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# Slicing Up Global Value Chains[†]

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In an already classic study of the iPod, Dedrick, Kramer, and Linden (2010) discuss how the iPod is assembled in China from several hundred components and parts that are sourced from around the world. This production network is led by Apple, a US-based company, which is estimated to capture between one-third and one-half of an iPod's retail price. Asian firms like Toshiba from Japan and Samsung from South Korea capture another major part as profits from manufacturing high-value components, such as the hard-disk drive, display, and memory. In contrast, assembling and testing activities by Chinese workers is estimated to capture no more than 2 percent. Other studies of tablets, mobile telephones, and laptops suggest a similar pattern of specialization; advanced nations deliver capital and high-skilled labor, capturing most of the value, while emerging countries contribute low-skilled activities that add little value: in another vivid example, Ali-Yrkkö, Rouvinen, Seppälä, and Ylä-Anttila (2011) discuss the Nokia N95 smartphone.

Such case studies are mainly conducted for high-end electronics and for one point in time, which raises obvious questions about the extent to which they represent broader patterns. How pervasive is the process of international production fragmentation for a

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[†] To access the Appendix, visit
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wider set of products? How does the factor content of these production chains change over time when fragmentation deepens? And how do specialization patterns differ between high-income and emerging economies that participate in these chains? In this paper, we provide a macroeconomic and longitudinal analogy of the iPod exercise, using many countries and many manufacturing products. We "slice up the global value chain" (to borrow the term from Krugman 1995) using a decomposition technique that has recently become feasible due to the development of the World Input-Output Database (Timmer et al. 2014). We trace the value added by all labor and capital that is directly and indirectly needed for the production of final manufacturing goods. The production systems of these goods are highly prone to international fragmentation as many stages can be undertaken in any country with little variation in quality.

We seek to establish a series of facts concerning the global fragmentation of production that can serve as a starting point for future analysis. After a short overview of our data and methods, we discuss four major trends. First, international fragmentation, as measured by the foreign value-added content of production, has rapidly increased since the early 1990s when it made its appearance on a global scale (Feenstra 1998). Second, in most global value chains there is a strong shift towards value being added by capital and high-skilled labor, and away from less-skilled labor. This suggests a pervasive process of technological change that is biased towards the use of skilled labor and capital. Third, within global value chains, advanced nations increasingly specialize in activities carried out by high-skilled workers. The direction of this change follows the intuitive notion of comparative advantage driven by relative factor endowments across countries, but the pace at which it occurs has not been established before. Fourth, emerging economies surprisingly specialize in capital-intensive activities; the capital share in their value added is rising, while the share of low-skilled labor in their value added is declining.

## International Fragmentation and Factors of Production: Method and Data

Before laying out some patterns as to how the international fragmentation of production is occurring, it is useful to offer some background on terminology, methods, and data.

### Concepts and Definitions

We wish to study the production fragmentation of final products. A final product is consumed, in contrast to intermediate products that continue on in the production process. Consumption is broadly defined to include private and public consumption, as well as investment. A global value chain of a final product is defined as the value added of all activities that are directly and indirectly needed to produce it. This global value chain is identified by the country-industry where the last stage of production takes place before delivery to the final user: for example, the global value chain of electronics from Chinese electrical equipment manufacturing, or of

cars from German transport equipment manufacturing. However, it is important to note that the fact that a product is "completed" in a particular country does not necessarily mean that domestic firms are governing the value chain: for example, Apple governs the production network of iPods, although they are completed in China. For more on governance in global value chain production, a useful starting point is Gereffi (1999).

The fragmentation of production processes can take many forms, sometimes characterized as "snakes" and "spiders" (Baldwin and Venables 2013). Snakes involve a sequence in which intermediate goods are sent from country A to B, and incorporated into intermediate goods sent from B to C, and so on until they reach the final stage of production. Spiders involve multiple parts coming together from a number of destinations to a single location for assembly of a new component or final product. Most production processes are complex mixtures of the two. To stick with commonly used terms, we refer to all fragmented production processes as "chains," despite the snake-like connotation of this term.

In this paper we will focus on the global value chains of final manufacturing products, which we refer to as "manufactures." Of course, these do not only contain activities in the manufacturing sector, but also in other sectors such as agriculture, utilities, and business services that provide inputs at any stage of the production process of manufactures. These indirect contributions are sizeable and will be explicitly accounted for through the modeling of input-output linkages across industries. The value added in manufactures chains accounts for about 23 percent of global GDP in 1995. Similar analysis of global production of final services is possible in principle, but the current data is not detailed enough to do so.

**The World Input-Output Database**

To measure value added in global value chains, we need to track the flow of products across industries and countries. The World Input-Output Database, which is freely available at http://www.wiod.org, has been specifically constructed for this type of analyses (Timmer et al. 2014; Dietzenbacher et al. 2013). It provides world input-output tables for each year since 1995 covering 40 countries, including all 27 countries of the European Union (as of January 1, 2007) and 13 other major economies: Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey, and the United States. These 40 countries represent more than 85 percent of world GDP. In addition, a model for the remaining noncovered part of the world economy is provided such that the value-added decomposition of final output is complete. It contains data for 35 industries covering the overall economy, including agriculture, mining, construction, utilities, 14 manufacturing industries, and 17 services industries. The tables have been constructed by combining national input-output tables with bilateral international trade data, following the conventions of the System of National Accounts.[1]

[1] An online appendix available with this paper at http://e-jep.org offers more detail on the construction of this data.

