50 (12.52)</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>-0.0003 (-15.10)</td>
</tr>
<tr>
<td>DISTANCE$^2$</td>
<td>3.26E-08 (8.36)</td>
</tr>
<tr>
<td>C</td>
<td>24.86 (4.20)</td>
</tr>
</tbody>
</table>

# observations | 1654 | 1654 | 1654

$R^2_{\text{raw}}$ | 0.83 | 0.88 | 0.81

Skewness | -0.20 | -0.05 | 0.03
Kurtosis | 2.89 | 2.83 | 2.66
Jarque-Bera | 12 (0.0025) | 3 (0.2267) | 8 (0.0164)

| White | 45 (0.9677) | 55 (0.7813) | 47 (0.9369) |

Notes: 1. The first letters, P and H in the regressors denote parent, and host countries, respectively. All variable definitions are presented on Table VI.1a. 2. All models are estimated using White heteroscedasticity consistent standard errors and covariances. The figures reported in parenthesis are t-statistics. $R^2_{\text{raw}}$ is computed on the original scale. The residual statistics are based on the weighted residuals. The figures reported in parenthesis for JB and White statistics are the probability values that the JB and White statistics exceed the observed value under the null.-a small value leads to the rejection of null hypothesis of normal distribution or homoscedasticity. 3. Fixed effect specifications include home and host country dummies. 4. For $\lambda=0$, seventeen (1% of total data set) outlier observations are given zero weights for estimations. For $\lambda=0.1$ and 0.2, three outlier observations are given zero weight in each case.
7. Conclusions

In this chapter a new empirical model based on theoretical analysis is specified to capture the effects of scale economies and agglomeration tendencies, in addition to the effects of relative endowments and trade costs. The specification required a response variable transformation in order to become compatible with the assumptions of linear estimation methods. Application of the Box-Cox transformations resulted in successful linearization of the model, however, failed to eliminate the problems of non-constant variance and non-normality of residuals. Hence, despite the transformation, the model failed to meet the standard regression assumptions indicating a need for the weighted least squares (WLS) estimation technique in order to obtain the efficient estimates. The WLS estimation of the model, using the weights obtained from Glejser variance estimation method, removed the heteroscedasticity problem. As a result, the WLS estimation outperformed the OLS estimation, and the Glejser method outperformed the other methods of variance estimation to obtain weights in this model.

Weighted least squares estimation on the transformed variables log(AFFSALE) and AFFSALE$^{0.1}$, provide good fits and the model residuals meet all standard assumptions. As the transformations are very close to each other, using the logarithmic transformation will be more beneficial for ease of coefficient interpretations. Moreover, logarithmic transformation is a more common transformation, and hence there will be more potential for future model comparisons. On the overall, the estimation results indicate the market potential of the home and host countries, availability of cheap factors of production and skilled labour in the host country encourage multinational investment. Similarities between countries in their income levels, tastes and cultures are also important factors. In addition, in the technologically intensive sectors, agglomeration tendencies of firms tend to make that country more attractive to potential new investors. The results are in line with the propositions suggested.

There is further need in the literature for studies combining theoretical analysis with empirical estimation. As more detailed data becomes available to researchers which
enables distinguishing the activities of vertically and horizontally integrated MNFs, better specifications can be obtained. There is also scope for further sector-based empirical analysis to identify different motivations on the location decisions of multinational firms. An alternative methodology to estimate a multinational production model to the one employed in this chapter may be employing a two-stage estimation technique. In the current model, the transformed response variable models have caused loss of data on the reported zero values. Therefore, a two-stage estimation may be beneficial, where in the first stage multinationals make the decision of whether to invest or not to invest, then at the second stage decide on the level of production.
1. Introduction

Although many CGE models have attempted to explain the potential effects of regional integration on multinational investment, there is still a lack of a specific theory on the subject. The crucial issue is whether trade and FDI are substitutes or complements. If trade and FDI are substitutes, then the removal of trade barriers will entail that markets will be increasingly served by exports rather than overseas production. On the other hand, if trade and FDI are complementary, then trade liberalisation will stimulate FDI flows. The relation between trade and affiliate production is linked to the type of active multinational firms in equilibrium, that whether MNFs operating in a country or sector have vertically or horizontally integrated production structures. In other words, MNFs with market or efficiency seeking motives may give different responses to policy changes. Since vertically and horizontally integrated production motives prevail in different conditions, countries and sectors with different characteristics should also respond integration policies in a different manner.

In recent years there has been an increase in interest on the effects of European economic integration on foreign direct investment flows. The regional integration policies applied in Europe are more comprehensive than applied among various other countries, as they go beyond removal of trade and investment barriers and aim to harmonize monetary and fiscal regimes as well. The gradual changes which took place in Europe from the formation of a Common Market to the adoption of a Single Currency create a suitable background to analyse the effects of various stages of regional integration on multinational investment. The purpose of this chapter is to investigate the determinants of
location decisions of MNFs in Europe with special emphasis on the impact of the formation of the European Union (EU). The analysis will involve three components of integration: Membership to EU, the Single Market Programme (SMP) and Currency Union. The first question to be answered is whether MNFs find different characteristics attractive in central and peripheral countries, and whether the integration process had an impact on this perception. The second question is whether multinational firms become more sensitive to factor-based differences between member states as a result of regional economic integration, and less sensitive to changes in market conditions in the host country. The third question of interest is whether there are any sectoral differences in the investment patterns of multinational firms and whether the integration process had different effects on each sector. For these analyses the affiliate production model specified in the previous chapter will be expanded to include various integration variables.

The plan of this chapter is as follows: Section 2 summarizes the theoretical expectations on the potential consequences of economic integration regarding foreign direct investment and affiliate production. In addition to this detailed information on the data sets and variables used for estimations are provided. Section 3 discusses the full sample and split sample estimation results for the aggregate manufacturing sector. Section 4 presents the findings for the sectoral determinants of US affiliate production in Europe.

2. Model Specification and Data

a. Theoretical Insights

Theoretical studies have yielded ambiguous results for the potential consequences of economic integration on foreign direct investment patterns. The problem is that the outcome may vary depending on both the character of existing foreign direct investment and the characteristics of countries. Whether the production structure of multinational firms is horizontal or vertical, and in a related manner whether it is import-substituting or export-oriented makes a difference. Integration policies between developed countries
(North-North integration) may differ from the characteristics of integration between developing countries (South-South integration) or agreements taking place between countries with differing levels of development (North-South integration). The effects of these policies depend on how competitive and complementary the economies are. The patterns of trade and investment before the regional integration are also important determinants of how much adjustment is necessary after the agreement. Moreover, some dynamic long-term effects may also be present. A detailed survey on the subject of regional integration and FDI could be found in Blomstrom and Kokko (1997), and Dunning (1997).

It is reasonable to expect that regional integration will have different impacts on investors from the participating economies and outside investors. The first hypothesis suggested by the trade and FDI literature is that the Internal Market Programme will have a positive effect on intra-EC trade, and an ambiguous effect on intra-EC FDI. Depending on the form and height of existing non-tariff barriers, it is likely to have ambiguous effect on extra-EC trade, but a positive effect on extra-EC FDI and intra-EC trade by foreign affiliates of non-EC MNFs (Dunning, 1997). As a result of the elimination of the tariff jumping motive, the intra-regional FDI is expected to decrease and be substituted by trade. However, if regional integration results in trade creation, it is likely that changes in regional production will be required which would motivate a shifting of investment from one participating country to another to reap the benefits of regional comparative advantages. Hence the reduction of trade barriers could stimulate FDI flows by enabling MNFs to operate more efficiently across international borders by utilising a vertical organisation structure. Production in different activities would become more concentrated in those regions where each activity is performed more efficiently. Hence, rather than the total amount of FDI activity in the region, the allocation of activity among countries within the region may be influenced for intra-regional FDI. On the other hand, for inter-regional flows there are three major reasons to expect increases in FDI activity. The first is the tariff jumping effect. The inflows of FDI from outsiders into the region could go up if the average level of protection against non-regional countries increases as a result of regional integration. Integrated countries may prefer to promote regionally produced
goods. The second is the internalisation effect, which indicates that the integrated common market may be large enough to bear the fixed costs for the establishment of new foreign affiliate. The third reason is competition. The outsider firms may lose their export markets as a result of the regional integration since regional trade is free from tariffs. This might stimulate them to start producing within the integrated area. In addition to these, horizontally organised multinational affiliates producing in several countries may rearrange their network of affiliates, so whole region could be supplied from a smaller number of affiliates located in member countries with most favourable economic conditions.

Regional integration agreements may also liberalize capital flows by directly or indirectly reducing or eliminating restrictions on inward direct investment such as by the elimination of trade related investment measures (e.g. requirements for foreign affiliates to satisfy specific export targets) or by strong investor property rights which reduce the risk of direct or indirect expropriation. A significant effect of regional integration agreements is the long term credibility they bring to participating countries. The agreements may create a more predictable policy environment for foreign investors who might otherwise fear that purely national reform efforts are temporary and that various kinds of restrictions may be reintroduced. These effects are likely to be most important for North-South agreements, where the south partners may benefit both from a credible policy environment and access to the markets of the northern partner countries, and South-South agreements where increased credibility benefits both (Blomstrom and Kokko (1997). In addition to these there may be some dynamic effects that influence the levels of FDI inflows through increased economic growth and efficiency over the medium or long term. Increased FDI flows into a region are also important forces behind the competitive pressure that is expected to encourage local producers to adopt efficient production strategies and methods. It is also likely that FDI will stimulate technology transfers and diffusion both directly and through technology spillovers to local firms. These dynamic benefits might increase the attractiveness of the integrated areas as a location for both national and foreign investors. On the other hand, one must also consider that if integration influences the regional industry’s average size, R&D intensity,
marketing investments etc, there may also be dynamic effects that stimulate outflows of FDI from the integrating region. In the current theoretical and empirical literature there is no consensus regarding the size and significance of these dynamic effects.

Economic integration is expected to lead to a more concentrated geographical distribution of economic activity in the EC in technology-intensive sectors in which plant level economies of scale relative to transport costs are important, but a less concentrated pattern where products are more dependent on classical resource endowments (i.e. unskilled labour) for their competitiveness (Dunning, 1997). Countries characterized by relatively unprotected and efficient domestic markets prior to regional integration are likely to enjoy more foreign and domestic investment, since they are not likely to host import substituting foreign investment that might be withdrawn as a result of regional integration. Sectors characterised by high initial levels of trade protection combined with relatively weak locational advantages may suffer decreases in investments both by foreign and domestic firms. The more investing companies perceive the market as integrated, the individual country markets will be treated as being unimportant, leading to sectoral specialization in production across countries.

b. Model specification

Chapter 6 has provided an empirical specification parallel to the findings of computational general equilibrium simulations. In this chapter this specification is expanded by the inclusion of various variables to capture different aspects of integration. Different than most regional integration agreements, the European integration is not only concerned with the elimination of trade barriers, but also aims to harmonize the monetary and fiscal regimes of member countries. Therefore, the effect of EU membership is divided into three categories. The first is the common market effect which covers the reduction or elimination of tariff and non-tariff barriers. As a result of the common market, multinationals are faced by a larger market potential as well as a choice of countries to invest according to production efficiencies of countries without the loss of the potential market. The second category is the monetary union effect which investigates
the impact of harmonised monetary policies between member countries. The third is the impact of reduced long-term riskiness brought by membership in the EU. This membership provides increased credibility to the member country due to a long term commitment to macroeconomic stability and European economic integration.

The following models are specified to estimate the determinants of multinational production (1-3). The first model is the same specification used in the previous chapter. The second model analyses the outcome of a membership to EU, while the third model partitions the EU membership effects into common market (SMP), harmonised monetary policies and long-term macroeconomic stability and commitment to integration. Hence, the third model could be treated as the general model, and the first two as the restricted versions of the general specification.

\[
\begin{align*}
\text{AFFSALE} &= \beta_0 + \beta_1 \text{TOTINCOME} + \beta_2 \text{PINCOMESH} + \beta_3 \text{PINCOMESH}^2 \\
&+ \beta_4 (\text{HINCOMESH} \times \text{HCOMP}_{skl}) + \beta_5 \text{HSKLRATIO} \\
&+ \beta_6 (\text{PSCALE} \times \text{HINCOMESH}) + \beta_7 \text{HTRADEC} + \beta_8 \text{PTRADEC} + \varepsilon \\
&\text{(1)}
\end{align*}
\]

\[
\begin{align*}
\text{AFFSALE} &= \text{mod.el.1} + \beta_9 \text{(EU)} + \varepsilon \\
&\text{(2)}
\end{align*}
\]

\[
\begin{align*}
\text{AFFSALE} &= \text{mod.el.1} + \beta_9 \text{EU} + \beta_{10} \text{SMP} + \beta_{11} \text{MU} + \varepsilon \\
&\text{(3)}
\end{align*}
\]

c. **Variables and Data**

In order to test the effects of integration on multinational production in Europe, a subset of the data used in the previous chapter has been utilised. The data set includes all European countries as host economies, rather than only EU countries, to allow for different levels of integration within the data set. The data is organized as a panel, where each country pair represents a cross section. The main advantage of using a panel data set is the ability to control for individual heterogeneity. Time series and cross section studies not controlling for this heterogeneity run the risk of obtaining biased results. Panel data allows for an increased number of data points and hence additional degrees of freedom.
As a result panel data may reduce the gap between the information requirements of a model and the information provided by the data. A large number of data points also reduces the collinearity among explanatory variables and hence improve the efficiency of econometric estimates. Incorporating information relating to both cross section and time series variables can also substantially reduce the problems that arise when there is an omitted variables problem. The effects that are not detectable in pure cross section or time series models become more identifiable. Additionally, biases resulting from aggregation over cross sections or time series are eliminated (Greene, 2003; Baltagi, 2001).

The dependent variable is the affiliate sales (or production depending on data availability) in European host countries by all investing parent (home) countries. The affiliate sales (or production) data covers the period 1985-1998, with 1028 (prior to estimations) observations. The data is composed of 25 host European countries, and around 35 parent countries, providing over 200 cross section country pairs. The data has an unbalanced and non-contiguous nature due to missing observations in reports and lack of data reporting for some countries and time periods. The time span for cross sections ranges between 1-14 observations. The average time span is approximately 4.5 years per country pair. Furthermore, the number of observations is biased for the second half of data, the period 1985-1991 including 189 observations and the period 1992-1998 including 839 observations.

