**Job Dynamics and Global Supply Chains**

Bart Los a

Robert Stehrer b

Marcel P. Timmer a

Gaaitzen de Vries a

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**Affiliations**

a Groningen Growth and Development Centre, Faculty of Economics and Business, University of Groningen.

b Vienna Institute for International Economic Studies.

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**Abstract**

In this paper we propose a new method to analyse the changing structure of employment in advanced countries based on a modelling of the input-output structure of the world economy. Demand for jobs, characterised by skill type and sector of employment, is driven by changes in technology, trade and consumption. Using a structural decomposition technique we analyse the relative importance of these drivers in 21 advanced countries for the period 1995-2008. We derive a new measure of technological change in vertically integrated production chains and show that it is skill-biased.

 For the advanced region as a whole, technological change would drive down overall employment by 57 million, keeping other drivers constant. Increasing trade in intermediate and final products would lead to an additional loss of 31 million jobs. But the effects are highly uneven across skill-types. For low-skilled (LS) and medium-skilled (MS) jobs technological change and trade would contribute to a decline of 69 and 29 million. This was counterbalanced by increasing global consumption as the number of LS and MS jobs increased by 4 million. Changes are more dramatic for LS and MS workers in manufacturing as their employment declined by 13 million, for two-third due to global technological change, confirming the “routinezation” hypothesis. In addition technological change in global supply chains was skill-biased contributing positively to demand for high-skilled (HS) jobs in the economy with only a minor negative effect of trade. Also changes in global consumption added substantially to HS job demand, in particular outside the manufacturing sector.

**Introduction**

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 hypothesized as 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.[[1]](#footnote-1) 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.[[2]](#footnote-2) 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, Dorn and Hanson, 2012).

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, Vogel and Wang (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 that are important exporters to advanced countries.

The most important contribution of this paper is to provide an estimate a conceptual framework for analysing changes in the demand for jobs in advanced nations through a modelling of 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 in advanced countries, 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 21 advanced countries for the period 1995-2008. The methodology used is akin to the one used in the context of measuring vertical specialisation (Hummels, Ishii and Yi, 2001) and trade in value added (Johnson and Noguera, 2011, Trefler and Zhu, 2010).

The paper is organised as follows. In section 2 we provide a descriptive analysis of the major changes in employment structures. A simple example of a global supply chain (GSC) is given in an illustration of the decomposition method. The decomposition method is formally introduced in section 3. We first model changes in skill use within a particular GSC chain conditional on its output, and then seek to model the demand for each GSC’s output. By seperating these two effects we can get a clearer estimate of the effects of technology and trade on labour demand, as in Goos, Manning and Salomons (2012). Section 4 describes the data.We then evaluate to what extent the changes in jobs per skilltype and country can be explained by each of the different channels affecting labour demand in section 5. Section 6 concludes.

**2. The Intuition: Jobs in the Global Supply Chain for German Cars**

The ideas behind the analysis of the consequences of changing trade patterns, technological progress and shifts in consumption demand can best be explained by means of an example. We consider the global supply chain for German transport equipment products[[3]](#footnote-3) and analyse the changes in the number and geographical location of jobs related to this production chain. The German car industry provides a vivid example of the strong processes of outsourcing (of manufacturing activities to domestic non-manufacturing), and of off-shoring (moving activities out the domestic economy

The German car industry sells both products that are used as intermediate inputs (e.g. parts and components) and final products that are sold to consumers and firms that use these as capital goods. We define the latter type of products as the output of the (global) supply chain for German cars. To produce these final products, the German car manufacturing industry employs labour. The essential aspect of our supply chain perspective is the fact that upstream industries also use labour that is required to enable the German car industry to produce cars.[[4]](#footnote-4) Examples are the electrical and optical equipment industry, the metal products manufacturing industry, the basic metals industry and the mining industry that produces the iron ore that goes into steel. If supplier-users transactions would mainly occur between industries in the same country, the term “*global* supply chain” would not be appropriate. Recently supply chains have recently become much more international, described as the “second wave of unbundling” (Baldwin, 2006). Companies set up subsidiaries in distant countries to benefit from locational advantages with regard to specific production processes, or subcontract these activities to foreign firms. As a consequence, demand for cars assembled in Germany does not only induce employment in Germany itself, but also in various industries in other countries.

