THE DEMAND FOR SKILLS 1995-2008: A GLOBAL SUPPLY CHAIN PERSPECTIVE

ECONOMICS DEPARTMENTS WORKING PAPERS No. 1141

By Bart Los, Marcel P. Timmer and Gaaitzen J. De Vries

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Authorised for publication by Jean-Luc Schneider, Deputy Director, Policy Studies Branch, Economics Department.

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JT03360434

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ABSTRACT/RÉSUMÉ

The demand for skills 1995-2008: A global supply chain perspective

We propose a new method to analyse the changing skills structure of employment in countries based on the input-output structure of the world economy. Demand for jobs, characterized by skill type and industry of employment, is driven by changes in technology, trade and consumption. Using structural decomposition analysis, we study the relative importance of these drivers for the period 1995-2008. In doing so, we derive a new measure of technological change in vertically integrated production chains and show that it has been skill-biased. We find that skill-biased technological change has played the most important role in the different employment growth rates of high-skilled, medium-skilled and low-skilled labour in advanced countries. For emerging countries, the patterns of employment growth are very heterogeneous.

JEL classification codes: F16; F66; D57
Keywords: Demand for skills; Global supply chains; World input–output tables; Trade; Technological change.

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Analyse de l’évolution de la demande de compétences entre 1995 et 2008 sous l’angle des chaînes d’approvisionnement mondiales

Nous proposons une nouvelle méthode pour étudier l’évolution de la structure de l’emploi en termes de compétences dans les pays, qui s’appuie sur une analyse entrées-sorties de l’économie mondiale. La demande d’emplois, selon le type de compétences et le secteur d’activité, est tirée par l’évolution des technologies, des échanges et de la consommation. À partir d’une analyse par décomposition structurelle, nous examinons le poids relatif de chacun de ces moteurs sur la période 1995-2008. Nous obtenons ainsi une nouvelle mesure du progrès technologique dans les chaînes de production intégrées verticalement, qui montre que le progrès technologique privilégie les qualifications. Nous estimons que, dans les pays avancés, c’est ce phénomène qui permet en premier lieu d’expliquer les différences entre les taux de croissance de l’emploi des travailleurs hautement qualifiés, moyennement qualifiés et peu qualifiés. Dans les pays émergents, les taux de croissance de l’emploi sont très variables.

Classification JEL : F16 ; F66 ; D57
Mots clés : demande de compétences ; chaînes d’approvisionnement mondiales ; tableaux entrées-sorties ; échanges ; progrès technologique.
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THE DEMAND FOR SKILLS 1995-2008: A GLOBAL SUPPLY CHAIN PERSPECTIVE

By

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1. Introduction

1. The structure of employment in the economy is constantly evolving. In past decades, the share of jobs in the services sector in advanced countries increased relative to industry, and there was a shift in favour of skilled relative to unskilled workers. Technological change, international trade and changes in consumption are often hypothesised to be major driving forces behind this process of structural change. Typically, the increasing share of services employment has been attributed to sector-biased technological change and non-homothetic preferences. The shift in favour of skilled workers in advanced countries was mainly attributed to skill-biased technological change, with only a minor role for trade. However, quantifying the effects of these determinants in empirical work is not straightforward and recently this consensus view is being challenged again (see e.g. Autor et al., 2013).

2. A major bottleneck in this type of work is the lack of an empirical identification of global supply chains and their evolution. Typically, use is made of measures of foreign direct investment, imports and exports over GDP or the share of intermediate imports in overall imports. Even when this type of data is available at the country-industry-time level, it is still not capturing how activities are combined together in global supply chains. One of the contributions of this paper is to provide an empirical method for identifying global supply chains in the sense of Costinot et al. (2012) and to measure the rate and skill-biased nature of technological change in these chains. A second bottleneck is in the modelling of the skill and job content of imports from the emerging world, in particular China. What matters for the effect of imports on domestic labour demand is its skill content which can only be inferred from data on the skill content of the production activities carried out by the exporting country (Krugman, 2008). We have collected new data on the use of labour by industry and skill type in a wide range of developing countries.

1. Bart Los, Marcel P. Timmer and Gaaitzen J. De Vries are from the University of Groningen, Faculty of Economics and Business, Groningen Growth and Development Centre. The authors would like to thank Asa Johansson and Giuseppe Nicoletti for helpful discussions and comments. They are also grateful to participants at a seminar at OECD in Paris (13 September 2013) for suggestions. The World Input-Output Database project on which much of this paper is based was funded by the European Commission, Research Directorate General as part of the 7th Framework Programme, Theme 8: Socio-Economic Sciences and Humanities, grant Agreement No.225 281. More information on the WIOD-project can be found at www.wiod.org.

2. See e.g. Ngai and Pissarides (2007) and Gollin et al. (2002) building upon the ideas of Chenery and Clark (1959) and Baumol (1967).

3. See e.g. Autor and Katz (1999), a more recent overview by Feenstra (2010), Acemoglu and Autor (2011), and Michaels et al. (2014).
that are important exporters to advanced countries. This data also allows us to present results on the relative importance of the factors underlying change in the demand for skills in a number of important emerging economies, viz. Brazil, China, India and Indonesia.

