

# CAPTURING THE GAINS



*economic and social upgrading  
in global production networks*

<sup>1</sup> Schwartz Center for Economic Policy Analysis, Department of Economics, The New School for Social Research, New York

email: [jianx409@newschool.edu](mailto:jianx409@newschool.edu)

<sup>2</sup> Schwartz Center for Economic Policy Analysis, Department of Economics, The New School for Social Research, New York

email: [milbergw@newschool.edu](mailto:milbergw@newschool.edu)

Capturing the Gains 2012  
ISBN : 978-1-907247-90-3

Vertical specialization and industrial upgrading:  
a preliminary note

Xiao Jiang <sup>1</sup>

William Milberg <sup>2</sup>

April 2012

Working Paper 10

## **Abstract**

Vertical specialization is a measure of the import content of exports. Given the widely recognized importance of trade in tasks and global production networks, vertical specialization has recently gained the attention of international trade researchers and policy makers. In this note, we use measured changes in the within-country pattern of vertical specialization to gauge the relevance of task trade for industrial upgrading and economic development. We first calculate vertical specialization (VS) for five countries between 1995 and 2005 – USA, China, India, Brazil and South Africa. We then construct our own measure – the import content of export expansion ratio (ICEER) – to isolate changes in import content from the growth in exports. Since the ICEER measure captures structural change in the import content of exports for each country at the sectoral level, we use ICEER as a proxy for the kind of industrial upgrading associated with raising the proportion of export value accruing to the domestic sector. We name this kind of upgrading ‘vertical upgrading’.

**Keywords:** vertical specialization, industrial upgrading, global production networks, international trade, input-output analysis

**Xiao Jiang** is Research Assistant at the Schwartz Center for Economic Policy Analysis, Department of Economics, The New School for Social Research, New York.

**William Milberg** is Professor of Economics at the Schwartz Center for Economic Policy Analysis, Department of Economics, The New School for Social Research, New York.

**Acknowledgements:** This is a preliminary note. Comments are welcome and can be sent to [milbergw@newschool.edu](mailto:milbergw@newschool.edu). Financial support from the Capturing the Gains project (DFID Trade Policy Unit) is gratefully acknowledged. Thanks to Gary Gereffi, Hubert Escaith, Sebastien Miroudot, Timothy Sturgeon and William Powers for fruitful discussion of the issue. We are especially indebted to Joonkoo Lee, Gary Gereffi, and John Pickles for their detailed comments and suggestions on previous drafts of our paper. Remaining errors are the responsibility of the authors.

## 1 Introduction

Vertical specialization is a measure of the import content of exports. Given the widely recognized importance of trade in tasks and of global production networks, vertical specialization has recently gained the attention of international trade researchers in academe and international organizations<sup>1</sup>. Miroudot et al. (2009) report that trade in intermediates accounted for almost 60 percent of world trade in goods in 2007, up from just over 50 percent in 1999. For services trade, over 70 percent was intermediates trade in 2007. Netting out imports contained in exports is also central to measuring the domestic value added in trade. In extreme cases of vertical specialization, such as China's involvement in the production and export of the Apple iPod or iPad, the exporter generates very little value added in relation to the overall export value – as low as five percent according to one study.<sup>2</sup> This indicates that there can be a large difference between the reported value of bilateral or sectoral exports and the value added contained in those exports.<sup>3</sup> In this short note we seek to connect the analysis of vertical specialization to the question of industrial upgrading within a sector. Researchers have defined various forms of industrial upgrading.<sup>4</sup> Here we focus on a kind of industrial upgrading that is directly related to vertical specialization, upgrading associated with capturing domestically a higher proportion of export value. We name this particular form of industrial upgrading 'vertical upgrading'. If a country's sector reduces the import content of exports (netting out the effect of export growth), then we say the sector has upgraded vertically within a global production network.

This note has six sections. In Section 2, we present a simplified algebraic definition of vertical specialization and discuss the role of the proportionality assumption. In Section 3 we present the calculations of vertical specialization for five countries: Brazil, China, India, the US and South Africa. We compare the calculations to previous studies and then analyse them by looking comparatively across countries and over time. We interpret a decline in vertical specialization as an indicator of industrial upgrading, but add a number of reasons for caution in this interpretation. In Section 4 we introduce our own measure of structural change in the import content of export, in an attempt to overcome some limits of the simple vertical specialization (VS) measure. We term our measure the 'import content of export expansion ratio', or ICEER, and use it in a discussion of industrial upgrading in global value chains. Section 5 concludes.

## 2 Calculating vertical specialization

To calculate vertical specialization, the input-output coefficients, trade data, and import content of inputs are combined to give a measure of how much import content is used directly and indirectly in the production of a unit of exports. The fundamental equations for calculating vertical specialization, following the seminal paper by Hummels et al. (2001), are given as (1) and (2) below:

$$IC = A^M \cdot [I - A]^{-1} \cdot X \quad (1)$$

<sup>1</sup> See, for example, Hummels et al. (2001), Koopman et al. (2010), WTO (2011), Escaith et al. (2010) and Meng et al. (2011). In 2012, the WTO and OECD announced a joint project to generate an entirely new set of trade data based on vertical specialization. For a critique of this approach to understanding global supply chains, see Sturgeon and Memedovic (2011).

<sup>2</sup> See Linden et al., (2007), Xi and Detert, (2010) as well as Monge's (2010) treatment of the 'domestic content of exports' in Costa Rica.

<sup>3</sup> Baldone et al. (2006), using similar examples, show that in the presence of high levels of vertical specialization, trade flows will not reflect patterns of comparative advantage.

<sup>4</sup> For a concise summary of the vast literature on industrial upgrading, see Milberg and Winkler (2011).

where  $A^D$  is the matrix of domestic technical coefficients, which can be computed from a country's basic input-output flows data,  $[I - A]^{-1}$  is the Leontief inverse matrix, which establishes the relation between per unit final use and sectoral input demand,  $X$  is the vector of exports, and  $A^M$  is a matrix of import coefficients, that is a matrix of the proportion of inputs that is imported, per unit of output. When the export vector is pre-multiplied by the Leontief inverse matrix, we get a vector of outputs that are required in order to satisfy this vector of export demands. Pre-multiplying  $[I - A]^{-1} \cdot X$  by  $A^M$  gives the import content of the inputs that are used in order to produce the exports,  $IC$ .

To represent  $IC$  as a share of exports, we multiply  $IC$  by the inverse diagonal matrix of total exports  $\bar{X}^{-1}$ , which gives the degree of vertical specialization,  $VS$ :

$$VS = A^M \cdot [I - A]^{-1} \cdot X \cdot \bar{X}^{-1} \quad (2)$$

One difficulty with the calculation of vertical specialization lies in the fact that the matrix  $A^M$  is neither reported nor computable in most input-output datasets. A method that is widely adopted in the field to deal with this issue is using the so-called 'proportionality assumption', whereby every sector is assumed to import inputs of material and services in the same proportion as the economy-wide import reliance for that input.<sup>5</sup> This assumption provides a straightforward way to overcome the problem of a lack of data on imported inputs. In Appendix 1 we present a clear method for constructing  $A^M$ . Once we have constructed  $A^M$  using the proportionality assumption, then  $VS$  can be calculated using available input-output data.