International input-output tables as recently constructed within the World Input-Output Database (WIOD) project allow for quantification of the labour inputs that can be attributed to final demand for German cars.[[5]](#footnote-5) Such an international input-output table contains systematic information on the intermediate input requirements per unit of output for each industry in each country covered by the table. It also contains information on the countries-of-origin of these intermediate inputs and a detailed account of the value of final products delivered by each of the industries in each of the countries, by country-of-destination and use category (i.e., household consumption, government consumption, gross fixed capital formation, etc.). Since the WIOD database also contains information about labour inputs by skill category for the same set of industries and countries, it is possible to use relatively simple input-output analyses to account for changes in employment patterns in the global supply chain for German cars.

*Job Dynamics: Descriptives*

Figure 1 depicts patterns of labour inputs associated with the production of German cars, for 1995 and 2008.

**Figure 1: Numbers of jobs in the global supply chain for German transport equipment (in thousands)**



Source: Authors’ elaborations on WIOD Database, April 2012 release. EU15 does not include Germany (DEU). E-Asia includes Japan, South Korea and Taiwan.

It shows that the worldwide number of jobs involved in the production of German cars has increased from about 2.6 million to slightly more than 4.6 million, over the pre-crisis period of 13 years. The geographical distribution of this 75% increase has been very uneven, however. In Germany (DEU) itself, the number of jobs grew by just 27%, while the number of jobs in the countries that recently accessed the EU (EU12), China (CHN) and the Rest of the World (RoW) grew by 87%, 220% and 133%, respectively. Consequently, the share of German jobs in all jobs in this supply chain decreased from 51% to 37%.

Figure 2 (which focuses on jobs in the “old” EU-15) depicts a different type of marked change in the global supply chain for German cars between 1995 and 2008. While the number of manufacturing jobs remained virtually stable at one million, the number of non-manufacturing jobs grew from 585 thousand to just over a million. The workers in these sectors were all producing intermediate inputs for the German car manufacturing industry, or to suppliers of other intermediate input suppliers. In Germany itself, the number of jobs in manufacturing decreased not only in relative terms, but even in absolute terms, a clear indicator of a strong outsourcing process.

Finally, Figure 3 gives an impression of the changing skill content of the EU15-jobs for this global supply chain. Low-skilled labour in the EU15 did not benefit from the overall increase in jobs (+4% over the period 1995-2008), while medium-skilled labour and high-skilled labour experienced increases in numbers of jobs of 28% and 67%, respectively.

**Figure 2: Manufacturing jobs vs. non-manufacturing jobs in the global supply chain for German transport equipment, EU15 (in thousands)**



Source: Authors’ elaborations on WIOD Database, April 2012 release. EU15 does not include Germany.

**Figure 3: Jobs by skill group in the global supply chain for German transport equipment, EU15 (in thousands)**

Source: Authors’ elaborations on WIOD Database, April 2012 release. EU15 does not include Germany. HS: high-skilled; MS: medium-skilled; LS: low-skilled.

Figures 1-3 show that job dynamics within the global supply chain for German transport equipment have been strong, in many respects. The EU15 in general and Germany itself in particular benefited only to a minor extent from the increase in global employment associated with demand for German cars. The shares of sectors in this EU15-employment also changed substantially, with more and more people working in non-manufacturing industries, while employment in manufacturing did not grow. The degree to which the skill composition of the jobs in the EU15 changed in a relatively short period is also remarkable, with low-skilled employment stagnating and medium-skilled and especially high-skilled labour gaining considerably.

*Job Dynamics: Quantifying Contributions of Sources of Change*

In the next section of the paper, we present our framework to account for changes as discussed above in mathematical terms. Here we provide the basic intuitions. The point of departure is the notion that changes in employment in a country, in an industry and/or of a skill group within a supply chain can be due to two broad types of change: (i) change in the worldwide demand for the output of the chain, and (ii) change in labour requirements per unit of output of the global supply chain. Changes in demand for output of the supply chain (“size” effects) will, ceteris paribus, only lead to proportional changes in employment by job type or location of employment. On the other hand, changing labour requirements per unit of global supply chain output are not necessarily neutral. Such “within” effects account for the changes in shares of countries, sectors and skill groups as depicted in Figures 1-3.