The main exogenous variables used to proxy market size, the similarity between country sizes, comparative advantages of countries, the level of skilled labour and agglomeration are the same as in the previous chapter. The effects of EU integration are analysed in two levels. At the first level a binary variable $HEU$ is added in order to capture all the impact

---

1 More information on the data set is provided in the previous chapter. In this chapter only positive levels of affiliate sales are taken into account since a log-linear specification is used following the results of last chapter.
2 Austria, Belgium, Bulgaria, Croatia Denmark, Greece, Finland, France Germany, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovak Rep, Slovenia, Spain, Sweden, Switzerland, Turkey, UK, Ukraine.
3 All European host countries and Argentine, Australia, Canada, Japan, Korea, Mexico, New Zealand, Singapore, the USA.
of European Union membership. This variable takes the value of one when the host county is a member of European Union, and zero otherwise\(^4\). In the second level of analyses a binary variable to represent the Single market programme (HSMP) is introduced in order to distinguish the customs union effect (reduction or elimination in tariff and non-tariff barriers). This variable takes the value of one when the host country is a member of the Single Market Programme\(^5\). A positive coefficient for this variable represents the importance given to reaching a larger market by multinational firms. In other terms, this variable represents the joint EU market potential. As a result of the inclusion of HSMP variable, HEU dummy only captures the reduced riskiness through a long term commitment to macroeconomic stability and integration. In addition to these, an exchange rate volatility measure (EXCV) is included in order to investigate the potential effects of harmonized monetary policies between countries. This variable captures the potential effects of currency union for EU member host-home country pairs, and the effects of exchange risk on the location decisions of MNFs originating from non-EU countries. Although the time span of the data set does not cover the period of the introduction of the single currency, it is still possible to investigate the potential effects of a monetary union through this exchange rate volatility measure. EXCV is calculated as the five year moving standard deviation of the annual percentage change of the bilateral exchange rate between the home and host countries. An increase in EXCV may lead risk adverse firms to reduce their FDI with the expectations of macroeconomic instability. Independent of this factor, foreign direct investment may be reduced with exchange rate volatility, if an affiliate imports inputs or exports output. On the other hand, it may encourage the source country to replace exports to the partner country by local production to avoid exchange uncertainty (higher transaction costs). The variable may also capture similarity between countries as currency unions are more integrated than countries with their own currencies.

\(^4\) The binary variable HEU has an entry of '1' for the following counties: For 1985-1999: Belgium, Germany, France, Italy, Luxemburg, Netherlands, Denmark, Ireland, UK, Greece. For 1986-1999 Spain and Portugal. For 1995-1999 Austria, Finland and Sweden.

\(^5\) The Single European Act was signed in 1986, setting out a timetable for completing the single market by 1993. However, this series takes 1989 and onwards as a period of single market, since 95% of legislation was completed at the end of 1988. Hence the binary variable HSMP has an entry of '1' for the following counties: For 1989-1999: Belgium, Germany, France, Italy, Luxemburg, Netherlands, Denmark, Ireland, UK, Greece, Spain and Portugal. For 1994-1999: Austria, Finland, Iceland, Norway and Sweden.
### TABLE VII.1a
Description of Variables and Expected Signs

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description of Variable</th>
<th>Expected sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFFSALE</td>
<td>Real volume of production (or sales) by affiliates of parent country-j in host country-i. All turnover and production data are in million USD converted from local currency by using average exchange rates and deflated by the US wholesale price index.</td>
<td>Dependent variable</td>
</tr>
<tr>
<td>GDPSUM</td>
<td>Sum of home and host country real GDP data measured in bill. of 1995 constant USD.</td>
<td>(+)</td>
</tr>
<tr>
<td>PGDP</td>
<td>Share of parent country real GDP in total real GDP of parent and host countries.</td>
<td>(+)</td>
</tr>
<tr>
<td>PGDP</td>
<td>This variable aims to capture dissimilarities in sizes of home and host countries.</td>
<td>(-)</td>
</tr>
<tr>
<td>HGDPSH</td>
<td>Share of host country GDP, calculated as host country real GDP divided by the sum of home and host country real GDP levels.</td>
<td>(+)</td>
</tr>
<tr>
<td>HSKLRATIO</td>
<td>The ratio of skilled labour in host country divided by the total labour force of that country. The variable aims to capture skilled labour availability in host country.</td>
<td>(+)</td>
</tr>
<tr>
<td>PSKLRATIO</td>
<td>The ratio of skilled labour in parent country divided by the total labour force of that country. The variable aims to capture technology intensity of parent country affiliates.</td>
<td>(+)</td>
</tr>
<tr>
<td>HCOMPSKL</td>
<td>The comparative advantage index of the host country is constructed as the ratio of skilled labour to unskilled labour ratio of the host country divided by the equivalent ratio for parent country. Hence, a higher HCOMPSKL ratio indicates a higher comparative advantage in skilled labour for the host country.</td>
<td>(-)</td>
</tr>
<tr>
<td>HTRADEC</td>
<td>Host country trade cost constructed as one minus the share of foreign trade in GDP. The assumption used is that the more open a country is the lower the trade costs will be.</td>
<td>(+)</td>
</tr>
<tr>
<td>PTRADEC</td>
<td>Parent country trade cost, constructed as above.</td>
<td>(-)</td>
</tr>
<tr>
<td>SIMILAR</td>
<td>A dummy variable included to capture the effects of similarities such as language, culture and tastes, takes the value one if the country pairs share a border or if they have the same official language.</td>
<td>(+)</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>The distance between the capital cities of home and host country pairs (as crow flies). Dissimilarities between two countries increase parallel to distance.</td>
<td>(-)</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>Squared DISTANCE variable. Proxies transport (shipment) costs between countries.</td>
<td>(+)</td>
</tr>
<tr>
<td>HSMP</td>
<td>Programme. A positive coefficient for this variable represents the importance given by MNFs to market potential (all countries within customs union).</td>
<td>(+)</td>
</tr>
<tr>
<td>HEU</td>
<td>This variable takes the value of one when the host country is a member of the Single Market Programme. A positive coefficient for this variable represents the importance given by MNFs to market potential (all countries within customs union).</td>
<td>(+)</td>
</tr>
<tr>
<td>HEU</td>
<td>Exchange rate volatility variable is calculated as the five year moving standard deviation of the annual percentage change of the bilateral exchange rate between the home and host countries.</td>
<td>(+, -)</td>
</tr>
<tr>
<td>INTRA-SECTOR</td>
<td>The share of total manufacturing (or the sub-sector) of host country in total European production. A higher share indicates the presence of stronger supply linkages.</td>
<td>(+)</td>
</tr>
</tbody>
</table>
3. Testing the Impact of Integration on Aggregate Manufacturing Affiliate Production in Europe

This section will provide the estimation results on the aggregate manufacturing production data set. The models are estimated using panel data estimation techniques, for which further information could be found in various text books such as Greene (2003), Petersen (2004), Baltagi (2001), Wooldridge (2002) and Hsiao (1986, 2003). After a brief summary of the main features of these estimation techniques to clarify the reason of model choice, the estimation results for full and split sample results are provided.

a. Fixed versus Random Effects Specification

A panel data regression differs from a regular time series or cross section regression in that it has a double subscript on its variables representing the cross section and time. The basic regression model takes the form (1),

\[ y_{it} = X'_{it} \beta + Z_i' \alpha + \epsilon_{it} \]  

(1)

where \( y_{it} \) denotes the dependent variable for individual-\( i \) in period \( t \). There are two different types of independent variables, those that for an individual may vary over time, and those that are time constant. The former are collected in the vector \( X_{it} \), and the latter in \( Z_i \). There are \( K \) regressors in \( X_{it} \), not including a constant term. The heterogeneity, or individual effect is \( Z_i' \alpha \), where \( Z_i \) contains a constant term and a set of individual or group specific variables which may be observed or unobserved.

If \( Z_i \) is observed for all individuals, then ordinary least squares provides consistent and efficient estimates of the slope vector \( \beta \). This specification is called the total equation, and the least squares estimator of this specification is referred to as the total estimator or the pooled or ordinary least squares estimator. It ignores the grouped nature of the data with repeated observations on each individual. It corresponds to what would be specified
and estimated with cross sectional data analysis except that each individual may contribute with more than one observation.

If $Z_i$ includes unobservable variables which are correlated with $X_{it}$, then the least squares estimator of $\beta$ is biased and inconsistent as a result of omitted variable problem. Therefore, unobserved variables need to be taken into account as is in within fixed effects equation 2 below, where $\alpha_i$ is a group specific constant term. Since this equation can be estimated with the least squares estimator it is referred to as the within, fixed effects or sometimes the least squares dummy variable (LSDV) estimator 6. In order to avoid the dummy variable trap, or perfect multicollinearity, the restriction given in (3) needs to be imposed.

$$y_{it} = \mu + X_{it}'\beta + \alpha_i + \varepsilon_{it}$$

(2)

$$\sum_{i=1}^{N} \alpha_i = 0$$

(3)

If the number of cross sections is large, instead of including a large number of dummies $(n-1)$, LSDV parameters can be obtained by estimating a transformed version of this model. Since averaging equation 2 over time gives equation 4 and averaging across all observations gives equation 5, below, the OLS estimation of deviations from group means (6) will provide the correct parameter estimates 7.

$$\bar{y}_i = \mu + \bar{X}_i'\beta + \bar{\alpha}_i + \bar{\varepsilon}_i$$

(4)

$$\bar{y}_i = \mu + \bar{X}_i'\beta + \bar{\varepsilon}_i$$

(5)

$$(y_{it} - \bar{y}_i) = (X_{it} - \bar{X}_i)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_i)$$

(6)

6 The model can be expanded to include fixed time effects as below:

$$y_{it} = \mu + X_{it}'\beta + \alpha_i + \gamma_i + \varepsilon_{it}$$ where $\gamma_i$ are time effects.

7 After obtaining estimates of $\beta$ from regression 6, the estimates for $\mu$ can be recovered from equation (5) and the estimates of $\alpha_i$ from equation (4): $\hat{\mu} = \bar{Y}_t - \hat{\beta}\bar{X}_t$, $\hat{\alpha}_i = \bar{Y}_i - \hat{\mu} - \hat{\beta}\bar{X}_t$. 

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The joint significance of the group effects could be tested by performing an F-test. The major advantage of the fixed effects procedure is that one can control for all unmeasured variables and get consistent estimates of $\beta$ for variables that vary over time. The danger of omitted-variable bias is reduced. The main drawback of this procedure is that only the effects of variables $X_{it}$ that vary over time can be estimated. This is a major problem because in most applications the time constant variables are very important. In addition to this a large number of degrees of freedom are used up in estimating the effects of the individual-specific dummy variables.

Another specification which takes into account the grouped nature of the data is the random effects equation (7), where $u_i$ is an individual specific error term and is assumed to be independent of the observed variables $X_{it}$ and of $\varepsilon_{it}$.

$$y_{it} = X_{it}'\beta + \alpha + u_i + \varepsilon_{it}$$  \hspace{1cm} (7)

The main drawback of random-effects procedure is that one must assume that the unobserved time-constant variables captured by $u_i$ are independent of the observable variables. This is a strong assumption and its violation leads to inconsistent estimates of $\beta$. Its main advantage, on the other hand, is that one can estimate the effects of both time-constant and time-varying variables, and it uses information on all individuals and all variables on each individual, even those that are constant over time.

As a first step of the feasible generalised least squares estimation, the estimates of the variance components need to be obtained. By using these estimates an estimator for the

---

8 Eviews provides three quadratic unbiased estimators from choices of Swamy-Arora, Wallace-Hussain and Wansbeek-Kapteyn. Briefly, the three QUE methods use the expected values from quadratic forms in one or more sets of first-stage estimated residuals to compute moment estimates of the component variances. The methods differ only in the specifications estimated in evaluating the residuals, and the resulting forms of the moment equations and estimators. The Swamy-Arora estimator of the component variances, cited most often in textbooks, uses residuals from the within (fixed effect) and between (means) regressions. In contrast, the Wansbeek and Kapteyn estimator uses only residuals from the fixed effect (within) estimator, while the Wallace-Hussain estimator uses only OLS residuals. In general, the three should provide similar answers, especially in large samples.
composite residual covariance (Σ) is formed, and these are used in a weighted least squares procedure to form the feasible GLS estimates. The transformation of yi for GLS is given in (8). The same transformation is applied on Xi.

\[ \sum \frac{1}{\sigma_e} Y_i = \frac{1}{\sigma_e} \begin{bmatrix} Y_{i1} - \Theta \bar{Y}_i \\ Y_{i2} - \Theta \bar{Y}_i \\ \vdots \\ Y_{iT} - \Theta \bar{Y}_i \end{bmatrix}, \text{ where } \Theta = 1 - \frac{\sigma_e}{\sqrt{\sigma_e^2 + T\sigma_u^2}} \] (8)

If Θ equals one (σ_e = 0 or T → ∞), then the fixed effect and random effects models would be indistinguishable. On the other hand if Θ equals zero, then generalised least squares is identical to ordinary least squares.

Although the random effects estimator uses data more effectively than fixed effects estimator, it relies on the assumption that the unmeasured time-constant variables captured by u_i are independent of the observable (measured) time varying (X_it) or time constant (Z_it) regressors. If this assumption is not true, then GLS estimators of slope coefficients become biased and inconsistent. Baltagi (2001) provides various asymptotic equivalent forms of Hausman specification test which is suitable for testing this assumption.

b. Results of Regression Analysis: Full sample results

The estimation results for model 1 (i.e. restricted model without integration effects) are provided in Table VII.1. Pooled regression model (column 2) gives correctly signed,

---

9 For unbalanced panel data group specific Θ_i should be used: \[ \Theta_i = 1 - \frac{\sigma_e}{\sqrt{\sigma_e^2 + T_i \sigma_u^2}} \]

10 Table VII.1 reports robust coefficient covariances estimated using a cross section SUR panel corrected standard errors (PCSE) methodology, which is robust to cross equation (contemporaneous) correlation, as
significant coefficients for all variables, but the model shows signs of significant 
misspecification in terms of a very low Durbin-Watson statistic indicating first order 
serial correlation, and a significant White statistic confirming the existence of 
heteroscedastic variance structure. Both problems could be a result of omitted variables 
from the regression.