Note that, due to a lack of direct data on imported inputs, vertical specialization is merely an approximation of the import content of exports using each country's input-output data. A given  $VS$

tells us the proportion of a sector's export value that is imported, assuming the proportionality assumption holds. It is also not difficult to imagine that for each country some of the sectors might have  $VS$  greater than one because of this methodology. That is resulted from the fact that these

are sectors that happen to have high trade deficit and at same time relatively low outputs. The combination of these two factors will make the approximated  $A^M$  matrix much larger than the actual

one. The  $VS$  values that are above one are indeed very difficult to interpret in terms of the

proportion of export values that are imported. Nevertheless, a  $VS$  value, above or below one, is at

least an indication of the degree of import dependence of a sector's exports.

It is also crucial to point out the difference between vertical specialization and the idea of 'value-added trade' – a concept often mentioned in trade policy discussion and in global value chains research. Value-added trade is a special case of vertical specialization. A unit of exports consists of inputs and value-added. The value-added part of the export value is value-added trade. We can further decompose inputs into the production of exports into foreign and domestic inputs. Vertical specialization measures the proportion of the export unit value that is contributed by imported inputs. One minus vertical specialization ( $1 - VS$ ) then measures the domestic content embodied in export value. However, in general, value-added trade is only part of domestic content. The rest

<sup>5</sup> The assumption was first adopted by Feenstra and Hanson (1999) in the study of US offshoring. See Winkler and Milberg (2009) for a test of the empirical importance of the proportionality assumption.

is accounted for by domestic inputs. The domestic content of exports (again,  $1 - VS$ ) can be very close to value-added trade in a special case when a country imports foreign inputs and exports an assembled product. This is the case for processing trade, whose significance has been documented in China and Mexico.<sup>6</sup> At the other extreme is the case when a country imports inputs that simply substitute foreign for domestic inputs. In this case, a change of domestic content would have nothing to do with value-added trade. Nevertheless, even in the latter, extreme case, a change in  $VS$  would have effects on a country's domestic value-added, since it would indicate a fall in the production of domestic goods as inputs to the export good. This idea will be discussed in detail in Section 4.

### **3 Vertical specialization for China, India, Brazil, South Africa and the USA**

As a demonstration of our method and its application to the issue of industrial upgrading, we selected five countries and used the method presented in the previous section to calculate vertical specialization indices for all sectors for each of the three years of data. The procedure is the following:

1. Extract the basic flow matrix, the vector of total imports, the vector of total exports, and the vector of total outputs from each country's input-output tables.
2. Check the country's sectoral specification table and conduct necessary aggregations, in order for the sectors to be comparable across the countries.
3. Sectors with zero exports and/or imports are taken out to avoid unreasonable results. This is done in a way that is consistent with each country's table's sectoral specifications.
4. Construct the  $A$  matrix using the standard input-output algorithm.
5. Construct the  $v_i$  vector using the (transformed) proportionality assumption, as stated in Appendix 1. Calculate  $VS$  using equation (2).
6. Due to the proportionality assumption, for each country there are a few sectors (mostly service sectors) that give negative vertical specialization indices. We delete these sectors.

Following this procedure, we used the OECD input-output dataset to calculate levels of  $VS$  for the USA, China, India, Brazil and South Africa for 1995, 2000 and 2005. The full results are reported in Appendix 2, but a few comments are in order. We note, first of all, that the degree of vertical specialization increased for all countries over the past 15 years – a clear indication of the general growth in international production networks in trade

Second, our calculations are quite close to those of Koopman et al. (2010), despite the fact that their work uses a different algorithm and a variety of data sets.<sup>7</sup> The comparison of the results for those five countries is reported in Table 1.

---

<sup>6</sup> See Ma and Van Assche (2010) on China and Bergin et al. (2009) on Mexico.

<sup>7</sup> Hummels et al. (2001) calculated  $VS$  indices using the OECD input-output database, but since they covered a much earlier time period, no comparison with our calculations is possible.

**Table 1: Aggregate VS by country, comparison between the author's results and Koopman et al. (2010) for the year 2005**

Authors	USA	China	India	Brazil	South Africa
Koopman et al. (2010)	12.9	35.7	20.1	12.7	18.2
This paper	17.0	32.1	13.8	14.2	23.7

Sources: Authors' calculation and Koopman et al. (2010).

Note that in this particular five-country sample we do not see any systematic upward or downward bias in our measure of VS compared to Koopman et al. (2010). Only in the case of India and South Africa do the two methods give results that differ by more than five percentage points. This does not seem particularly large, however, given that they rely on different algorithms and slightly different coverage in terms of sectors.

To get some intuitive feel for the levels and changes in vertical specialization in our sample, we compare across sectors within countries. Figures 1a - 1e show the calculations for the USA, China, India, Brazil and South Africa, in selected sectors. In the case of the USA (Figure 1a), vertical specialization increased in all selected sectors between 1995 and 2005, except for two. Electrical machinery and textiles show the clearest increase. These are two of the most well-known cases of globalized production, where US firms have increasingly relied on imported inputs, and thus would be expected to show the most evidence of increase in vertical specialization. In China (Figure 1b) the decrease in vertical specialization is greatest in the selected manufacturing sectors, again consistent with China's much heralded success in those sectors. From the perspective of developing country firms, upgrading in a sector means relying less on imported inputs. At same time, 'business and other services' sector showed the most rapid increase. As for India (Figure 1c), all sectors show an increase in vertical specialization, except the computer-related sectors and the business-related sectors – the two major service sectors for India. Brazil had a decrease in vertical specialization in the primary and tertiary sectors, but an increase in the selected manufacturing sectors. Finally, for South Africa there is a marked increase in vertical specialization in all sectors between 1995 and 2005.

#### **4 Vertical specialization and economic upgrading**

The global increase in vertical specialization reflects the increased prominence of global value chains. The presence of such global value chains – with lead firms governing often complicated networks of suppliers – has transformed the structure of international trade and the nature of economic development. Economic development has become synonymous with 'upgrading' in global value chains, defined as a shifting of production from lower to higher value added parts of global value chains, or the ability of producers 'to make better products, to make products more efficiently, or to move into more skilled activities' (Pietrobelli and Rabellotti, 2006, p. 1). Humphrey (2004) and Humphrey and Schmitz (2002) identify various distinct types of economic upgrading, including process upgrading, product upgrading, functional upgrading and intersectoral upgrading. Process upgrading is the improvement in the production process of a given product in the supply chain that results in higher value added in production. Product upgrading is the shift into a higher value added product within the same global value chain. Functional upgrading refers to the move into higher value added aspects of a given production process. Intersectoral upgrading (sometimes referred to as chain upgrading) involves moving into completely new product areas that generate higher value added. In addition to the aforementioned four types of upgrading, we designate a fifth



type – ‘vertical upgrading’. If over a period of time a particular sector's exports contain less import content, holding everything else constant, then we say that this sector has experienced vertical upgrading. This type of upgrading is particularly useful in thinking about the implications of changes in the intersectoral pattern within a country of changes in vertical specialization.

