Functional Specialization in International Trade

This preliminary draft: August 2014

Marcel P. Timmer\textsuperscript{a}, Robert Stehrer\textsuperscript{b}, Gaaitzen J. de Vries\textsuperscript{a}

\textsuperscript{a} Groningen Growth and Development Centre, University of Groningen, The Netherlands
\textsuperscript{b} The Vienna Institute for International Economic Studies (WIIW)

Corresponding author:
Gaaitzen J. de Vries
Groningen Growth and Development Centre
Faculty of Economics and Business
University of Groningen, the Netherlands
\texttt{g.j.de.vries@rug.nl}

Acknowledgments

We are grateful for comments and suggestions received from many colleagues, but in particular Richard Baldwin, Bart Los, and Zhi Wang. This paper was presented at the CompNet workshop at the Central Bank of Italy (Rome, March 2014), IDE Jetro in Japan (Tokyo, May 2014), and the IO conference in Portugal (Lisbon, July 2014).
Abstract

The activities of firms are spatially separated due to declining trade and communication costs. As a result, countries vertically specialise in international trade. Comparative advantage is no longer defined in terms of products or sectors, but in tasks or functions. To date, empirical evidence is scarce however. In this paper we extend recent empirical models to analyse patterns of functional specialisation in international trade. We present a new index of revealed comparative advantage based on the type of activities carried out in global value chains, such as R&D and design, production, logistics and after sale services. It combines detailed occupation and wage data with a world input-output database to trace value added trade flows across 40 countries. Our findings show that since 1995 mature economies are specializing in services activities, while emerging markets specialise in fabrication activities. This process accelerated in the early 2000s and has continued apace after the global financial crisis. Consistent with theory, changes in functional specialization in international trade are mainly related to changes in function intensity within sectors.

*Journal of Economic Literature bibliographic codes:* F14, F60, O19

*Key words:* Specialisation; international trade; tasks.
“Regarding your article on Intel’s chipmaking operations in Costa Rica (...), I would like to clarify that the company has not left the country. It is relocating its assembly and test operations to Asia, but its global services centre and its engineering and design centre will remain in Costa Rica with 1,400 employees.”

Anabel González, Minister of foreign trade, San José, Costa Rica

(Letters, The Economist May 10th 2014)

Introduction

The activities of firms are spatially separated due to declining trade and communication costs. This fundamentally alters the nature of international trade, with profound implications for the geographical location of activities, the gains from trade and the performance of labour markets (Feenstra, 2010). Due to the cross-border fragmentation of production, the value of a country’s exports is different from what it actually contributes to the production process (Johnson, 2014). The above quote on Intel’s computer chip making operations in Costa Rica is revealing. The relocation of assembly activities to Asia will have a major impact on the export composition of Costa Rica, because the export of computer chips comprised a major part of Costa Rica’s goods exports. However, the fragmentation of the value chain not only involves tangible production activities, but also business functions like R&D, sales, marketing, and ICT services. These activities remain in Costa Rica and may add substantial value to Intel’s products as well as generate incomes and jobs in Costa Rica. If assembly activities add little value to a product, the country to which Intel relocates assembly activities may now look like a dominant exporter in computer chips, but in fact contribute very little value added to those exports (Dedrick et al. 2010). Central to the focus of this paper, it is a basic point that should be born in mind in analyses of revealed comparative advantage in international trade.

As a result of production fragmentation, analyses of revealed comparative advantage based on gross export data is increasingly misleading and generates surprising results. For example, di Mauro and Forster (2008) find that the specialization...
pattern of European countries that adopted the euro has not changed much during the 1990s and 2000s. They relate this finding to the inability of gross exports statistics to capture the value added in internationally fragmented production. Measurement of value added exports require world input-output tables that track the flows of goods and services across intermediate usage. These have only recently become available and has resulted in analysis of revealed comparative advantage based on value added exports, see Timmer et al. (2013) and Koopman et al. (2014). These studies find that specialization patterns did change in many countries during the past decades. For example, value added exports in European countries increased in activities related to the production of machinery and transport equipment, while it declined in activities related to the production of non-durables (Timmer et al. 2013). Such findings seem more in line with expectations than the suggestion of stagnant patterns of comparative advantage based on gross export data.

This paper goes one step further and provides a breakdown of value added exports into the set of business functions involved. It allows an analysis of comparative advantage based on tasks or functions. Offshoring decisions by firms often seem to occur for groups of workers with a coherent set of activities, such as design, assembly, testing, or ICT services (Sturgeon and Gereffi, 2009). This approach is also in part motivated by anecdotal evidence such as Intel’s chip making operations in Costa Rica. Managers of firms do not have particular tasks in mind, but rather a set of tasks collected in a particular business function. We therefore examine international specialization in functions rather than tasks. Recent surveys at national statistical institutes have started to collect this type of data for the international sourcing efforts of firms.

---

2 Grossman and Rossi-Hansberg (2008) present a model of offshoring with a continuum of tasks. We examine functions, which are a more ubiquitous feature of production processes than a particular task.
Table 1. International sourcing of business functions. Shares of firms carrying out international sourcing.

<table>
<thead>
<tr>
<th></th>
<th>Denmark</th>
<th>Finland</th>
<th>The Netherlands</th>
<th>Norway</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core business functions</td>
<td>52</td>
<td>58</td>
<td>55</td>
<td>40</td>
<td>82</td>
</tr>
<tr>
<td>Distribution</td>
<td>23</td>
<td>19</td>
<td>23</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>Marketing and sales</td>
<td>17</td>
<td>25</td>
<td>12</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>ICT services</td>
<td>27</td>
<td>25</td>
<td>26</td>
<td>28</td>
<td>22</td>
</tr>
<tr>
<td>Administration</td>
<td>18</td>
<td>20</td>
<td>23</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Engineering</td>
<td>20</td>
<td>10</td>
<td>6</td>
<td>14</td>
<td>..</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>15</td>
<td>15</td>
<td>13</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Other functions</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>17</td>
<td>..</td>
</tr>
</tbody>
</table>

Source: Nielsen (2008)

Notes: The table shows shares for firms that did carry out international sourcing. Firms with 50 or more employees, except for the Netherlands which covers firms over 100 employees.

Consider the European Union survey of international sourcing (Nielsen, 2008). Table 1 shows international sourcing practices in Denmark, Finland, the Netherlands, Norway and Sweden among firms with 50 or more employees (100 or more in the case of the Netherlands) during the period 2001-2006. The survey asked managers questions about the outsourcing of business functions. For managers of large firms, choices about how to bundle and unbundle business functions has become a central preoccupation in strategic decision-making. However, for the majority of firms this is not an issue, as they do not outsource functions. Approximately 85 percent of the firms reported that they do not outsource business functions.