3. The most important contribution of this paper is to provide a conceptual framework for analysing changes in the demand for jobs through modelling the input-output structure of the world economy, building upon the pioneering work of Leontief (1936, 1941). Based on a world input-output model we decompose changes in employment, characterised by skill type and sector of employment, into changes in global supply chain technology, international trade and consumption. Using a structural decomposition technique we analyse the relative importance of the main drivers in a large set of countries for the period 1995-2008. The methodology used is akin to the one used in the context of measuring vertical specialisation (Hummels et al., 2001) and trade in value added (Johnson and Noguera, 2011; Trefler and Zhu, 2010).

4. The paper is organised as follows. In Section 2, a stylised example of a global supply chain (GSC) is introduced to illustrate the decomposition method in an intuitive way. Section 4 describes the data. We then evaluate to what extent the changes in jobs per skill-type and country can be explained by each of the different channels affecting demand for skills in Section 5. Section 6 concludes.

2. The global supply chain approach to labour demand: the intuition

5. Due to advances in information and communication technology, reductions in transportation costs and reductions in trade barriers, companies have experienced increasing opportunities to relocate part of the production processes leading to final products to countries where the availability and costs of the production factors are most favourable for these specific activities (Baldwin, 2006). As is stressed in the case study literature (e.g. Dedrick et al., 2010), these relocations can be governed within the firm (by means of FDI) or by agreeing on contracts with specialised foreign suppliers. No matter what form is chosen, such relocation decisions have consequences for the distribution of demand for jobs (of different types) in the countries involved, both the home and the host countries. The internationally dispersed activities that together yield a final product (i.e. a consumption product or a physical capital good) are often called a Global Supply Chain (GSC). At the level of specific products, like the iPod and other high-end electronic products, much research has been done to see in which countries the labour involved in the GVC has been employed and where value added was generated. At a more macro level, such studies are much more recent.

6. To explain how input-output analysis can be used to sketch such macroeconomic pictures, the illustration in Figure 1 might be helpful. We consider a final product (e.g. a car) with Country 3 as the “country-of-completion”. The country-of-completion is the country in which the last stage of production takes place before it is shipped to wholesalers, retailers or consumers. Domestic and foreign demand for Country 3’s cars will require labour (and other production factors) in 3’s car industry itself.

7. It will also generate employment in upstream industries in Country 3 itself, for example because the car manufacturer needs intermediate inputs from the business services industry. Next to domestically sourced intermediate inputs, other intermediate inputs (metal products, for example) are imported from Country 2. The manufacturing of these metal products require labour inputs as well and the metal products

4. The discussion in the main text focuses on quantifications of the sources of change in skills demand in aggregate economies and two main broad sectors. More detailed results are presented in sets of tables in Appendix B.

5. See Appendix A for a detailed, more formal explanation of the methodology.
manufacturers in their turn also need intermediate inputs, partly produced in Country 2 and partly in Country 1. Due to demand for final products completed in Country 3, jobs are created in all three countries. We will label Countries 1, 2 and 3 as “countries-of-employment”, to highlight the locations of the labour inputs associated with the production of a final good with a specific country-of-completion.

Figure 1. A stylised global supply chain

Source: Los et al. (2014).

8. Using well-established techniques from the field of input-output analysis (Miller and Blair, 2009), information contained in World Input-Output Tables can be deployed to estimate the (gross) output levels of all industries in each of the countries required to meet final demand (i.e. consumption and investment demand) for a specific product group with a specific country-of-completion. After these output levels are determined, information about the labour requirements per unit of output can be combined with the output levels to arrive at an estimate for the employment levels associated with the specific final demand level studied. If the employment levels associated with final demand for all products with all countries-of-completion are estimated in this way, these will exactly sum to actual labour inputs in each of the industries in each of the countries-of-employment. In this analysis, World Input-Output Tables are thus
seen as descriptions of the world production structure, which is considered to be an evolving network of Global Supply Chains.6

9. The focus of this report is on the relative importance of changes in determinants of the level of demand of jobs in countries (and sectors within these countries). Our analysis is among the first ones to frame the quantification of these effects in a setting of internationally fragmented Global Supply Chains, as in the theoretical work of Costinot et al. (2012). In our analysis, two situations will be compared, for two years (1995 and 2008, in the empirical study). In the most elaborate version of our empirical analysis, the contributions of six determinants are quantified. We illustrate this along the lines of Figure 1:

1. Changes in GSC-technology. We define the GSC-technology for a car completed in Country 3 as the factor inputs (in quantity terms) anywhere in the world and in any industry required to produce a million US dollar of final output of the car industry in Country 3. Since workers in Country 1 might be much less productive than workers in Country 3, we express labour in terms of efficiency units (which are defined as US workers in our empirical study). Technological progress in this GSC will, ceteris paribus, lead to lower demand for labour in all three countries and in all industries;

2. Changes in efficiency. If the productivity levels of workers in initially low-productivity Country 1 catch up to the productivity level of the country of which a worker is considered to be an efficiency unit (Country 3), labour demand in Country 1 will, ceteris paribus, decline;

3. Changes in location-of-intermediate stages. If some of the intermediate inputs required by Country 3’s car manufacturers were initially purchased from domestic suppliers but are bought in Country 2 at a later stage, the associated labour inputs will also be relocated from Country 3 to Country 2.

4. Changes in location-of-completion. If cars with Country 3 as the country-of-completion lose market share (for example to cars from Country 4), labour demand in all countries that contribute to Country 3’s car GSC will be reduced, ceteris paribus. Changes in preferences of users can cause changes like these, but also decisions by lead firms to relocate their assembly activities.