One also needs detailed value-added accounts that provide information on labor and capital used in production. Three types of workers are identified on the basis of educational attainment levels as defined in the International Standard Classification of Education (ISCED). "Low skilled" (ISCED categories 0, 1, and 2) roughly corresponds to less than secondary schooling. "Medium skilled" (3 and 4) means secondary schooling and above, including certain professional qualifications, but below college degree. "High skilled" (5 and 6) includes those with a college degree and above. For most advanced countries, this data is constructed by extending the EU KLEMS database (O'Mahony and Timmer 2009). For other countries, additional data has been collected according to the same principles. Workers include the self-employed and family workers, and an imputation for their income is made. Capital income is derived as a residual and defined as gross value added minus labor income. It represents remuneration for capital in the broadest sense, including physical capital (such as machinery and buildings), land (including mineral resources), intangible capital (such as patents and trademarks), and financial capital.

**Decomposing Global Value Chains**

Our aim is to decompose the value of a final product into the value added by all labor and capital employed in its global value chain. We begin by modeling the world economy as an input-output model in the tradition of Leontief (1936) and trace the amount of factor inputs needed to produce a certain amount of final output. Leontief's seminal insight is rather straightforward and intuitive: to produce output one needs labor, capital, and intermediate inputs. These intermediates need to be produced themselves, involving again production factors and intermediates, and so on until all intermediates are accounted for. He provided a mathematical model that allows one to trace the inputs needed in all the stages of production. For an introduction to input-output analysis, Miller and Blair (2009) provide a useful starting point.[2] As an end result, the value of any particular final product is decomposed into the value added by all labor and capital that was needed in any stage of production. In this way, one can provide a consistent accounting system of all value added and all global value chains in the world, as illustrated by Figure 1.

The final column in Figure 1 provides the value added by workers and capital employed in a particular industry and country. A row shows the distribution of this value added across all global value chains in which the industry participates. The global value chains are represented by the columns. There is one column for each final good or service produced in each country. The cells in the column show the origin of all value added needed for the production of the final good. The

[2] A formal description of the method can be found in the appendix with the papers at the JEP website: http://e-jep.org. Our approach is related to Johnson and Noguera (2012a) and Koopman, Wang, and Wei (2014). Rather than using Leontief's insight to analyze the value-added content of trade flows, we focus on the value-added content of final demand. This is more in the spirit of work by Dietzenbacher and Romero (2007) and Antràs, Chor, Fally, and Hillberry (2012), who compute the average number of "transactions" a dollar of a given product will go through before being sold for final use.

*Figure 1*
**An Accounting Framework for Global Value Chains**

| | | | Final products of a global value chain, identified by country and industry of completion | | | | | | | Value added |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Country 1 | | | ... | Country M | | | |
| | | | Industry 1 | ... | Industry N | ... | Industry 1 | ... | Industry N | |
| Value added from country-industries participating in global value chains | Country 1 | Industry 1 | | | | | | | | |
| | | ... | | | | | | | | |
| | | Industry N | | | | | | | | |
| | ... | ... | | | | | | | | |
| | Country M | Industry 1 | | | | | | | | |
| | | ... | | | | | | | | |
| | | Industry N | | | | | | | | |
| Total final output value | | | | | | | | | | World GDP |

*Note:* Cell values represent the value added generated in the country-industry given in the row, within the global value chain corresponding to the country-industry of completion given by the column.

sum across all participating industries makes up the gross output value of the final product, given in the bottom row. Note that these industries are domestic as well as foreign. As all final products are being consumed somewhere in the world, output values will equal expenditure. Thus both the columns and the rows add up to world GDP as global final expenditure must be equal to global value added by national accounting convention.

In Table 1, we provide a real world example of the results of such decomposition for the final output of the transport equipment manufacturing industry in Germany—in short, German cars.[3] By summing over all value that is added by labor and capital employed in German industries, the domestic value-added content of the product can be calculated. This includes value added in the car industry itself, but also in other German industries that deliver along the production chain, including services industries. Between 1995 and 2008, the domestic value-added content dropped from 79 to 66 percent. On the flip side, the foreign value-added share increased as intermediates were increasingly imported, generating income for labor and capital employed outside Germany. The foreign value-added share is an indicator of the international fragmentation of production and will be used later on.

[3] In this example, as well as in the remainder of the paper, we will analyze the value of final products at basic prices, which is the ex-factory gate price before delivery to the final consumer. This means that retail trade margins and net taxes are not included. Retail margins can be sizable, and the World Input-Output Database provides data to analyze these margins as well, but this is outside the scope of the present paper as retailing is an activity that is still mainly domestic by nature.

*Table 1*
**Slicing Up the Global Value Chain of German Cars**
(*percent of final output value*)

| | *1995* | *2008* |
|---|---|---|
| **German value added** | **79%** | **66%** |
| High-skilled labor | 16% | 17% |
| Medium-skilled labor | 34% | 25% |
| Low-skilled labor | 7% | 4% |
| Capital | 21% | 20% |
| **Foreign value added** | **21%** | **34%** |
| High-skilled labor | 3% | 6% |
| Medium-skilled labor | 6% | 9% |
| Low-skilled labor | 4% | 4% |
| Capital | 8% | 15% |
| **Total final output** | **100%** | **100%** |

*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.
*Note:* The table gives a breakdown of the value added to final output from German transport equipment manufacturing (ISIC rev. 3 industries 34 and 35).