In our analytical framework, we distinguish between three types of within effects: technological change, offshoring and productivity catch-up. First, the effects of *off-shoring* of activities are measured based on the changes in the shares of intermediate inputs from various countries. If Germany offshores particular activities to other countries, this will lead to a lower use of German labour, ceteris paribus. Second, *technological change* within the global supply chain is considered. We define the global supply chain technology as the quantities of labour of a particular skill type required per unit of output of the supply chain. This includes all labour involved, irrespective of the country of location. Labour is measured in efficiency units, expressed in US-equivalents based on relative labour productivity differences. An increase in technology will lead to a lower demand for jobs, ceteris paribus. The technology can be biased to the extent that the reduction in jobs can differ across skill-types. Thirdly, the productivity of labour in a particular country can increase relative to the US (so-called *catch-up*). If this is the case, the demand for jobs in this country will decline, ceteris paribus.

 We distinguish three size effects that have no impact on the labour demand in a particular global supply chain, but will have an impact on size of output of the various supply chains in the world. The first effect is related to *import competition* and measures the change in jobs of a particular country due to shifts in the shares of this country in satisfying global demand for a particular product. The second effect is an *Engel effect*, measuring the effects of a change in the structure of global demand in terms of products. The third effect is a *country demand effect* that measures the effects of changes in the final demand levels for all products in each country.

**3. Methodology**

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, 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).

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

*xi* = $u\_{k}^{'}\hat{l}\_{i}$**q** (1)

The diagonal matrix $\hat{l}\_{i}$ 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.[[6]](#footnote-6) 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.

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 US) 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. (2012) label this approach the “Global Value Chain perspective”.

Denoting the number of countries in a WIOT by *m*, we define **Z** as the *mn*x*mn*-matrix that contains all domestic and international deliveries of intermediate inputs. The corresponding *mn*x*mn*-matrix **A** of intermediate inputs requirements per unit of gross output can be obtained as $A=Z\hat{q}^{-1}$. The fact that the production of intermediate inputs often requires intermediate inputs itself is taken into account if the so-called *mn*x*mn*-“Leontief inverse” is considered. The typical element *bij* of this matrix **B** ≡ (**I** – **A**)-1, in which **I** stands for the *mn*x*mn*-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 (3) as

*xi* = $u\_{k}\hat{l}\_{i}$**Bf** (2)

in which **f** is an *mn*-vector with final demand levels for each of the *n* products delivered by each of the *m* countries.

In what follows, we will specify three determinants of intertemporal changes in *xi* that affect the product $\hat{l}\_{i}$**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 (*mix* effects).

We first look at demand for final products and trade in final products, which together define the mix effects. 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 US 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[[7]](#footnote-7)

$f=\left[T^{\*}°\left(S^{\*}∙\hat{c}\right)\right]u$ (3)

**c** is an *m*-vector. Its typical element *ci* contains total final demand exerted by country *i*. **S\*** is an *mn*x*m*-matrix constructed by stacking *m* identical *n*x*m*-matrices of final demand shares for each of the *n* outputs. The rows of the *n*x*m* matrices that together form **S\*** 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. **T\*** is an *mn*x*m*-matrix of final product trade coefficients. It is constructed by stacking *m* *n*x*m*-matrices **T**, of which the typical element *tij* represents the share of the country considered in final demand for product *i* in country *j*. **u** is an *m*-elements summation vector consisting of ones.

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.

If the production of final products is a fragmented process organized in (global) value chains, the *mn*-vector **l***iw***’**≡ **l***i***’B** gives a more appropriate measure of the techniques used to produce final products. **l***iw* gives the worldwide inputs of labour of skill group *i* used to produce one unit of each of the *mn* final products, irrespective of the location of the activities required. Changes in **l***iw* 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 $π$, the typical element of which contains the industry-specific labor productivity levels of labor relative to levels in the US.[[8]](#footnote-8) This allows us to specify a global value chain’s technology in terms of labour measured in efficiency units, **l***i\****’**≡ ($π°$**l***i*)**’B**.