5. Changes in consumption compositions. If consumers (at home and abroad) decide to change the composition of their consumption bundle away from cars to electronic products, labour demand in the countries and industries contributing to Country 3’s car GSCs will be reduced (unless they contribute more to GSCs for electronics);

6. Changes in consumption levels. If consumers (at home and abroad) increase their spending over time, more cars completed in Country 3 will be sold (ceteris paribus) and consequently more workers will be employed in each of the industries in the countries-of-employment involved in this GSC.

10. In the input-output model, the changes listed above can be considered as exogenous and mutually independent. Furthermore, they are exhaustive: the total change in the demand for labour (or labour of a

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6. Wolff (1985) considered productivity in “vertically integrated industries”. A GSC can be seen as an internationally vertically integrated industry.
particular skills level) can be attributed to these six types of change, without a residual being left unexplained.\textsuperscript{7}

11. For reasons of exposition, we will present most of the empirical results after having merged the effects 1) and 2) into a “technology” effect. Effects 3) and 4) together constitute the “trade” effect.\textsuperscript{8} “Consumption” effects (which include changes in the patterns and levels of investment demand) are obtained by adding effects 5) and 6).

12. It should be stressed that the method adopted in this paper does not aim at explaining changes in the demand for skills in particular countries and industries-of-employment. The focus is on accounting for these changes, to see which determinants have contributed most. In a next step, which clearly falls outside the scope of this paper, the most important “proximate sources of change” can be subjected to further analysis, with the aim to see which “ultimate sources of change” have been behind this. Another limitation that should be emphasised here is that the input-output decomposition methodology does not allow us to consider effects of the changes in demand on factor prices. Hence, we cannot study the consequences of technology effects, trade effects and consumption effects on the often divergent wages of low-skilled, medium-skilled and high-skilled workers.

3. Data issues

13. Almost all data required for the analysis underlying this report were taken from the World Input-Output Database (free and publicly available at www.wiod.org). The steps used to construct the 1995-2008 time series of World Input-Output Tables (from National Accounts data, national Supply and Use tables and bilateral trade statistics) have been described in detail in Dietzenbacher et al. (2013). Data expressed in national currencies have been converted to US dollars by means of market exchange rates. Information about the construction of data (based on educational attainment, ISCED levels) regarding skills use by each of the industries in each of the countries can be found in the Sources and Methods document that goes with the database (Timmer, ed., 2012). For most countries, Labour Force Surveys were the main source of data. Data limitations prevent us from using skill inputs expressed in fulltime equivalents, but self-employed are included.

14. For the specific purposes of this report, a World Input-Output Table for 2008 expressed in prices of 1995 was required.\textsuperscript{9} We estimated such a table by deflating all industry outputs by industry-specific gross output deflators. This double-deflation method implies that industry value added is obtained as a residual. It is well-known that these residuals can be affected substantially by measurement and aggregation error, but this is not relevant for this study: value added figures do not play a role in the analysis.

15. The expression of labour inputs in efficiency units (required to arrive at meaningful numbers describing changes in GSC-technologies) required indicators of relative productivity levels of workers in

\textsuperscript{7} This exhaustiveness only holds if all final products, including agricultural products, mining products, construction and services, are supposed to have a GVC. As opposed to Timmer et al. (2013), which focuses on manufactures GVCs, we consider all final products throughout this report.

\textsuperscript{8} Note that relocation of the production of components (intermediate inputs) would lead to effect 3), while relocation of assembly activities (e.g. of consumer electronics products from the US to China) would lead to effect 4).

\textsuperscript{9} Using tables in current prices would have led to an overestimation of output growth, among other things, because of inflation. As a consequence, changes in GVC-technologies would have been overestimated as well.
the countries involved. To compare productivity across countries and sectors, a key issue is how to convert real value added into common currency units. Conceptually, the appropriate rate of exchange is a Purchasing Power Parity (PPP). Inklaar and Timmer (2013) provide detailed PPP estimates in the GGDC productivity level database (see www.ggdc.net). These estimates of relative prices across sectors are based on price data collected by the World Bank in the 2005 ICP round except for agriculture, which is based on unit value information from FAO. Basic headings from the ICP round are matched to sectors that are the main producers of the good or service and PPPs are estimated using the EKS method. The FAO data for agriculture are used in the CPD method to estimate agricultural PPPs (Rao, 2005). It is well known that relative prices vary substantially across tradable and non-tradable sectors, such that the use of aggregate PPPs is not appropriate. Therefore, we used two PPPs: for tradable and for non-tradable industries. Because of data limitations, we had to assume that labour productivity levels of countries relative to the United States changed identically across skill categories.

4. Results

16. Let us first focus on quantifying the actual changes in demand for skills, which we would like to split into the changes in underlying factors using the decomposition methodology, focusing on total economies first. Figure 2 clearly shows that demand for high-skilled workers increased in all countries. With the exception of Japan, demand for medium-skilled labour also increased everywhere. In most countries, demand for low-skilled labour declined. The clear exceptions are Indonesia and India, but some demand growth for low-skilled labour is also found for Australia.