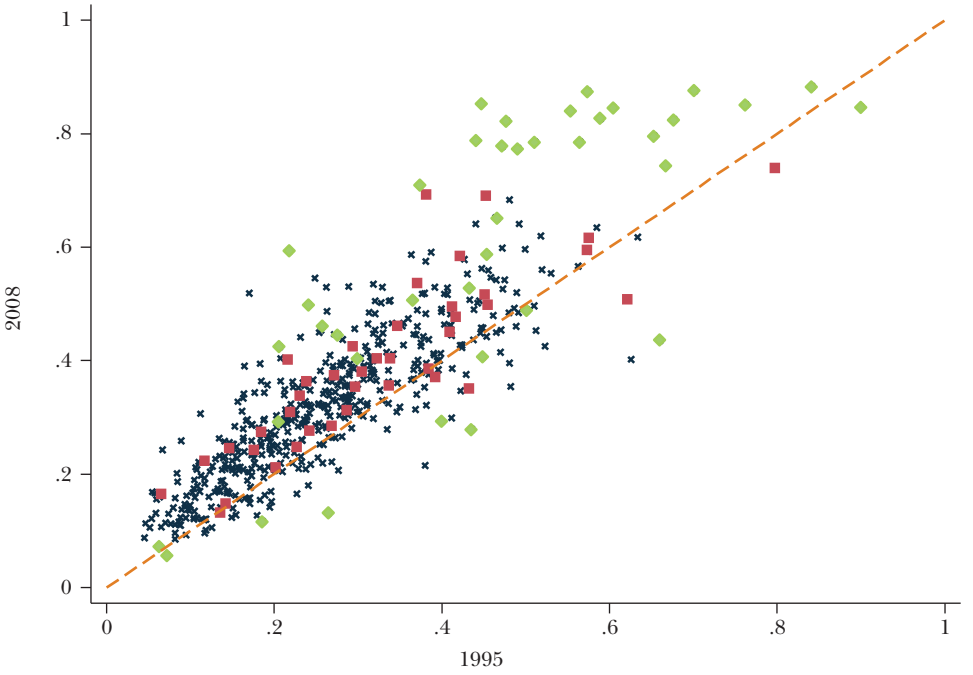
The factor content of the global value chain of German cars changed as well. To see this, one can sum over value added by all labor, irrespective of its location, and similarly for capital. We find that the value added by capital increased from 29 to 35 percent, while the share of labor dropped from 71 to 65 percent. The drop in labor was almost exclusively for less-skilled workers in Germany. The share for high-skilled workers both within and outside Germany increased.

The patterns of shifting location and factor content of activities in the global value chain of German cars are representative for many other chains of manufactures, as we will see in the remainder of this paper. Throughout we will focus on the period from 1995 to 2008 because our data starts in 1995, and 2008 marks the end of a period as the global financial crisis struck. The findings do not depend on the particular choice of beginning or ending year as all of the trends we discuss in this paper are gradual and monotonic, unless noted otherwise.

## Trend 1: International Fragmentation of Production is Expanding

With plummeting costs of communication and coordination, it has become increasingly profitable to split the production process, with each stage at its lowest-cost location. Knowledge about the extent and development of international production fragmentation remains sketchy however. Some empirical papers have studied cross-border fragmentation based on foreign investment flow data of firms

*Figure 2*
**Foreign Value-Added Shares in 560 Global Value Chains, 1995 and 2008**




*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.
*Notes:* Each dot represents the share of foreign value added in output of a manufactures global value chain in 1995 and 2008. Shares are plotted for 560 global value chains, identified by 14 manufacturing industries of completion in 40 countries. Squares indicate global value chains of electrical equipment (ISIC rev. 3 industries 30–33), and diamonds indicate petroleum refining (ISIC 23). The dashed line is the 45-degree line.

and their affiliates: for example, see Fukao, Ishido, and Ito (2003) and Ando and Kimura (2005) for Japanese firms; Hanson, Mataloni, and Slaughter (2005) for US firms; and Marin (2011) for German and Austrian multinationals. Macroeconomic evidence has been presented by Hummels, Ishii, and Yi (2001) and Johnson and Noguera (2012a, b), who found increasing vertical specialization in trade for most countries (see the contribution of Johnson in this symposium for an overview). Here we provide complementary analysis that provides direct evidence of fragmentation focusing on the value chains of final products.

In Figure 2, we plot foreign value-added shares in 1995 on the horizontal axis and 2008 on the vertical axis, together with a 45-degree line. Products are identified by the country and industry of completion, so we have data for 560 final products from 14 manufacturing industries in 40 countries for each year. For 85 percent of the product chains, the foreign value-added share has increased, indicating the pervasiveness of international fragmentation. The (unweighted) average foreign share rose from 28 to 34 percent.

The extent of fragmentation varies greatly across products. Petroleum products are represented by diamonds in the figure. They have very high foreign value-added shares because most countries do not have access to domestic oil feedstock, reflected in a cluster of diamond-shaped points in the upper part of Figure 2. Value chains for electrical equipment, typically regarded as the paragon of international production fragmentation, are shown by square points. For these products, foreign value-added shares are indeed above average and increased from 33 to 40 percent. In contrast, manufactured foodstuffs have relatively low shares, as most of the intermediates are sourced from local agriculture. But even for these products, foreign shares have increased over time.

The global financial crisis created a dip in fragmentation in 2008 and 2009, but Los, Timmer, and de Vries (forthcoming) show that the trend picked up again in 2010. Contrary to the anecdotes of multinationals re-shoring production, they found no serious signs of a major reversal yet. However, they do find a major change in the geographical nature of fragmentation. In the 1990s, fragmentation mainly took place within regional blocks: North America (NAFTA), the European Union, and Asia. But in the 2000s, global value chains have started to become truly global with the advance of emerging economies as major suppliers of intermediates. Whether this trend towards global fragmentation of value chains will continue in the future will depend on a host of determinants, including developments in wages and productivity, costs of transportation and trading, coordination costs, risk considerations, and the strength of linkages between various activities. For example, Baldwin and Venables (2013) argue that certain high-value-added tasks may well remain clustered in space because of strong localized complementarities, leading to possibly large discontinuities in the fragmentation process. Furthermore, offshored activities that are currently low-skilled-labor intensive might be re-shored if technological progress makes mechanized production in capital-abundant countries cheaper. It remains to be seen how the different forces will play out in the future.