Since pooled regression do not take the grouped nature of the data, a random effects 
model is estimated by generalised least squares (GLS) to make use of this additional 
information. Additionally, some time–constant variables such as distance and similarity 
dummy used in the previous chapter are included in the regression. As explained in 
section (3.a), random effects estimation method assumes individual effects to be 
independent of all other observed variables used in the regression and if this assumption 
does not hold the results are not reliable. The statistical software package used for the 
estimations in this chapter, Eviews 5.0, does not have a built in feature to calculate the 
Hausman misspecification statistic. In order to calculate an asymptotic equivalent of this 
statistic a variable addition test is performed on an artificial regression where the GLS 
residuals are regressed on $\mathbf{X}$ and $\mathbf{X}$, where $\mathbf{X}$ is a matrix of deviations from means and 
$\mathbf{X}$ is a matrix of regressors averaged over time. Hausman’s test statistic can be obtained 
from this artificial regression by a Wald coefficient test on all additional variables. The 
test rejects the null hypothesis of random effects model being the appropriate choice of 
model at all levels of significance. The estimated values of error components also support 
this result, since nearly all of the variation (93%) in the disturbance term is explained by 
variation within the groups with only a small remainder explained by variation across 
groups. In addition to these, the model also shows signs of serial correlation with a low 
Durbin-Watson statistic.

well as different error variances in each cross section. The methodology (PCSE) is a variant of White 
robust covariances, in which residuals are replaced by moment estimators for the unconditional variances. 
Heteroscedasticity across time would probably be not relevant in this case, since the time series includes a 
relatively small number of observations.)
### TABLE VII.1b

**Fixed versus Random Effects**

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LOG (AFFSALE) : 1985-1998</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Method</td>
</tr>
<tr>
<td>GDPSUM</td>
<td></td>
</tr>
<tr>
<td>PGDPSh</td>
<td></td>
</tr>
<tr>
<td>PGDPSh²</td>
<td></td>
</tr>
<tr>
<td>HCOMPₚₑₓ</td>
<td></td>
</tr>
<tr>
<td>HSKLRATIO</td>
<td></td>
</tr>
<tr>
<td>PSKLratio*HGDPSH</td>
<td></td>
</tr>
<tr>
<td>HTRADEC</td>
<td></td>
</tr>
<tr>
<td>PTRADEC</td>
<td></td>
</tr>
<tr>
<td>SIMILAR</td>
<td></td>
</tr>
<tr>
<td>DISTANCE</td>
<td></td>
</tr>
<tr>
<td>DISTANCE²</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

| # observations     | 1006   | 1005   | 1006   |
| # cross sections   | 238    | 238    | 238    |

| F-statistic (cross section) | -      | -      | 39 (0.0000) |
| F-statistic (time effect)   | -      | -      | 0.53 (0.9999) |
| Wald stat (Hausman)         | -      | 24.58 (0.0062) | - |

| $R^2$                       | 0.4757 | 0.9583 | 0.9601 |

| Durbin Watson              | 0.17   | 1.38   | 1.93   |
| White                      | 117 (0.0000) | 29 (0.114) | 261 (0.3764) |

**Notes:**
1. AFFSALE is the volume of real turnover in a host country. The first letters, P and H in the regressors denote parent, and host countries, respectively. All variable definitions are presented in Table VII.1.a.
2. All models are estimated using White cross section panel corrected standard errors (PCSE) and covariance (degrees of freedom corrected). The figures reported in parenthesis are t-statistics. (**) represent 5% significance level and (*) represent 10% significance level. The figures reported in parentheses for Wald, F and White statistics are the probability values that the statistics exceed the observed value under the null-a small value leads to the rejection of null hypothesis.
3. Fixed effect specifications include home and host country pairs.
Finally, the model is estimated by a fixed effects specification (column 3)\(^1\). All variables have correct signs and except trade cost variables they are significant at 5% significance level\(^2\). Moreover, the model shows no signs of serial correlation with a DW statistic close to 2 (DW=1.93) and the White test rejects the existence of any significant heteroscedasticity. Individual effects are also found to be jointly significant, while the joint significance of time effects is strongly rejected. The insignificance of time effects may be explained by a low time span and a large number of cross sections. In addition to this, the use of share variables may have an offsetting effect on the effects of time.

Table VII.2 reports the full sample estimation results of the models with integration variables. As expected EU membership of the host country provides a positive effect in total on the production and sales activities of multinational firms (column 2). The levels of other coefficients in the model do not seem to be affected by the inclusion of this dummy variable. The model does not show any significant serial correlation or heteroscedasticity. Trade cost variables are not included in this specification since integration variables also capture the same information (when included trade cost variables were insignificant). The next model in column 3 (Table VII.2) investigates the partitioned effects of integration through a single market effect (HSMP) and a monetary union or harmonised monetary policy effect (EXCV). When these variables are included the EU membership variable (HEU) only captures the long-term stability of host country and hence lower risks involved. The estimation results demonstrate that countries benefit from being in a regional common market agreement which eliminates (or lowers) trade

\(^1\) The fixed country effects include home and host country pairs rather than separate home and host country dummies as used in Chapter 6. Therefore, for instance, UK affiliate turnover in Germany is treated as a separate country fixed effect to that of UK affiliate turnover in France. In the previous chapter (Chapter 6) they would be captured by PUK (parent UK) dummy together. Hence, the number of cross sections used in estimations of this chapter is higher than those of in Chapter 6.

\(^2\) The model is estimated using HGDPSH*HCOMPSKL and only HCOMPSKL. The use of HCOMPSKL alone provided a slightly better fit due to higher similarity between the relative endowments of country pairs compared to the country pairs of Chapter 6.
TABLE VII.2
Full Sample Regression Results

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LOG (AFFSALE) : 1985-1998</th>
<th>Least Squares Dummy Variable Estimation (Fixed Effects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDPSUM</td>
<td>0.0005 (7.2)**</td>
<td>0.0005 (7.8)**</td>
</tr>
<tr>
<td>PGDPSH</td>
<td>21.06 (3.5)**</td>
<td>20.15 (3.4)**</td>
</tr>
<tr>
<td>PGDPSH²</td>
<td>-16.41 (-2.9)**</td>
<td>-15.89 (-2.9)**</td>
</tr>
<tr>
<td>HCOMP_SKL</td>
<td>-1.43 (-2.7)**</td>
<td>-1.15 (-2.0)**</td>
</tr>
<tr>
<td>HSKLRATIO</td>
<td>6.58 (3.6)**</td>
<td>4.97 (2.8)**</td>
</tr>
<tr>
<td>PSKLRA TIO * HGDP SH</td>
<td>5.99 (2.1)**</td>
<td>7.15 (2.6)**</td>
</tr>
<tr>
<td>HEU</td>
<td>0.35 (4.8)**</td>
<td>0.22 (2.4)**</td>
</tr>
<tr>
<td>HSMP</td>
<td></td>
<td>0.22 (2.9)**</td>
</tr>
<tr>
<td>EXCV</td>
<td></td>
<td>-0.18 (-5.6)**</td>
</tr>
<tr>
<td>C</td>
<td>-0.97 (-0.5)</td>
<td>-0.88 (-0.5)**</td>
</tr>
</tbody>
</table>

| # observations     | 1009                        | 1009                                                   |
| # cross sections   | 241                         | 241                                                    |

\[ R^2 \] 0.9473 0.9482 0.9523

Durbin Watson

\begin{tabular}{lccc}
 & 1.93 & 1.95 & 2.07 \\
White & 262 (0.3141) & 269 (0.2338) & 247 (0.6117) \\
\end{tabular}

Notes: 1. AFFSALE is the volume of real turnover in a host country. The first letters, P and H in the regressors denote parent, and host countries, respectively. All variable definitions are presented in Table VII.1a. 2. All models are estimated using White cross section panel corrected standard errors (PCSE) and covariance (degrees of freedom corrected). The figures reported in parenthesis are t-statistics. (**) represent 5% significance level and (*) represent 10% significance level. The figures reported in parentheses for F and White statistics are the probability values that the statistics exceed the observed value under the null-a small value leads to the rejection of null hypothesis. 3. Fixed effect specifications include home and host country pairs.
costs. A larger market potential (i.e. common market) seems to be an important decision factor for multinationals. The \textit{HEU} variable still captures some significant positive effects, indicating countries, on the overall, benefit from the long-term commitment to macroeconomic stability, development and regional integration.

Although in the literature there is no consensus on the potential effects of exchange rate volatility (here used as a proxy for potential effects of exchange rate risk in general, and the effects of harmonised monetary policy and Currency Union between EU home-host country pairs), in this specification, higher exchange rate volatility has a significant negative impact on multinational production. This finding may be as a result of exchange volatility being associated with expectations of macroeconomic instability in the host country or an indication of dissimilarity between countries. Another possibility which may reduce investment by multinationals at higher exchange rate volatility may be their reliance on imported inputs from home country or exports of final product to home country. After the inclusion of integration variables, home and host country market sizes (\textit{GDPSUM, PGDPSHARE}), similarity between countries (\textit{PGDPSHARE}²) and agglomeration of production continue to be significant factors on the location decisions of multinationals. Relative endowments, on the other hand, although correctly signed do not seem to have a major importance. The multinational firms investing in Europe seem to be influenced from market-seeking motives rather than efficiency-seeking motives. Yet, the MNFs originating from countries with high economies of scale, also choose locating in close proximity to other competitors and suppliers to benefit from strong supply linkages, innovatory capabilities, a good infrastructure and/or a pool of skilled labour.

\textbf{c. Results of Split Sample Regression Analysis: Central versus Peripheral}

In order to examine whether multinationals find different characteristics attractive in central and peripheral countries the data set is divided into two groups of countries as central countries (i.e. Belgo-Lux Economic Region, the Netherlands, Germany, the UK,
TABLE VII.3  
Central versus Peripheral European Countries

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LOG (AFFSALE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Least Squares Dummy Variable Estimation (Fixed Effects)</td>
</tr>
<tr>
<td>GDPSUM</td>
<td>0.0002 (2.0) **</td>
</tr>
<tr>
<td>PGDPSh</td>
<td>36.57 (2.8) **</td>
</tr>
<tr>
<td>PGDPSh^2</td>
<td>-21.50 (-1.8) *</td>
</tr>
<tr>
<td>HCOMPskl</td>
<td>-0.45 (-0.8)</td>
</tr>
<tr>
<td>HSKLratio</td>
<td>2.32 (0.58)</td>
</tr>
<tr>
<td>PSKLratio*HGDPSH</td>
<td>5.05 (1.2)</td>
</tr>
<tr>
<td>HEU</td>
<td>0.02 (0.1)</td>
</tr>
<tr>
<td>HSMP</td>
<td>0.50 (2.9) **</td>
</tr>
<tr>
<td>EXCV</td>
<td>-0.17 (-2.9) **</td>
</tr>
<tr>
<td>C</td>
<td>-3.88 (-1.3)</td>
</tr>
</tbody>
</table>

# observations 502 495 457 464  
# cross sections 122 118 122 118

\[ \bar{R}^2 \] 0.9619 0.9313 0.9672 0.9329

Durbin Watson 1.82 2.29 2.00 2.34

Notes: 1. AFFSALE is the volume of real turnover in a host country. The first letters, P and H in the regressors denote parent, and host countries, respectively. All variable definitions are presented in Table VII.1.a. 2. All models are estimated using White cross section panel corrected standard errors (PCSE) and covariance (degrees of freedom corrected). The figures reported in parenthesis are t-statistics. (**) represent 5% significance level and (*) represent 10% significance level. 3. Fixed effect specifications include home and host country pairs.
France and Italy) and peripheral countries (i.e. Denmark, Ireland, Spain, Portugal, Greece and other European countries).

Estimations for both country groups provide the same signs for size and relative endowment coefficients (Table VII.3). Total market size seems to be the most important determinant for both country groups indicating the similarity in the investment tendencies of multinationals. In addition to total market size \((GDPSUM)\), relative size of parent country \((PGDPSHARE)\), and size similarity \((PGDPSHARE^2)\) are also statistically significant factors for multinationals investing in central European countries. This means a large parent and a similarly sized host country are important determinants for FDI activity. For peripheral countries, on the other hand, similarity with the parent country and higher levels of skilled are not statistically significant at 5%. An interesting result is that for central European countries the effect of integration is completely captured by the single market effect \((HSMP)\), and the coefficient is also much larger than the whole sample one. As a result of having an already large host market and less distance to other large markets (other central European countries), central countries reap the benefits of common market in terms of foreign investment. The coefficient of the same variable is negative and insignificant at 5% level for peripheral countries. On the other hand, membership to EU provides a positive effect on multinational activity for peripheral countries. Peripheral countries seem to benefit from a commitment to political and macroeconomic stability and integration with other EU countries. For central countries, on the contrary, membership to EU has also positive but a statistically insignificant effect. The reason for this could be their already existing dependability on commitment to stability and economic development given their past performance. Hence, membership to EU does not seem to bring additional attraction to multinational investors through reduced long term risks. In fact the potential positive effects of macroeconomic and political stability are probably already captured by a larger host market size. In addition to these, exchange rate volatility has a negative sign for both country groups, but statistically significant only for the central European countries data set.
To sum up, the results indicate that the Single Market programme has only benefited market oriented large countries, rather than small peripheral countries. This result may be an indication of the fact that multinational firms do not yet see Europe as a completely integrated area to start seeking for efficiency gains from locational advantages. On the contrary, peripheral countries benefit from increased credibility through membership to the EU. These results support the hypothesis that integration between North-North countries may have different effects on inward multinational investment than North-South integration agreements.