Vertical specialization measures a country's import content of exports, and the vertical specialization index indicates the degree of foreign dependence of a country's export to foreign imports. Thus, as we noted above for the case of Chinese manufacturing, if a sector of a country is able to successfully reduce its import content or foreign dependence, this implies that the particular sector of that country has experienced vertical upgrading. One can imagine a unit of export is composed of three parts – domestic inputs, foreign inputs and domestic value added. From a purely accounting perspective, a reduction of foreign inputs will have two effects. First, the reduction of foreign inputs comes from an increase in the use of domestic inputs. This would mean that more value is added domestically through the ‘backward linkage effect’<sup>8</sup> channelled through higher input demand. The second effect is more typical for the case of processing trade (the first special case if we recall Section 1), that is as foreign inputs are reduced, domestic value-added increases because a larger segment of the value-adding process is performed domestically. Precisely due to the existence of these two effects, if a larger share of export value is being contributed domestically, then, we view it as (vertical) upgrading.

Linking the idea of vertical specialization to upgrading thus requires us to determine how a country's vertical specialization changes over time. The change in vertical specialization is often measured by comparing the VS indices at two points in time. For example, Miroudot and Ragoussis (2009) calculate the percentage changes in vertical specialization at the aggregate level from 1995 to 2000 for a panel of 34 countries. While this method of comparison gives us a very general picture of how vertical specialization changed over a period of time, the method has a few shortcomings, in particular when our purpose is to use our comparison to gauge functional upgrading. Most importantly, since vertical specialization is a ratio (of import content to exports, as expressed in equation (2)), we do not know whether changes in the ratio result from changes in import content (the numerator) or in exports (the denominator). For example, when we say that China's chemical sector's vertical specialization fell from 38.5 percent in 1995 to 20.0 percent in 2005, we do not know to what extent this change was due to a change in the propensity to vertically specialize or simply the result of a change in exports.

Vertical specialization is significant today in magnitude and in its geographic scope because of the globalization of production, which has been well documented.<sup>9</sup> It is not surprising, then, that measured VS shows an increase for most sectors in all countries over time (see Hummels et al., 2001; Miroudot and Ragoussis, 2009; and WTO, 2011). However, if a country as a whole has increased its vertical specialization ratio over time, it does not necessarily mean that this country has experienced vertical downgrading. On the contrary, since economic development increasingly requires participation in global production networks, a broad rise in VS would be expected. What matters more is how the pattern of vertical specialization has changed within this country, that is across sectors.

---

<sup>8</sup> Hirschman (1958). See Appendix 2 for a detailed discussion of domestic value-added through backward linkages.

<sup>9</sup> See Krugman (1995), Gereffi (1994, 1999) and Feenstra (1998) for some early discussion of the importance of vertically disintegrated, globalized production.

To conclude, in order to link vertical specialization to industrial upgrading, we are more concerned with how the cross-sectoral pattern of vertical specialization changes over time, rather than with the country-wide change of import content to export ratio. In the next subsection, we propose a new measure that is better able to capture the change in the sectoral pattern of each country's vertical specialization compared to the **VS** measure.

#### 4.1 The import content of export expansion ratio, or '**ICEER**'

Here, we propose a new measure of change of import content of export which is able to avoid the shortcomings of change of **VS** mentioned in the last subsection. This measure involves measuring the change of import content while normalizing growth in exports. By doing so, we isolate the change in vertical specialization due strictly to changes in import content. We call this the import content of export expansion, or **ICEE**, and define it as follows:

$$ICEE_{ij} = IC_{ij}^{05} - IC_{ij}^{95} \cdot \frac{E_{ij}^{05}}{E_{ij}^{95}} \quad (3)$$

In equation (3),  $IC_{ij}$  is the import content of country  $i$ 's sector  $j$ 's export, which can be computed

from equation (1). The superscripts represent the two time periods we are interested in comparing, in our case 1995 and 2005.  $E_{ij}^{05}/E_{ij}^{95}$  shows how many times sector  $j$ 's export has grown between

1995 and 2005. This value pre-multiplied by sector  $j$ 's 1995 import content ( $IC_{ij}^{95}$ ) is the

counterfactual level of import content, had the import content grown at the same rate as exports between 1995 and 2005. In other words, this is sector  $j$ 's import content for the year of 2005 if the propensity of vertical specialization had stayed the same between 1995 and 2005 for country  $i$ . Subtracting this value from 2005 import content ( $IC_{ij}^{05}$ ) gives us the amount of the change in import

content that occurs purely as a result of a change in the structure of vertical specialization.<sup>10</sup> Thus, if for sector  $j$  the degree of vertical specialization stays the same over time, or the import content of export has grown at the same rate as export growth for country  $i$ , then  $ICEE_{ij}$  would be zero. In

general, however, this difference will deviate from zero. The **ICEE** shows the degree and direction

of change in a sector's import content that is purely due to the change in the vertical specialization pattern. This is closer to our notion of industrial upgrading.

The vector of  $ICEE_{ij}$  values can be transformed into a vector of ratios by multiplying it by the inverse

diagonal matrix of  $IC_{ij}^{05}$ , as follows:

$$ICEER_{ij} = ICEE_{ij} \cdot \overline{IC_{ij}^{05}}^{-1} \quad (4)$$

We computed the  $ICEER_{ij}$  for the five countries in our sample for the period 1995-2005. Results for selected sectors are presented by bar charts in Figure 2. The USA and South Africa have

<sup>10</sup> Since we are comparing values from two different time periods, we should adjust one of the values by the producer price index to make the two values comparable. In our calculations presented below, we deflate the 2005 import content by the GDP deflator, since we do not have producer price indexes for all countries.



experienced significant import content expansion between 1995 and 2005 for all selected sectors, i.e. vertical downgrading in all selected sectors. The three rapidly developing countries – China, India and Brazil – had varied results across sectors, with some sectors experiencing expanding import content and some shrinking. This indicates that some sectors are experiencing vertical upgrading, and others are vertical downgrading.

Comparing Figure 2 to Figure 1, we can see that  $ICEER$  reveals some important information that is concealed in  $VS$  measure. Take China as the example. In Figure 1b, we see that between 1995 and 2005, the textiles sector saw a slight reduction in the import content of exports ratio ( $VS$ ). But in Figure 2b, the structural reduction of the import content for the textiles sector is relatively large. Figure 1b also shows that China's chemicals and pharmaceuticals sector had a clear reduction in the import content of exports ratio, but in Figure 2b, the direction of change reverses for the chemicals and pharmaceuticals sector (positive  $ICEER_{i,j}$ ). This difference tells us that, for the Chinese textiles sector, between 1995 and 2005, although its import content of exports ratio fell slightly, the growth of its import content is much less than the growth of this sector's exports. Therefore, structurally speaking, as indicated by the  $ICEER_{i,j}$ , the import content of exports for this sector had fallen more drastically than indicated by the change in  $VS$ . For China's chemical and pharmaceuticals sector, the import content of exports ratio fell (as seen in Figure 1b). However, as seen in Figure 2b, the  $ICEER$  rose for this sector in China. This is because the  $ICEER$  measure adjusts for export growth, which was apparently the most important factor in the decline of vertical specialization. When we adjust for export growth, we see that the import content rises. In other words, comparing the import content in 2005 to the counterfactual level of import content, where the propensity of vertical specialization is held constant, the  $ICEER$  measure shows that the import content has expanded. The  $ICEER$  shows the changing structure of import content more clearly than  $VS$ . We can also see this in the US case. Comparing Figure 1a to Figure 2a, we see that the direction of change reverses for the radio television and communication equipment sector and business-related services sector.