The 15 percent of surveyed firms that do outsource, mainly outsource their core business function (the primary activity of the firms). Typically the production of final goods or services is outsourced. Product case studies about these business practices abound, ranging from Barbie dolls to Iphones (Feenstra, 1998; Dedrick et al. 2010). However, other functions are outsourced as well. For example, about 25 percent of firms that outsource report that they have outsourced ICT services. About 15 percent even

---

3 Canada recently also adopted this survey in the Survey of Changing Business Practice in the Global Economy. The US BLS is collecting similar statistics in its Mass Layoff Statistics Program (Brown, 2008). See Gereffi and Sturgeon (2009) for an overview.
outsource their R&D activities. So far, these surveys do not allow the quantification and analysis of functional specialization in international trade as done here.

This paper examines functional specialization patterns in international trade for a set of forty advanced and emerging countries during the period from 1995 to 2011. We extend the empirical model of Koopman et al. (2014) and Los et al. (2014) to analyse patterns of functional specialisation in international trade. We quantify functional specialization by combining detailed occupation and wage data with a world input-output database to trace value added trade flows across countries. This allows us to present a new index of revealed comparative advantage based on the type of activities carried out in global value chains, such as R&D and design, production, logistics and after sale services.

This paper is related to earlier theoretical literature that divided a firms’ activities in headquarter and production as in Markusen (2002). In a similar vein, Duranton and Puga (2005) present an urban model with headquarter and production activities, in which cities shift from sectoral to functional specialization. More recently, Markusen and Venables (2013) presented a Ricardian model with comparative advantage determined at the business activity and not at the sector level. In their model, specialization is initially in goods or sectors. A country produces those goods which make intensive use of the business function in which it has a comparative advantage. But as fragmentation costs fall, it becomes attractive to split the production process of a good and perform each activity in the location that has the greatest efficiency advantage. In this model, lower communication and coordination costs induce firms to fragment production processes and as a result there will be a shift from sectoral towards functional specialization. In this paper we adopt the model by Deardorff (2001) to show that a similar shift from product to functional specialization can be modelled in a standard Heckscher-Ohlin setting.

The enriched Ricardian and Heckscher-Ohlin models have two clear empirical predictions that are tested in this paper. First, they suggest that as fragmentation costs fall one expects a shift in comparative advantage towards those business functions in which the country has a cost (as in the HO model) or a (Ricardian) productivity

---

4 The unit of analysis in Markusen and Venables (2013) is a city, but nothing precludes the model from being used in an international context. In appendix B we adopt their model to the context of this paper.
advantage. This hypothesis is examined by adopting the standard Balassa (1965) type of revealed comparative advantage to the current context. Second, these models suggest that functional specialization in international trade is driven by changes in sector function intensity. For example, what one expects is an increase in the share of say design and marketing activities in value added exports from U.S. electronics industry, and not so much a change in the sector composition of exports (e.g. a decreasing share of electronics value added exports). We test this model prediction by using a decomposition method that splits up functional specialization in international trade into changes due to sector function intensity and changes in the value added export composition.

The remainder of this paper is organized as follows. Section 1 briefly outlines the Heckscher-Ohlin model, where we adopt Deardorff (2001) to the context of this paper and derive the main empirical predictions. In section 2 we extend the methodology by Koopman et al. (2014) and Los et al. (2014) and add a decomposition of value added exports based on business functions. The construction of the global input-output tables and the business function database is discussed in section 3. In section 4 we present our results on revealed comparative advantage in business functions. Section 5 examines the nature of functional specialization. In particular it decomposes functional specialization in international trade to examine whether specialization mainly relates to changes in function intensity within sectors. Section 6 provides concluding remarks.

1. Fragmentation and functional specialization in a Heckscher-Ohlin model

Functional specialization due to falling fragmentation costs can easily be shown in a Heckscher-Ohlin model. With fragmentation, the broad Heckscher-Ohlin predictions still hold: countries carry out those tasks that are relatively intensive in their relatively abundant business functions (Grossman and Rossi-Hansberg, 2008). We use the HO model to derive two main predictions that are tested in this paper. The model predicts that countries will specialize in those functions in which it has a comparative advantage. Additionally, it predicts that this functional specialization in international trade is mainly related to increased function intensity within sectors.
First, we briefly outline the logic in a simple Heckscher-Ohlin setting, elaborating on Deardorff (2001). Assume a two country, two goods and two business functions Heckscher-Ohlin setting. In what follows, we compare the function content of production in both countries before and after fragmentation. Figure 1 shows the unit cost lines of the two countries: CD for the advanced, and AB for the emerging country. The unit cost line represents the combination of workers in both business functions that together cost one dollar. The slope of this line depends on the wage ratio of the workers involved in both functions, indicating that the emerging country is relatively abundant in function A (one may think of fabrication activities), and the advanced country in function B (one may think of R&D and engineering activities). Note that we assume the absence of equalization in function prices, such that the lines are different. Also drawn are the unit value isoquants of goods 1 and 2, reflecting the quantities of inputs needed to produce one dollar of output of the good.

**Figure 1.** Functional specialization when fragmentation is possible

*Note:* this example is elaborated from Deardorff (2001).
The production process of the goods requires both business functions. However, good 1 is relatively more intensive in function B and will therefore be produced in the advanced country. The amounts of both functions used are given by OX. Similarly, good 2 is relatively intensive in function A and produced in the emerging country with inputs OY. Suppose that for the production of good 1, OF inputs of business function A are needed whereas FX inputs of business function B are needed. It is obvious that there is no gain for the advanced country to fragment its production process domestically. The vector sum of OF and FX is equal to OX such that no profit can be made from fragmentation within the country. Potentially, a profit could be made by shifting the OF task to the emerging country to benefit from the lower price of function A.

Initially the additional production costs of coordinating tasks across borders are too high, for example because of trade barriers, tariffs, transport costs, communication and other coordination costs. But now suppose that these costs are falling, such that international production fragmentation becomes profitable. What will happen to the function content of production in the two countries? As the tasks requiring function A are offshored, production in the advanced country will become more intensive in function B.

So far, the Hecksher-Ohlin model has been studied using two production factors (capital and labour) or labour with different educational attainment. A stylized empirical finding from a framework with labour of different skill types is that advanced countries specialize in high skilled activities, whereas emerging countries specialize in low skilled activities (Timmer et al., 2014). However, in the setup of this paper, skilled workers can perform different tasks (e.g. R&D, design or marketing). High-skilled workers in Great Britain may specialize in financial services, in the Netherlands in logistics and say in Sweden’s transport equipment industry in design activities. This implies that functional specialization across countries is an empirical issue.