Another issue to investigate is how regional integration affects different determinants of FDI over time. Theoretical hypothesis expect for an increase in the importance given to factor based differences as a result of integration. Since SMP has started in 1986 and the data set used does not include years before 1985, it is not possible to divide the data set into pre-SMP and post SMP sets. Therefore, the 1990-1998 time period is used to test if any changes through time have occurred on the determinants of multinational activity in central and peripheral countries. This period covers the time when most policy changes have already taken place, and locational adjustments for production may be expected. Nevertheless, the factors affecting multinational production are more or less the same as in full time span versions of central and peripheral country models, and there does not seem to be a shift in the importance given to factor based differences. Rather, similarity in country sizes seems to have gained importance for peripheral countries. This may be due the increased growth in the market sizes of these countries during 1990-98, which makes them more attractive for market oriented MNFs.

d. Results of Split Sample Regression Analysis: EU-EU versus EU-NEU

According to multinational production theories, integration among regions is expected to have different effects on the investments of intra-EU and extra-EU multinational firms. In order examine the affiliate patterns of intra-EU and extra-EU based multinational companies, the data set is split into two. The first group involves affiliate sales of EU countries in other EU countries (EU-EU). The second group covers affiliate sales of non-
**TABLE VII.4**

EU versus Non-EU Multinationals in European Union

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LOG (AFFECTSALE)</th>
<th>Least Squares Dummy Variable Estimation (Fixed Effects)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDPSUM</td>
<td>0.0009 (2.7) **</td>
<td>0.0004 (5.4) **</td>
</tr>
<tr>
<td>PGDPSSH</td>
<td>4.60 (0.7)</td>
<td>57.27 (3.78) **</td>
</tr>
<tr>
<td>PGDPSSH^2</td>
<td>-8.52 (-1.5)</td>
<td>-39.44 (-3.9) **</td>
</tr>
<tr>
<td>HCOMP_SKL</td>
<td>-0.71 (-1.7) *</td>
<td>0.23 (0.3)</td>
</tr>
<tr>
<td>HSKLRATIO</td>
<td>2.24 (0.9)</td>
<td>-0.9 (-0.5)</td>
</tr>
<tr>
<td>PSKLRATIO*HGDPSH</td>
<td>1.92 (0.6)</td>
<td>8.6 (2.7) **</td>
</tr>
<tr>
<td>HSKRRATIO</td>
<td>0.25 (1.5)</td>
<td>0.35 (2.5) **</td>
</tr>
<tr>
<td>EXCV</td>
<td>-0.15 (-2.3) **</td>
<td>-0.13 (-2.7) **</td>
</tr>
<tr>
<td>C</td>
<td>5.7 (3.2) **</td>
<td>-10.48 (-2.2) **</td>
</tr>
</tbody>
</table>

| # observations    | 393              | 354             | 372              | 316            |
| # cross sections  | 100              | 85              | 100              | 84             |

\[ R^2 \]

|                | 0.9707           | 0.9683          | 0.9717           | 0.9707         |

Durbin Watson

|                | 1.76             | 1.82            | 1.81             | 2.04           |

Notes: 1. AFFECTSALE is the volume of real turnover in a host country. The first letters, P and H in the regressors denote parent, and host countries, respectively. All variable definitions are presented in Table VII.1.a. 2. All models are estimated using White cross section Panel corrected standard errors and covariance (degrees of freedom corrected). The figures reported in parenthesis are t-statistics. (***) represent 5% significance level and (*) represent 10% significance level. 3. Fixed effect specifications include home and host country pairs.
EU countries in EU member countries (EU-NEU). The factors affecting EU countries to produce in other EU countries are mainly total market considerations (GDPSUM, (+)) and comparative advantage in labour ($HCOMP_{SKL}$, (-)). All variables have the expected signs (column 2).

The NEU countries, on the other hand, prefer larger total market ($GDPSUM$, (+)), a large parent country and a similarly sized but slightly smaller host country ($PGDSPHARE$, (+) and $PGDSPHARE^2$, (-)). MNFs originating from non-EU member countries with higher technology intensities also show a preference of choosing locations with strong supply linkages (i.e. clusters of manufacturing sector firms). To sum up, the results indicate significant differences in the factors determining the location decisions of MNFs originating from EU or non-EU member countries. While non-EU multinationals choose their EU investment locations mainly based on market considerations, EU multinationals invest in other EU multinationals not only due to market size but also due to comparative advantage in labour. This supports the hypothesis that within the integrated region there may be a reallocation of production resources reflecting more closely the patterns of comparative advantages. Being in the Single Market Program has a positive and significant effect for attracting non-EU multinational investment, and a positive, but insignificant, effect on EU multinationals investing in other EU countries. Exchange rate volatility has negative and significant effect for both EU and non-EU countries investing in the EU region.

The potential effects of regional integration on different determinants of FDI over time are examined by performing the same tests on the samples with 1990-98 time span. For EU multinationals investing in other EU countries relative endowments seem to have become more important. The coefficient for $HCOMP$ (comparative advantage of host country in skilled labour) is higher in absolute value and has a higher t-statistic. Moreover, the variable $HSKLRATIO$ (abundance of host country skilled labour) is now significant at 10% level, and the total market effect ($GDPSUM$) has a lower coefficient and a t-statistic. Non-EU countries, on the other hand, continue to choose their locations mainly according to market considerations. Another interesting result is that exchange
rate volatility is insignificant for both country groups during 1990-98. For EU multinationals, this variable has even changed its sign to positive indicating that lower exchange rate volatility will reduce the locations attractiveness for these investors. Considering the fact that exchange rate volatility has dropped over time for most country pairs (especially for EU member pairs), very low levels of exchange rate volatility is expected to have an insignificant effect on attracting multinationals. The results are compatible with the non-monotonic results of CGE simulations that a change in trade costs may not have the same effect for initially high or low trade costs. The results for the coefficients of $EXCV$ variable may be interpreted to draw results for the potential consequences of the Currency Union where all exchange rate volatility is eliminated. According to the results of EU-EU estimation, the formation of Currency Union may have a negative but an insignificantly small level of effect on the production of multinationals.

4. A Sectoral Perspective on the Location Determinants of Multinational Production and the Effects of Regional Integration

Most empirical studies on multinational production or investments use aggregate manufacturing data due to lack of detailed data at the sectoral level. However, this may have led to overlooking some potential differences between investment patterns of sub-sectors of manufacturing. Each sub-sector produces at different levels of technology intensities, with different plant versus firm level of scale economies. The results in Chapter 5 illustrated that sectoral characteristics have a significant impact on the type of dominant firms. Higher total economies of scale support MNF activity in a sector. In sectors with higher plant versus firm-level scale economies and low trade costs, finding a cheaper production location is the main objective for the MNFs. On the other hand, sectors with high firm-level scale economies support horizontally integrated MNFs. These firms are mainly attracted by a large host market similar to home country, and higher transaction costs, which may be due to factors such as high shipment costs, tariffs, dissimilarities in tastes and culture, or exchange rate risk. Hence, multinationals may show different investment patterns depending on the characteristics of the sector. It is
important to observe the determinants for the location decision of multinationals at the sectoral level to determine policies to attract multinationals in sectors which would bring the most benefit in the long term.

Although OECD provides data by sector, this data set is not detailed at the host and home country pair level. Therefore only USA affiliate data obtained from the USA Bureau of Economic Analysis (BEA)\textsuperscript{13} is used for the analyses. Statistics on U.S. multinational companies (MNFs) produced by the BEA provide a comprehensive and integrated data set for empirical analysis of MNFs and of the effects of MNFs on the economies of home and host countries. BEA produces balance of payments and direct investment position data as well as financial and operating data of affiliates. The balance of payments and direct investment position data focus solely on the value of transactions between U.S. parents and their foreign affiliates and the cumulative value of parents' investments in their affiliates. The financial and operating data, in contrast, provide a wide variety of indicators of the overall domestic and foreign operations of U.S. MNFs, irrespective of the degree of intra-MNF funding. Both types of data are collected in mandatory surveys conducted regularly by BEA (annual sample surveys and benchmark surveys (or censuses) currently conducted every 5 years). In the sample surveys, reports are not required for small affiliates, in order to reduce the reporting burden on the U.S. companies that must file. Instead, BEA estimates the data for these affiliates by extrapolating forward their data from the most recent benchmark survey on the basis of the movement of the sample data. Thus, coverage of the U.S.-MNF universe is complete in non-benchmark, as well as benchmark periods.

Sales by majority-owned non-bank foreign affiliates (MOFA)\textsuperscript{14} in 22 European countries in selected sectors (total manufacturing and four sub-manufacturing sectors\textsuperscript{15}) are used as

\textsuperscript{13} The USA Bureau of Economic Analysis (BEA) is an agency of the Department of Commerce, and along with the Census Bureau and STAT-USA is a part of the Department's Economics and Statistics Administration. The web-link for the BEA is: www.bea.gov

\textsuperscript{14} MOFA's are foreign affiliates in which the combined ownership of all U.S. parents exceeds 50 percent.

\textsuperscript{15} The sub-sectors used in estimations are food and kindred products (FOOD), primary and fabricated metals (METAL), transportation equipment (TRANSPORT) and other manufacturing (OTHERM) sectors. The food sector is composed of grain mill and bakery products and beverages, the primary and fabricated metals sector is composed of primary metal industries, ferrous and nonferrous, the transportation
the dependent variables. The panel data covers the 1985-2000 period for all countries except Czech Republic, Hungary, Poland and Russia where only 1999-2000 data are reported. In addition to this other manufacturing sector only covers 1985-1998 period. There is also sectoral missing data due to suppressions to avoid disclosure individual companies’ data. Despite these missing data USA affiliate sales in Europe data has a much longer average time span than the manufacturing data set employed in the previous sections of this chapter.

Since only one parent country is involved, slight changes are applied on the choice of exogenous variables without loosing the theoretical background derived in the CGE simulations. Instead of $PGDP_{SH}$ and $PGDP_{SH}^2$, a size difference ($SIZEDIFF$) variable is used. This variable is calculated as the squared difference of the GDP shares of parent (USA) and host countries. A negative coefficient is expected to show the preference of US MNFs towards a large host country. In order to capture the motives for vertical multinationals, which are mostly attracted to large host countries with cheap labour, $HGDPSH*HCOMP_{SKL}$ variable is used. Since a large host market ($HGDPSH$) is expected to have a positive effect, while comparative advantage in skilled labour is expected to have a negative effect, the overall impact of the interactive variable is expected to be negative. A new variable, $STMANUF$ (or $SFOOD$, $SMETAL$ etc.), is included to capture the agglomeration effects of intra-sector linkages (this variable is labelled as intra-sector in Table VII.5). This variable is calculated as the share of total manufacturing (or the sub-sector being estimated) of host country in total European production. A higher share indicates the presence of stronger supply linkages in the country for that sector. The EU integration variables, $HSMP$ and $HEU$, are defined the same as before, separating the potential effects of a common market (i.e. a larger market potential for the US MNFs) and long-term credibility benefits of EU membership on US multinational firms. The effect of exchange risk on MNF decisions is measured by the EXCV variable.

equipment sector is composed of motor vehicles and equipment, the other manufacturing sector is composed of tobacco products, textile products, lumber, wood, furniture and fixtures, paper and allied products, printing and publishing, rubber products, miscellaneous plastic products, glass products, stone, clay and other non-metallic mineral products, instruments and related products.
The preliminary least squares estimations showed signs of misspecification despite the inclusion of host country dummy variables. The Durbin-Watson test statistic was very low in all cases pointing to the existence of serious first order autocorrelation. Consequently, the models are re-estimated using 'Period SUR' weights\textsuperscript{16} to adjust for autocorrelation and heteroscedasticity in the model. For some sectors the problem of serial correlation continued despite weighted estimation. Therefore, lagged forms of the exogenous variables are also added in these models to capture the dynamic nature of the data causing serial correlation. Although an attempt to apply a dynamic panel estimation technique was made, the results were not satisfactory due to the unbalanced and non-contagious nature of the observations and by the limited number of time observations due to suppressed data in most sub-sectors. Table VII.5 provides the estimation results for location determinants of US multinationals in Europe for selected sectors. The use of 'Period SUR' weights and lagged exogenous variables, where required, removed the autocorrelation problem in all cases.

All coefficient estimates for total manufacturing sector have the expected signs (column 2). The US multinationals increase their activities in European countries as the total income of home and host countries becomes larger and size difference between the pair gets smaller. The results for these two coefficients support the hypothesis that market size is an important factor for US multinationals. Relative factor costs and skilled labour abundance, on the other hand, are insignificant. Many previous empirical studies have found evidence of US FDI being market-oriented rather than resource-seeking. These findings also support US MNFs being market oriented rather than resource seeking in the total manufacturing sector. Integration in Europe also encourages further multinational production through the presence of a larger market ($HSMP, (+)$) and commitment to macroeconomic stability and integration ($HEU,(+)$). Different to the previous results in this chapter, exchange rate volatility shows a significant positive effect. This may be due to horizontally integrated production structure of US multinationals investing in Europe.

\textsuperscript{16} Using Period SUR weights adjusts for period heteroscedasticity and serial correlation in the residuals. This class of covariance structures allows for arbitrary period serial correlation and period heteroscedasticity between residuals for a given cross section, but restricts residuals in different cross sections to be uncorrelated. Additionally, cross section specific effects in the model are handled through fixed effects method.


### TABLE VII.5

Regression Results by Sector

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>LOG (AFFSALE)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method</strong></td>
<td><strong>TMANUF</strong></td>
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<tr>
<td><strong>Sector</strong></td>
<td>****</td>
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<tr>
<td>GDPSUM</td>
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<tr>
<td>SIZEDIFF</td>
<td>-4.77 (-3.2)**</td>
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<tr>
<td>HGDP<strong>HCOMP</strong>SRL</td>
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<td>HSKLRATIO</td>
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<tr>
<td>INTRA-SECTOR</td>
<td>2.33 (2.6)**</td>
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<td>INTRA-SECTOR -1</td>
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<tr>
<td>HEU</td>
<td>0.22 (5.4)**</td>
</tr>
<tr>
<td>HSMP</td>
<td>0.29 (12.8)**</td>
</tr>
<tr>
<td>EXCV</td>
<td>0.02 (2.0)**</td>
</tr>
<tr>
<td>C</td>
<td>8.95 (7.4)**</td>
</tr>
</tbody>
</table>

| **# observations** | 287 | 230 | 200 | 136 | 129 |
| **F-statistic (cross section)** | 11239 (0.0000) | 107 (0.0000) | 112 (0.0000) | 3459 (0.0000) | 1129 (0.0000) |
| **R²**             | 0.96 | 0.84 | 0.90 | 0.79 | 0.90 |
| **Durbin Watson (initial)** | 0.35 | 0.20 | 0.43 | 0.07 | 0.14 |
| **Durbin Watson weighted** | 1.90 | 1.84 | 2.00 | 1.90 | 2.02 |
| **White**          | 15 (0.3449) | 12 (0.5910) | 16 (0.3133) | 5.7 (0.9909) | 16 (0.4442) |

**Notes:**
1. AFFSALE is the volume of real turnover in a host country. The first letters, P and H in the regressors denote parent, and host countries, respectively. All variable definitions are presented in Table VII.1.a.
2. All models are estimated using Period SUR weights and White Period SUR panel corrected standard errors (PCSE) and covariance (degrees of freedom corrected). The figures reported in parenthesis are t-statistics. (**) represent 5% significance level and (*) represent 10% significance level. The figures reported in parentheses for F and White statistics are the probability values that the statistics exceed the observed value under the null-a value smaller than 0.05 leads to the rejection of null hypothesis. The rejection of null hypothesis for F test indicates the joint significance of cross sections. The rejection of null hypothesis for White test indicates the presence of heteroscedasticity.
3. Fixed effect specifications include host countries.
Uncertainty in exchange rates forms part of transaction cost, and US firms prefer to eliminate this cost by producing abroad. In addition to these, agglomeration effects from intra industry linkages, measured here by the share of the intra-sector in Europe, have a positive and a statistically significant effect, indicating that US MNFs prefer locations with strong supply linkages.