![Figure 2. Changes in demand for skills, total economy (1995-2008, in 000s of jobs)](image)

Source: Authors’ calculations on World Input-Output Database (November 2013 release)

17. Figure 2 gives absolute changes in the demand levels, which mainly leads to insights into global patterns in job creation. It shows that many changes in the EU15 and the United States are dwarfed by changes in countries like China and India, in particular when employment of medium-skilled labour is concerned. To get more insights into the impacts of changes in individual countries, however, changes expressed in proportional growth rates relative to 1995 are probably more useful (Figure 3).
18. Figure 3 shows that the decline in demand for low-skilled labour was felt most strongly in Japan, and among the large economies in Europe in France and the United Kingdom. Germany hardly lost low-skilled jobs. The demand for medium-skilled labour grew fastest in Brazil, followed by Australia and Indonesia. The relative growth in employment of high-skilled labour was fastest in China, but growth rates in the EU were considerably higher than in the United States and Japan.

19. How did employment in sectors contribute to these changes at the total economy level? We have studied changes in skills demand for two industry groupings (see Appendix B). Figure 4a shows how the broad sectors defined as those in the most aggregated classification scheme (Aggregation scheme 1 in Appendix B) contributed to the change in total economy demand for low-skilled labour. For all countries included, natural resources industries (agriculture and mining) used less low-skilled labour over time. In manufacturing, China and India were the only two countries that experienced an increase in the demand for labour. Other industries (construction and public utilities) employed more low-skilled labour in 2008 than in 1995 in the emerging and natural resources-rich countries, but less low-skilled labour elsewhere. Business services contributed positively in all advanced countries, but did not mean much for total changes in low-skilled labour demand in the emerging countries. With the exceptions of Germany and Australia, other services employed less low-skilled workers in 2008 in advanced countries, but considerably more in emerging countries.
Figure 4a. Contributions of broad sectors to change in demand for low-skilled labour (1995-2008)

Source: Authors’ calculations on World Input-Output Database (November 2013 release).

N_RES: Natural resources industries; MAN: Manufacturing industries; OTH_I: Other industries; BUS_S: Business services industries; OTH_S: Other services industries.

Figure 4b. Contributions of broad sectors to change in demand for high-skilled labour (1995-2008)

Source: Authors’ calculations on World Input-Output Database (November 2013 release).

N_RES: Natural resources industries; MAN: Manufacturing industries; OTH_I: Other industries; BUS_S: Business services industries; OTH_S: Other services industries.

20. Figure 4b shows that the growth in high-skilled jobs has predominantly taken place in other services. Especially in advanced countries, though, about 20% of the high-skilled job growth took place in
the business services industries. In Indonesia and India the natural resources sector contributed much more than in other countries. The manufacturing sector has been relatively unimportant as a growing employer of high-skilled labour.

21. To what extent have the six proximate sources of change introduced in Section 2 contributed to changes in skills demand between 1995 and 2008? To this end, we employ our structural decomposition analysis, the details of which are set out in Appendix A. Figure 5a illustrates the results for the total economy of the EU15, while Figure 5b refers to the market economy.

**Figure 5a. Six-effects decomposition of changes in demand for skills (in 000s of jobs), 1995-2008, EU15, total economy**

![Graph showing six-effects decomposition for total economy](image)

Source: Authors’ calculations on World Input-Output Database (November 2013 release).

**Figure 5b. Six-effects decomposition of changes in demand for skills (in 000s of jobs), 1995-2008, EU15, market economy**

![Graph showing six-effects decomposition for market economy](image)

Source: Authors’ calculations on World Input-Output Database (November 2013 release).
22. The grey parts of the bars give the skills employment in 1995, and the six coloured bars relate to the sources of change between 1995 and 2008. As a consequence, the lengths of the bars to the right of the vertical axis minus the lengths of the bars to the left of the vertical axis represent skills employment in 2008. The changes in consumption levels effect has been the major contributor to growth of employment in the EU15, for all skills. It should be stressed that this effect is not only due to growth in consumption in the EU15 itself, but is also fostered by the increasing demand by consumers (and investors) in the emerging countries. Changes in efficiency also account for more employment: labour productivity in the EU15 grew slower than in the United States, as a consequence of which an equal input of efficiency units required more jobs. These two effects led to positive employment growth for mediums-skilled and high-skilled workers, but were not sufficient to compensate for the downward pressure exerted by the other effects for low-skilled labour. The effects of improvements in GSC-technology in particular have left their marks for this skills group. The skill bias in technological change within GSCs is very apparent: while this effect considered in isolation would have led to higher employment of high-skilled labour, lesser-skilled workers would have faced lower employment. The relocation of both intermediate and final stages of production also contributed to the decrease in low-skilled employment.

23. The tendencies sketched for the total EU15-economy are also clearly reflected in the results for the market economy of the EU15. The relative importance of changes in the location of stages of production is larger, however. While we estimate that roughly 80% of the economy-wide losses in LS-employment as a consequence of GSC-technology took place in the market economy, these percentages amount to as much as 98% and 99% for the LS-job losses due to changes in the location of intermediate production stages and changes in the location-of-completion, respectively. These results reflect the fact that many nonmarket services can only be produced in the country were consumption takes place.

24. After having illustrated results for the detailed six-factor structural decomposition for the EU15 economy, we now turn to comparisons of results for several countries, within and outside the EU. From this stage onwards, we will present results based on the three-factor aggregation of decomposition results outlined in Section 2: To what extent have “technological change”, “changes in trade” and “changes in consumption” been responsible for the changes depicted in Figures 2-4? Table 1 gives results for the total economy.