We aim to test two key predictions from this theoretical framework. First, we expect that due to increasing production fragmentation, shifts in comparative advantage of business functions are observed across countries. Second, we expect that functional specialization in international trade is related to changes in function intensity within sectors. That is, economic sectors do not disappear in an economy but they increasingly focus on those functions in which the country has a comparative advantage. Before we

---

These predictions also follow from the Ricardian model proposed by Markusen and Venables (2013).
test these predictions, we outline the measurement of value added exports by business function and the data needs.

2. Methodological approach

This section outlines a global input-output accounting framework to measure business function shares in domestic value added exports. John and Noguera (2012) use this framework to measure value added exports related to foreign final demand. We follow Koopman, Wang, and Wei (2014) and Los et al. (2014), by also incorporating domestic value added in exports of intermediates that is ultimately absorbed in the domestic economy. Here, we split domestic value added exports by specific business functions. By tracing the value added of business functions at the various stages of production in an international input-output model, it is possible to provide an ex-post accounting of gross exports.

Assume B business functions, S sectors and N countries. The gross output of an industry is produced by combining domestic production factors with intermediate inputs. These intermediates may be sourced at home or abroad. To track the shipments of intermediate and final goods within and across countries it is necessary to define source and destination countries, as well as source and destination sectors. For a particular product, we define $i$ as the source country, $j$ as the destination country, $s$ as the source sector and $t$ as the destination sector. Market clearing implies that the quantity of a product produced equals the quantities of this product used domestically and abroad. Since we only observe the value of products traded, we assume that each product has only one price, irrespective of its use, such that the revenue for the producer equals the value of use across destinations.\(^6\) The product market clearing condition can then be written as

$$y_i(s) = \sum_j f_{ij}(s) + \sum_t m_{ij}(s,t)$$

(1)

where $y_i(s)$ is the value of output in sector $s$ of country $i$, $f_{ij}(s)$ the value of goods shipped from this sector for final use in any country $j$, and $m_{ij}(s,t)$ the value of goods

\(^6\) In the empirical analysis we will use input-output tables at basic prices, which exclude trade and transportation margins and net taxes. This price concept comes closest to the assumption made here.
shipped from this sector for intermediate use by sector \( t \) in country \( j \). Note that the use of goods can be at home (in case \( i = j \)) or abroad (\( i \neq j \)).

Using matrix algebra, the market clearing conditions for each of the SxN goods can be combined to form a compact global input-output system. Let \( \mathbf{y} \) be the vector of production of dimension \((SNx1)\) stacking output in each country-sector, and \( \mathbf{F} \) the matrix with dimension \((SNxN)\) stacking final demand in each country for output from each country-sector. We further define a global input-output matrix \( \mathbf{A} \) of dimension \((SNxSN)\) with elements \( a_{ij}(s,t) = m_{ij}(s,t)/y_j(t) \), which are intermediate input coefficients describing the output from sector \( s \) in country \( i \) used as intermediate input by sector \( t \) in country \( j \) as a share of output in the latter sector. The matrix \( \mathbf{A} \) describes how a given product in a country-sector is produced with different combinations of intermediate products and can be written as

\[
\mathbf{A} = \begin{bmatrix}
A_{11} & A_{12} & \cdots & A_{1N} \\
A_{21} & A_{22} & \cdots & A_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
A_{N1} & A_{N2} & \cdots & A_{NN}
\end{bmatrix}
\]

where \( A_{ij} \) is the SxS matrix with typical elements \( a_{ij}(s,t) \). The diagonal sub-matrices track the requirements for domestic intermediate inputs, while the off-diagonal elements track the requirements for foreign intermediate inputs. The matrix \( \mathbf{A} \) summarizes the flows of all intermediate goods across sectors and countries and using this we can rewrite the stacked SxN market clearing conditions from (1) as

\[
\begin{bmatrix}
\mathbf{y}_1 \\
\mathbf{y}_2 \\
\vdots \\
\mathbf{y}_N
\end{bmatrix}
= \begin{bmatrix}
A_{11} & A_{12} & \cdots & A_{1N} \\
A_{21} & A_{22} & \cdots & A_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
A_{N1} & A_{N2} & \cdots & A_{NN}
\end{bmatrix}
\begin{bmatrix}
\mathbf{y}_1 \\
\mathbf{y}_2 \\
\vdots \\
\mathbf{y}_N
\end{bmatrix}
+ \begin{bmatrix}
f_{11} & f_{12} & \cdots & f_{1N} \\
f_{21} & f_{22} & \cdots & f_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
f_{N1} & f_{N2} & \cdots & f_{NN}
\end{bmatrix}
\begin{bmatrix}
\mathbf{y}_1 \\
\mathbf{y}_2 \\
\vdots \\
\mathbf{y}_N
\end{bmatrix}
\]

In this expression, \( \mathbf{y}_i \) represents the S-vector with production levels in country \( i \), and \( \mathbf{f}_{ij} \) indicates the S-vector of final demands in country \( j \) for the products of country \( i \). In compact form, the system can be expressed as

\[
y = \mathbf{Ay} + \mathbf{Fu}
\]

(2)
in which \( u \) is a column summation vector of appropriate length. Rearranging (2) we arrive at the fundamental input-output identity introduced by Leontief (1949)

\[
y = (I - A)^{-1} Fu
\]  

\( I \) is an \((SNxSN)\) identity matrix with ones on the diagonal and zeros elsewhere. \((I - A)^{-1}\) is famously known as the Leontief inverse. It represents the total production values in all stages of production that are generated in the production process of one unit of final output. To see this, let \( z \) be a column vector with the first element representing the global consumption of goods from a particular country-sector, while all the remaining elements are zero. The production of final output \( z \) requires intermediate inputs given by \( Az \). In turn, the production of these intermediates requires the use of other intermediates given by \( A^2z \), and so on. As a result the increase in output in all sectors is given by the sum of all direct and indirect effects \( \sum_{k=0}^{\infty} A^k z \). This geometric series can be rewritten as \((I - A)^{-1}z\).