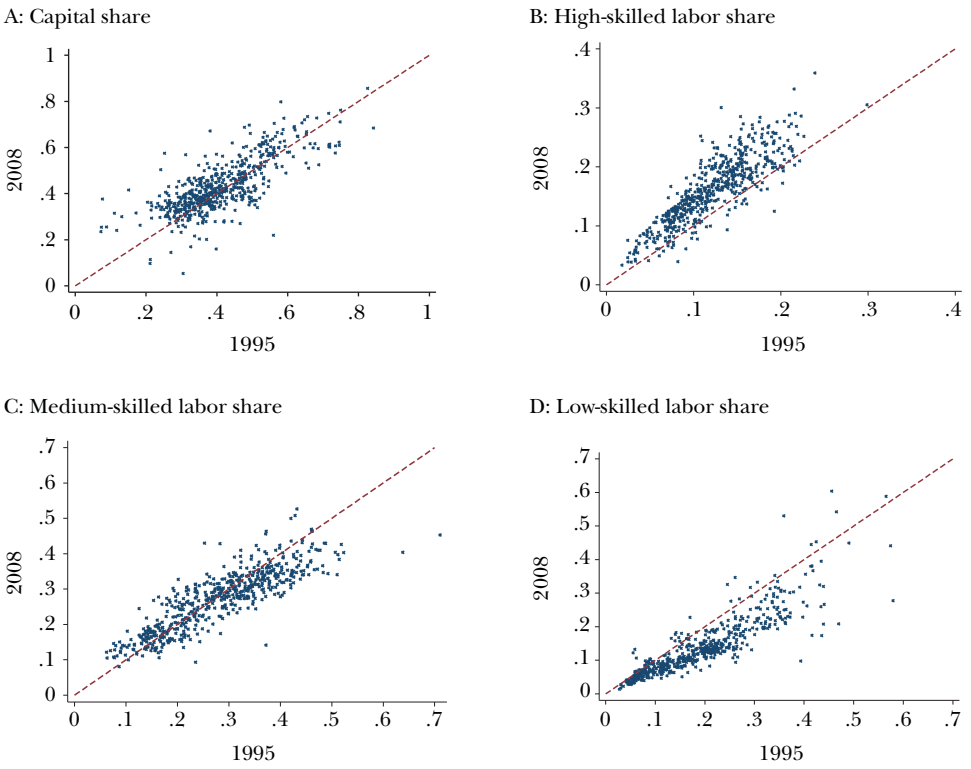
## Trend 2: More Value Added from High-Skilled Labor and Capital

The opening up of China, India, and other emerging economies provided an enduring increase in the global supply of low-skilled labor. How has this affected the factor income distribution in global value chains? This is driven by the relative prices of various types of labor and capital, as well as possibilities for factor substitution, both within and across countries. We first provide evidence on factor content changes at the global level, followed by specialization trends in high-income and emerging economies separately. After that we offer some discussion of a framework that might be suitable when thinking about these trends.

Changes in factor income shares in global value chains have been plotted in Figure 3. The value of final manufacturing goods is decomposed into value added by four factors: capital and low-, medium-, and high-skilled labor. (In our approach, value added and income of factors are equivalent, so these terms will be used

*Figure 3*

**Factor Shares in Value Added of 560 Global Value Chains of Manufactures, 1995 and 2008**




*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.
*Notes:* Factor shares in value added of 560 global value chains, identified by 14 manufacturing industries of completion in 40 countries, in 1995 (x-axis) and in 2008 (y-axis). The dashed line is the 45-degree line.

interchangeably.) For each factor we show on the horizontal axis the income share in 1995 and on the vertical axis the share in 2008. Points above the 45-degree line indicate global value chains in which the factor has increased its share. As before, we have in total 560 value chains: 14 manufacturing product groups with 40 possible countries of completion. In 64 percent of the chains, the share of value added by capital has increased. The average increase was about 1 percentage point, with a large variance: in some chains the capital share increased by more than 20 percentage points. It was particularly strong in those production chains where the final output was high, such as transport equipment and machinery with China, Germany, and the United States as countries of completion, in which capital shares increased by 8 percentage points or more. The increase in income shares for high-skilled workers was particularly pervasive and positive, happening in 92 percent of the chains. The

*Table 2*
**Factor Shares in Global Value Chains of All Manufactures**

| **Value added** | *1995* | *2008* | *2008 minus 1995* |
|---|---|---|---|
| **Total (billion US$)** | **$6,586** | **$8,684** | **$2,098** |
| By: | | | |
| capital (%) | 40.9% | 47.4% | 6.5% |
| high-skilled labor (%) | 13.8% | 15.4% | 1.5% |
| medium-skilled labor (%) | 28.7% | 24.4% | −4.2% |
| low-skilled labor (%) | 16.6% | 12.8% | −3.8% |

*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.
*Notes:* The table presents shares of production factors in total value added based on all global value chains of manufactures. Shares add up to 100 percent. Value added is at basic prices (hence excluding net taxes, trade, and transport margins on output). It is converted to US dollars with official exchange rates and deflated to 1995 prices with the US Consumer Price Index. Figures shown may not add due to rounding.

unweighted average was about 4 percentage points, with a much lower variance than for capital. A notable outlier is the US electrical equipment industry where the share increased by 12 percentage points. On the flip side, the income shares for medium- and low-skilled labor dropped in many value chains. The medium-skilled share declined in 56 percent of the cases, with an average of 1 percentage point. The decline has been particularly severe in major chains, like those of machinery and of transport equipment with Germany and the United States as countries of completion (6 to 8 percentage points decline). The clearest trend is found for low-skilled shares, which declined in 91 percent of the cases. The average decline was 5 percentage points with occasional declines of more than 10 percentage points, in particular in European food chains—for example, with France, Italy, and Spain as countries of completion. As we will see later, declines in low-skilled shares are not only found in chains ending in high-income countries, but also in many chains that have a low-income economy as country-of-completion.