#### 4.2 $ICEER$ and vertical upgrading in global value chains

The  $ICEER_{i,j}$  can be used directly as a measure of vertical upgrading and downgrading. Since the  $ICEER_{i,j}$  indicates the direction and degree of the structural change of a country's import content, then a negative  $ICEER_{i,j}$  indicates a structural reduction of the foreign import content in sector  $j$ 's export for a particular country. A negative  $ICEER_{i,j}$  thus means a reduction in the import content of exports and reflects a country's increased participation in the value chain, i.e. vertical upgrading. A positive  $ICEER_{i,j}$  implies the opposite – that is an increased reliance on imports and thus vertical downgrading.

Table 2 summarizes our findings for a sample of five countries and eight sectors. Vertical upgrading (a decline in  $ICEER_{i,j}$ ) is indicated with a plus sign, and vertical downgrading (a rise in  $ICEER_{i,j}$ ) is indicated with a negative sign. We see again the successes of China, India and Brazil, and the downgrading observed across all sectors in South Africa and the USA.

**Table 2: Vertical upgrading and downgrading for five countries, based on the sign of *ICEER* (+ designates upgrading, - designates downgrading)**

Sector No.	1	5	9	17	18	19	29	31
USA	-	-	-	-	-	-	-	-
China	-	+	-	+	+	-	+	-
India	-	-	-	+	-	-	-	+
Brazil	-	+	-	+	-	-	-	+
South Africa	-	-	-	-	-	-	-	-

Sources: Authors' own calculation.

Lastly, a few words need to be said about the limitations of vertical upgrading and its measure – *ICEER*. First, if a sector upgrades vertically (using the measure of *ICEER*), it does not necessarily mean that this sector has upgraded to higher value-added production.<sup>11</sup> That is because an increase in domestic content may only involve the substitution of domestic inputs for foreign inputs with no effect on value added. Second, vertical upgrading does not say anything about technological change. For example, a sector with high *ICEER* might be experiencing functional or chain upgrading (rather than vertical upgrading) because of a shift to higher-tech and higher value added foreign inputs as it produces a higher value added product domestically. Thus a high *ICEER* (vertical downgrading) could be observed at the same time that there is functional or chain upgrading. Third, vertical upgrading as measured by *ICEER* assumes proportional adjustment of quantity changes to price changes. Since import content is equal to the import price multiplied by quantity of imports, then if foreign input prices change but quantity demanded does not adjust smoothly, then, the change in *ICEER* would be the result of a price change alone. We should add that these shortcomings are quite typical of analysis done using an input-output framework.<sup>12</sup> Despite these shortcomings, *ICEER* nonetheless given a clear indication of a sector's degree of participation in global production networks.

## 5. Conclusion: vertical specialization and economic development

Vertical specialization is a measure of the degree of internationalization of production in international trade, a product of the growth over the past 25 years in global production networks or global value chains. In this preliminary note, we have tried to connect vertical specialization to the notion of industrial upgrading in global value chains. We linked vertical specialization with industrial upgrading using a new measure that captures the degree and direction of the structural change of vertical specialization – the import content of export expansion ratio (or *ICEER*). The *ICEER* measure isolates that part of the change of import content that is purely due to the change in the propensity to vertically specialize. We have argued that the *ICEER* is a more suitable candidate for

<sup>11</sup> For the detailed exposition of the difference between domestic value-added trade and domestic content, see Koopman et al. (2011).

<sup>12</sup> See Miller and Blair, 2009 for a discussion.

understanding upgrading if we define vertical upgrading as the structural reduction of foreign inputs per unit of exports.

For the panel of five countries, USA, China, India, Brazil and South Africa, we computed both *VS* and *ICEER* using the OECD input-output database data, and reported the results for the aggregate as well as for the selected sectors. We used the *ICEER* calculations to illustrate sectoral up/down grading, which helps to identify the functional upgrading and downgrading sectors for each country. It is evident from this table that those fast-growing countries experienced a structural reduction in the import content of their exports for some of the main sectors between 1995 and 2005.

While the *ICEER* measure is capable of helping us to identify if a sector in a country is experiencing vertical upgrading or downgrading, it says nothing about a country as a whole, since in general a country will have sectors with both positive and negative *ICEER*s. This suggests some possible extensions of the current analysis. In addition to expanding our sample of countries and sectors, the next step in the research on vertical specialization will be to assess its relevance for economic development. This will require constructing country-wide upgrading and downgrading indices and assessing how changes in the structure of vertical specialization correspond to indicators of sustainable economic development, including productivity growth and wage growth. The goal of the project is to connect the research on vertical specialization to the theory and measurement of economic development in which global value chains are recognized as an organizing institution.

## References

- Baldone, S., Fabio, S. and Tajoli, L. (2006). 'On some effects of international fragmentation of production on comparative advantages, trade flows, and the income of countries'. CESPRI Working Paper No. 187.
- Bergin, P., Feenstra, R. and Hanson, G. (2009). 'Offshoring and volatility: evidence from Mexico's maquiladora industry'. *American Economic Review*. 4(99): 1664-1671(8).
- Escaith, H., Lindenberg, N. and Miroudot, S. (2010). 'International supply chain and trade elasticity in times of global crisis'. *Staff Working Paper, ERSD-2010-08, WTO*.
- Feenstra, R. (1998). 'Integration of trade and disintegration of production in the global economy'. *Journal of Economic Perspectives*, 12(4), Autumn, 31-50.
- Feenstra, R., and Hanson, G. (1999). 'The impact of outsourcing and high-technology capital on wages: estimates for the United States, 1979-1990'. *The Quarterly Journal of Economics*, 114(3): 907-940.
- Gereffi, G. (1999). 'International trade and industrial upgrading in the apparel commodity chain'. *Journal of International Economics*, 48: 37-70.
- Gereffi, G. (1994). 'The organization of buyer-driven global commodity chains', in Gereffi, G. and Korzeniewicz, M. (eds.), *Commodity Chains and Global Capitalism*. Westport, CT: Greenwood Press.
- Hirschman, A. (1958). *The Strategy of Economic Development*. Boulder, CO: Westview Press Inc.
- Hummels, D., Ishii, J. and Yi, K. (2001). 'The nature and growth of vertical specialization in world trade'. *Journal of International Economics*, 54, 75-96.
- Humphrey, J. (2004). 'Upgrading in global value chains'. *ILO Policy Integration Department Working Paper No. 28*.
- Humphrey, J. and Schmitz, H. (2002). 'How does insertion in global value chains affect upgrading in industrial clusters?' *Regional Studies*, 9, 1017-1027. December.
- Koopman, R., Powers, W., Wang, Z. and Wei, S. (2010). 'Give credit where credit is due: tracing value added in global production chains'. *NBER Working Paper Series, Working Paper No. 16426*.
- Krugman, P. (1995). 'Growing world trade: causes and consequences'. *Brookings Papers in Economic Activity*, 1, 327-377.
- Lau, L., and Yotopoulos, P. (1970). 'A test for balanced and unbalanced growth'. *The Review of Economics and Statistics*, 4(52), 376-384.
- Linden, G., Kraemer, K. and Dedrick, J. (2007). 'Who captures value in a global innovation

system? The case of Apple's iPod'. Recent Work, Personal Computing Industry Center, UC Irvine, CA.