Next, consider a row vector \( v^\text{dom} = [v_i \ 0] \), which contains value added per unit of gross output ratios in sectors of source country \( i \). The elements for other countries are set to zero, since we are at this stage interested in \( i \)'s domestic value in its exports. Using Leontief's insight, actual GDP in country \( i \) equals

\[
\text{GDP}_i = v^\text{dom}(I - A)^{-1}Fu.
\]  

What amount of domestic value added is related to gross exports of country \( i \)? To measure this, Los et al. (2014) create a counterfactual world in which \( i \) does not export anything, while leaving the rest of the economic structure of the world unaffected (this is a variant of the well-known hypothetical extraction method in input-output analysis). That is, exports by country \( i \), of intermediates in block \( A \) and for final demand in \( F \), are set to zero. The counterfactual matrices \( A^* \) and \( F^* \) are given by
\[
\begin{bmatrix}
A_{11} & 0 & \cdots & 0 \\
A_{12} & A_{22} & \cdots & A_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
A_{N1} & A_{N2} & \cdots & A_{NN}
\end{bmatrix}
\quad \text{and} \quad
\begin{bmatrix}
f_{11} & 0 & \cdots & 0 \\
f_{21} & f_{22} & \cdots & f_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
f_{N1} & f_{N2} & \cdots & f_{NN}
\end{bmatrix}
\]

such that \(i\)'s counterfactual GDP can be obtained by post-multiplying the counterfactual Leontief inverse with counterfactual final demand as:

\[
\text{GDP}_i^* = \nu^{\text{dom}}(1 - A^*)^{-1}F^* u. \tag{5}
\]

Following the logic of hypothetical extraction, domestic value added of exports (DVA) from country \(i\) is derived as the difference in GDP in the actual and counterfactual situations:\(^7\)

\[
\text{DVA}_i = \text{GDP}_i - \text{GDP}_i^* \tag{6}
\]

This approach can easily be extended to examine domestic value added exports by business function. Define \(b_{i,b}(s)\) as the direct input of a business function per unit of gross output produced in sector \(s\) of country \(i\) and create the stacked vector \(\mathbf{b}\) with dimension \(SN \times 1\) from these business function coefficients. An element in this vector is country- and sector-specific, for example the value added generated by design or engineering activities in the German transport industry to produce one dollar of output in that country-industry. The value added from all business functions in the German transport industry sums to value added per unit of gross output of that country-industry, such that \(\nu_i(s) = \sum_{b=1}^{B} b_{i,b}(s)\).

In equations (4) and (5), \(\nu^{\text{dom}} = [\nu_i \quad 0]\) is replaced by \(b_{\text{dom}}^b = [b_{i,b} \quad 0]\), and domestic value added exports of a business function is obtained as

---

\(^7\) Note this measure differs from “value added exports” (known as VAX) as introduced by Johnson and Noguera (2012). They defined VAX as the “domestic value added that is absorbed in other countries”. Los et al. (2014) show that their approach can also be represented by this method. In this case, flows are only extracted from the final demand matrix. Counterfactual final demand is specified as if there is no demand for final products in country \(j\), either inside the country or abroad. VAX of \(i\) can be derived by subtracting counterfactual GDP from actual GDP as in (6). VAX is smaller than DVA by definition, as it excludes the value added reflected back to the home country.
\[DVA_{i,b} = GDP_{i,b} - GDP^*_{i,b}\]  

(7)

where \(DVA_i = \sum_{b=1}^{g} DVA_{i,b}\).

This DVA measure has a close link to the export value decomposition made by Koopman et al. (2014). It corresponds to domestic value added exports in Koopman et al. (2014), which is the sum of the first five terms in their decomposition equation (36). That concept is used by them in an analysis of revealed comparative advantage. We will extend their analysis of comparative advantage in what follows. Before that, we describe the data that is used.

3. The World Input-Output Database and Data on Business Functions

This section briefly describes the World Input-Output Database (WIOD) that is used to measure domestic value added exports. Second, we describe the construction of a new cross-country cross-industry dataset of business functions.

3.1 The World Input-Output Database

WIOD provides a time-series of world input-output tables from 1995 to 2011 (Timmer et al. 2014). The major advantage of this data set is that it provides a set of tables consistent with national accounts data to facilitate comparisons across countries and over time. It covers forty countries, including all EU 27 countries and 13 other major advanced and emerging economies, namely Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey and the United States. These countries were chosen by considering both the requirement of data availability of sufficient quality and the desire to cover a major part of the world economy. Together, the countries cover more than 85 per cent of world GDP in 2008, at current exchange rates. In addition a model for the remaining non-covered part of the world economy is
estimated, called the “rest of the world” region. For our purposes it is important to have a closed model of the world economy. The WIOTs are built up from published and publicly available statistics from national statistical institutes around the world, plus various international statistical sources such as OECD and UN National Accounts, UN Comtrade and IMF trade statistics. As building blocks for the tables, national supply and use tables (SUTs) were used. Time series of national SUTs were derived and linked across countries through detailed bilateral international trade statistics to create so-called international SUTs. These were subsequently used to construct the world input-output tables. In addition to these tables, the WIOD provides data on the quantity and prices of factors inputs, including data on workers and wages. We combine this information with occupation and wage data to derive shares of business function value added exports in total domestic value added exports.

3.2 Data on Business functions

A key element in our approach is the mapping of occupations and their relative wages to business functions. This mapping is described in Table 2.\(^8\) We use the list of functions distinguished by Sturgeon and Gereffi (2009), which itself are derived from a list of generic business functions first proposed by Porter (1985). For expositional convenience, business functions are grouped into three stages: the pre-fabrication, the fabrication, and the post-fabrication stage. The fabrication and the post-fabrication stage are split into low- and high-skilled activities. Pre-fabrication activities include R&D, design and commercialization, which mainly involve professional occupations. The ‘core’ fabrication stage includes a set of low-skilled occupations such as machine operators and assemblers, but also high-skilled occupations like technicians. Post-fabrication activities include marketing, logistics, and after-sales services. Low-skilled workers involved in these activities are clerks, whereas managers are considered high-skilled.

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Stage</th>
<th>Type of business</th>
<th>skill</th>
<th>Occupations</th>
</tr>
</thead>
</table>

\(^8\) This is a rough mapping of occupations to business functions. If the quality and availability of data increases, this mapping should be further refined.
<table>
<thead>
<tr>
<th>Function included</th>
<th>Distinction</th>
<th>(1 digit ISCO 88)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-fabrication</td>
<td>Professionals</td>
<td></td>
</tr>
<tr>
<td>Fabrication</td>
<td>Low-skilled</td>
<td>Service workers and shop and market sales workers; Craft and related trades workers; Plant and machine operators and assemblers; Elementary occupations</td>
</tr>
<tr>
<td>High-skilled</td>
<td>Technicians and associate professionals</td>
<td></td>
</tr>
<tr>
<td>Post-fabrication</td>
<td>Low-skilled</td>
<td>Clerks</td>
</tr>
<tr>
<td>Marketing, advertising and brand management, specialized logistics, after-sales services</td>
<td>High-skilled</td>
<td>Legislators, senior officials and managers</td>
</tr>
</tbody>
</table>

Notes: Classification of occupations based on ISCO88. Authors’ mapping. List of business function derived from Sturgeon and Gereffi (2009).