Sub-sectors illustrate slight differences in the importance given to each locational determinant. The demand in food sector is shaped by regional factors such as tastes and cultures. Therefore, proximity to consumers is an important consideration for producers. Hence, the motives are towards a more horizontally integrated production structure for MNFs. The sector is also characterised by large dispersion rather than concentration. These characteristics are also reflected in the activities of US MNF in Europe (column 3). A large host market \((GDPSUM, (+))\) with a similar market size to the parent county \((SIZEDIFF, (-))\) is preferred, while cost factors and agglomeration benefits are not primary factors. Membership to the Single Market Programme also plays a vital role \((HSMP, (+))\) for MNFs in search for a larger market potential with similar characteristics.

Metal sector, on the other hand, relies heavily on raw materials (column 4). Although the regression is based on two factors of production, unskilled and skilled labour, the agglomeration variable captures the tendency of metal sector firms locating together in certain locations. The exchange risk also affects the location decision of US MNFs in the metal sector adversely, mainly due to the costs involved in importing inputs and exporting output. The US MNFs in transport sector are mainly affected by cost considerations (column 5). These firms prefer locations with large market, cheap labour \((HGDP*HCOMP_{SKL})\) and strong supply linkages \((TRANSPORT and TRANSPORT_{t-1})\). Proximity to firms operating in the same sector is of great significance. This agglomeration effect is in line with the CGE results, as transportation sector is characterised by high technology intensity. The market target of transport sector US MNFs is the Single Market free trade zone \((HSMP, (+))\) rather than individual host countries or the US market. As opposed to transport sector, other manufacturing sector is mainly characterised by low total scale economies (column 6). For the US MNFs in this sector, the market potentials of parent and host countries \((GDPSUM, (+), SIZEDIFF, (-))\)
are important, as well as relative cost of unskilled labour in the host economy. In addition to large host market with cheap labour \((HGDP\text{SH}^*HCOMP_{SKL}, (-))\), the locations chosen are expected to have sufficient skilled labour \((HSKL_{RATIO}, (+))\). The removal of trade barriers has made countries in the Single Market programme \((HSMP, (+))\) more desirable to US MNFs. An interesting result of the regression for other manufacturing sector is that the agglomeration variable has a significant negative coefficient. This result is compatible with the characteristics of the sector, as the sector has low technology intensity, intensive competition and hence is not likely to benefit from clusters. The negative coefficient of the agglomeration variable signifies the competition effect within the sector which leads to a dispersed structure.

5. Conclusions

This chapter provides empirical evidence on four issues. First, there is evidence that the country origin of parent firm has an impact on the choice of affiliate location within an integrated region. While non-EU originated multinationals choose their EU investment locations mainly based on market considerations, EU originated multinationals invest in other EU countries not only due to their market potential, but also due to their comparative advantage in labour. More importantly, as integration deepens factor cost differentials and abundance of host country skilled labour gains further importance, while host country market effect starts loosing its importance. This evidence supports the hypothesis that within an integrated region there may be a re-distribution of FDI reflecting more closely the patterns of comparative advantages.

Second, these results support the hypothesis that integration agreements between developed countries may have different effects on inward multinational investment than those of between developed and developing countries. The European regional integration seems to have resulted in central countries reaping the benefits of common market policy in terms of foreign direct investment. On the other hand, peripheral countries seem to attract inward investment as a result of their commitment to political and macroeconomic stability and integration with other EU countries.
Third, exchange rate volatility has a negative and significant effect for MNFs originating both from EU and non-EU countries and investing in the EU region. The interesting part of the result is that this variable loses its significance as EU integration deepens by time. This finding may be interpreted as a currency union policy will have insignificant effect on the attractiveness of a host economy for multinational production. Hence, the benefits a host country may gain from a regional integration is limited to an enlarged market potential through common market policies and reduced long-term macroeconomic risk as a result of an international commitment.

Fourth, the chapter also provides evidence on sectoral differences for the factors motivating multinational production. Multinational firms operating in sectors with high technology (or capital) intensity or in sectors which are highly dependent on specific natural resources tend to find locations with industrial clusters attractive. On the contrary, multinationals in sectors with low technology (or capital intensity) tend to show a dispersed structure.
VIII. CONCLUSIONS

This thesis has sought to contribute to the development of a theoretical model which captures the main firm, sector and location characteristics of multinational firm activity that also fits well with empirical observations. For this purpose, the knowledge capital model (Markusen and Venables, 1995, 1996) is extended by intra and inter-industry supply linkages to allow multinational firms to be attracted to a country to exploit the agglomeration externalities created by pooling of national or other multinational firms. The computational general equilibrium (CGE) simulation results replicate various stylized characteristics of multinational production such as their compatibility with technology or capital intensive sectors and that that higher firm level scale economies tend to encourage horizontal multinational production while higher plant level scale economies promote vertical multinational production. Similar income and relative endowments yield higher total affiliate production at higher trade costs attracting horizontal multinational firms with tariff-jumping motives. Multinational firms prefer countries with higher market potential, cheap labour but with sufficient skilled-labour. In addition to these, affiliate production is attracted to locations where intermediate inputs are cheaper, as long as competition for factors of production by all sectors do not make the location disadvantageous. Locating close to intermediate sectors may result in agglomeration economies in high technology sectors at low trade costs and hence further attraction of firms into the country. The findings on the effects of supply linkages are important, since MNFs in some sectors show an increasing tendency for locating in close proximity to clusters of related firms. The findings are also not confined to only manufacturing sectors with intermediate input demand. More and more MNFs choose to contract their whole production systems, or headquarter activities such as call centres and concentrating on their core activities. Consequently, having a strong supplier network within the country is becoming an important factor for attracting multinationals into the country.
The propositions derived from the CGE simulations on the market size, relative factor costs, trade costs and agglomeration economies are tested empirically for the manufacturing sector using a large bilateral country data set constructed to represent a range of developed and developing home and host country partners. The estimation results indicate the market potential of the home and host countries, availability of cheap factors of production and skilled labour in the host country encourage multinational investment. Similarities between countries in their income levels, tastes and cultures are also important factors. Additionally, in the technologically intensive sectors, agglomeration tendencies of firms tend to make that country more attractive to potential new investors. A sector level analysis of US MNFs investing in Europe complements these empirical results by revealing the differences among location choices of affiliates from various manufacturing sub-sectors. The empirical findings are supportive of the propositions suggested.

The empirical analyses are also expanded to investigate the determinants of location decisions of MNFs in Europe and the impact of the European integration policies on multinational production. The propositions obtained from the findings of CGE simulations are combined with three components of integration (i.e. membership to EU, the Single Market Programme and currency union) to test the effects of each stage of integration on multinational production in different country groups. There is empirical evidence that the country origin of parent firm has an impact on the choice of affiliate location within an integrated region. While non-EU originated multinationals choose their EU investment locations mainly based on market considerations, EU originated multinationals invest in other EU countries not only due to their market potential, but also due to their comparative advantage in labour. More importantly, as integration deepens factor cost differentials and abundance of host country skilled labour gains further importance, while host country market effect starts loosing its importance. This evidence supports the hypothesis that within an integrated region there may be a re-distribution of FDI reflecting more closely the patterns of comparative advantages. Besides, the European regional integration seems to have resulted in central countries reaping the benefits of common market policy in terms of foreign direct investment. On the other
hand, peripheral countries seem to attract inward investment as a result of their commitment to political and macroeconomic stability and integration with other EU countries. Empirical evidence also suggests that currency union policy will have insignificant effect on the attractiveness of a host economy for multinational production. Hence, the benefits a host country may gain from a regional integration is limited to an enlarged market potential through common market policies and reduced long-term macroeconomic risk as a result of an internationally binding commitment.

To sum up, neither the market-related factors, nor the cost differentials alone are adequate to explain all multinational activity. Rather they should be taken into consideration jointly with various other factors to determine the overall comparative advantage of the host country, such as technology level in the country, agglomeration economies, political stability and sound macroeconomic structure, openness towards foreign investment, adequate skilled work force, good infrastructure, institutional efficiency and reliability. On the theoretical front, there is scope for extending the knowledge capital model to allow for other sources of agglomeration economies through skilled and unskilled-labour mobility between countries or technological spillovers which reduce the cost of subsequent innovations in a region. On the empirical front, there is further need in the literature for studies combining theoretical analysis with empirical estimation. As more detailed data becomes available to researchers which enables distinguishing the activities of vertically and horizontally integrated MNFs, better specifications can be obtained.
APPENDIX: GAMS Model

The GAMS software package makes it relatively easy to transfer mathematical specifications of CGE models into executable computer programs. This appendix gives the code for the model in Chapter IV and simulations in Chapter V. After the main characteristics of GAMS language and software are briefly explained, the code is developed and explained in stages. The model consists of 50 variables, so that it can also be run in a student version of GAMS\(^1\).

1. A Brief Note on GAMS Syntax

In GAMS terminology, the indices are called 'SETS', given (exogenous) data are called 'PARAMETERS', decision variables are called 'VARIABLES' and constraints and the objective function are called 'EQUATIONS'. Every declaration of a set, parameter, variable or equation has a logical name followed by an optional description field.

A variable in GAMS identifies a quantity that can be manipulated in the solution of an optimization problem or a system of simultaneous equations. Variable bounds are set by the user either explicitly or through default values associated with variable type such as POSITIVE VARIABLE (this means that variables listed thereafter are non-negative) or FREE VARIABLE (this means that variable value can range from minus to plus infinity). Variables have attributes that can be used in specifying a fixed value (-.fx) or lower (-.lo) and upper bounds (-.up). Unassigned upper bounds are set at plus infinity, and non-initiated lower bounds at minus infinity. Variable attributes also include solution (activity or current value) and marginal levels (-.1 and -.m, respectively) obtained after the execution of a solve statement. These attributes are reset to a new value when a model

\(^1\) A free student version can be downloaded from the GAMS website: http://www.gams.com. The site also includes documentation on user guides and solver manuals.
containing the variable is solved. Variables may be used in direct assignments referenced with their suffixes.

An equation in GAMS identifies a relationship in the model to be optimized or solved which is one of the constraints that must be satisfied in choosing the solution levels for the variables. Equations are declared the same way as sets, parameters and variables, then are specified using a double period (...) command. The main difference between equations and direct assignments (with = sign) are that while equations are only executed when the model they belong is solved, direct assignments are executed as they appear.

A grouping of equations that constitute a mathematical program is called a MODEL. In a mixed complementary problem a model identifies the equations present in the model and their complementary relationships with the problem variables. A number of attributes of models may be accessed by the user in the form of numerical values. These include attributes that contain information about the results of a solver performed (i.e. model solution status, solver termination status, number of infeasibilities in the solution etc.), attributes that tell a solver or GAMS to use of certain features (i.e. name of the solver, use of solver options file, using user defined internal scaling factors etc.) and attributes that pass information to the solver or GAMS giving various setting that are also subject to option statement settings (i.e. iteration limit, limit on number of variables and equations in output, maximum time available to solve, amount of memory allocated etc.)

A semicolon is used to tell GAMS end of a command is reached. In principle all lines should end with a semicolon except when you declare a list of parameters, variables or equations. Then this list is regarded as a single block and should end with a semicolon. Comment lines are either enclosed by a $ONTEXT - $ONFFTEXT command pair or denoted by an asterisk in the first column.
2. About the Model

The codes below assign the title of the model and provide some comment lines on the main purpose of the model.

\[
\text{\texttt{STITLE Oligopolistic CGE Model with MNCs-noindustrylinkbenchmark}} \\
\text{\texttt{SONTEXT \hspace{3em} Purpose: This model calibrates parameters of an economy with the}} \\
\text{\texttt{\hspace{7em} following characteristics:\hspace{3em}}} \\
\text{\hspace{12em} - Two countries with open economies, no government, no savings and}} \\
\text{\hspace{12em} investment} \\
\text{\hspace{12em} - Two commodities (X, Y) used for consumption by households} \\
\text{\hspace{12em} - Two commodities (X,Z) used as intermediate inputs for production of X} \\
\text{\hspace{12em} - One household with Cobb-Douglas utility function in each country} \\
\text{\hspace{12em} - Two factors of production: skilled labor and unskilled labor} \\
\text{\hspace{12em} - Skilled and unskilled labour are mobile between sectors, but immobile} \\
\text{\hspace{12em} between countries and are exogenously fixed} \\
\text{\hspace{12em} - Sector Y is a perfectly competitive industry producing a homogenous} \\
\text{\hspace{12em} product under CRTS using both factors of production. Sector Y incurs no} \\
\text{\hspace{12em} trade costs for export sales. Price of Y is used as a numeraire.} \\
\text{\hspace{12em} - Sector Z is a perfectly competitive industry producing a homogenous} \\
\text{\hspace{12em} product under CRTS using only skilled labour. Sector Z incurs transport} \\
\text{\hspace{12em} costs for export sales.} \\
\text{\hspace{12em} - Sector X is a Cournot oligopoly producing a homogenous product} \\
\text{\hspace{12em} under IRTS using both factors of production and intermediate} \\
\text{\hspace{12em} products, X and Z. Hence there are intra-industry and inter-industry} \\
\text{\hspace{12em} supply linkages. Sector X has both firm level and plant level scale} \\
\text{\hspace{12em} economies. Sector X incurs transport costs for export sales.} \\
\text{\hspace{12em} - In sector X domestic and/or multinational firms can operate due to} \\
\text{\hspace{12em} fragmentation of production stages. Domestic firms supply the foreign} \\
\text{\hspace{12em} country via exports. Horizontal multinationals make local production} \\
\text{\hspace{12em} in both countries. Vertical multinationals produce in the foreign} \\
\text{\hspace{12em} country, and export to the home country.} \\
\text{\hspace{12em} - Technology transfer is costly.} 
\]
- The cost of a second plant is small compared to the cost of establishing a new local firm.
- MNCs incur some fixed cost in the host country.