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*x*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:

$R\_{i}=\left\{\hat{π}\hat{l}\_{i}B\right\}\hat{l}\_{i}^{\*}^{-1}$ (4)

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 US. Given global value chain technologies and the specific activities in the chains performed in the focal country, higher productivity levels lead to lower demand.

Writing $\hat{l}\_{i}B=\hat{π}^{-1}R\_{i}\hat{l}\_{i}^{\*}$ and substituting Equation (3) into Equation (2), we can express the employment of skill type *i* in period 0 in the focal country as[[9]](#footnote-9)

*xi0* = $u\_{k}^{'}\hat{π}\_{0}^{-1}R\_{i0}\hat{l}\_{i0}^{\*}\left[T\_{0}^{\*}°\left(S\_{0}^{\*}∙\hat{c}\_{0}\right)\right]u$(5)

*xi1*- *xi0* (the difference between demand for a skill at two points in time) can be written as:

*xi1*- *xi0* = $u\_{k}^{'}\hat{π}\_{1}^{-1}R\_{i1}\hat{l}\_{i1}^{\*}\left[T\_{1}^{\*}°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$ - $u\_{k}\hat{π}\_{0}^{-1}R\_{i0}\hat{l}\_{i0}^{\*}\left[T\_{0}^{\*}°\left(S\_{0}^{\*}∙\hat{c}\_{0}\right)\right]u$=

$u\_{k}^{'}\left〈\hat{π}\_{1}^{-1}-\hat{π}\_{0}^{-1}\right〉R\_{i1}\hat{l}\_{i1}^{\*}\left[T\_{1}^{\*}°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$ + (6a)

 $u\_{k}^{'}\hat{π}\_{0}^{-1}\left〈R\_{i1}-R\_{i0}\right〉\hat{l}\_{i1}^{\*}\left[T\_{1}^{\*}°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$+ (6b)

 $u\_{k}^{'}\hat{π}\_{0}^{-1}R\_{i0}\left〈\hat{l}\_{i1}^{\*}-\hat{l}\_{i0}^{\*}\right〉\left[T\_{1}^{\*}°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$+ (6c)

 $u\_{k}^{'}\hat{π}\_{0}^{-1}R\_{i0}\hat{l}\_{i0}^{\*}\left[\left〈T\_{1}^{\*}-T\_{0}^{\*}\right〉°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$+ (6d)

 $u\_{k}^{'}\hat{π}\_{0}^{-1}R\_{i0}\hat{l}\_{i0}^{\*}\left[T\_{0}^{\*}°\left(\left〈S\_{1}^{\*}-S\_{0}^{\*}\right〉∙\hat{c}\_{1}\right)\right]u$+ (6e)

 $u\_{k}^{'}\hat{π}\_{0}^{-1}R\_{i0}\hat{l}\_{i0}^{\*}\left[T\_{0}^{\*}°\left(S\_{0}^{\*}∙\left〈\hat{c}\_{1}-\hat{c}\_{0}\right〉\right)\right]u$ (6f)

As mentioned above, we identified six determinants of changes between initial period 0 and final period 1 in the domestic demand for skill group *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.

Equation (6a) represents the changes in domestic demand for labour of skill type *i* that can be attributed to productivity catch-up to the United States (*catch up effect*). Equation (6b) gives the employment of skill group *i* in the focal country in the final year if only the shares of global value chains as captured by countries would have changed (*off shoring effect*). In a similar vein, (6c) shows what would have happened if the only technological change within global value chains would have been the only source of change (*tech change effect*). (6d) indicates the demand in period 1 in the counterfactual case in which market shares of global value chains would have changed, but everything else would have remained stable (*import competition effect*). Equation (6e) isolates the effects of changes in consumption patterns (*Engel effects*), while (6f) focuses on the effects of differential rates of consumption growth in the *m* countries considered (*country demand effect*).[[10]](#footnote-10)

***Analyses for sectors***

The expressions introduced above can be used to obtain insights into the contribution of a number of effects on economy-wide demand for labour of particular skill intensities. To focus on the contributions of these effects on demand for skill demand in a specific part of the economy (such as the manufacturing sector), a few minor modifications are needed. If demand for low-skilled manufacturing workers is analyzed, the effects due to technological change in global value chains should not be affected by progress in agricultural or services activities. To this end, we have to re-specify **l**\* and **R**.