Ma, A., and Van Assche, A. (2010). 'China's role in global production networks'. Mimeo. HEC Montreal, Department of International Business.

Meng, B., Yamano, N. and Webb, C. (2011). 'Application of factor decomposition techniques to vertical specialization measurements'. *IDE Discussion Paper No. 276*.

Milberg, W. and Winkler, D. (2011). 'Economic and social upgrading in global production networks: problems of theory and measurement'. *International Labour Review*. December.

Miller, R., and Blair, P. (2009). *Input-Output Analysis: Foundations and Extensions*. Cambridge: Cambridge University Press.

Miroudot, S. and Ragoussis, A. (2009). 'Vertical Trade, Trade Costs, and FDI'. *OECD Trade Policy Working Paper No. 89*, OECD Publishing.

Miroudot, S., Lanz, R. and Ragoussis, A. (2009). 'Trade in intermediate goods and services'. *OECD Trade Policy Working Papers No. 93*, OECD Publishing.

Monge-Arino, F. (2010). 'Costa Rica: trade opening, FDI attraction and global production sharing'. *WTO Staff Working Paper. ERSD-2011-09*.

Pietrobelli, C. and Rabelloti, R. (2006). 'Clusters and value chains in Latin America: in search of an integrated approach', in C. Pietrobelli and R. Rabelloti (eds.), *Upgrading to Compete: Global Value Chains, Clusters, and SMEs in Latin America*. Washington, DC: Inter-American Development Bank.

Sturgeon, T., and Memedovic, O. (2011). 'Mapping global value chains: intermediate goods trade and structural change in the world economy'. *Working Paper Development Policy and Strategic Research Branch*. UNIDO.

Winkler, D. and Milberg, W. (2009). 'Errors from the proportionality assumption: application to German labor demand'. *Working Paper*, Schwartz Center for Economic Policy Analysis, the New School for Social Research.

World Trade Organization (WTO) (2011). 'Trade patterns and global value chains in East Asia: from trade in good to trade in tasks'. World Trade Organization monograph in conjunction with IDE-JETRO.

Xi, Y. and Detert, N. (2010). 'How the iPhone widens the US trade deficit with the PRC'. *Working Paper No. 257*. ADBI. Tokyo: Asian Development Bank Institute.

## Appendix 1: Construction of the $A^M$ matrix

The proportionality assumption can be expressed as follows:

$$\sum_{j=1}^n z_{ij}^M \cdot \overline{M}_i^{-1} = \sum_{j=1}^n z_{ij} \cdot \overline{Y_i + M_i}^{-1}$$

where  $z_{ij}$ : the intermediate use of sector i's outputs as inputs for sector j.

$z_{ij}^M$ : The part of  $z_{ij}$  that is foreign (imported).

$\overline{M}_i^{-1}$ : The diagonal matrix of total imports (and its inverse pre-multiplied by  $\sum_{j=1}^n z_{ij}^M$  gives us a vector of proportions of imported inputs to total imports).

$\overline{Y_i + M_i}$ : The vector of total absorptions where  $Y_i$  is the vector of total outputs.

Thus, the left hand of the equation above is the proportion between imported intermediates and total imports, and it is assumed to be equal to the right hand side – the ratio between total intermediate inputs and total absorptions – by the proportionality assumption. To make this equation operational, we apply vector cross-multiplication, giving:

$$\sum_{j=1}^n z_{ij}^M \cdot \sum_{j=1}^n \overline{M}_i^{-1} = \overline{M}_i \cdot \overline{Y_i + M_i}^{-1} = v_i$$

Equation (3) states that the ratio between imported intermediates to total intermediates is the same as the ratio between imports to total absorption for each sector – the proportionality assumption stated in a different way. Let us call this vector of ratios  $v_i$ . Notice that the  $v_i$  here is easily computable using input-output data on imports and total outputs.

This new equation states that the ratio of imported intermediates to total intermediates is the same as the ratio of imports to total absorption for each sector – the proportionality assumption stated in a different way. We call this vector of ratios  $v_i$ . Notice that  $v_i$  is easily computable using input-

output data on imports and total outputs.

Under the proportionality assumption, the vector of ratios,  $v_i$ , is the same as the ratios of imported

intermediate goods to total intermediate goods. In this case, the  $A^M$  matrix can be constructed by

pre-multiplying the  $A$  matrix by the diagonal matrix of  $v_i$  as shown in the matrix algebra below:

$$A^M = \mathcal{D}_i \cdot A = \begin{bmatrix} \frac{M_1}{M_1 + Y_1} \cdot a_{11} & \dots & \frac{M_n}{M_n + Y_n} \cdot a_{1n} \\ \frac{M_2}{M_2 + Y_2} \cdot a_{21} & \dots & \frac{M_n}{M_n + Y_n} \cdot a_{2n} \\ \vdots & \ddots & \vdots \\ \frac{M_n}{M_n + Y_n} \cdot a_{n1} & \dots & \frac{M_n}{M_n + Y_n} \cdot a_{nn} \end{bmatrix} \quad (4)$$

Once we have constructed  $A^M$  using the proportionality assumption, then VS can be calculated using available input-output data.



## Appendix 2: Domestic content of export and value-added

If a country substitutes domestic inputs for some of the imported inputs it uses to produce export, then, holding everything else constant, we would observe a reduction of foreign content (or an increase in domestic content). We would not necessarily see an increase in the value-added generated directly by the exports. However, there would be an increase in domestic value-added due to the increased production of inputs at home. Let  $\Delta f$  be the change of domestic final demand led by a change in domestic inputs demand in the production of exports. So then, change in domestic value-added is shown in the equation below:

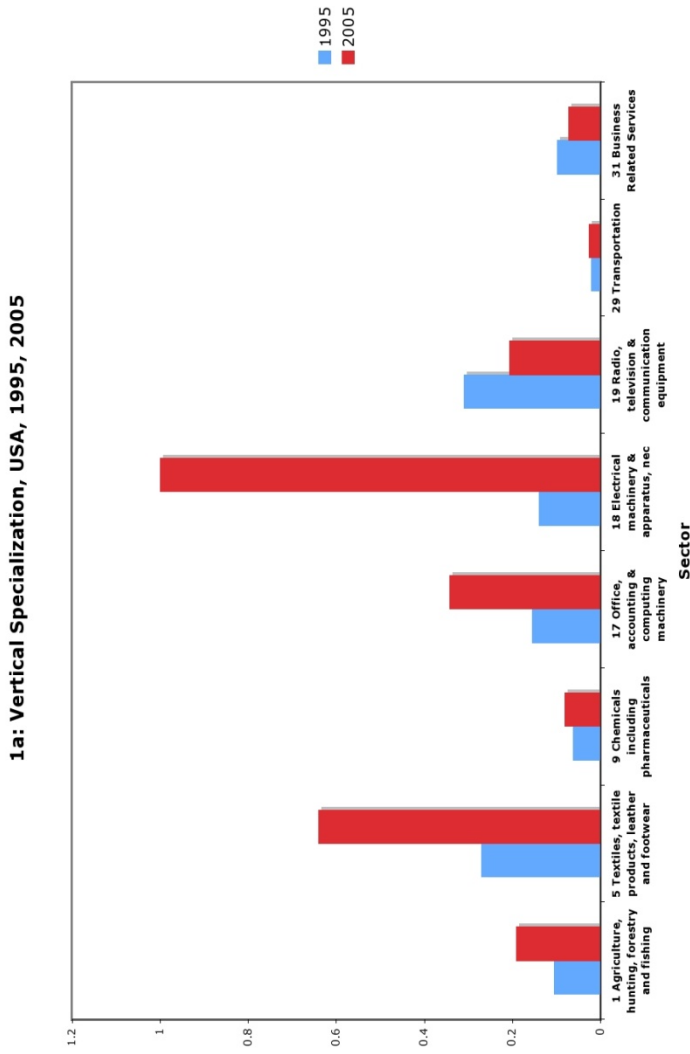
$$\Delta VA = v \cdot [I - A]^{-1} \cdot \Delta f$$

In the equation above,  $v$  is the vector of value-added coefficients, each element in this vector shows the amount of value-added generated with a unit of output. The Leontief inverse multiplied by  $\Delta f$  gives us the change in output due to the change in domestic inputs demand. Finally,  $\Delta VA$  is the domestic value-added change ultimately caused by the change in demand for domestic inputs.

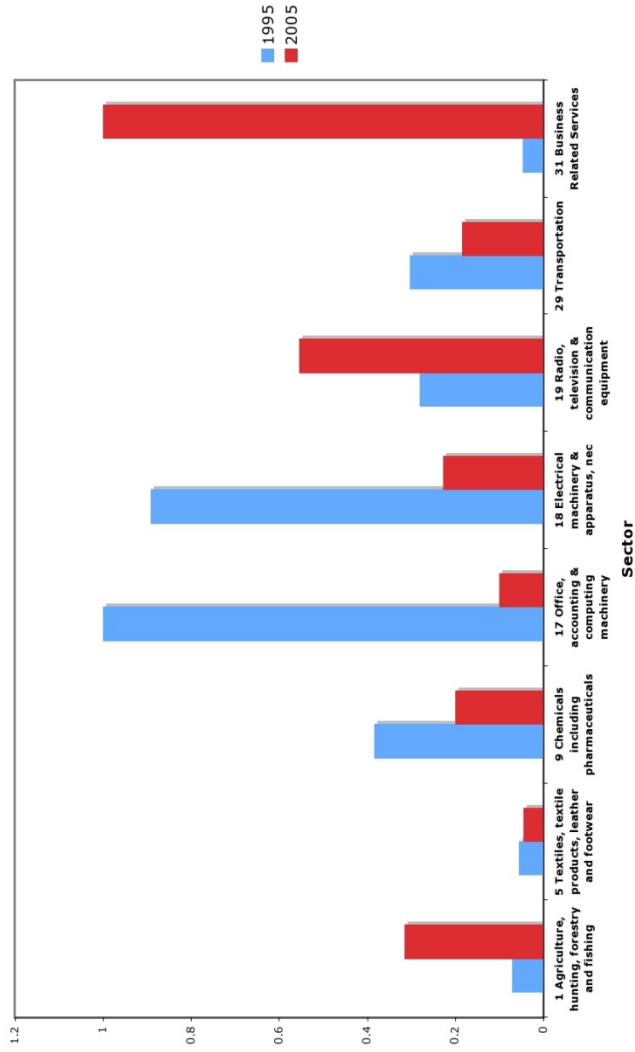
What is buried in the equation above is the important idea of backward linkages. Typically, such linkages are characterized by the 'ripple effect' on an entire economy of a unit change of a sector's final output. For example, a unit increase in agriculture demand will stimulate both the manufacturing and service sectors, because in order to produce an additional unit of agriculture good, outputs from almost all sectors of the economy will be demanded as inputs. This is called the 'total backward linkage' effect by Hirschman (1958). A sector's total backward linkage can be computed by the corresponding column sum of the of the Leontief inverse matrix ( $\sum_{j=0}^n a_{i,j}$ ). In the

context of substituting for foreign inputs with domestic inputs, additional domestic value-added is created because additional outputs are generated by higher demand for domestic outputs as inputs for export production.

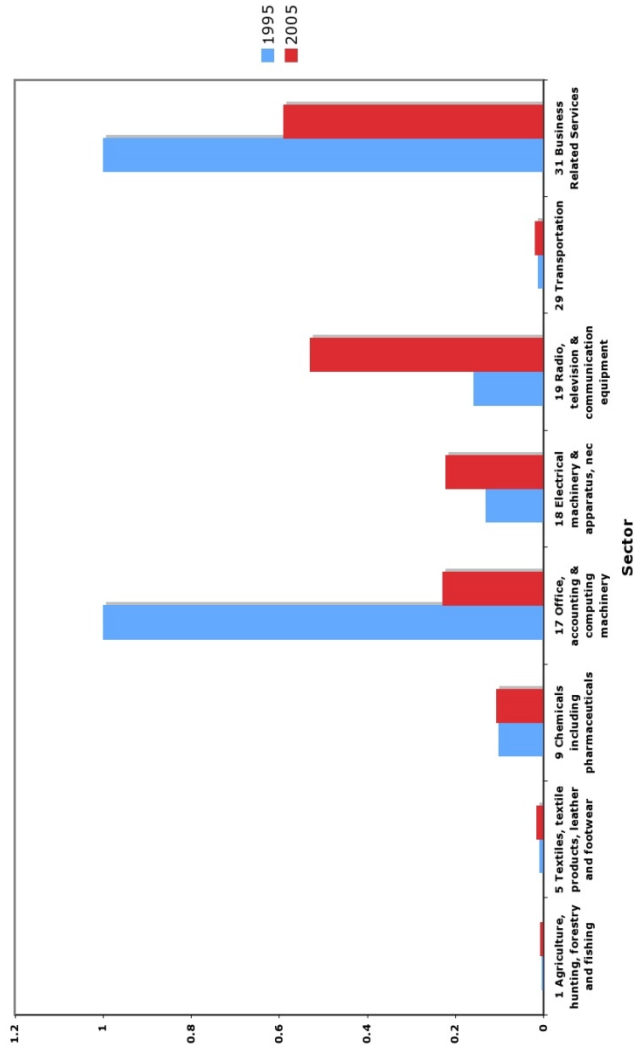
Figure 1: Vertical specialization, selected countries and sectors, 1995 and 2005, ratio