The mapping of occupations is exhaustive. The employment shares by business function sum to 1. Combining employment data with relative wages, we also create an exhaustive split of the labour share in value added. The capital share in value added is proportionally distributed based on the labour shares across production stages. Ideally, some assets like machinery equipment should be assigned to the production stage. And intangible capital is probably mainly related to pre- and post-fabrication activities. Current data availability on capital shares by asset types do not allow this distinction. Labour and capital shares of a particular business function are combined.

Two-digit occupational shares by detailed industry are derived from the EU labour force surveys for European countries, from the Occupational Employment Statistics (OES) surveys for the US and from the Japan Industry Productivity Database.
for Japan. This information is combined with wage data by occupation from the 2002 Structure and Earnings Survey for Europe, the OES for the US, and the historical statistics published by Japan’s statistical office. The other countries included in the analysis are Australia, Brazil, Canada, India, Indonesia, South Korea, Mexico, Russia, Turkey, and Taiwan. Typically, information on occupation by industry can be found in population censuses, labor force surveys, or other sources. However, for most countries no information on wages by occupation is available. We have used the Occupational Wages around the World (OWW) database (Oostendorp, 2012) to estimate relative wages. Appendix A describes the construction of the dataset in detail.

This allows us to estimate the vector $\mathbf{b}_i^{\text{com}}$, which is subsequently used to measure domestic value added exports of that particular business function. We are able to do this annually for the period from 1995 to 2011. The sum of business function value added exports equals domestic value added exports as in Koopman et al. (2014). We use it to examine changes in comparative advantage in the next section and explore the nature of functional specialization in section 5.

4. Revealed Comparative Advantage in Business Functions

To what extent are countries specializing in particular tasks or functions? The standard tool to analyse this is by means of revealed comparative advantage (RCA) analysis. The concept of revealed comparative advantage, introduced by Balassa (1965), refers to the relative trade performance of countries in particular products. If the trade pattern is assumed to reflect differences across countries in relative costs and non-price factors, it ‘reveals’ the comparative advantage of the exporting country. Traditionally, this is based on comparing a country’s share in world exports of a particular product group or industry to its share in overall exports. However, due to rapidly increasing production fragmentation, a country that looks like a dominant exporter in a particular product or sector may in fact contribute very little value added to those exports.

---

9 An RCA analysis is based on observed trade patterns. Observed trade patterns can, for example, be distorted due to government policies and as a result may misrepresent comparative advantage. Over time, the RCA index has been extensively criticized, but most agree that RCA measures are a useful proxy in determining whether or not a country has a comparative advantage, though less useful in indicating the extent of comparative advantage (Balance et al. 1987). See Vollrath (1991) for a discussion and alternative measures.
Thus, an RCA analysis performed on the basis of gross export values does not fully reflect the effects of international production fragmentation. As an alternative, RCA can be performed on the basis of domestic value added exports. Hence the usefulness of RCA analysis is retained, albeit with a different interpretation. The original RCA index can be rewritten as

\[
RCA = \frac{DVA_{i,b} / \sum_b DVA_{i,b}}{\sum_i \sum_b DVA_{world,b} / \sum_i \sum_b DVA_{world,b}}
\]

(8)

where, \(DVA_{i,b}\) are the domestic value added exports of business function \(b\) from country \(i\). The numerator represents the percentage share of a given business function in a country’s domestic value added exports. The denominator represents the percentage share of a given function in world value added exports. Hence, the RCA index gives a comparison of a country’s value added exports structure to the world value added export structure. If the RCA index is above 1, the country is said to be specialised in that function and vice versa whereas RCA is below 1.

In Figure 2 we provide the results of an RCA analysis for a select set of advanced and emerging countries included in WIOD.\(^{10}\) The analysis is based on domestic value added exports for five groups of business functions (see column 1 of table 2) over the period 1995 to 2011. For the USA, the results reveal a comparative advantage in post-fabrication activities, both by low and high skilled workers. Over time, this comparative advantage has grown in particular after the 1990s. Initially, in 1995, the US did not have a comparative advantage in pre-fabrication activities like design and R&D, but our findings suggest a very strong specialization pattern since. Results for other advanced countries (Germany, France, and Great Britain) also suggest a revealed comparative advantage in service activities either before or after fabrication and increasing specialization over time.

In contrast, Indonesia, China, Turkey and to a lesser extent Brazil reveal a comparative advantage in the fabrication stage. For example, the revealed comparative advantage of Indonesia is in low-skilled fabrication activities and changes only modestly

---

\(^{10}\) Results for all countries are available upon request.
during the period analyzed. China also has a revealed comparative advantage in low-skilled fabrication stages. But interestingly, its comparative advantage in high-skilled fabrication activities as well as low-skilled post-fabrication activities is increasing during the past decade. In Turkey and Brazil we observe that the comparative advantage in low-skilled fabrication activities declines whereas that in high-skilled fabrication activities increases.

These findings are indicative of functional specialization in international trade as fragmentation costs have fallen during the past decade (Baldwin, 2006).

**Figure 2.** Revealed comparative advantage by business function groups. Selected countries, 1995 to 2011.
Notes: A refers to pre-production activities; BL to fabrication activities by low-skilled workers; BH to fabrication activities by high-skilled workers; CL to post-fabrication activities by low-skilled workers; CH to post-fabrication activities by high-skilled workers.

The country coverage in WIOD and the business function database that we constructed is particularly well suited to analyze differences in specialization patterns across Europe, since 27 EU countries are included. Table 3 presents indices of revealed comparative advantage for these countries for the years 1995 and 2011. The table distinguishes between the old EU 15 countries and the EU 12 new member states that joined in 2004 and later. Countries are ranked using GDP in current US dollars (in 2008).

The results suggest substantially different in specialization patterns across the European Union. Some countries like Germany, France and Great Britain have a comparative advantage in R&D, design, and other pre-fabrication activities and specialized since 1995. However, value added exports of other EU 15 countries like Greece, Portugal and Spain and many EU 12 countries do not reveal a comparative advantage in these activities. In contrast, many of these countries add value by performing low-skilled fabrication activities. At least in 1995. Over time, this pattern changed for many countries, partly due to the rise of other large factory economies like China (see figure 2). Yet, in 2011, large EU12 countries such as Poland, the Czech and the Slovak Republic still have a comparative advantage in production activities. In 1995 no EU12 country had a comparative advantage in high-skilled fabrication activities. Yet, in 2011 various new member states specialized in this direction, for example Slovenia and also the Czech and Slovak Republic.

While informative, in the next section we aim to explore what causes and drives these functional specialization patterns.
Table 3. Revealed comparative advantage by business function groups, 1995 and 2011.