25. If everything else would have remained equal, technological change would have led to a reduction of the total number of jobs in all countries. It has been skill-biased though. With the exception of the United States, China and India, high-skilled employment would have grown, even if technological change would have been the only source of change. For all countries, these effects on high-skilled labour would have been dwarfed by huge reductions in the demand for low-skilled and medium-skilled jobs (in the United States, more than 80% of the reduction in total jobs would have been medium-skilled jobs, whereas in the EU15 most of the jobs lost would have been low-skilled jobs).

26. If only patterns of international trade would have changed, emerging countries would have seen substantial increases in total jobs, while the advanced countries would have seen reductions. In China, the creation of more than 200 millions of jobs can be attributed to changes in trade patterns. In the EU15, about 6.5 millions of low-skilled jobs were lost due to changes in trade, while roughly 4.7 millions of medium-skilled jobs in the United States can be considered as having been traded away.

27. Changes in consumption have led to increases in the demand for jobs of all skills levels. For Japan, however, the positive effect has been almost negligible with respect to low-skilled employment. Together with China, Japan is the only country for which the increase in total jobs as a consequence of consumption change has not been sufficient to compensate for the loss of total jobs as a consequence of technological change.
Table 1. Contributions of determinants to changes in skills demand (total economy)

<table>
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<th>skill</th>
<th>technology</th>
<th>trade</th>
<th>consumption</th>
<th>total</th>
<th>total(%)</th>
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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
28. Assessing the relative importance of the three sources of change in more general terms, our results show that changes in technology have been the most important driver of differences in the growth rates of demand for skills in advanced countries. These have in general been reinforced by changes in trade patterns, to an extent that is far from non-negligible. Consumption growth (combined with changes in the composition of consumption) has had a positive effect on demand for all skills, but these positive effects have not been substantial enough to keep the number of low-skilled jobs at a stable level over the 1995-2008 period. In most emerging countries, changes in consumption have led to high employment growth, as a consequence of which the net effects of consumption change and technological change have often been positive. The favourable employment effects of changes in trade patterns were only substantial in China, and much smaller in the other emerging countries studied here (and even negative in India).

29. So far, results have been presented for total economies. Figures 4a and 4b showed that the numbers of workers did not change evenly across broad sectors in most countries, over the 1995-2008 period. Tables 2 and 3 present the decomposition results for changes in employment of skills for manufacturing and market services separately (note that Appendix B contains sets of results for finer-grained industry-aggregates).

30. For employment in manufacturing, we find that changes in technology and trade both have contributed substantially to the decline in LS-employment. These effects also exerted a downward pressure on MS-employment. For HS jobs, we find that about two-thirds of the employment-reducing effects of trade were offset by an upward effect of technology, which gives more prominence to the skill-biased technological change hypothesis. A closer look at the three major EU15-countries for which we separately report results shows that the UK-workers suffered considerably more from trade effects than workers in France and Germany. Nevertheless, the loss of MS- and HS-employment in German manufacturing due to trade effects is noticeable.

31. All skill types of workers in the United States and Japan faced downward pressures on their employment from both technical change and trade effects. In the United States, the technology effects were almost three times as large as the trade effects, both for LS-labour and MS-labour. In Japan, the impacts were much more asymmetric. The trade effect was much less important for MS-workers in manufacturing than for LS-workers in the same sector. The employment-enhancing effects of changes in consumption were not sufficient to compensate for the employment-reducing effects of technology and trade, which mainly represents the sluggish growth of consumption and investment demand in Japan itself.

32. For Brazil, China and Indonesia, we find upward effects of trade on total employment in the manufacturing industry, while this effect has a minus sign for India. While all skill categories experienced higher employment levels due to trade in China and Indonesia, the effects for China were much stronger. In Brazil, trade did not benefit the demand for LS-labour in manufacturing.

33. Turning to market services in the EU15, we find very unevenly distributed effects of technology again. Employment of HS-workers increased substantially, while technological progress would have reduced employment of MS-labour and LS-labour if trade and consumption effects would have been zero. This pattern is not only found for the EU15 as a whole, but can also be observed for the three major economies in this region separately (with the exception of LS-labour in Germany). A much less homogeneous pattern is found for the effects of trade. British and French employment in market services was hit by trade, while employment in German services was positively affected by changing trade patterns. Germany seems to be a non-typical EU15 country in this respect. Except for low-skilled labour in France’s and the United Kingdom’s services sector, the employment-enhancing effects of growing consumption inside and outside the EU15 have been sufficiently sizable to ensure positive growth rates of market services employment in its economically most important countries.
Table 2. Contributions of determinants to changes in skills demand (manufacturing)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
## Table 3. Contributions of determinants to changes in skills demand (market services)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Results for the United States again show that LS-labour and MS-labour faced more or less similar adverse employment effects of changing technology and trade, while the downward pressure of these sources of change were substantially less marked for HS-labour (in particular regarding technology effects). For Japanese market services, consumption change was too sluggish to prevent a loss in jobs for low-skilled workers of more than 50%. In China and India, HS-employment in market services grew considerably, not only due to upward consumption effects, but also as a consequence of favourable effects of changes in trade patterns. These effects were also present for LS-workers and MS-workers, but to a lesser extent.

5. Conclusions

This paper uses data from the WIOD database to quantify the contributions of changes in

(i) technology;

(ii) trade; and

(iii) consumption to changes in employment levels of high-skilled, medium-skilled and low-skilled labour in a number of sectors in various countries. The World Input-Output Tables allow us to view the world economy as a network of Global Supply Chains. Technological change affects the factor requirements per unit of output of these chains. To pay justice to this view, we developed a new concept of technological change which is not defined for national industries as is usually done, but for GSCs themselves. Furthermore, changes in the location of the production of raw materials, parts and components as well as final products have an impact on employment levels in countries (and industries within these countries). Finally, changes in the composition and volume of national consumption bundles have effects on the relative sizes of GSCs and therefore on the amount of skills demanded in countries contributing to GSCs.