The expression for the total economy amounts of labour of skill type *i* required for the production of one unit of final product for each of the global value chains is **l***i\****’**≡ ($π°$**l***i*)**’B**. We now introduce an *mn*-elements selection vector that focuses on the industries for which labour requirements in global value chains should be included in an appropriate measure of technological change in global value chains. This vector **u**ind contains ones for “country-industries” that should be taken into account (for example, all manufacturing industries in the world), and zeros elsewhere. We can now write **l***i,ind\****’**≡ $u\_{ind}^{'}$($\hat{π}\hat{l}\_{i}$)**’B**. This implies that the expression for **R***i* (the shares of country-industries in global value chain requirements of labour of skill type *i*) should change accordingly. The appropriate expression is $R\_{i,ind}=\left\{u\_{ind}^{'}\hat{π}\hat{l}\_{i}B\right\}\hat{l}\_{i,ind}^{\*}^{-1}$. The decomposition equation that yields is

*xi1,ind*- *xi0,ind* =

$\left(u\_{ind}° u\_{k}\right)^{'}\hat{π}\_{1}^{-1}R\_{i1,ind}\hat{l}\_{i1,ind}^{\*}\left[T\_{1}^{\*}°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$ - $\hat{\left(u\_{ind}° u\_{k}\right)^{'}π}\_{0}^{-1}R\_{i0,ind}\hat{l}\_{i0,ind}^{\*}\left[T\_{0}^{\*}°\left(S\_{0}^{\*}∙\hat{c}\_{0}\right)\right]u$=

$\left(u\_{ind}° u\_{k}\right)^{'}\left〈\hat{π}\_{1}^{-1}-\hat{π}\_{0}^{-1}\right〉R\_{i1,ind}\hat{l}\_{i1,ind}^{\*}\left[T\_{1}^{\*}°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$ + (7a)

 $\left(u\_{ind}° u\_{k}\right)^{'}\hat{π}\_{0}^{-1}\left〈R\_{i1,ind}-R\_{i0,ind}\right〉\hat{l}\_{i1,ind}^{\*}\left[T\_{1}^{\*}°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$+ (7b)

 $\left(u\_{ind}° u\_{k}\right)^{'}\hat{π}\_{0}^{-1}R\_{i0,ind}\left〈\hat{l}\_{i1,ind}^{\*}-\hat{l}\_{i0,ind}^{\*}\right〉\left[T\_{1}^{\*}°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$+ (7c)

 $\left(u\_{ind}° u\_{k}\right)^{'}\hat{π}\_{0}^{-1}R\_{i0,ind}\hat{l}\_{i0,ind}^{\*}\left[\left〈T\_{1}^{\*}-T\_{0}^{\*}\right〉°\left(S\_{1}^{\*}∙\hat{c}\_{1}\right)\right]u$+ (7d)

 $\left(u\_{ind}° u\_{k}\right)^{'}\hat{π}\_{0}^{-1}R\_{i0,ind}\hat{l}\_{i0,ind}^{\*}\left[T\_{0}^{\*}°\left(\left〈S\_{1}^{\*}-S\_{0}^{\*}\right〉∙\hat{c}\_{1}\right)\right]u$+ (7e)

 $\left(u\_{ind}° u\_{k}\right)^{'}\hat{π}\_{0}^{-1}R\_{i0,ind}\hat{l}\_{i0,ind}^{\*}\left[T\_{0}^{\*}°\left(S\_{0}^{\*}∙\left〈\hat{c}\_{1}-\hat{c}\_{0}\right〉\right)\right]u$ (7f)

**4. Data**

To implement the decomposition above, one needs to have a database with linked consumption, production and income flows within and between countries. For individual countries, this type of information can be found in input-output tables. However, national tables do not provide any information on bilateral flows of goods and services between countries. For this type of information researchers have to rely on datasets constructed on the basis of national input-output tables in combination with international trade data. Various alternative datasets have been built in the past of which the GTAP database is the most widely known and used (Narayanan and Walmsley, 2008). Other datasets are constructed by the OECD (Yamano and Ahmad 2006) and IDE-JETRO (2006). However, all these databases provide only one or a limited number of benchmark year input-output tables which preclude an analysis of developments over time. And although they provide separate import matrices, there is no detailed break-down of imports by trade partner. For this paper we use a new database called the World Input-Output Database (WIOD) that aims to fill this gap. The WIOD provides a time-series of world input-output tables from 1995 onwards, distinguishing between 35 industries and 59 product groups. Using a novel approach national input-output tables of forty major countries in the world are linked through international trade statistics, covering more than 85 per cent of world GDP.