What are the macroeconomic effects? In the analysis above, each product chain was considered irrespective of its size. But bigger chains play a larger role in the global economy than smaller ones. Chains of products like food, transport equipment, and machinery typically have larger final output, as well as chains ending in bigger economies. To account for this, we take final output of all manufactures together (by summing over 560 manufactures chains) and provide a similar decomposition of value added. In effect, the factor shares are now weighted by the final output of their chain. The results are given in Table 2. Global expenditure on manufactures increased by almost one-third, from $6,586 billion in 1995 to $8,684 billion in 2008 (in constant 1995 prices). We find that the shares of value added by capital and high-skilled workers increased at this aggregate level. This confirms that the patterns found above are not driven by developments in small chains only, but are

economically significant. The share of value added by capital increased by more than 6 percentage points as the upward shift was most pronounced in bigger chains. The share of high-skilled workers increased as well, but not as fast, with 1.5 percentage points. The shares of low- and medium-skilled workers declined both by about 4 percentage points.

Thus, we find a bifurcation in the factor content of global value chains with increasing capital and high-skilled labor income on the one hand, and declining shares for medium- and particularly for low-skilled labor on the other. Together capital and high-skilled labor captured 55 percent of manufactures value in 1995, increasing to 63 percent in 2008. This increase is especially marked at the end of the 1990s and again from 2003 to 2006. The latter period coincides with a step up in the global presence of China after its accession to the World Trade Organization in 2001. This finding is consistent with the model of Rodrik (1997). He argues that the opening up of international capital markets increased the opportunities for quick relocation of capital. In his argument, this led to a decline in the bargaining power of labor around the world, limiting the share of labor in value added vis-à-vis capital.

## Trend 3: Enhanced Specialization in High-Skilled Labor in High-Income Countries

What happened to the location of value added in global value chains? And did specialization patterns vary between regions? To this end, we group Australia, Canada, Japan, South Korea, Taiwan, the United States, and the 15 pre-2004 members of the European Union in one group and place all other countries in the world in another group. Roughly speaking, this can be viewed as a comparison of the high-income countries of the world and other countries that play an active role in international trade (Hanson 2012). The share of high-income countries in total value added generated in all manufactures chains declined from 74 percent in 1995 to 56 percent in 2008. The share of high-income East Asia declined from 21 to 11 percent. Shares in North America and high-income Europe declined by around 4 percentage points each. In contrast, emerging regions have rapidly increased shares by 18 percentage points. China is responsible for half of this increase, from 4 to 13 percent, accelerating in the period after it joined the World Trade Organization in 2001. Shares also rapidly increased in other emerging economies, including Brazil, Russia, India, and Mexico.[4]

[4] This is shown in Appendix Table 1, available online with this article at http://e-jep.org. Given sizable flows of foreign investment, part of the value added in emerging regions will accrue as income to multinational firms headquartered in advanced regions. However, analyzing capital income on a national rather than a domestic basis is notoriously difficult. To establish the full link from production value-added to factor incomes and finally to personal income distributions, one would additionally need data on the actual ownership of firms (Lipsey 2010).

*Table 3*
**Factor Shares in Global Value Chains of Manufactures, by Region**

| *Value added in value chains of manufactures* | *1995* | *2008* | *2008 minus 1995* |
|---|---|---|---|
| **In high-income countries (billion US$)** | **$4,863** | **$4,864** | **$1** |
| By: | | | |
| capital (%) | 35.9% | 38.7% | 2.9% |
| high-skilled labor (%) | 16.8% | 21.8% | 5.0% |
| medium-skilled labor (%) | 33.3% | 30.3% | −3.0% |
| low-skilled labor (%) | 14.0% | 9.1% | −4.9% |
| **In other countries (billion US$)** | **$1,723** | **$3,820** | **$2,097** |
| By: | | | |
| capital (%) | 55.2% | 58.4% | 3.2% |
| high-skilled labor (%) | 5.4% | 7.1% | 1.7% |
| medium-skilled labor (%) | 15.6% | 17.0% | 1.4% |
| low-skilled labor (%) | 23.8% | 17.5% | −6.3% |
| **Worldwide (billion US$)** | **$6,586** | **$8,684** | **$2,098** |

*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.
*Notes:* Shares of production factors in total value added in a region, based on all global value chains of manufactures. Value added by a region is sum of value added by labor and capital on the domestic territory. High-income countries include Australia, Canada, and the United States; Japan, South Korea, and Taiwan; and all 15 countries that joined the European Union before 2004. Value added and expenditure is at basic prices (hence excluding net taxes, trade, and transport margins on output). It is converted to US dollars with official exchange rates and deflated to 1995 prices with the US Consumer Price Index. Figures may not add due to rounding.