**Social Accounting Matrix**
- rows represent receipts, columns represent payments

(equal income, endowment and prices between countries, only hor-MNCs exist)

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<th>Factor m.</th>
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**fixed costs of initially inactive firm types:**

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**OFFTEXT**
3. Declaration and Initialization: Benchmark equilibrium

SAM benchmark values are initiated to calculate the parameter (exogenous) values. Initial values of variables are indicated with Z added to their names.

PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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<td>YJZ</td>
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<td>initial consumption of Y in j</td>
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<td>initial consumption of X in i</td>
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<td>CXIZ</td>
<td>initial consumption of X in j</td>
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<td>MIZ</td>
<td>Household income in j</td>
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<td>initial total demand (absorption) for Y in i (in values)</td>
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<td>initial total demand for Y in j</td>
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<td>initial total demand for X in j</td>
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<td>initial total demand for Z in i</td>
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<td>/10/</td>
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<td>initial SKL req. of h-X firms HQed in i obtained from i</td>
<td>/22/</td>
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<td>/0/</td>
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<td>/10/</td>
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<td>fixed SKL req. of d-X firm HQed in j obtained in i</td>
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<td>FSKLXI</td>
<td>fixed SKL req. of h-X firm HQed in j obtained in i</td>
<td>/1.6/</td>
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<tr>
<td>FSKLXI</td>
<td>fixed SKL req. of v-X firm HQed in I obtained in i</td>
<td>/3.6/</td>
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FSKLXVIJI fixed SKL req. of v-X firm HQed in I obtained in j /1.6/
FSKLXVIJI fixed SKL req. of v-X firm HQed in j obtained in I /3.6/
FSKLXVIJI fixed SKL req. of v-X firm HQed in I obtained in I /1.6/
G fixed unskilled labor requirement of X firm /0.8/

tx unit of L req. to ship one unit of X /0.3/
tz unit of L req. to ship one unit of Z /0.3/

sigmaFX elasticity of substitution for sector X /3/

*parameters to be derived from initial database
MKXHIIIZ initial markup rate of h-X firm HQed in i selling in i
MKXHIJIZ initial markup rate of h-X firm HQed in i selling in j
MKXHJJIZ initial markup rate of h-X firm HQed in j selling in j
MKXHJIZ initial markup rate of h-X firm HQed in j selling in i
PXIZ initial price of output X in i
PXIZ initial price of output X in j
XHIIZ initial Q of X prod. by one h-firm based in i selling in i
XHIJIZ initial Q of X prod. by one h-firm based in i selling in j
XHJJIZ initial Q of X prod. by one h-firm based in j selling in j
XHJIZ initial Q of X prod. by one h-firm based in j selling in i
Ax scale parameter for sector X
Ay scale parameter for sector Y
Az scale parameter for sector Z
betaFXS CES share parameter for sector X
betaFXL CES share parameter for sector X
betaFY Cobb-Douglas share parameter for sector Y
xbsz initial units of SKL required to prod one unit of X
xblz initial units of L required to prod one unit of X
gammax share of X as an intermediate product in final product
gammax share of Z as an intermediate product in final product
gammava share of value added in final product
alphaH Cobb-Douglas share parameter for HHds
*Computation of parameters and coefficients for calibration using SAM:

\[
MKXHIIZ = l/(NHIZ+NHJZ) ;
MKXHIJZ = l/(NHIZ+NHJZ) ;
MKXHJJZ = l/(NHIZ+NHJZ) ;
MKXHJIZ = l/(NHIZ+NHJZ) ;
\]

*Marginal costs (or marginal revenues) should be equal in both sectors in general equilibrium. For sector Y: \( PY=MC=1 \), so that for sector X:

* MR =MC =1, PX(1-mk)=1

\[
PXIZ = l/(1-MKXHIIZ) ;
PXJZ = l/(1-MKXHJJZ) ;
\]

*total supply and demand of products in country i

\[
XHIIZ = 50/(NHIZ*PXIZ) ;
XHIJZ = 50/(NHIZ*PXJZ) ;
XHJJZ = 50/(NHJZ*PXJZ) ;
XHJIZ = 50/(NHJZ*PXIZ) ;
\]

*parameters of production functions:

* Value added = \( A*(beta*(S**ro)+(1-beta)*(L**ro))**v/ro \), where

* v is one due to CRTS. Minimizing the standard cost function of VA wrt a given level of output gives the standard first order condition as:

* PS/PL=(beta/(1-beta)*(S/L)**ro-1.

* 1/(1-ro) equals to the elasticity of substitution (sigma)

* Cobb-Douglas prod. func.(sector Y) has unit elasticity of substitution (ro=0)

* Sector Z uses only S (Z=A*S)

\[
\begin{align*}
\beta_{FY} &= SKLYIZ*PSKLIZ(SKLYIZ*PSKLIZ + LYIZ*PLIZ) ; \\
\beta_{FXS} &= (PSKLIZ*(SKLXHIIZ-12)**(1/sigmaFX))/(PSKLIZ*(SKLXHIIZ-12) **(1/sigmaFX)) \\
&+ PLIZ*((LXHIIZ-2)**(1/sigmaFX)) ; \\
\beta_{FXL} &= (1-betaFXS) ; \\
\alpha_y &= YI7J((SKLYIZ**betaFY)*(LYIZ**(1-betaFY))) ; \\
\alpha_x &= (40)/((betaFXS*(SKLXHIIZ-12)**(sigmaFX-1))/ \\
\end{align*}
\]

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\[
\sigma_{FX} + (\beta_{FXL})*(L_{XIIZ-2})*((\sigma_{FX} - 1)/\sigma_{FX})))**(\sigma_{FX}/(\sigma_{FX}-1))
\]

\[
x_{blz} = (((\beta_{FXL})*\sigma_{FX})*(P_{LIZ}*(-\sigma_{FX}))/
(ax*(\beta_{FXS})*P_{SKLIZ}*(1-\sigma_{FX})) + 
((\beta_{FXL})*\sigma_{FX})*(P_{LIZ}*(1-\sigma_{FX})))**
(\sigma_{FX}/(\sigma_{FX}-1)))
\]

\[
x_{bsz} = (\beta_{FXS})*\sigma_{FX})*P_{SKLIZ}*(-\sigma_{FX})/
(ax*(\beta_{FXS})*P_{SKLIZ}*(1-\sigma_{FX}) + 
(\beta_{FXL})*\sigma_{FX})*P_{LIZ}*(1-\sigma_{FX})))**
(\sigma_{FX}/(\sigma_{FX}-1)))
\]

\[
gamma_{max} = 0/(N_{HI} * X_{HII})
\]

\[
gamma_{max} = 1/(N_{HI} * X_{HII})
\]

\[
gamma_{max} = 0/(N_{HI} * X_{HII})
\]

\[
A_{z} = 1
\]

*parameters of consumer function

\[\alpha_{H} = CX_{I}Z/M_{I}Z\]

4. **Declaration of Model Variables and Equations (50 variables)**

Auxiliary variables (or intermediate variables) are used to increase the clarity of the model. They are defined as free variables. Since the price of sector Y equals one, this variable can be replaced in equation specifications by one to keep the number of variables to be solved at fifty.

**POSITIVE VARIABLES**

- \(P_{SKLI}, P_{SKLJ}, P_{LI}, P_{LJ}, \)
- \(* PY (equals to 1), \)
- \(P_{ZI}, P_{ZJ}, Z_{II}, Z_{IJ}, Z_{JI}, Z_{JI} \)
- \(P_{XI}, P_{XJ}, X_{DI}, X_{DJ}, Y_{I}, Y_{J}, \)
- \(X_{HI}, X_{HII}, X_{VII}, X_{VJI}, X_{VII}, X_{HII}, X_{HJI}, X_{VJI}, X_{VJI}, \)
- \(N_{DI}, N_{DI}, N_{HI}, N_{HJ}, N_{VI}, N_{VI}, M_{I}, M_{J} \)

\[235\]
FREE VARIABLES
MKXDII, MKXDII, MKXHII, MKXHIJ, MKXVII, MKXVIJ
MKXDII, MKXDII, MKXHII, MKXHIJ, MKXVII, MKXVIJ
bsi, bli, bsj, blj

EQUATIONS
*Firms: input demands and output supply functions
EQXBLI, EQXBSI, EQXBLJ, EQXBSJ
EQXDII, EQXDIJ, EQXHII, EQXHIJ, EQXVII, EQXVIJ
EQXDJJ, EQXDJI, EQXHJJ, EQXHJI, EQXVJJ, EQXVJI
EQMKXDII, EQMKXDIJ, EQMKXHII, EQMKXHIJ, EQMKXVII, EQMKXVIJ
EQMKXDJJ, EQMKXDJI, EQMKXHJJ, EQMKXHJI, EQMKXVJJ, EQMKXVJI

*Income balance
EQCONEXPI, EQCONEXPJ
EQPROFITYI, EQPROFITYJ,
EQPROFITZII, EQPROFITZIJ, EQPROFITZJJ, EQPROFITZII,
EQFCXDI, EQFCXHI, EQFCXVI, EQFCXDJ, EQFCXHJ, EQFCXVJ

*Market Clearing: demand=supply
EQSKLBALI, EQLBALI, EQSKLBALJ, EQLBALJ
* EQYBAL (to be paired with PY if it were used in variables)
EQZBALI, EQZBALJ, EQXBALI, EQXBALJ

5. Specification of model equations (50 equations)
Positive variables are associated with inequalities, while free variables are associated
with equalities. The bounds on the variables determine the relationship satisfied by the
function. If a variable is fixed in a GAMS model, the paired equation is completely
dropped from the model.
EQXBLI.  
  bli = \( E = (\beta FXL^{*}\sigma FX + PLI^{*}) \)  
  (\(-\sigma FX)/(\alpha^{*}(\beta FXS^{*}\sigma FX^{*}) \)  
\[ \text{PSKL}^{*}(1-\sigma FX) + (\beta FXL^{*})^{*}\sigma FX^{*} \]  
*PLI^{*}(1-\sigma FX))**(sigmaFX/(sigmaFX-1))) ;

EQXBSI.  
  bsi = \( E = (\beta FXS^{*}\sigma FX + PSKL^{*}) \)  
  (\(-\sigma FX)/(\alpha^{*}(\beta FXS^{*}\sigma FX^{*}) \)  
\[ \text{PSKL}^{*}(1-\sigma FX) + (\beta FXL^{*})^{*}\sigma FX^{*} \]  
(1-\sigma FX))**(sigmaFX/(sigmaFX-1))) ;

EQXBLJ.  
  blj = \( E = (\beta FXL^{*}\sigma FX + PLI^{*}) \)  
  (\(-\sigma FX)/(\alpha^{*}(\beta FXS^{*}\sigma FX^{*}) \)  
\[ \text{PSKL}^{*}(1-\sigma FX) + (\beta FXL^{*})^{*}\sigma FX^{*} \]  
(1-\sigma FX))**(sigmaFX/(sigmaFX-1))) ;

EQXBSJ.  
  bsj = \( E = (\beta FXS^{*}\sigma FX + PSKL^{*}) \)  
  (\(-\sigma FX)/(\alpha^{*}(\beta FXS^{*}\sigma FX^{*}) \)  
\[ \text{PSKL}^{*}(1-\sigma FX) + (\beta FXL^{*})^{*}\sigma FX^{*} \]  
(1-\sigma FX))**(sigmaFX/(sigmaFX-1))) ;

EQXDI.  
  P LI*bli+PSKL*bsi*gammaava+PZI*gammaaz  
  +PXI*gammaax=G= PXI*(1-MKXDII*gammaava) ;

EQXDII.  
  (PLI*bli+PSKL*bsi)*gammaava+PZI*gammaaz  
  +PXI*gammaax = G = PXI*(1-MKXDII*gammaava) ;

EQXHII.  
  (PLI*bli+PSKL*bsi)*gammaava+PZI*gammaaz  
  +PXI*gammaax = G = PXI*(1-MKXHI*gammaava) ;

EQXHI.  
  (PLI*blj+PSKL*bsj)*gammaava+PZI*gammaaz  
  +PXJ*gammaax = G = PXJ*(1-MKXHI*gammaava) ;

EQXVII.  
  (PLI*blj+PSKL*bsj)*gammaava+PZI*gammaaz  
  +PXJ*gammaax = G = PXI*(1-MKXVII*gammaava) ;

EQXVI.  
  (PLI*blj+PSKL*bsj)*gammaava+PZI*gammaaz  
  +PXJ*gammaax = G = PXI*(1-MKXVI*gammaava) ;

EQXDJ.  
  (PLI*blj+PSKL*bsj)*gammaava+PZI*gammaaz  
  +PXJ*gammaax = G = PXI*(1-MKXDJJ*gammaava) ;

EQXDJI.  
  (PLI*blj+PSKL*bsj)*gammaava+PZI*gammaaz  
  +PXJ*gammaax = G = PXI*(1-MKXDJJ*gammaava) ;