Another crucial element for this type of analysis are detailed value-added accounts that provide information on the use of various types of labour (distinguished by educational attainment level) and capital in production, both in quantities and values. While this type of data is available for most advanced OECD countries (O’Mahony and Timmer, 2009), it is not for many emerging countries.

*World Input-Output Tables (WIOTs): concepts and construction*

In this section we outline the basic concepts and construction of our world input-output tables. Basically, a world input-output table (WIOT) is a combination of national input-output tables in which the use of products is broken down according to their origin. In contrast to the national input-output tables, this information is made explicit in the WIOT. For each country, flows of products both for intermediate and final use are split into domestically produced or imported. In addition, the WIOT shows for imports in which foreign *industry* the product was produced. This is illustrated by the schematic outline for a WIOT in Figure 4. It illustrates the simple case of three regions: countries A and B, and the rest of the world. In WIOD we will distinguish 40 countries and the rest of the World, but the basic outline remains the same.

The rows in the WIOT indicate the use of output from a particular industry in a country. This can be intermediate use in the country itself (use of domestic output) or by other countries, in which case it is exported. Output can also be for final use[[11]](#footnote-11), either by the country itself (final use of domestic output) or by other countries, in which case it is exported. Final use is indicated in the right part of the table, and this information can be used to construct the **c** vector defined in section 2. The sum over all uses is equal to the output of industries, denoted by **q** in section 2.

**Figure 4** **Schematic outline of World Input-Output Table (WIOT), three regions**



A fundamental accounting identity is that total use of output in a row equals total output of the same industry as indicated in the respective column in the left-hand part of the figure. The columns convey information on the technology of production as they indicate the amounts of intermediate and factor inputs needed for production. The intermediates can be sourced from domestic industries or imported. This is the **A** matrix from section 2. The residual between total output and total intermediate inputs is value added. This is made up by compensation for production factors. It is the direct contribution of domestic factors to output. We prepare the F matrix from section 2 on this information after breaking out the compensation of various factor inputs as described in Section 3.2.

 As building blocks for the WIOT, we will use national supply and use tables (SUTs) that are the core statistical sources from which NSIs derive national input-output tables. In short, we derive time series of national SUTs. Benchmark national SUTs are linked over time through the use of the most recent National Accounts statistics on final demand categories, and gross output and value added by detailed industry. This ensures both intercountry and intertemporal consistency of the tables. As such the WIOT is built according to the conventions of the System of National Accounts and obeys various important accounting identities. National SUTs are linked these across countries through detailed international trade statistics to create so-called international SUTs. This is based on a classification of bilateral import flows by end-use category (intermediate, consumer or investment), intermediate inputs are split by country of origin.

These international SUTs are used to construct the symmetric world input-output. The construction of our WIOT has a number of distinct characteristics.

We rely on national supply and use tables (SUTs) rather than input-output tables as our basic building blocks. SUTs are a natural starting point for this type of analysis as they provide information on both products and industries. A supply table provides information on products produced by each domestic industry and a use table indicates the use of each product by an industry or final user. The linking with international trade data, that is product based, and factor use that is industry-based, can be naturally made in a SUT framework.[[12]](#footnote-12)

To ensure meaningful analysis over time, we start from industry output and final consumption series given in the national accounts and benchmark national SUTs to these time-consistent series. Typically, SUTs are only available for a limited set of years (e.g. every 5 year)[[13]](#footnote-13) and once released by the national statistical institute revisions are rare. This compromises the consistency and comparability of these tables over time as statistical systems develop, new methodologies and accounting rules are used, classification schemes change and new data becomes available. By benchmarking the SUTs on consistent time series from the National Accounting System (NAS), tables can be linked over time in a meaningful way. This is done by using a SUT updating method (the SUT-RAS method) as described in Temurshoev and Timmer (2011) which is akin to the well-known bi-proportional (RAS) updating method for input-output tables. For this updating data on gross output and value added by industry is used, alongside data on final expenditure categories from the National Accounts.