<table>
<thead>
<tr>
<th>Country</th>
<th>Pre-fabrication activities</th>
<th>Fabrication activities (low skilled)</th>
<th>Fabrication activities (high skilled)</th>
<th>Post-fabrication activities (low skilled)</th>
<th>Post-fabrication activities (high skilled)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>1.46</td>
<td>1.59</td>
<td>0.91</td>
<td>0.74</td>
<td>1.05</td>
</tr>
<tr>
<td>France</td>
<td>1.51</td>
<td>1.67</td>
<td>0.91</td>
<td>0.67</td>
<td>0.90</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1.51</td>
<td>1.51</td>
<td>0.77</td>
<td>0.55</td>
<td>0.48</td>
</tr>
<tr>
<td>Italy</td>
<td>0.61</td>
<td>1.13</td>
<td>0.85</td>
<td>0.71</td>
<td>0.70</td>
</tr>
<tr>
<td>Spain</td>
<td>0.82</td>
<td>0.94</td>
<td>1.18</td>
<td>0.86</td>
<td>0.64</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1.48</td>
<td>1.65</td>
<td>0.86</td>
<td>0.67</td>
<td>0.85</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.41</td>
<td>1.66</td>
<td>0.88</td>
<td>0.60</td>
<td>0.70</td>
</tr>
<tr>
<td>Sweden</td>
<td>1.27</td>
<td>1.55</td>
<td>1.03</td>
<td>0.81</td>
<td>1.13</td>
</tr>
<tr>
<td>Austria</td>
<td>0.72</td>
<td>0.87</td>
<td>0.87</td>
<td>0.62</td>
<td>1.07</td>
</tr>
<tr>
<td>Greece</td>
<td>0.73</td>
<td>0.90</td>
<td>1.23</td>
<td>0.69</td>
<td>0.55</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.97</td>
<td>1.40</td>
<td>1.13</td>
<td>0.75</td>
<td>0.85</td>
</tr>
<tr>
<td>Finland</td>
<td>1.17</td>
<td>1.68</td>
<td>1.05</td>
<td>0.74</td>
<td>0.69</td>
</tr>
<tr>
<td>Ireland</td>
<td>1.05</td>
<td>1.76</td>
<td>1.09</td>
<td>0.58</td>
<td>0.28</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.65</td>
<td>0.80</td>
<td>0.92</td>
<td>0.89</td>
<td>0.80</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>1.63</td>
<td>2.64</td>
<td>0.54</td>
<td>0.31</td>
<td>1.13</td>
</tr>
<tr>
<td>Poland</td>
<td>0.98</td>
<td>1.03</td>
<td>1.26</td>
<td>1.04</td>
<td>0.58</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>0.92</td>
<td>0.66</td>
<td>1.18</td>
<td>1.01</td>
<td>0.88</td>
</tr>
<tr>
<td>Romania</td>
<td>1.02</td>
<td>0.97</td>
<td>1.53</td>
<td>1.41</td>
<td>0.53</td>
</tr>
<tr>
<td>Hungary</td>
<td>1.09</td>
<td>1.33</td>
<td>1.12</td>
<td>0.89</td>
<td>0.66</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>0.87</td>
<td>0.77</td>
<td>1.23</td>
<td>1.00</td>
<td>0.87</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1.03</td>
<td>1.40</td>
<td>1.10</td>
<td>0.76</td>
<td>0.88</td>
</tr>
<tr>
<td>Lithuania</td>
<td>0.91</td>
<td>1.30</td>
<td>1.26</td>
<td>0.98</td>
<td>0.37</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>1.11</td>
<td>0.98</td>
<td>1.22</td>
<td>1.13</td>
<td>0.65</td>
</tr>
<tr>
<td>Latvia</td>
<td>0.99</td>
<td>1.25</td>
<td>1.23</td>
<td>0.91</td>
<td>0.80</td>
</tr>
<tr>
<td>Cyprus</td>
<td>0.68</td>
<td>1.03</td>
<td>1.22</td>
<td>0.79</td>
<td>0.80</td>
</tr>
<tr>
<td>Estonia</td>
<td>1.03</td>
<td>1.60</td>
<td>1.09</td>
<td>0.79</td>
<td>0.78</td>
</tr>
<tr>
<td>Malta</td>
<td>0.65</td>
<td>0.94</td>
<td>1.17</td>
<td>0.88</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Notes: The table distinguishes between the old EU 15 countries and the EU 12 new member states that joined in 2004 and later. Countries are ranked using GDP in current US dollars (in 2008).
5. The Sectoral Nature of Functional Specialization

A key implication of the model proposed by Markusen and Venables (2013) and the adaptation of the Heckscher-Ohlin model to the current context in section 1, is that the intensity in the use of business functions differs across sectors. Comparative advantage is determined at the level of functions and not products. The lowering of communication and coordination costs or other barriers to production fragmentation induces a country to specialize in those tasks in which it has a comparative advantage. That is, sectors do not disappear, but activities within these sectors increasingly focus on those functions in which the country has a comparative advantage. From these model we therefore expect that changes in country-level functional shares, are mainly due to changes within sectors.

To examine this hypothesis, we decompose the change in country-level functional shares into changes in sector function intensity and changes in the sector composition of overall value added exports. We use a conventional shift-share decomposition. Note that a country’s business function share in value added exports is an export-weighted average of the sector’s business function shares in sector value added exports. The decomposition is then given by

\[
\frac{\Delta DVA_{i,b,t}}{DVA_{i,t}} = \sum_s \left( (\Delta \varphi_{i,s,b,t} \times 0.5 \times (\omega_{i,s,t} + \omega_{i,s,t-1})) + (\Delta \omega_{i,s,t} \times 0.5 \times (\varphi_{i,s,b,t} + \varphi_{i,s,b,t-1})) \right)
\]

(9)

where \(DVA_{i,b,t}\) and \(DVA_{i,t}\) are total value added exports of business function \(b\) and total value added exports for country \(i\) in period \(t\). And \(\varphi_{i,s,b,t}\) is country \(i\), sector \(s\)’s share of value added exports of a business function in sector \(s\)’s value added exports in period \(t\) (so \(\frac{DVA_{i,s,b,t}}{DVA_{i,s,t}}\)), and \(\omega_{i,s,t}\) is the sectors value added share in period \(t\) (\(\frac{DVA_{i,s,t}}{DVA_{i,t}}\)).