Concomitant with this change in location of production, specialization patterns changed as well. In the traditional Heckscher–Ohlin model of trade, countries will focus on producing goods intensive in those factors that are relatively abundant. As a production chain fragments across countries, one might expect that the standard Heckscher–Ohlin predictions will still hold: the rise of China and other emerging economies accelerates the erosion of mature economies' comparative advantage in labor-intensive production tasks, while simultaneously offering new opportunities for offshoring (Hanson 2012). Thus, advanced countries will focus more on activities that require high-skilled labor and capital, and other countries will specialize in less-skilled activities.

To test these predictions, we provide more information on the factor content of global value chain production in the two regions in Table 3. The upper panel shows that in the high-income countries the share of capital increased from 36 to 39 percent, while the share of labor declined correspondingly. But the major income shift is observed across labor categories. The value added by high-skilled workers increased by 5 percentage points, while the combined share of medium- and

*Table 4*

**Changes in Factor Shares over 1995–2008 in Global Value Chains of Manufactures, by Country**

*(in percentage points)*

| | *Capital* | *Low-skilled labor* | *Medium-skilled labor* | *High-skilled labor* |
|---|---|---|---|---|
| United States | 3.9 | −1.9 | −5.9 | 4.0 |
| Japan | 4.5 | −5.4 | −2.1 | 3.1 |
| Germany | 6.8 | −2.8 | −7.4 | 3.4 |
| France | 0.2 | −8.7 | 0.1 | 8.4 |
| United Kingdom | −3.4 | −8.0 | 1.2 | 10.2 |
| Italy | −1.1 | −14.8 | 10.4 | 5.5 |
| Spain | 0.1 | −12.9 | 4.7 | 8.1 |
| Canada | 1.8 | −2.0 | −4.6 | 4.8 |
| Australia | 6.0 | −8.4 | −0.9 | 3.3 |
| South Korea | 9.3 | −11.6 | −5.6 | 8.0 |
| Netherlands | 5.5 | −7.3 | −7.1 | 8.9 |
| **Total all high-income** | **2.9** | **−4.9** | **−3.0** | **5.0** |
| China | 9.3 | −9.3 | −2.1 | 2.0 |
| Russian Federation | 1.1 | −1.6 | −2.4 | 2.8 |
| Brazil | −6.7 | −4.8 | 7.5 | 4.0 |
| India | 4.5 | −5.9 | −1.7 | 3.1 |
| Mexico | 6.4 | −4.2 | −0.5 | −1.7 |
| Turkey | −12.7 | 4.5 | 5.2 | 3.1 |
| Indonesia | 5.3 | −8.1 | 1.3 | 1.6 |
| **World minus all high-income** | **3.2** | **−6.3** | **1.4** | **1.7** |
| **World** | **6.5** | **−3.8** | **−4.2** | **1.5** |

*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.
*Notes:* See Table 3. In this table, the percentage point changes in factor shares are given for each country. Changes in four factors for each country add up to zero by definition, but here they may not due to rounding. Countries are ranked by GDP.

low-skilled workers declined by 8 percentage points. The direction of this change is in line with the Heckscher–Ohlin intuition, but the magnitude of the changes differs across countries. In Table 4, we provide similar decompositions for individual countries. Looking first at the high-income group of countries, capital income shares increased in most countries, except in the United Kingdom and Italy, with the largest increases found in Germany and South Korea (7 and 9 percentage points). The value-added share by high-skilled workers increased in all countries in this group, ranging from around 3 percentage points in Australia, Germany, and Japan and 4 in the United States to more than 8 in France, the Netherlands, South Korea, and the United Kingdom. Income shares of other labor declined all around in the high-income countries. In Canada, Germany, and the United States, medium-skilled labor shares declined faster than low-skilled shares. In other countries like France, the United Kingdom, Italy, and Spain, as well as in South Korea

and Australia, low-skilled workers' income shares suffered most, sometimes by more than 10 percentage points.

Declining incomes and jobs for less-skilled workers have stirred major policy concerns, mostly framed in terms of "manufacturing decline," and have prompted various initiatives for "re-industrialization" in a number of former industrial strongholds. Setting aside the merits of such proposals, it is important to note that with fragmented production, sectors like "manufacturing" are becoming the wrong way to evaluate economic performance and to frame public policies. Competitiveness is no longer solely determined by domestic clusters of manufacturing firms but relies increasingly also on the successful integration of other tasks in the chain, both domestic and foreign ones. To illustrate, the production of final manufactures involves not only jobs in the manufacturing sector but also jobs outside manufacturing that are indirectly related through the delivery of intermediate goods and services. In fact, in 2008 the latter made up almost half of all jobs related to manufactures production. Specialization in global value chains might therefore lead to declining jobs in traditional manufacturing but might also generate new jobs outside manufacturing. Indeed, in almost all high-income countries, the number of services jobs related to manufacturing production increased during this period, with the notable exceptions of the United Kingdom and the United States. In Germany and Italy, this increase was even faster than the decline in manufacturing jobs such that the net effect was positive (Timmer, Los, Stehrer, and de Vries 2013). Trade, labor, and industrial policies would do well to take into account the increased vertical integration of production within and across countries (Baldwin and Evenett 2012).