EQXHJJ.  
  (PLI*blj+PSKL*bsj)*gammaava+PZI*gammaaz
\[ + \text{PXJ} \ast \text{gammav} = G = \text{PXJ} \ast (1 - \text{MKXHJJ} \ast \text{gammav}) \]

\[ EQXHJJ. \quad (\text{PLI} \ast \text{bli} + \text{PSKLI} \ast \text{bsi}) \ast \text{gammav} + \text{PZI} \ast \text{gammaz} \]

\[ + \text{PXi} \ast \text{gammav} = G = \text{PXI} \ast (1 - \text{MKXHJI} \ast \text{gammav}) \]

\[ EQXVJJ. \quad (\text{PLI} \ast \text{bli} + \text{PSKLI} \ast \text{bsi}) \ast \text{gammav} + \text{PLI} \ast \text{tx} + \text{PZI} \ast \text{gammaz} \]

\[ + \text{PXi} \ast \text{gammav} = G = \text{PXI} \ast (1 - \text{MKXVJI} \ast \text{gammav}) \]

\[ EQXVJI. \quad (\text{PLI} \ast \text{bli} + \text{PSKLI} \ast \text{bsi}) \ast \text{gammav} + \text{PZI} \ast \text{gammaz} \]

\[ + \text{PXi} \ast \text{gammav} = G = \text{PXI} \ast (1 - \text{MKXVJI} \ast \text{gammav}) \]

\[ EQMXDII. \quad \text{MKXDII} \ast (\alpha\text{H} \ast \text{MI} + \text{PXi} \ast \text{gammav}) \ast \{(\text{NDI} \ast \text{XDII} \]

\[ + \text{NHI} \ast \text{XHII} + \text{NHJ} \ast \text{XHJI} + \text{NVJ} \ast \text{XVJI}) + (\text{NDI} \ast \text{XDII} \]

\[ + \text{NVJ} \ast \text{XYJI}) = E = \text{PXI} \ast \text{XDII} \]

\[ EQMXDIJ. \quad \text{MKXDIJ} \ast (\alpha\text{H} \ast \text{MJ} + \text{PXJ} \ast \text{gammaz}) \ast \{(\text{NDJ} \ast \text{XDII} \]

\[ + \text{NHJ} \ast \text{XHJJ} + \text{NHJ} \ast \text{XHJI} + \text{NVI} \ast \text{XVIJ}) + (\text{NDJ} \ast \text{XDII} \]

\[ + \text{NVI} \ast \text{XYIJ}) = E = \text{PXI} \ast \text{XHII} \]

\[ EQMXHI. \quad \text{MKXHI} \ast (\alpha\text{H} \ast \text{MI} + \text{PXi} \ast \text{gammav}) \ast \{(\text{NDI} \ast \text{XDII} \]

\[ + \text{NHI} \ast \text{XHII} + \text{NHJ} \ast \text{XHJI} + \text{NVJ} \ast \text{XVJI}) + (\text{NDI} \ast \text{XDII} \]

\[ + \text{NVJ} \ast \text{XYIJ}) = E = \text{PXI} \ast \text{XHII} \]

\[ EQMXVII. \quad \text{MKXVII} \ast (\alpha\text{H} \ast \text{MI} + \text{PXi} \ast \text{gammav}) \ast \{(\text{NDI} \ast \text{XDII} \]

\[ + \text{NHI} \ast \text{XHII} + \text{NHJ} \ast \text{XHJI} + \text{NVJ} \ast \text{XVJI}) + (\text{NDI} \ast \text{XDII} \]

\[ + \text{NVJ} \ast \text{XYIJ}) = E = \text{PXI} \ast \text{XHII} \]

\[ EQMXXVIJ. \quad \text{MKXVIJ} \ast (\alpha\text{H} \ast \text{MJ} + \text{PXJ} \ast \text{gammaz}) \ast \{(\text{NDJ} \ast \text{XDII} \]

\[ + \text{NHJ} \ast \text{XHJJ} + \text{NHJ} \ast \text{XHJI} + \text{NVI} \ast \text{XVIJ}) + (\text{NDJ} \ast \text{XDII} \]

\[ + \text{NVI} \ast \text{XYIJ}) = E = \text{PXI} \ast \text{XHII} \]

\[ EQMXDJI. \quad \text{MKXDJI} \ast (\alpha\text{H} \ast \text{MI} + \text{PXi} \ast \text{gammav}) \ast \{(\text{NDI} \ast \text{XDII} \]

\[ + \text{NHI} \ast \text{XHII} + \text{NHJ} \ast \text{XHJI} + \text{NVJ} \ast \text{XVJI}) + (\text{NDI} \ast \text{XDII} \]

\[ + \text{NVJ} \ast \text{XYIJ}) = E = \text{PXI} \ast \text{XDII} \]

\[ EQMXHJJ. \quad \text{MKXHJJ} \ast (\alpha\text{H} \ast \text{MJ} + \text{PXJ} \ast \text{gammaz}) \ast \{(\text{NDJ} \ast \text{XDII} \]

\[ + \text{NHJ} \ast \text{XHJJ} + \text{NHJ} \ast \text{XHJI} + \text{NVI} \ast \text{XVIJ}) + (\text{NDJ} \ast \text{XDII} \]

\[ + \text{NVI} \ast \text{XYIJ}) = E = \text{PXI} \ast \text{XDII} \]

\[ 238 \]
\[ \text{EQMXXHJ} = \text{MKXXHJ} \cdot (\alpha H \cdot M + \text{PXJ} \cdot \text{gammaXX} \cdot (\text{NDI} \cdot \text{XDI} \\
+ \text{NHI} \cdot \text{XHI} + \text{NHJ} \cdot \text{XHJ} + \text{NVJ} \cdot \text{XVJ} ) + (\text{NDJ} \cdot \text{XDJI} \\
+ \text{NVI} \cdot \text{XVII}) ) = \text{PXJ} \cdot \text{XHJ} \]
\[ \text{EQMXXVJ} = \text{MKXXVJ} \cdot (\alpha H \cdot M + \text{PXJ} \cdot \text{gammaXX} \cdot (\text{NDJ} \cdot \text{XDJI} \\
+ \text{NHI} \cdot \text{XHI} + \text{NHJ} \cdot \text{XHJ} + \text{NVJ} \cdot \text{XVJ} ) + (\text{NDI} \cdot \text{XDI} \\
+ \text{NVI} \cdot \text{XVII}) ) = \text{PXJ} \cdot \text{XVJ} \]
\[ \text{EQMXXVI} = \text{MKXXVI} \cdot (\alpha H \cdot M + \text{PXJ} \cdot \text{gammaXX} \cdot (\text{NDI} \cdot \text{XDI} \\
+ \text{NHI} \cdot \text{XHI} + \text{NHJ} \cdot \text{XHJ} + \text{NVJ} \cdot \text{XVJ} ) + (\text{NDJ} \cdot \text{XDJI} \\
+ \text{NVI} \cdot \text{XVII}) ) = \text{PXJ} \cdot \text{XVI} \]

*Income balance*

\[ \text{EQCONEXPI} = M_I = G = \text{PLI} \cdot \text{SLI} + \text{PSKLI} \cdot \text{SSKLI} \]
\[ \text{EQCONEXP} = M_J = G = \text{PLJ} \cdot \text{SLJ} + \text{PSKLJ} \cdot \text{SSKLJ} \]

\[ \text{EQFCXDI} = \text{PLI} \cdot G + \text{PSKLI} \cdot \text{FSKLI} \cdot \text{XDII} = G = \text{PXI} \cdot \text{MKXI} \\
* \text{gammaXX} \cdot \text{XDI} + \text{PXJ} \cdot \text{MKXI} \cdot \text{gammaXX} \cdot \text{XDI} \]
\[ \text{EQFCXHII} = \text{PLI} \cdot G + \text{PSKLI} \cdot \text{FSKLI} \cdot \text{XHII} + \text{PLJ} \cdot G + \text{SKLI} \cdot \text{FSKLI} \cdot \text{XHII} \\
= G = \text{PXI} \cdot \text{MKXI} \cdot \text{gammaXX} \cdot \text{XHII} + \text{PXJ} \\
* \text{MKXI} \cdot \text{gammaXX} \cdot \text{XHII} \]
\[ \text{EQFCXVI} = \text{PLI} \cdot G + \text{PSKLI} \cdot \text{FSKLI} \cdot \text{XVI} + \text{PSKLI} \cdot \text{FSKLI} \cdot \text{XVII} \\
= G = \text{PXI} \cdot \text{MKXI} \cdot \text{gammaXX} \cdot \text{XVI} + \text{PXJ} \\
* \text{MKXI} \cdot \text{gammaXX} \cdot \text{XVI} \]
\[ \text{EQFCXDI} = \text{PLI} \cdot G + \text{PSKLI} \cdot \text{FSKLI} \cdot \text{XDIII} = G = \text{PXI} \cdot \text{MKXI} \\
* \text{gammaXX} \cdot \text{XDI} + \text{PXJ} \cdot \text{MKXI} \cdot \text{gammaXX} \cdot \text{XDI} \]
\[ \text{EQFCXHII} = \text{PLI} \cdot G + \text{PSKLI} \cdot \text{FSKLI} \cdot \text{XHII} + \text{PLI} \cdot G + \text{SKLI} \cdot \text{FSKLI} \cdot \text{XHII} \\
= G = \text{PXI} \cdot \text{MKXI} \cdot \text{gammaXX} \cdot \text{XHII} + \text{PXJ} \\
* \text{MKXI} \cdot \text{gammaXX} \cdot \text{XHII} \]
\[ \text{EQFCXVI} = \text{PLI} \cdot G + \text{PSKLI} \cdot \text{FSKLI} \cdot \text{XVI} + \text{PSKLI} \cdot \text{FSKLI} \cdot \text{XVII} \\
= G = \text{PXI} \cdot \text{MKXI} \cdot \text{gammaXX} \cdot \text{XVI} + \text{PXJ} \\
* \text{MKXI} \cdot \text{gammaXX} \cdot \text{XVI} \]

\[ \text{EQPROFITYI} = \text{PLI} \cdot ((\text{YI} / \text{AY}) \cdot (\text{PSKLI} / \text{PLI}) ** \text{betaFY} \cdot ((1 - \text{betaFY})} / \text{betaFY} ** \text{betaFY}) + \text{PSKLI} \cdot ((\text{YI} / \text{AY}) \cdot (\text{PLI} / \text{PSKLI}) \\
** (1 - \text{betaFY}) \cdot (\text{betaFY} / (1 - \text{betaFY})) ** (1 - \text{betaFY}))} \]
\[
= G = P Y Z * Y I
\]

**Market Clearing**

\[
E Q S K L B A L I . \quad S S K L J = G = ((Y I / a y) * ((P L J / P S K L J) ** (1-betaFY))
\]

\[
* (betaFY/(1-betaFY)) ** (1-betaFY)) + (N D I * (F S K L X D I I
\]

\[
+ gamma va * b si * (X D I I + X D I J) + N H I * (F S K L X H I I
\]

\[
+ gamma va * b si * X H I I ) + N H I * (F S K L X H I I + gama mava
\]

\[
* b si * X H I I ) + N V I * (F S K L X V I I ) + N V I * (F S K L X V I I
\]

\[
+ gamma va * b si * (X V I I + X V I I J ) ) + ((1/az) * (Z I I + Z I I J ));
\]

**E Q S K L B A L J . \quad S S K U = G = ((Y J / a y) * ((P L J / P S K L J) ** (1-betaFY))
\]

\[
* (betaFY/(1-betaFY)) ** (1-betaFY)) + (N D J * (F S K L X D J J
\]

\[
+ gamma va * b sj * (X D J I + X D J J ) + N H J * (F S K L X H J J
\]

\[
+ gamma va * b sj * X H J J ) + N H J * (F S K L X H J J + gama mava
\]

\[
* b sj * X H J J ) + N V J * (F S K L X V J ) + N V I * (F S K L X V I J
\]

\[
+ gamma va * b sj * (X V I J + X V I I J ) ) + ((1/az) * (Z J I + Z J I J ));
\]

**E Q L B A L I . \quad S L I = G = ((Y I / a y) * ((P S K L I / P L J) ** betaFY) * ((1-betaFY)
\]

\[
/ betaFY) ** betaFY) + (N D I * (G + gamma va *
\]

\[
* b l i * (X D I I + X D I J ) + t x * X D I J ) + N H I * (G + gamma va * b l i *
\]

\[
X H I I ) + N H J * (G + gamma va * b l i * X H I I ) + N V J
\]

\[
* (G + gamma va * b l i * (X V J I + X V J J ) + t x * X V J J ) + (t z * Z J I );
\]

**E Q L B A L J . \quad S L J = G = ((Y J / a y) * ((P S K L J / P L J) ** betaFY) * ((1-betaFY)
\]

\[
/ betaFY) ** betaFY) + (N D J * (G + gamma va *
\]

\[
* b l j * (X D J I + X D J J ) + t x * X D J J ) + N H J * (G + gamma va * b l j *
\]

\[
X H J J ) + N H I * (G + gamma va * b l j * X H J J ) + N V I
\]

\[
* (G + gamma va * b l j * (X V J I + X V J J ) + t x * X V J J ) + (t z * Z J I ));
\]

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6. Model

Economic equilibrium problems are solved as mixed complementarity problems. In these problems there are exactly as many variables as there are equations and each variable must be specified as being complementary with one and only one equation. The name of the equation is followed by a period (.) and the name of the associated complementary variable.

Model linkage/ EQXBLI.BLI, EQXBSI.BSI, EQXBLI.BLI, EQXBSI.BSI, EQXDIIXDII, EQXDIIXDII, EQXHII.XHII, EQXHIIXHII, EQXHII.XHII, EQXVII.XVII, EQXVII.XVII, EQXVIIXVII, EQXVIIXVII, EQXDIIXDII, EQXDIIXDII, EQMKXDIIMKXDII, EQMKXDIIMKXDII, EQMKXHII.MKXHII, EQMKXHII.MKXHII, EQMKXHII.MKXHII, EQMKXHII.MKXHII,
7. Boundaries and initial levels for endogenous variables

Before a model is solved, it is necessary to initialize all choice variables and all relevant bounds.

\[
\begin{align*}
PSKII.LO &= 0.0001; \\
PSKII.LO &= 0.0001; \\
PLI.LO &= 0.0001; \\
PLJ.LO &= 0.0001; \\
PXI.LO &= 0.00011; \\
PXJ.LO &= 0.0001; \\
\ast\ PZI.LO &= 0.0001; \\
\ast\ PZII.LO &= 0.0001; \\
XDII.LO &= 0.001; \\
XDII.LO &= 0.001; \\
XHIII.LO &= 0.001; \\
XHIII.LO &= 0.001; \\
XVIII.LO &= 0.001; \\
XVIII.LO &= 0.001; \\
XDII.LO &= 0.001; \\
XDII.LO &= 0.001;
\end{align*}
\]
\[
XHJJ. LO = 0.001; \\
XHIJ . LO = 0.001; \\
XVJJ. LO = 0.001; \\
XVJI. LO = 0.001; \\
bsi. lo = 0.0001; \\
blj. lo = 0.0001; \\
bsj. lo = 0.0001; \\
blj. lo = 0.0001; \\
YI. LO = 0.0001 ; \\
YJ. LO = 0.0001 ; \\
ZII. LO =0.0001 ; \\
ZIJJ. LO =0.0001 ; \\
ZIJJ. LO =0.0001 ; \\
ZIJJ. LO =0.0001 ; \\
PSKLJJ. L = PSKLIZ; \\
PSKLJJ. L = PSKLIZ; \\
PLJ. L = PLIZ; \\
PLJ. L = PLIZ; \\
PXJ. L = PXIZ; \\
PXJ. L = PXIZ; \\
PZJ. L = PZIZ; \\
PZJ. L = PZIZ; \\
YII. L = YIZ; \\
YJ. L = YJZ; \\
ZII. L = ZIIZ; \\
ZIJJ. L = ZIJJZ; \\
XHIJ. L = XHIJJZ; \\
XHIJ. L = XHIJJZ; \\
XHIJ. L = XHIJJZ; \\
XHIJ. L = XHIJJZ; \\
XHIJ. L = XHIJJZ; \\
XHIJ. L = XHIJJZ; \\
XHIJ. L = XHIJJZ; \\
XHIJ. L = XHIJJZ;
8. Adding options

    option mcp = path ;
    *This provides the name of the solver to solve the MCP model.
    linkage.iterlim = 50000 ;
    *This option provides a new upper limit on the number of iterations.
    linkage.limrow = 0 ;
    *This option limits the number of equations in output.
    linkage.limcol = 0 ;
    *This option limits the number of variables in output.