Each sector’s contribution is divided into a contribution due to changes in the sector-level business function shares (the within effect, the first term in equation 9), and a contribution due to the changes in the sector-level value added export share (the

\[\text{We obtain sector DVA exports by diagonalizing } \mathbf{v}_{dom} \text{ in section 2.}\]
between effect, the second term in equation 9). Thus, the decomposition gives a breakout of changes in the share of a business function in value added exports of the US into changes in functional intensity within sectors and changes in the composition of US value added exports.

We add up all the sector contributions into a total “within” and a total “between” contribution. The results for the United States and Europe are shown in Table 3. The second column in table 3 shows the changes in shares of the business function groups in total value added exports. In both the US and Europe, the shares of services activities in total value added exports increased. The share of low-skilled fabrication activities declined in both. High-skilled fabrication activities also decreased as a share in total value exports of the US, but it increased in Europe, which might be related to the functional specialization patterns in the EU12 discussed in the previous section. The two subsequent columns show whether this change is due to changes in function intensity within sectors or due to changes in the sector composition of exports. Our results suggest that changes in function intensity within sectors are dominant both the US and Europe as they account for over 50 percent of the change observed. This is indicative evidence in support of the theoretical prediction derived in section 1.

Table 3. Decomposition of the change in country-level business function shares in total value added exports

<table>
<thead>
<tr>
<th></th>
<th>Change in functional specialization share of value added exports (2011 minus 1995)</th>
<th>Contribution of:</th>
<th>Change in sector share of value added exports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Change in</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sector functional intensity</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-fabrication activities</td>
<td>0.074</td>
<td>87%</td>
<td>13%</td>
</tr>
<tr>
<td>Fabrication activities (low skilled)</td>
<td>-0.092</td>
<td>79%</td>
<td>21%</td>
</tr>
<tr>
<td>Fabrication activities (high skilled)</td>
<td>-0.013</td>
<td>201%</td>
<td>-101%</td>
</tr>
<tr>
<td>Post-fabrication activities (low skilled)</td>
<td>0.004</td>
<td>306%</td>
<td>-206%</td>
</tr>
<tr>
<td>Post-fabrication activities (high skilled)</td>
<td>0.026</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Average EU:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-fabrication activities</td>
<td>0.053</td>
<td>67%</td>
<td>33%</td>
</tr>
<tr>
<td>Fabrication activities (low skilled)</td>
<td>-0.089</td>
<td>65%</td>
<td>35%</td>
</tr>
<tr>
<td>Fabrication activities (high skilled)</td>
<td>0.035</td>
<td>72%</td>
<td>28%</td>
</tr>
<tr>
<td>Post-fabrication activities (low skilled)</td>
<td>-0.004</td>
<td>54%</td>
<td>46%</td>
</tr>
<tr>
<td>Post-fabrication activities (high skilled)</td>
<td>0.005</td>
<td>51%</td>
<td>49%</td>
</tr>
</tbody>
</table>
6. Concluding remarks

This paper extended recent empirical models to analyse patterns of functional specialization in international trade. We presented a new index of revealed comparative advantage based on the type of activities carried out in global value chains, such as R&D and design, production, logistics and after sale services. It combines detailed occupation and wage data with a world input-output database to trace value added trade flows across 40 countries. Our findings show that since 1995 mature economies are specializing in services activities, while emerging markets specialise in fabrication activities. This process accelerated in the early 2000s and has continued apace after the global financial crisis.

In addition, we present empirical support for a key prediction of increased production fragmentation in Deardorffs' (2001) Heckscher-Ohlin model and the Ricardian model proposed by Markusen and Venables (2013), namely that firms increasingly focus on those functions in which the country has a comparative advantage. From this model we therefore expect that changes in country-level functional shares, are mainly due to changes within sectors. Our decomposition results suggest that changes in functional specialization in international trade are indeed mainly driven by changes within sectors.

References


Appendix A. Data
This appendix describes the main sources and methods to construct the business functions database.

European countries
We use data from the European Labour Force Survey (EU LFS). In this study we use data at the two digit level of the International Standard Classification of Occupations (ISCO-88). This provides us data for 27 occupations which we can attribute to the 35 industries in the WIOT. From 2005 onwards this data is available for each of the 27 EU member states (with some exceptions due to change to NACE Rev. 2 classification). For the preceding years back to 1995 there are some missing data, in particular for the Central and Eastern European member states but for the EU-15 countries data is complete for the period 1995-2008. However, in many cases there have been methodological changes in the allocation of jobs which have been reclassified. To avoid artificial results from such breaks the data have been adjusted backwards by removing the breaks in the series at the level of industry x occupations by reallocating occupations within industries if the change surpasses a certain threshold. After that a Hodrick–Prescott filter was applied to smooth the data. This provides a rather smooth time series from 1995-2008.

USA
We use the Occupational Employment Statistics (OES) from the Bureau of Labor Statistics. For 1997 to 2001 we use the national statistics, 3-digit SIC and major occupational groupings. For 2002 to 2011 we use the May rounds, with national statistics for 3-digit NAICS industries and major occupational groupings (4-digit NAICS industries for 2002). We calculate employment and the wage bill by business function at the most detailed industry level. Subsequently, these are matched and aggregated to the industries and business function groups distinguished (see table 1).

Before 1997, occupation by industry data is available for select industries in 1995 (no OES data is available for 1996). These data contain no wage estimates. In addition,
because not all sector of the economy are available in 1995, it is not possible to calculate total national employment for a given occupation by summing across industries. We assume constant shares for 1995 and 1996, equal to 1997.

*Japan*

We use annual occupational employment data from the Japan Industry Productivity database for the period from 1995 to 2010. Relative wage data is derived from the monthly contractual cash earnings by occupation for the same period. This relative wage data is available in Japan’s historical statistics database available at Statistics Japan. We calculate employment and the wage bill by business function at the most detailed industry level. Subsequently, these are matched and aggregated to the industries distinguished.

*Other countries*

Other countries include in the analysis are Australia, Brazil, Canada, India, Indonesia, South Korea, Mexico, Russia, Turkey, and Taiwan. Typically information on employment by industry can be found in population censuses, labor force surveys, or other sources. However, for most countries no information on wages by occupation is available. We have used the Occupational Wages around the World (OWW) database (Oostendorp, 2012) to estimate relative wages. OWW standardizes wage estimates from the ILO October Inquiry for about 160 occupations. These occupations are matched to the 1-digit ISCO 1988 classification.\(^{12}\) Subsequently we match these to the various production stages (see table 1) and compute the average monthly wage by country, stage, and year. Following Oostendorp (2012), we use the standardized wage with country-specific calibration and imputation and lexicographic weighting (labeled w3wl), which is recommended for use because it provides the largest sample; uses country-specific calibration to the extent possible; and uses lexicographic weights favoring raw data reported in standard format. The relative average wage by country and business function for the years after 1995 is used to compute the labor share. That is, we multiply

---

\(^{12}\) We are grateful to Remco Oostendorp for providing us this correspondence table.
employment by production stage and industry with the relative average wage by business function. The share of each function in the total wage bill is used to split the labor share.