Ideally, we would like to use official data on the destination of imported goods and services. But in most countries these flows are not tracked by statistical agencies. Nevertheless, most do publish an import IO table constructed with the import proportionality assumption, applying a product’s economy-wide import share for all use categories. For the US it has been found that this assumption can be rather misleading in particular at the industry-level (Feenstra and Jensen, 2009; Strassner, Yuskavage and Lee, 2009). Therefore we are not using the official import matrices but use detailed trade data to make a split. Our basic data is bilateral import flows of all countries covered in WIOD from all partners in the world at the HS6-digit product level taken from the UN COMTRADE database. Based on the detailed description products are allocated to three use categories: intermediates, final consumption, and investment, effectively extending the UN Broad Economic Categories (BEC) classification. We find that import proportions differ widely across use categories and importantly, also across country of origin. For example, imports by the Czech car industry from Germany contain a much higher share of intermediates than imports from Japan. This type of information is reflected in our WIOT by using detailed bilateral trade data. The domestic use matrix is derived as total use minus imports.

Another novel element in the WIOT is the use of data on trade in services. As yet no standardised database on bilateral service flows exists. These have been collected from various sources (including OECD, Eurostat, IMF and WTO), checked for consistence and integrated into a bilateral service trade database (see Stehrer et al., 2010, for details). Although the maximum of existing information is used, there are clear gaps in our knowledge at lower levels of aggregation.

Based on the national SUTs, National account series and international trade data, international SUTs are prepared for each country. As a final step, international SUTs are transformed into an industry-by-industry type world input-output table. We use the so-called “fixed product-sales structure” assumption stating that each product has its own specific sales structure irrespective of the industry where it is produced (see e.g. Eurostat, 2008). For a more elaborate discussion of construction methods, practical implementation and detailed sources of the WIOT, see Timmer et al. (2012).

*Factor input requirements*

For factor input requirements we collected country-specific data on detailed labour and capital inputs for all 35 industries. This includes data on hours worked and compensation for three labour types and data on capital stocks and compensation.

Labour types are distinguished on the basis of educational attainment levels as defined in the ISCED classification (low-skilled: ISCED 1 + 2; medium-skilled: ISCED 3 + 4 and high-skilled: ISCED 5 + 6). These series are not part of the core set of national accounts statistics reported by NSIs; at best only total hours worked and wages by industry are available from the National Accounts. Additional material has been collected from employment and labour force statistics. For each country covered, a choice was made of the best statistical source for consistent wage and employment data at the industry level. In most countries this was the labour force survey (LFS). In most cases this needed to be combined with an earnings surveys as information wages are often not included in the LFS. In other instances, an establishment survey, or social-security database was used. Care has been taken to arrive at series which are time consistent, as most employment surveys are not designed to track developments over time, and breaks in methodology or coverage frequently occur.

Labour compensation of self-employed is not registered in the National Accounts, which as emphasised by Krueger (1999) leads to an understatement of labour’s share. This is particularly important for less advanced economies that typically feature a large share of self-employed workers in industries like agriculture, trade, business and personal services. We make an imputation by assuming that the compensation per hour of self-employed is equal to the compensation per hour of employees. Capital compensation is derived as gross value added minus labour compensation as defined above.

For most advanced countries labour and capital data is constructed by extending and updating the EU KLEMS database ([www.euklems.org](http://www.euklems.org)) using the methodologies, data sources and concepts described in O’Mahony and Timmer (2009). For other countries additional data has been collected according to the same principles. This is described in full in Erumban et al. (2012).