## Trend 4: Enhanced Specialization in Capital in Emerging Economies

What happened to specialization patterns in the rest of the world? Based on the standard Heckscher–Ohlin predictions, one might expect the value-added share of less-skilled workers to increase in this region. This did not happen, as shown in the lower part of Table 3. The share of low-skilled workers declined by 6 percentage points from 24 percent in 1995 to 18 percent in 2008. The share of medium-skilled workers increased, but only by one percentage point. This is not to say that the number of workers employed in global value chains in manufacturing declined. On the contrary: 42 million jobs in China were added, 20 million in India, 6 million in Brazil, and 2 million in Mexico. (These figures are spelled out in Appendix Table 2, available online with this article at http://e-jep.org.) But in these countries as a whole, wages remained relatively low, and global value chain production mainly benefited capital. In 1995, the value-added share of capital in emerging economies was already high at 55 percent, compared to 36 percent in the high-income region. This is perhaps not surprising because these countries are abundant in labor, but it actually increased even further by 3 percentage points in the period up to 2008. The capital share in China increased by almost 10 percentage points. Capital shares in other major emerging economies like India, Indonesia, and Mexico also increased,

by around 5 percentage points, as shown in Table 4. These developments fit a modern variant of the classical story of surplus labor by Lewis (1954). With capital being globally mobile, it will relocate to locations with high rental-wage ratios. As long as there is a reservoir of unskilled labor that can be employed at wages well below their marginal productivity, rental-wage ratios will remain high. Thus, the income share of capital will increase in early stages of development, rather than decline.

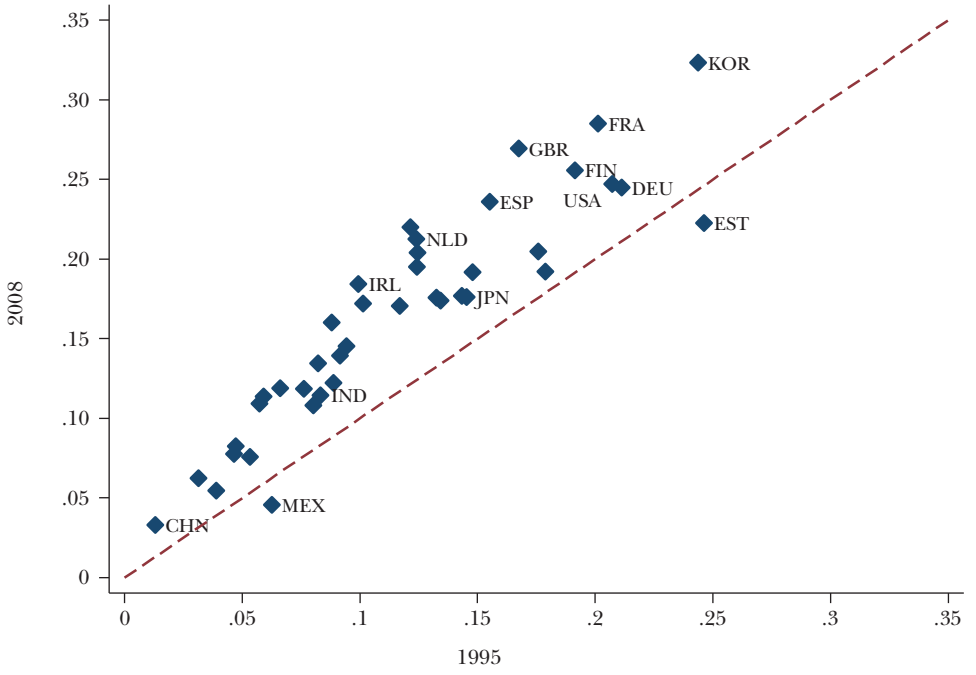
Table 4 also shows that the value-added share of high-skilled workers increased in almost all emerging economies. This echoes the changes that took place in Mexico when it entered into production chains with the United States in the 1980s (Feenstra and Hanson 1996). In their seminal model of offshoring (Feenstra and Hanson 1997), they related this to the establishment of so-called "maquiladoras" by US firms located across the US–Mexican border. Suppose that the good originally produced by the United States can be divided into two tasks. One task is relatively low-skilled intensive, like assembly of components, and the other task is high-skilled intensive, like producing high-tech components. As the relatively low-skilled task is offshored to Mexico, production in the United States will become more high skilled, further specializing in its abundant factor. Average skill intensity in Mexico increased after fragmentation in the 1980s. However, this is only one possible outcome, which will depend on the skill intensity of the offshored task compared to the existing skill intensity of production in the country (Arndt and Kierzkovski 2001; Feenstra 2010). It could also be that the average skill intensity of production would actually decrease rather than go up, as illustrated by more recent trends in Mexico; see Table 4. In fact, many outcomes are theoretically possible and to fully understand the complex patterns at work we need to further refine our thinking about the production process. In the final section, we sketch the main elements of such a framework.

## Tasks, Substitution, Complements, and Technological Change

Production processes in manufacturing have increasingly fragmented across national borders, and the change in their factor content was clearly biased towards high-skilled labor and capital. This pattern was not only found for activities carried out in high-income countries, but also in emerging economies. In particular, the widespread increase in the value-added share of high-skilled workers was remarkable. In Figure 4, we plot for each of the 40 countries in the World Input-Output Database the share of value added by high-skilled workers for 1995 on the horizontal axis and for 2008 on the vertical axis. All observations, except two (Mexico and Estonia), are above the dotted 45-degree line, indicating a global shift towards use of relatively more high-skilled workers in global value chains in all of these countries.

What might account for this pattern? In traditional models of production, factor shares are determined by the interplay of relative prices of factors, their elasticities of substitution, and the nature of technical change. For example, opening up Asian economies led to a shock in the global supply of unskilled workers. Whether this change will lead to an increase in its factor share will depend on the elasticity of

*Figure 4*
**Shares of High-Skilled Labor in Value Added of All Global Value Chains of Manufactures, by Country**




*Source:* Authors' calculations based on World Input-Output Database, November 2013 Release.
*Notes:* Shares of high-skilled workers in a country's value added, based on all global value chains of manufactures, in 1995 (x-axis) and in 2008 (y-axis). The dashed line is the 45-degree line. Indicated are China (CHN), India (IND), Mexico (MEX), Ireland (IRL), Japan (JPN), the Netherlands (NLD), Spain (ESP), the United Kingdom (GBR), Finland (FIN), France (FRA), Germany (DEU), South Korea (KOR), Estonia (EST), and the United States (USA).

substitution between unskilled workers in Asia and elsewhere, but also on the substitution possibilities between unskilled and skilled workers, as well as between unskilled workers and capital. Another important element is the rapid advance in the information and communication technology industry, driving down the relative price of information technology capital ( Jorgenson 2001). Again, the effects on the share of capital income will crucially depend on the substitution possibilities between information technology capital on the one hand, and various types of labor on the other.