Typically, information on employment split by occupation and industry is available. In what follows, we briefly describe the main sources and methods by country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Main source</th>
<th>Data available for the period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Labor force survey</td>
<td>2001-2008</td>
</tr>
<tr>
<td>Brazil</td>
<td>Labor force survey</td>
<td>2004, 2007</td>
</tr>
<tr>
<td>China</td>
<td>China Household Income Project</td>
<td>2002 (urban only)</td>
</tr>
<tr>
<td>Canada</td>
<td>Labor force survey</td>
<td>1995-2008</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Labor force survey</td>
<td>2007-2008</td>
</tr>
<tr>
<td>India*</td>
<td>NSS report 2007-2008</td>
<td>2007*</td>
</tr>
<tr>
<td>Turkey</td>
<td>Labor force survey</td>
<td>2002-2008</td>
</tr>
<tr>
<td>Taiwan*</td>
<td>Labor force survey</td>
<td>1995-2008*</td>
</tr>
</tbody>
</table>

*Notes: * Occupation data for total economy. For India use structure from Indonesia to split. For Taiwan we use the structure from South Korea to split up according to industries.

Appendix B. From Sectoral to Functional Specialization
This section presents a standard Ricardian model, but with comparative advantage determined at the business activity and not at the sector level, following Markusen and Venables (2013). The framework introduced here forms the basis for investigating trade in business activities across countries and industries. We show that lower communication and coordination costs induce more firms to fragment production processes and as a result countries will specialize in business activities according to their comparative advantage.
Consider a world economy comprising two countries and one factor of production, labour. There are \( i = 1, \ldots, I \) industries and constant returns to scale in the production of each good. Labour is immobile across countries and perfectly mobile across industries. If industries differ in productivity across countries, we have the standard setup of Ricardian comparative advantage. However, we assume competitiveness is not determined at the industry level but by business activities.

For simplicity, assume there are two business activities, A and B. We denote by \( z_{cj} \) the number of units of activity \( j \) (\( j = A, B \)) that can be produced with one unit of labour in country \( c \) (\( c = 1, 2 \)). Productivity differences give country 1 a comparative advantage in activity A and country 2 a comparative advantage in activity B, so

\[
\frac{z_{A1}}{z_{B1}} \geq \frac{z_{A2}}{z_{B2}} \quad \text{(and thus} \quad \frac{z_{B2}}{z_{A2}} \geq \frac{z_{B1}}{z_{A1}})\]

Assume that the share of each activity varies across industries. Firms in industries that make relatively more use of activity A will be attracted to country 1, whereas country 2 will attract firms making relatively more intensive use of B. Each industry has a certain number of firms that employ 2 units of labour of whom \( a(i) \) are employed on activity A and \( 2 - a(i) \) on B.

Integrated firms can produce in country 1 or 2 or choose to fragment production and locate one activity in country 1 and the other activity in country 2. Fragmenting production incurs additional costs, modelled in the traditional ‘iceberg’ form in terms of the price of output, so \( tp_i \). Assume that outputs of activities A and B are additive. The profits of integrated firms (labelled by subscript 1 and 2) and fragmented firms (labelled by subscript F) are given by

\[
\pi_1(i) = p_i[a(i)z_{A1} + (2 - a(i)z_{B1})] - 2w_1 \\
\pi_F(i) = p_i[a(i)z_{A1} + (2 - a(i)z_{B2})] - a(i)w_1 - (2 - a(i))w_2 - tp_i \quad (1) \\
\pi_2(i) = p_i[a(i)z_{A2} + (2 - a(i)z_{B2})] - 2w_2
\]
The production mode of firms will depend on the intensity in the use of activities. Firms in industries that intensively use activity A will produce in country 1. Firms in sectors that use both activities in similar proportions fragment production and produce activity A in country 1 and activity B in country 2. Firms that intensively use activity B will be integrated firms producing in country 2.

This relationship is illustrated in figure 1. The horizontal axis shows industries, ranked such that production in sectors closer to the origin is more intensive in activity A. The vertical axis shows employment per firm. The relative profitability for each production mode is indicated by the vertical dashed lines. The shaded area is total employment in country 1 if each industry contains just one firm. Employment consists of activities A and B for integrated firms plus activity A for fragmented firms. A set of simplifying assumptions is used, namely that the two countries and sectors are symmetrical, and the production intensity of industries of particular activities is linear in $i$ and symmetric. Also productivity differences between country 1 and 2 are symmetric. These assumptions imply wages in both countries are equal, so $w_1 = w_2$. The parameter $\gamma$ measures the intensity of business activities across sectors, with the middle industry $i$ equally intensive in A and B such that $a(i) = 1 + \gamma(1/2 - i)$.

**Figure 1.** Fragmented and integrated firms

Notes: sectors are ordered by intensity in activity A on the horizontal axis. Employment per firm is on the vertical axis.
The assumptions regarding symmetry also imply that the productivity advantage of activity A in country 1 is equal to country 2’s advantage in activity B. Hence, $\Delta q \equiv z_{A1} - z_{A2} = z_{B2} - z_{B1} > 0$. The production mode boundaries can then be derived from equations 1, which is

$$\pi_F(i_1) - \pi_1(i_1) = (2 - a(i_1))[p_i(\Delta q)] - tp_i = 0$$

$$\pi_F(i_2) - \pi_2(i_2) = a(i_2)[p_i(\Delta q)] - tp_i = 0.$$  \hspace{1cm} (2)

after substituting for $a(i) = 1 + \gamma(1/2 - i)$ in equations 2, this solves for

$$i_1 = \frac{1}{2} - \frac{1}{\gamma} \left[ 1 - \frac{t}{\Delta q} \right], \quad \text{and} \quad i_2 = \frac{1}{2} + \frac{1}{\gamma} \left[ 1 - \frac{t}{\Delta q} \right].$$ \hspace{1cm} (3)

Equations (3) show how the pattern of trade depends on fragmentation costs and comparative advantage. If $t = \Delta q$, there is no fragmentation. Denote this value $t^*$. For any value of $t < t^*$, some firms choose to fragment. And the smaller are communication and coordination costs, the more industries will become fragmented, which is given by $i_2 - i_1 = \frac{2}{\gamma} \left[ 1 - \frac{t}{\Delta q} \right]$. In terms of figure 1, this shifts the production mode boundary $i_1$ to the left and boundary $i_2$ to the right, expanding the range of industries in which firms will choose to fragment the production process.