**5. Results**

In this section we present a number of decomposition results for the changes in jobs over the period from 1995 to 2008. We first present the results for jobs in the total economy and then for jobs in manufacturing only. For convenience we do not depict all 6 determinants but club them into three namely: *Trade* including the effects of off shoring and import competition; *Technology* including the effects of catch up of domestic technology to the US and technological change in the global supply chains; and *Demand* including the effects of changes in the structure of demand both in terms of products and countries

In figure 1 we present the decomposition for changes in the number of jobs in the overall economy. We present data for advanced countries as a whole, including 21 advanced countries namely the EU-15, Australia, Canada, Japan, South Korea, Taiwan and the US; and separate results for Japan, Germany and the US.

**Figure 1 Decomposition of change in jobs by skill type, total economy, (in ‘000 jobs)**

1. **All advanced countries**



**(B) Germany**



**(C ) Japan**



**(d) US**



Source: Authors’ elaborations on WIOD Database, April 2012 release. HS: high-skilled; MS: medium-skilled; LS: low-skilled.

**Figure 2 Decomposition of change in jobs by skill type, manufacturing, (in ‘000 jobs)**

1. **All advanced countries**



**(B) Germany**



**(C ) Japan**



**(D) US**



Source: Authors’ elaborations on WIOD Database, April 2012 release. HS: high-skilled; MS: medium-skilled; LS: low-skilled.

**6. Conclusions (to be completed)**

In this paper we propose a new method to analyse the changing structure of employment in advanced countries based on a modelling of the input-output structure of the world economy. Demand for jobs, characterised by skill type and sector of employment, is driven by changes in technology, trade and consumption. Using a structural decomposition technique we analyse the relative importance of these drivers in 21 advanced countries for the period 1995-2008. We derive a new measure of technological change in vertically integrated production chains and show that it is skill-biased.

 For the advanced region as a whole, technological change would drive down overall employment by 57 million, keeping other drivers constant. Increasing trade in intermediate and final products would lead to an additional loss of 31 million jobs. But the effects are highly uneven across skill-types. For low-skilled (LS) and medium-skilled (MS) jobs technological change and trade would contribute to a decline of 69 and 29 million. This was counterbalanced by increasing global consumption as the number of LS and MS jobs increased by 4 million. Changes are more dramatic for LS and MS workers in manufacturing as their employment declined by 13 million, for two-third due to global technological change, confirming the “routinezation” hypothesis. In addition technological change in global supply chains was skill-biased contributing positively to demand for high-skilled (HS) jobs in the economy with only a minor negative effect of trade. Also changes in global consumption added substantially to HS job demand, in particular outside the manufacturing sector.

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1. See e.g. Ngai and Pissarides (2007) and Gollin, Parente and Rogerson (2002) building upon the ideas of Clark (1957) and Baumol (1967). [↑](#footnote-ref-1)
2. See e.g. Autor and Katz (1999) and a more recent overview by Feenstra (2010) and Acemoglu and Autor (2011). [↑](#footnote-ref-2)
3. For brevity, we will refer to these products as “German cars”. The numbers presented in this section refer to all final products of the German transport equipment industry (NACE industries 34 and 35). [↑](#footnote-ref-3)
4. See Antras et al. (2012). [↑](#footnote-ref-4)
5. See [www.wiod.org](http://www.wiod.org), for the publicly available tables that emerged from the WIOD project. [↑](#footnote-ref-5)
6. A hat (e.g.$\hat{y}$) indicates a diagonal matrix, with the elements of the vector **y** on the diagonal. [↑](#footnote-ref-6)
7. The symbol ◦ stands for the “Hadamard product”, obtained by cell-by-cell multiplication (i.e., **W** = **X** ◦ **Y** means that *wij* = *xijyij*, for all *i* and *j*). [↑](#footnote-ref-7)
8. The elements of $π$ can change over time, but are assumed to be identical across skill groups. [↑](#footnote-ref-8)
9. For ease of exposition, we did not include indices for time periods in the matrix algebra above. [↑](#footnote-ref-9)
10. 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 next section 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. [↑](#footnote-ref-10)
11. Final use includes consumption by households, government and non-profit organisations, and gross capital formation. [↑](#footnote-ref-11)
12. As industries also have secondary production a simple mapping of industries and products is not feasible. [↑](#footnote-ref-12)
13. Though recently, most countries in the European Union have moved to the publication of annual SUTs. [↑](#footnote-ref-13)