Substitution possibilities are hard to model and measure. Archetype models of growth and international trade rely on production functions where elasticities of substitution are rather restricted.[5] In these models, the production process is conceived of as a mapping from factor inputs to output, as if taking place in one

[5] The most often-used production functions are the so-called Cobb–Douglas and the constant elasticity of substitution (CES) functions. In the Cobb–Douglas function, elasticities are always one. Hence factor

stage. With fragmentation, however, it can be more useful to model the generation of output as a result of a set of "tasks" which are to be completed by various combinations of production factors. So rather than a direct mapping from labor and capital inputs to output, factors map into tasks, which subsequently map into output. This framework allows for a richer modeling of complementarities and substitution possibilities between various factors of production, both domestic and foreign.

An example of this is found in recent models of labor demand discussed in Acemoglu and Autor (2011). They outline a general framework that revolves around differences in comparative advantages of factors in carrying out tasks: all workers can carry out all tasks, but some are relatively better at carrying out certain tasks (hence are said to have a comparative advantage in this task). Substitution of skills across tasks is possible, such that there is an endogenous mapping from workers to tasks depending solely on labor supplies and the comparative advantages of the various skill types. The framework also allows for capital as an input, by modeling it as another source competing with labor for the supplying of certain tasks. For example, new information technology capital might be much better in handling routine administrative tasks than skilled white-collar labor. According to the "routinization hypothesis" put forward by Autor, Levy, and Murnane (2003), information technology capital complements highly educated workers engaged in abstract tasks, substitutes for moderately educated workers performing routine tasks, and has little effect on less-skilled workers performing manual tasks and tasks that require personal interactions, such as in many services. The latter tasks are less important in manufacturing global value chains, which is consistent with our observation that income shares for both low- and medium-skilled workers in manufactures are declining (Foster-McGregor, Stehrer, and de Vries 2013).

The increasing importance of intangible capital provides another potential explanation for the increasing value-added shares of capital and high-skilled workers. Recent investment in advanced countries is increasingly directed towards intangibles such as intellectual capital (including software and databases, research and development, and design), brand names, and organizational firm-specific capital (Corrado, Haskel, Jona-Lasinio, and Iommi 2012). To the extent that the build-up of intangibles requires high-skilled labor, this will increase demand for the latter. In an extended Heckscher–Ohlin framework, Haskel, Lawrence, Leamer, and Slaughter (2012) assume that skilled workers are more productive in tasks involving working with intangible capital and show how this might explain the evolution of relative wages in the United States. Moreover, intangibles like patents or trademarks are different from traditional capital assets as they typically have a large fixed-cost component. This often gives rise to imperfect product markets and possibilities for mark-ups. When firms operating in such an environment enlarge

cost shares cannot change over time. In the CES function, elasticities are also constant over time, but might vary from one. However, in cases of more than two factor inputs, they are difficult to define.

their scale of operations, capital is likely to gain more relative to labor. In a dynamic model of growth, increased openness and trade might reinforce higher levels of investment in intangibles as it expands the incentives for their creation: the larger the market in which the new invention will be used, the higher the potential for profits accruing to the investor.

## Concluding Remarks

International production fragmentation is underway. The patterns of specialization found in case studies like the iPod have a macroeconomic equivalent. Our findings fit a broad story in which firms in mature economies relocate their unskilled-labor-intensive production activities to lower-wage countries, while keeping strategic and high-value-added functions concentrated at home where the skilled workers and intangible capital they need are available. But this shift of activities was decidedly non-neutral: capital shares in value added increased in both high-income and emerging economies. Further, we found declining value-added shares of low-skilled workers in emerging economies, contradicting traditional notions of comparative advantage. Squaring these facts will be an interesting challenge for further research. One possible explanation is a shift in manufacturing technologies that could have led to a worldwide decline in the demand for unskilled workers. This question can only be investigated from a global value chain perspective as analyses focusing on industries cannot distinguish between offshoring and technological change.

More generally, the impact of trade and cross-border investments on the distribution of income across and within countries have been extensively debated (for an overview, see Harrison, McLaren, and McMillan 2011). In essence, international fragmentation expands the opportunities of countries to specialize according to comparative advantage and hence to gain from trade. As such, it is on average welfare improving, but not necessarily for all workers and owners of capital. We believe that the trade-offs involved can be better understood by conceptualizing the production process as a set of tasks to be performed by combinations of factor inputs. For example, Costinot, Vogel, and Wang (2012) develop a model in which heterogeneous workers sort themselves into various stages of the production process. They find that the consequences of opening up to trade on wage inequality may be very different from standard models, depending on the position of the workers in the chain. In particular, they find that in the less-advanced country all workers move to upstream stages of production, decreasing wage inequality at the bottom of the skill distribution but at the same time increasing it at the top.

Many outcomes are theoretically possible, and it becomes ultimately an empirical issue as to which patterns prevail. The development of world input-output tables is a first step in this investigation. Future statistical frameworks, based on further integration of micro- and macro-statistics will allow for increasingly richer explanations of the drivers and consequences of international production fragmentation.

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