Using our new decomposition method, we find that skill-biased technological change is the main culprit regarding downward pressures on employment of low-skilled and medium-skilled workers in advanced countries in 1995-2008. Relocations of stages of production (both of intermediate stages and the final stage) add significantly to this effect. The demand for high-skilled labour suffered much less from the consequences of technological change. Growth of consumption and investment demand (both in the advanced countries themselves and in emerging countries) had employment-enhancing effects. In many cases, these consumption effects were sufficiently large to make employment growth positive, but not always.

For emerging countries, we found heterogeneous patterns. While the analysis for China yielded particularly strong upward effects of trade changes in manufacturing employment, we found employment-reducing effects for Indian manufacturing (for all skill levels). India, however, appeared to have benefited from trade in generating employment in the broad market services sector.

The approach chosen in this paper might lead to further research. First, the structural decomposition analysis can be improved by not comparing 1995 and 2008 directly, but by chaining decomposition results obtained for annual changes. Second, it might be interesting to see to what extent domestic outsourcing has contributed to changes in employment patterns. In the current analysis, we implicitly assumed that all manufacturing workers carried out manufacturing tasks, while outsourcing services tasks to specialised suppliers might have increased over the 1995-2008 period. If so, this phenomenon might have affected the numbers appended to our concept of GSC-technology, since services firms tend to have input combinations that differ from those of manufacturing companies. Thirdly, and related to this, the identification of Global Supply Chains on the basis of global input-output tables can become much more accurate if these would explicitly contain information on the production processes and destinations of the output of firms that produce for domestic markets and of firms producing for foreign markets. Based on non-public data, Chen et al. (2012) show that evaluations of the Chinese export performance are affected considerably if a split between production for processing exports, regular exports and domestic use is made. Given the importance of specific processing exports activities in China, the results for other countries would most probably be revised to a lesser extent, but it would still be worthwhile to try to construct global input-output tables that contain such disaggregations.
REFERENCES


APPENDIX A: TECHNICAL DETAILS

1. We distinguish between low-skilled labour (LS, primary education and/or lower secondary education completed, 1997-ISCED 1 and 2), medium-skilled labour (MS, upper secondary education and/or post-secondary non-tertiary education completes, ISCED 3 and 4) and high-skilled labour (completed tertiary education (ISCED 5 and 6). Our point of departure is that effects of globalization (as a consequence of which an industry in a country does not necessarily stay engaged in the same activities needed to produce a unit of final product), skill-biased technological change, the evolution of compositions of consumption bundles and differential consumption growth rates translated into changes in the demand for labour of a particular skill group. To disentangle these effects, we use “World Input-Output Tables” (WIOTs) and associated employment by skill group figures that were constructed in the WIOD project (see Timmer (ed.), 2012). The accounting method we adopt is known in the input-output literature as “Structural Decomposition Analysis” and bears similarity to more widely known index number approaches (see Miller and Blair, 2009).

2. We suppose that the use of labour inputs is driven by demand. For any period, the scalar $x_i$ (which stands for the employment of skill group $i$ in the focal country) can be written as

$$x_i = u_k^i I_i q$$  \hspace{1cm} (1)

3. The diagonal matrix $I_i$ contains the quantities of labor requirements of skill type $i$ per unit of (gross) output in each of the $n$ industries in each of the $m$ countries. The $mn$-vector $q$ stands for (gross) output levels in each of the industries in each of the countries. $u_k$ is a $mn$-“selection vector”. It contains ones in the cells associated with the industries in the focal country. All other elements of $u_k$ are zero.

4. Following Leontief’s (1936, 1941) insights, output can be seen as the result of the interplay between final demand levels (demand for final consumer products and capital goods) and the intermediate inputs required to produce these final products. In input-output tables for a single country, exports are considered to belong to final demand for the focal country as well. Intercountry input-output tables such as those compiled in the WIOD project allow for a distinction between exports of final products (such as consumer electronics exported by China to the United States) and exports of intermediate products (such as electronic components exported by Japan to be used in assembly activities in China). This feature enables us to link all output (and employment) to demand for specific final products, sold by industries either inside or outside the focal country. Timmer et al. (2013) label this approach the “Global Value Chain perspective”.

5. Denoting the number of countries in a WIOT by $m$, we define $Z$ as the $mnxmn$-matrix that contains all domestic and international deliveries of intermediate inputs. The corresponding $mnxmn$-matrix $A$ of intermediate inputs requirements per unit of gross output can be obtained as $A = Zq^{-1}$. The fact that the production of intermediate inputs often requires intermediate inputs itself is taken into account if the so-called $mxmn$-“Leontief inverse” is considered. The typical element $b_{ij}$ of this matrix $B = (I - A)^{-1}$, in which $I$ stands for the $mnxmn$-identity matrix, indicates the output of each industry $i$ that is required per unit of final demand for the products delivered by industry $j$. We can thus rewrite Equation (1) as:

$$x_i = u_k^i I_i B f$$  \hspace{1cm} (2)

10. A hat (e.g. $\hat{y}$) indicates a diagonal matrix, with the elements of the vector $y$ on the diagonal.
in which \( f \) is an \( mn \)-vector with final demand levels for each of the \( n \) products delivered by each of the \( m \) countries.

