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D6.1 Labour Market Inequalities: Impacts of Technology and The Changing Nature of International Trade: 2000-2014

WP6 Assessing European labour market inequalities from different perspectives

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Summary

In this report, we propose a method to analyse the changing structure of employment in countries by business function (fabrication, R&D, management and marketing), based on the input-output structure of the world economy. Demand for jobs in particular functions is driven by changes in technology, trade and consumption. Using structural decomposition analysis, we study the relative importance of these drivers for the period 2000-2014. We derive a measure of technological change in GVCs. We find that technological change and changes in trade patterns have both played an important role in the decline of fabrication employment in large West-European countries. The role of trade tends to have been the most important for this business function. For labour demand regarding other business functions, changes in trade have been much less impactful. For East-European countries, somewhat mixed results were obtained regarding the role of trade, but labour-saving technological change exerted a clearly downward pressure on labour demand in all functions.

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Abstract

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1. Introduction

The employment structure of the global economy evolves constantly. 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 to be major driving forces behind this process of structural change. The growing share of services employment was often attributed to sector-biased technological change (slow productivity growth in services; 'Baumol's disease') and non-homothetic preferences (differences in Engel curves).[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] However, quantifying the effects of these determinants in empirical work is not straightforward and soon after the Global Financial Crisis view was challenged (see e.g. Autor et al., 2013, and the vast literature on the 'China shock' that this paper induced).

A major weakness in much of this work is the lack of an empirical identification of global value chains (GVCs) and their dynamics. Typically, measures of foreign direct investment, imports and exports over GDP or shares of intermediate imports in overall imports are used. 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 value 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. (2013) and to measure the rate and 'function-biased' nature of technological change in these chains. A second bottleneck is in the modelling of the job content of imports from emerging countries, in particular China and to a lesser extent Eastern European countries that got integrated in the European and world economies, after they became members of the European Union. What matters for the effect of imports on domestic labour demand in advanced countries is what kind of labour is 'embodied' in these products. Meaningful insights can only be obtained if data on the job content of the production activities carried out by the exporting country (Krugman, 2008) are available.

The relatively recent availability of global input-output tables and associated satellite data on employment allow for such analyses. In this paper, we build on methods developed in Reijnders and de Vries (2018). As opposed to their study, we use the 2016-release of the World Input-Output Database (Timmer et al., 2015; 2016) and harmonized data on the business functions that workers in the countries and industries covered by the input-output tables perform. These employment data by function are an update of the data used by Timmer et al. (2019) to quantify the 'functional specialisation' of countries.

[1] See e.g. Ngai and Pissarides (2007) and Gollin *et al*. (2002), which extended the ideas of Chenery and Clark (1959) and Baumol (1967).
[2] See e.g. Autor and Katz (1999) and overviews by Feenstra (2010), Acemoglu and Autor (2011), and Michaels *et al.* (2013).

We build on the conceptual framework for analysing changes in the demand for jobs through modelling the input-output structure of the world economy introduced by Reijnders and de Vries (2018), which had its roots in the work of Leontief (1936, 1941). Based on a world input-output model, we decompose changes in employment, characterised by business function, into changes in (i) 'global value chain technology', (ii) international trade and (iii) consumption. Using structural decomposition analysis we quantify the relative importance of the main drivers in a large set of countries for the period 2000-2014. 2014 is the most recent year for which the required data are available.