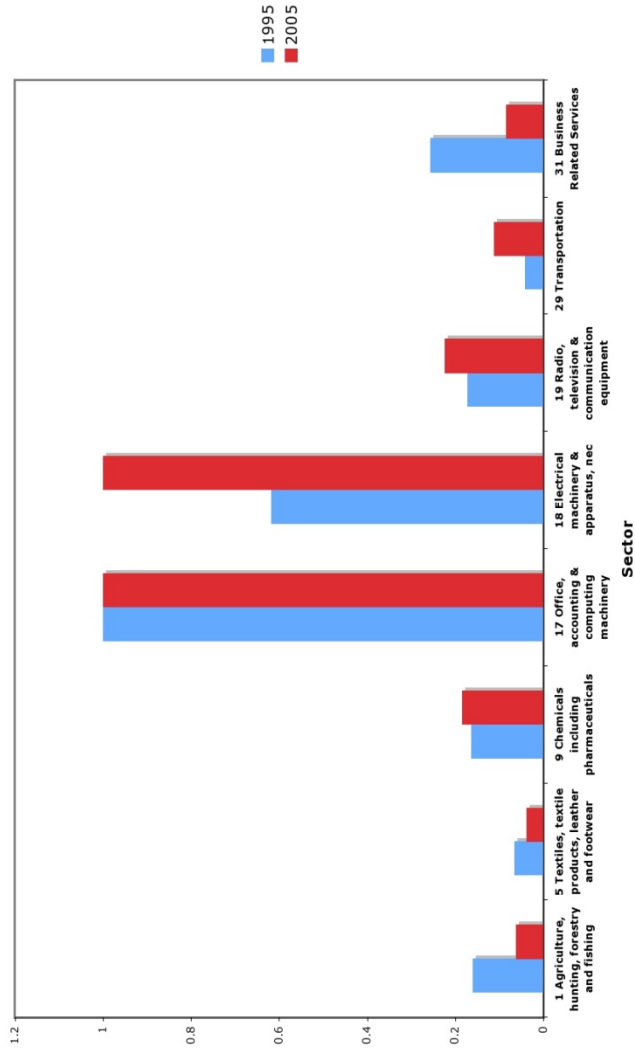
1b: China, Vertical Specialization, 1995, 2005



1c: Vertical Specialization, India, 1995, 2005



1d: Vertical Specialization, Brazil, 1995, 2005



1e: Vertical Specialization, South Africa, 1995, 2005

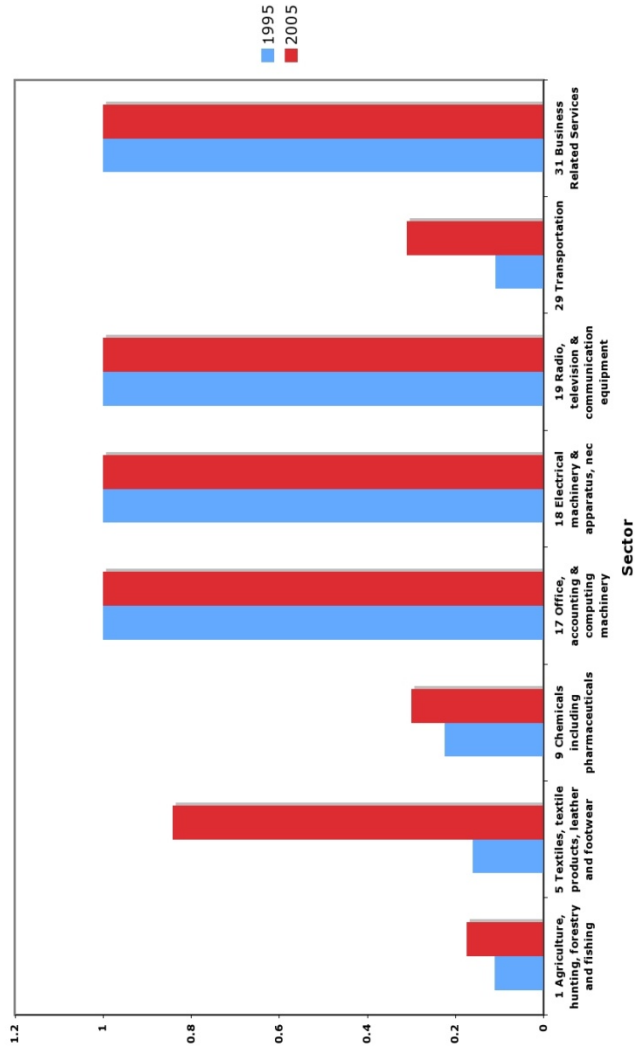
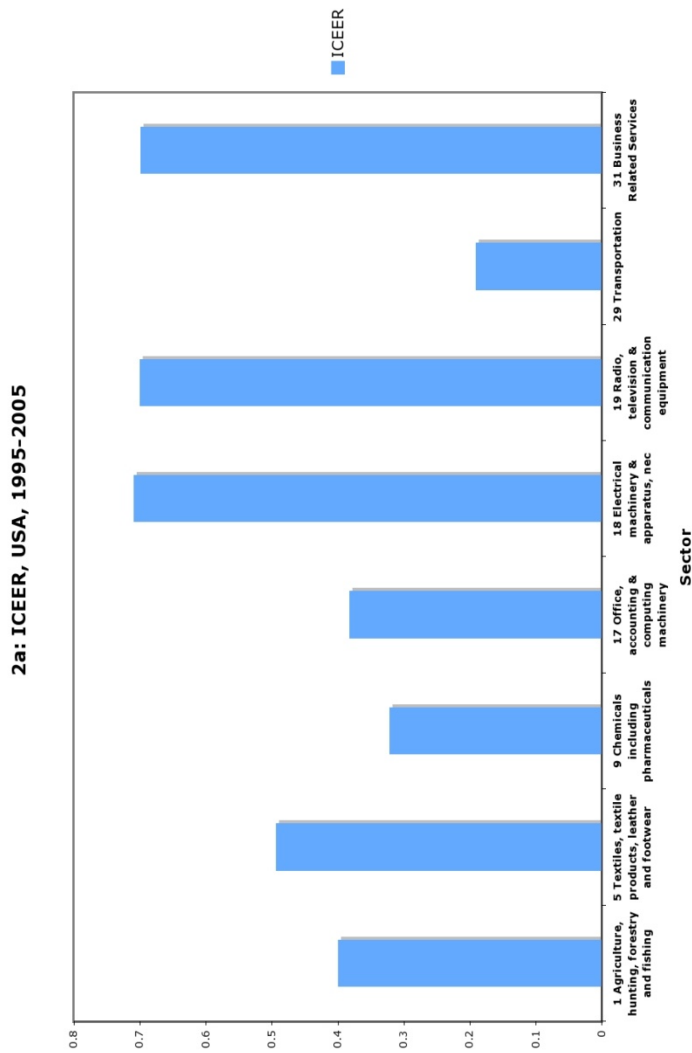
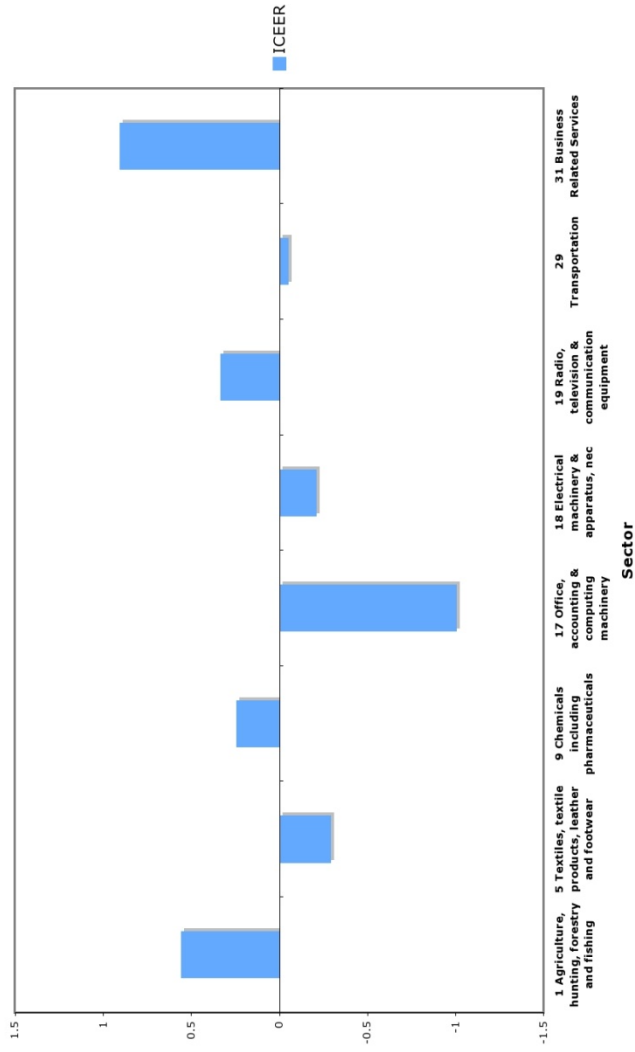