6. In what follows, we will specify three determinants of intertemporal changes in \( x_i \) that affect the product \( \mathbf{I}^\prime \mathbf{B} \) and three determinants that affect \( f \). The former effects relate to changes within global value chains, whereas the latter are associated with changes in the relative weights of global value chains.

7. We first look at demand for final products and trade in final products. We consider three sources of change in \( f \). First, total final demand as exerted by countries can change. Second, the composition of consumption bundles can change. If consumption demand in China grows faster than consumption demand in Japan, it is likely that product-specific income elasticities will also imply that the Chinese consumption bundle will change faster than its Japanese counterpart. Finally, market shares of countries in selling final products might change over time. Relocation of electronics assembly activities in the United States to China will imply that market shares of Chinese final electronics products will increase at the expense of market shares of American final electronics products will be reduced. These three factors can be incorporated into the analysis by expressing the final demand vector as:

\[
f = \mathbf{T}^\ast (\mathbf{S}^\ast \cdot \mathbf{c}) \mathbf{u}
\]

\( c \) is an \( m \)-vector. It’s typical element \( c_i \) contains total final demand exerted by country \( i \). \( \mathbf{S}^\ast \) is an \( mn \times mn \)-matrix constructed by stacking \( m \) identical \( nxm \)-matrices of final demand shares for each of the \( n \) outputs. The rows of the \( nxm \) matrices that together form \( \mathbf{S}^\ast \) are obtained by aggregating over final goods supplied by each of the trade partners: if German consumers would spend 0.1 of their total consumption on German food and 0.05 of their total consumption on French food, the share of food in German consumption would amount to 0.15. \( \mathbf{T}^\ast \) is an \( mn \times mn \)-matrix of final product trade coefficients. It is constructed by stacking \( mn \times mn \)-matrices \( \mathbf{T} \), of which the typical element \( t_{ij} \) represents the share of the country considered in final demand for product \( i \) in country \( j \). \( \mathbf{u} \) is an \( m \)-elements summation vector consisting of ones.

8. Equation (3) indicates how three factors together determine the relative importance of \( mn \) global value chains, a global value chain being defined as all activities required to produce the final product of an industry in a country. If skill-specific labour requirements would vary across global value chains, changes in relative importance of these chains could lead to changes in the relative demand for particular skills. Within such global value chains, however, (skill-biased) technological change and changes in the type of activities countries specialize into can also lead to differences in the amounts of labour of various skills that are deployed in the focal country. If Italy would contribute substantially to the value chain that ultimately produces British food products and the low-skilled labour requirements within this chain would decrease rapidly as a consequence of technological change, Italian low-skilled employment would decline, all other things equal. Alternatively, Italy could experience changes in the part of the value chain for British food products that it captures. Initially, it could contribute agricultural activities only, while Italy might also become responsible for some of the food processing activities in a later period. Generally, such changes also lead to changes in the extent to which labour of various skills is employed in the focal country.

9. If the production of final products is a fragmented process organized in (global) value chains, the \( mn \)-vector \( \mathbf{l}_i^w \equiv \mathbf{l}_i^\prime \mathbf{B} \) gives a more appropriate measure of the techniques used to produce final products. \( \mathbf{l}_i^w \) gives the worldwide inputs of labour of skill group \( i \) used to produce one unit of each of the \( mn \) final products for the ultimate consumer. The symbol \( \circ \) stands for the “Hadamard product”, obtained by cell-by-cell multiplication (i.e. \( W = X \circ Y \) means that \( w_{ij} = x_{ij} y_{ij} \), for all \( i \) and \( j \)).

\[11\]
products, irrespective of the location of the activities required. Changes in $l^w_i$ would only reflect skill-biased technological change if labour of a skill group would be equally productive across regions. Loosely speaking, if the productivity of an HS-worker in country A would be double that of a worker in country B and an HS-intensive activity would be relocated from A to B, we would observe technological change biased towards HS. To correct for this, we introduce an $mn$-productivity vector $\pi$, the typical element of which contains the industry-specific labor productivity levels of labor relative to levels in the United States. This allows us to specify a global value chain’s technology in terms of labour measured in efficiency units, $l^*_i = (\pi \cdot l^w_i)^B$.

10. It is important to note that the values in the cells of the matrix $B$ are not only determined by the technical production requirements in terms of intermediate inputs, but also by the shares of these intermediate inputs delivered by each of the potential countries-of-origin. As a consequence, some industries in some countries will employ more labour of a given skill group than expected on the basis of $l^*_i$, while others will employ less. Since a WIOT represents $mn$ industries in which labour is employed and $mn$ global value chains to which this labour contributes, we can compute an $mn \times mn$-matrix with shares of each of the $mn$ industries in total employment of skill type $i$ per unit of final demand produced by a global value chain. Rows correspond to industries of employment, columns correspond to the global value chains to which labour of type $i$ contributes:

$$R_i = \{\tilde{n}_i B\}^{i-1}_i$$

(4)

11. Finally, demand for labour of a skill group in the focal country as measured in numbers of jobs is affected by labour productivity relative to the United States. Given global value chain technologies and the specific activities in the chains performed in the focal country, higher productivity levels lead to lower demand.