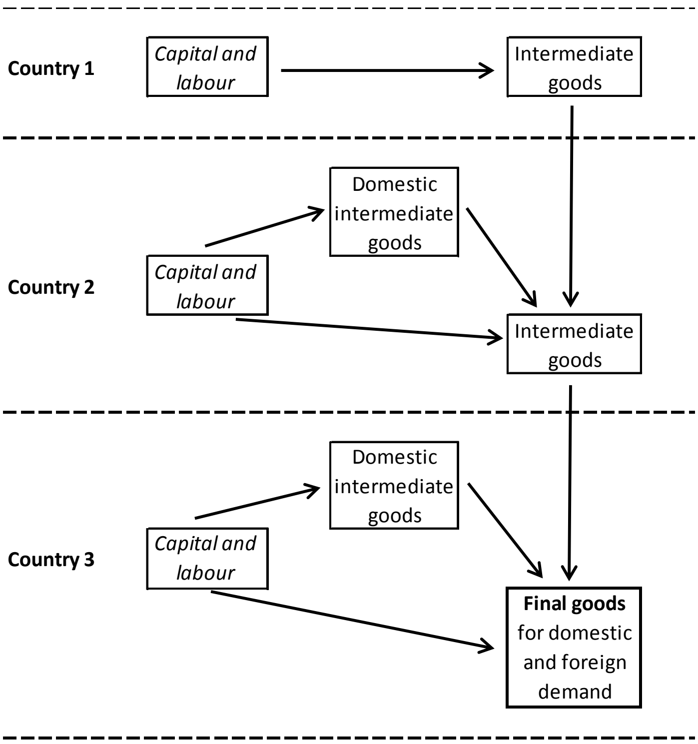
The paper is organised as follows. In Section 2, a stylized example of a global supply chain (GVC) is introduced to illustrate the decomposition method in an intuitive way. Section 3 describes the data. We then evaluate to what extent the changes in employment per function and country can be explained by each of the different channels affecting demand for labour by business functions in Section 4. Section 5 concludes.

2. The Intuition behind A GVC Perspective on Labour Demand[3]

Due to advances in ICT, reductions in transportation costs and trade liberalisation, firms have experienced increasing opportunities to relocate parts of the production processes of final products to countries where the availability and costs of the production factors are most favourable for these specific activities (Baldwin, 2006; 2016). Put differently, comparative advantages now play out at the level of sets of activities ('business functions') within industries, rather than at the level of entire industries. As is stressed in the case study literature (e.g. Dedrick et al., 2010, on high-end Apple consumer electronics), these relocations can be governed within the so-called lead firm (by means of foreign FDI) or by agreeing on contracts with specialized foreign suppliers. Irrespective of what type of governance 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 value chain (GVC). At the level of specific 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 (see, e.g., Johnson and Noguera, 2012; Timmer et al., 2013; 2014; Los et al., 2015).

[3] See Appendix A (which is based on Reijnders and de Vries, 2018) for a detailed, more formal explanation of the methodology.

Figure 1: A Stylized Global Value Chain



Source: Los *et al*. (2015)

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., electrical products) with Country 3 as the "country-of-completion" (e.g., France). 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 machinery will require labour (and other production factors) in 3's electrical equipment industry itself. It will also generate employment in upstream industries in Country 3 itself, for example because the electrical products 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 requires labour inputs as well and the metal products 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, labour demand increases in all three countries, in this example. 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.

In the context of this report, it is essential to emphasise that the labour inputs as depicted in Figure 1 are heterogeneous. The metal products that are imported from Country 2 might be fabricated there, but they might be designed in the metal products industry in a different country. As Timmer et al. (2019) showed in a macro-economic context, countries have specialised in providing labour performing specific business functions, after rapid improvements in internet technology made it less important for companies to co-locate e.g. R&D and fabrication activities in geographically nearby places (see also Baldwin, 2016).

Using well-established techniques from the field of input-output analysis (Miller and Blair, 2009), information contained in global 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 sum to actual labour inputs in each of the industries in each of the countries-of-employment. Global input-output tables can thus be seen as descriptions of the world production structure, which is considered to be an evolving network of GVCs.[4]

The focus of this report is on the relative importance of changes in determinants of the level of labour demand in countries. Our analysis follows Reijnders and de Vries (2018), which pioneered the quantification of these effects in a setting of internationally fragmented GVCs, complementing the theoretical work by Costinot et al. (2013) with empirical results.