9. Solving the model to check for the replication of the benchmark case

    solve linkage using mcp;
    display
        PSKII,L,PSKJ.L, PLII.L, PLJ.L, PXIL, PXJ.L, MII, MII,J.L,
        YI.L,YJ.L, XDII.L, XDII.J.L, XHII.L, XHIJ.L, XVII.L, XVII.J.L,
There are three control steps for writing a correct model. The first step involves the initial check of the model done by GAMS itself. Before the problems encountered in this step are resolved, GAMS will not proceed to solve the model. The second step is solving the model for the replication of the benchmark case. Third step is checking whether price homogeneity assumption is realized in the model.

GAMS contains many aids for checking a model. During the initial check of the program GAMS provides various information about the program. The first is the echo print of the program, which provides explanations of errors detected. The second is the ‘equation listing’, which shows the variables that appear in each constraint, and what individual coefficients and right-hand side value evaluate after the data manipulations have been done. GAMS also generate a ‘column listing’, which sorts coefficients by column rather than row. It is possible to limit the output in these listings by using options commands. The final information generated while a model is being prepared is the ‘statistics’ which provide details on the size and non-linearity of the model and the time spent on generation the model. The next part of the output contains details about the solution process including resource usage, iteration count, number of evaluation errors (these errors result due to numerical problems like division by zero), the solver status (the state of the program such as normal completion, iteration interrupt, resource interrupt, evaluation error limit etc) and model status (the state of the solution such as optimal, locally optimal, infeasible etc.). As soon as an error is detected, processing will be stopped, and hence a model will be never solved after an error has been detected. The only remedy is to fix the error and repeat the run.

There are three main types of errors; compilation errors, execution errors, model generation errors. Most of the compilation errors will be caused by simple mistakes.
(forgetting to declare an identifier, domain errors such as putting indices in the wrong order, leaving out a necessary semicolon, misspelling a label etc.). The explanatory error message text provides help to diagnose the problem and correct it. Execution errors are generally caused by illegal arithmetic operations such as division by zero or taking the log of a negative number. The execution of a solve statement can trigger additional errors which report on problems encountered during transformation of the model into a format required by the solver. Problems are most often caused by illegal or inconsistent bounds.

When the model is free from compilation and execution errors, the results should be checked that whether they replicate the benchmark values or not. This will prevent producing a model that does not represent the assumptions. The final consistency check is to test the price homogeneity of the model. For this test the price in the numeraire sector is fixed at two instead of one, and initial values of all prices are doubled. The model provided above passes the price homogeneity test, hence in equilibrium all prices are doubled and real variables (output etc) are unchanged.

10. Index sets and parameters for simulations

This section defines the index sets and parameters that will be needed to store the simulation results.

```plaintext
$TITLE INDUSTRYLINK TABLES
SETS
  stat   statistics /modelstat, solvestat/
  RT1   Table1-Number of firms in sector X
         /NDI,NDJ,NHI,NHJ,NVI,NVJ /
  RT2   Table2-Total Value of Production by country
         /PXI, PXJ, TQXI, TQXJ, AFFQXI, AFFQXJ, AFFQXHI, AFFQXVI, AFFQXHJ, AFFQXVJ /
  RT3   Table3-Total Quantity produced by country and firm type
         /QDEMXI, QDEMXJ, QQXI, QQXJ, QQXAFFI, QQXAFFJ /
```

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PARAMETER

QXDII quantity produced by XDII
QXDIJ quantity produced by XDIJ
QXHIII quantity produced by XHIII
QXHIJ quantity produced by XHIJ
QXVII quantity produced by XVII
QXVIJ quantity produced by XVIJ
QXDJJ quantity produced by XDJJ
QXDJII quantity produced by XDJJ
QXHJJ quantity produced by XHJJ
QXHIJ quantity produced by XHIJ
QXVJJ quantity produced by XVJJ
QXVIIJ quantity produced by XVIIJ

QDEMXI total quantity of X demanded in i
QDEMXJ total quantity of X demanded in j
QQXI total quantity produced in country i
QQXJ total quantity produced in country j
QQXAFFI total quantity produced by affiliates in country i
QQXAFFJ total quantity produced by affiliates in country j

TQXI total value of X produced in i
TQXJ total value of X produced in j

AFFQXI total value of X produced by affiliates in i
AFFQXJ total value of X produced by affiliates in j
AFFQXHI total value of X produced by horizontal affiliates in i
AFFQXVI total value of X produced by vertical affiliates in i
AFFQXHJ total value of X produced by horizontal affiliates in j
AFFQXVJ total value of X produced by vertical affiliates in j
$TITLE$ OLIGMNINTM Filling the TABLES

\[
\begin{align*}
QXDIJ &= XDII.L*NDI.L \\
QXDII &= XDII.L*NDI.L \\
QXHII &= XHII.L*NHI.L \\
QXHILL &= XHII.L*NHI.L \\
QXVII &= XVII.L*NVI.L \\
QX VilI &= XVII.L*NVI.L \\
QXDJI &= XDJJ.L*NDJ.L \\
QXDJJ &= XDJJ.L*NDJ.L \\
QXHJJ &= XHJJ.L*NHJ.L \\
QXHJJ &= XHJJ.L*NHJ.L \\
QXVJJ &= XVJJ.L*NVJ.L \\
QXVJI &= XVJI.L*NVJ.L \\
QQXI &= QXDII + QXDII + QXHII + QXHII + QXVII + QXVII \\
QQXJ &= QXDII + QXDII + QXHII + QXHII + QXVII + QXVII \\
QQXAFFI &= QXHII + QXVII + QXVII \\
QQXAFFJ &= QXHII + QXVII + QXVII \\
QDEMXI &= (alphaH*MII.L)/PXII.L + gammaX*QQXI \\
QDEMXJ &= (alphaH*MII.L)/PXII.L + gammaX*QQXJ \\
TQXI &= PXII.L*QXDII + PXI.I*QXDII + PXI.I*QXHII + \\
&\quad PXII.L*QXHII + PXI.I*QXVII + PXII.L*QXVII \\
AFFQXI &= PXII.L*QXHII + PXII.L*QXVII + PXII.L*QXVII \\
AFFQXHII &= PXII.L*QXHII \\
AFFQVXI &= PXI.I*QXVII + PXI.I*QXVII \\
TQXJ &= PXI.I*QXDII + PXI.I*QXDII + PXI.I*QXHII + \\
&\quad PXI.I*QXHII + PXI.I*QXVII + PXI.I*QXVII \\
AFFQXJ &= PXI.I*QXHII + PXI.I*QXVII + PXI.I*QXVII \\
AFFQXHJ &= PXI.I*QXHII \\
AFFQVXJ &= PXI.I*QXVII + PXI.I*QXVII \\
\end{align*}
\]
11. Simulations and Reporting

For a recursive dynamic simulation one could use the LOOP statement. It will execute the SOLVE command for every entry in the index set. Below, the results are stored for each entry of simulations. The variables (.L values) keep their value from one solution to the next assignment.

$TITLE General Equilibrium Simulations
$ONTEXT
Purpose: no industry linkages, high trade costs (tx=0.3)
$OFFTEXT

SINCLUDE NOINDUSTRYLINKBENCHMRK.GMS
SINCLUDE INDUSTRYLINKTABLES.GMS

SETS
box  loop starting from left-top corner /1*361/ ;
PARAMETERS
  sumstat(box,stat)
Table1(box,rt1) Number of firms in sector X
Table2(box,rt2) Total Value of Production by country
Table3(box,rt3) Total Quantity produced by country and firm type
;
PARAMETER  sklmu(box) share of world SKL endowment in country /
(1,38,39,76,77,114,115,152,153,190,191,228,229,266,267,304,305,342,343) 0.95
(2,37,40,75,78,113,116,151,154,189,192,227,230,265,268,303,306,341,344) 0.90
(3,36,41,74,79,112,117,150,155,188,193,226,231,264,269,302,307,340,345) 0.85
(4,35,42,73,80,111,118,149,156,187,194,225,232,263,270,301,308,339,346) 0.80
(5,34,43,72,81,110,119,148,157,186,195,224,233,262,271,300,309,338,347) 0.75
(6,33,44,71,82,109,120,147,158,185,196,226,234,261,272,299,310,337,348) 0.70
(7,32,45,70,83,108,121,146,159,184,197,222,235,260,273,298,311,336,349) 0.65
(8,31,46,69,84,107,122,145,160,183,198,221,236,259,274,297,312,335,350) 0.60
(9,30,47,68,85,106,123,144,161,182,199,220,237,258,275,296,313,334,351) 0.55

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\[
\begin{array}{cccccccccccccccccccc}
(10,29,48,67,86,105,124,143,162,181,200,219,238,257,276,295,314,333,352) & 0.50 \\
(11,28,49,66,87,104,125,142,163,180,201,218,239,256,277,294,315,332,353) & 0.45 \\
(12,27,50,65,88,103,126,141,164,179,202,217,240,255,278,293,316,331,354) & 0.40 \\
(13,26,51,64,89,102,127,140,165,178,203,216,241,254,279,292,317,330,355) & 0.35 \\
(14,25,52,63,90,101,128,139,166,177,204,215,242,253,280,291,318,329,356) & 0.30 \\
(15,24,53,62,91,100,129,138,167,176,205,214,243,252,281,290,319,328,357) & 0.25 \\
(16,23,54,61,92,99,130,137,168,175,206,213,244,251,282,289,320,327,358) & 0.20 \\
(17,22,55,60,93,98,131,136,169,174,207,212,245,250,283,288,321,326,359) & 0.15 \\
(18,21,56,59,94,97,132,135,170,173,208,211,246,249,284,287,322,325,360) & 0.10 \\
(19,20,57,58,95,96,133,134,171,172,209,210,247,248,285,286,323,324,361) & 0.05 \\
/ ;
\end{array}
\]

\begin{verbatim}
PARAMETER lmu(box) share of world SKL endowment in country 1 /
(1*19) 0.05,(20*38) 0.10,(39*57) 0.15, (58*76) 0.20, (77*95) 0.25,
(96*114) 0.30, (115*133) 0.35,(134*152) 0.40, (153*171) 0.45,(172*190) 0.50,
(191*209) 0.55, (210*228) 0.60, (229*247) 0.65, (248*266) 0.70, (267*285)
0.75, (286*304) 0.80, (305*323) 0.85, (324*342) 0.90, (343*361) 0.95 /
;
loop((box),
    SSKLI = 92*sklmu(box) 
    SSKLJ = 92*(1-sklmu(box)) 
    SLI = 308*lmu(box) 
    SLJ = 308*(1-lmu(box)) 

    solve linkage using mcp 

$INCLUDE INDUSTRYLINKTABLEFILL.GMS
**Fill tables
    sumstat(box,'modelstat') = linkage.modelstat 
    sumstat(box,'solvestat') = linkage.solvestat 

    table1(box,'NDI')= NDIL 
    table1(box,'NDJ')= NDJ.L 

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\end{verbatim}
After the model is solved for the counter-factual equilibrium and all data are transferred to tables, the model returns to the benchmark case before the next simulation.

SSKLI = 46;
SSKLJ = 46;
SLI = 154;
SLJ = 154;
PSKLL.L = 1;
PSKLJ.L = 1;
PLL.L = 1;
PLJ.L = 1;
\begin{verbatim}
PXJ.L  = 1.25 ;
PXJ.L  = 1.25 ;
YJ.L   = 100 ;
YJ.L   = 100 ;
XDJJ.L = 16 ;
XDJJ.L = 16 ;
XDJJ.L = 16 ;
XDJJ.L = 16 ;
XVJ.L  = 0.0001;
XVJ.L  = 0.0001;
XHJJ.L = 16 ;
XHJJ.L = 16 ;
XHJJ.L = 16 ;
XHJJ.L = 16 ;
NDJ.L  = 0 ;
NDJ.L  = 0 ;
NHJ.L  = 2.500 ;
NHJ.L  = 2.500 ;
NVJ.L  = 0 ;
NVJ.L  = 0 ;
MJ.L   = 200 ;
MJ.L   = 200 ;
MKXDDJ.J.L = 0.20 ;
MKXDDJ.J.L = 0 ;
MKXHJJ.J.L = 0.20 ;
MKXHJJ.J.L = 0.20 ;
MKXVII.J.L = 0 ;
MKXVII.J.L = 0.20 ;
MKXDJJ.J.L = 0.20 ;
MKXDJJ.J.L = 0 ;
MKXHJJ.J.L = 0.20 ;
MKXHJJ.J.L = 0.20 ;
\end{verbatim}
\[ MKXVJI.L = 0 ; \]
\[ MKXVJI.L = 0.20 ; \]
\[ bsi.L = 0.250 ; \]
\[ bli.L = 0.750 ; \]
\[bsj.L = 0.250 ; \]
\[blj.L = 0.750 ; \]

\begin{verbatim}
solve linkage using mcp ;
);
DISPLAY sumstat, table1, table2, table3;
\end{verbatim}

12. Storing the results in Excel spreadsheets

The procedure XLDUMP can be used export data from a GAMS program to a spreadsheet. It writes data and labels to a specified range overwriting what ever is there. The first command below, for example, tells GAMS to export the results in Table 1 to an excel spreadsheet named numberoffirmsonolinkage.xls. The data will be transferred to the sheet named ‘hightrpcost’ between columns a-g and rows 6-368.

\begin{verbatim}
$LIBINCLUDE XLDUMP TABLE1 NUMBEROFFIRMSNOLINKAGE hightrpcost!a6:g368
$LIBINCLUDE XLDUMP SUMSTAT NUMBEROFFIRMSNOLINKAGE hightrpcost!p56:s417
$LIBINCLUDE XLDUMP TABLE2 AFFILIATEPRODNOLINKAGE hightrpcost!a6:k368
\end{verbatim}