12. Writing $\hat{I}_i B = \tilde{n}^{-1} R_{i0} \hat{I}_i^*$ and substituting Equation (3) into Equation (2), we can express the employment of skill type $i$ in period 0 in the focal country as:

$$x_{i0} = u_k \tilde{n}_0^{-1} R_{i0} \hat{I}_i^*[T_0^*(S_0^* \cdot \hat{c}_0)]u$$

(5)

$X_{i1} - X_{i0}$ (the difference between demand for a skill at two points in time) can be written as:

$$x_{i1} - x_{i0} = u_k' \tilde{n}_1^{-1} R_{i1} \hat{I}_1^*[T_1^*(S_1^* \cdot \hat{c}_1)]u - u_k \tilde{n}_0^{-1} R_{i0} \hat{I}_0^*[T_0^*(S_0^* \cdot \hat{c}_0)]u =$$

$$u_k' (\tilde{n}_1^{-1} - \tilde{n}_0^{-1}) R_{i1} \hat{I}_1^*[T_1^*(S_1^* \cdot \hat{c}_1)]u +$$

$$u_k' \tilde{n}_1^{-1} (R_{i1} - R_{i0}) \hat{I}_1^*[T_1^*(S_1^* \cdot \hat{c}_1)]u +$$

$$u_k' \tilde{n}_1^{-1} R_{i0} (\hat{I}_1^* - \hat{I}_0^*) [T_1^*(S_1^* \cdot \hat{c}_1)]u +$$

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$$u_k' \tilde{n}_0^{-1} R_{i0} (T_0^* - T_0^*) [T_0^*(S_0^* \cdot \hat{c}_0)]u +$$

12. The elements of $\pi$ can change over time, but are assumed to be identical across skill groups.

13. For ease of exposition, we did not include indices for time periods in the matrix algebra above.
13. As mentioned above, we identified six determinants of changes between initial period 0 and final period 1 in the domestic demand for skill group \( \text{i} \), related to changes within global value chains and the relative weights of these chains. We isolate the partial effects of these determinants, assuming that the other five partial effects were zero.

14. Equation (6a) represents the changes in domestic demand for labour of skill type \( \text{i} \) that can be attributed to productivity catch-up to the United States (changes in efficiency). Equation (6b) gives the employment of skill group \( \text{i} \) in the focal country in the final year if only the shares of global value chains as captured by countries would have changed (changes in location-of-intermediate stages). In a similar vein, (6c) shows what would have happened if the only technological change within global supply chains would have been the only source of change (changes in GSC technology). (6d) indicates the demand in period 1 for the counterfactual case in which market shares of global value chains would have changed, but everything else would have remained stable (changes in location-of-completion). Equation (6e) isolates the effects of changes in consumption patterns (changes in consumption composition), while (6f) focuses on the effects of differential rates of consumption growth in the \( m \) countries considered (changes in consumption levels). The changes regarding the composition and levels of consumption also include the effects of changing patterns and levels of investment demand.

\[
\mathbf{u}_k \mathbf{n}_0^{-1} \mathbf{R}_{\text{i0}} \mathbf{\hat{i}} \mathbf{I}_{\text{i0}} \mathbf{T}_0 \mathbf{S}_0 \cdot (\mathbf{c}_1 - \mathbf{c}_0) \mathbf{u} \tag{6f}
\]

14. The decomposition as represented by Equations (6a-f) is not unique, since weights can be chosen differently (see Dietzenbacher and Los, 1998). The results presented in the report have been obtained as the arithmetic average over (6a-e) and its so-called polar form, in which all initial year weights in (6a-e) have been replaced by final year weights and the other way round.
APPENDIX B

1. This appendix presents the decomposition results for two aggregation schemes. In each of these, the 35 WIOD-industries have been merged in broader sectors. Sums over the sectors in each aggregation scheme thus equal the results for the total economy, as presented in Table 1 in the main text. Aggregation scheme 1 splits the total economy in 5 broad sectors, aggregation scheme 2 contains 11 sectors.

2. The decomposition results for Aggregation scheme 1 have been documented in Tables B.1a-e, those for Aggregation scheme 2 in Tables B.2a-k.

Table B.1a. Contributions of determinants to changes in skills demand (natural resources)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.1b. Contributions of determinants to changes in skills demand (manufacturing)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.1c. Contributions of determinants to changes in skills demand (other industry)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.1e. Contributions of determinants to changes in skills demand (other services)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.2a. Contributions of determinants to changes in skills demand (agriculture)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.2b. Contributions of determinants to changes in skills demand (mining)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.2c. Contributions of determinants to changes in skills demand (food manufacturing)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
### Table B.2d. Contributions of determinants to changes in skills demand (other nondurables manufacturing)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.2e. Contributions of determinants to changes in skills demand (refining; chemicals manufacturing)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.2f. Contributions of determinants to changes in skills demand (machinery and metal prods. manuf.)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.2h. Contributions of determinants to changes in skills demand (transport equipment manuf.)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.2i. Contributions of determinants to changes in skills demand (other industry)

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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
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Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
Table B.2k. Contributions of determinants to changes in skills demand (nonmarket services)

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<td>-789</td>
<td>-7.5</td>
</tr>
<tr>
<td>h</td>
<td>-4,414</td>
<td>72</td>
<td>8,778</td>
<td>4,436</td>
<td>62.9</td>
</tr>
</tbody>
</table>

Source: Authors’ calculations on World Input-Output Database (November 2013 release). Numbers of jobs are in 000s, percentage growth rates are expressed relative to skills demand in 1995.
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