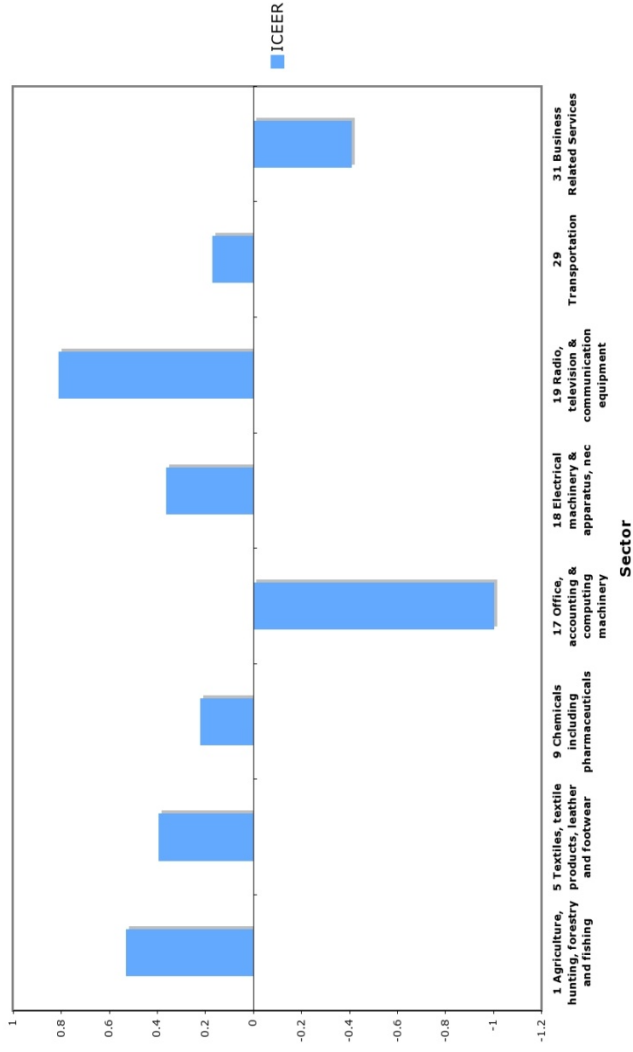
Figure 2: Import content of export ratio (ICEER), selected countries and sectors, 1995-2005



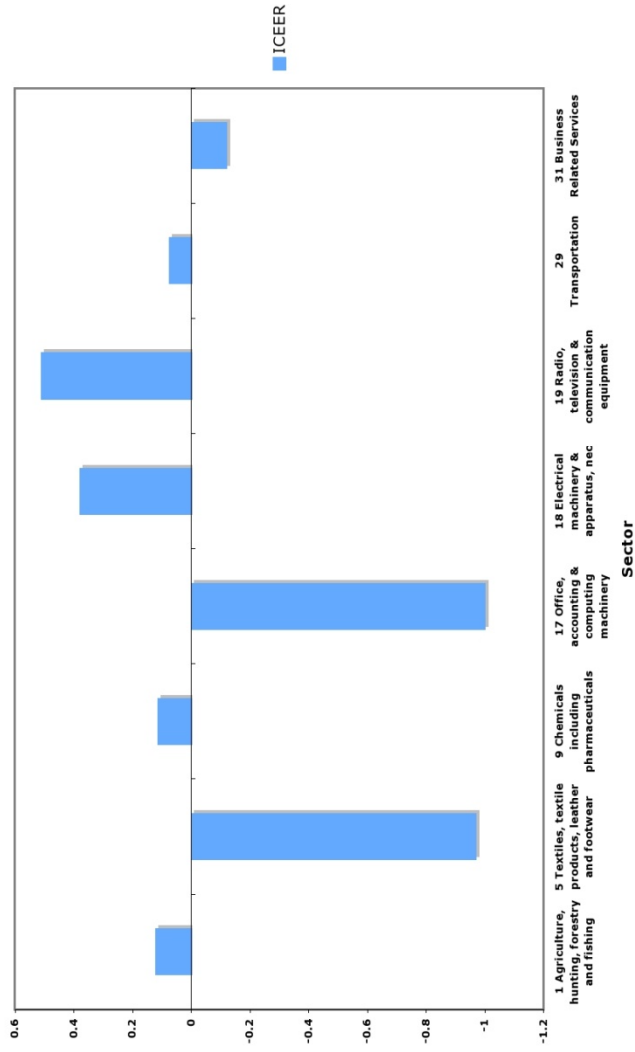
2b: China, ICEER, 1995-2005



2c: ICEER, India, 1995-2005



2d: ICEER, Brazil, 1995-2005



# CAPTURING THE GAINS



***economic and social upgrading  
in global production networks***

Capturing the Gains brings together an international network of experts from North and South. The research programme is designed to engage and influence actors in the private sector, civil society, government and multi-lateral organisations. It aims to promote strategies for decent work in global production networks and for fairer international trade.

*Published by:*

*Capturing the Gains  
The University of Manchester  
Humanities Bridgeford Street  
Building  
Oxford Road  
Manchester  
M13 9PL  
United Kingdom*

*[capturingthegains@manchester.ac.uk](mailto:capturingthegains@manchester.ac.uk)*

*[www.capturingthegains.org](http://www.capturingthegains.org)*