We will compare employment levels (by function) in 2000 and 2014, figuring out how large the effects of changes in technology and changes in trade patterns have been. Our empirical results split changes in employment into the effects of three factors, but in the underlying decomposition, the contributions of six determinants are quantified. We illustrate these along the lines of Figure 1:

1) ***Changes in GVC technology*.** We define the GVC technology for an electrical product completed in Country 3 as the labour inputs (in quantity terms) anywhere in the world and in any industry required to produce a million US dollar of final output of the electrical products 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

[4] Wolff (1985) considered productivity in 'vertically integrated industries'. A GVC can be seen as an internationally vertically integrated industry.

study). Technological progress in this GVC will, ceteris everything else equal, 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 an 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 (e.g. Country 2), labour demand in Country 1 will, ceteris paribus, decline (a given quantity of output can be produced with fewer workers);
3) ***Changes in location-of-intermediate stages (offshoring)*.** If some of the intermediate inputs required by Country 3's electrical products 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 electrical equipment from a Country 4, not in the figure), labour demand in all countries that contribute to Country 3's electrical products GVC will be reduced, everything else equal. 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 electrical equipment to recreational services, labour demand in the countries and industries contributing to Country 3's electricals GVC will be reduced;
6) ***Changes in consumption levels*.** If consumers (at home and abroad) increase their spending over time without changing the mix of products they purchase, more electrical products finalized 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 GVC.

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 (in an aggregate sense, but also split by function) can be attributed to these six types of change, without a residual being left unexplained.[5]

[5] 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.

For reasons of exposition, we will present the empirical results after having merged effects 1) and 2) into a "technology" effect. Effects 3), 4) and 5) together constitute the "trade" effect.[6] "Consumption" effects (which include changes in the levels of investment demand) are obtained are equal to effect 6).

We should stress that the method adopted in this paper does not have the objective to *explain* changes in the demand for labour performing specific functions in particular countries. The focus is on *accounting* for these changes, to see whether changes in technology or changes in trade contributed most to the observed changes.

3. Data

Almost all data required for the analysis underlying this report were taken from the World Input-Output Database. The steps used to construct the 2000-2014 time series of global input-output tables have been described in detail in Dietzenbacher et al. (2013) and Timmer et al. (2016). Information about the construction of data regarding the functional composition of the labour employed by each of the industries in each of the countries can be found in Timmer et al. (2019). The data used in this report are an update of the data used in that paper. For most countries, labour force surveys were the main source of data, for some other countries information from population censuses was used. The functions are an aggregation over occupations (classified according to the ISCO88 and ISCO08 codes).

For the specific purposes of this report, global input-output tables expressed in prices of the previous year were needed. These are available in WIOD (see, e.g., Timmer et al., 2021). We obtained the results for the decomposition over the entire period by performing the decomposition for the situations in year t and year t+1 (e.g., 2000-2001, 2001-2002, etc.) and finally adding up the results obtained for each determinant over the years.

The expression of labour inputs in efficiency units (required to arrive at meaningful numbers describing changes in GVC technologies) required indicators of relative productivity levels of workers in 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 (2014) provided detailed PPP estimates in the GGDC productivity

[6] 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). We add 5) to the trade effect because changes in the composition of consumption appear to be almost exclusively due to changes in the location of completion of final products.

level database. Updates of these productivity data are now available in the Penn World Tables and used in this report (variable *ctfp*, indicating total factor productivity at current PPPs). Because of data limitations, we had to assume that labour productivity levels of countries relative to the US changed identically across functions.

4. Results

We present the empirical results in three parts. We first focus on the decomposition results obtained for four large economies that belong to the group of countries that became EU member states before the period analysed in this report. Next, we consider a subset of countries in Eastern Europe, which got access to the EU Single Market during the period of analysis, and thereby played an important role in the increasing prominence of internationally fragmented production processes, GVCs. We conclude by presenting results for some countries outside Europe: the US, China, India and Turkey.

Table 1: Source of change in labour demand by function (2000-2014, major West-European EU economies; in percentages of 2000 employment by function)

a) France

	Fabrication	R&D	Management	Marketing
Technology	-18.8	-12.7	-25.5	-0.4
Trade	-32.2	-13.6	-17.1	-18.1
Consumption	32.6	40.1	39.2	38.7
Total	-18.4	13.7	-3.4	20.3

b) Germany

	Fabrication	R&D	Management	Marketing
Technology	-20.2	-1.6	-29.2	-1.0
Trade	-23.2	-17.0	-25.1	-20.8
Consumption	32.5	38.8	33.9	38.0
Total	-10.8	20.3	-20.4	16.2

c) Italy

	Fabrication	R&D	Management	Marketing
Technology	6.8	0.5	-18.1	10.2
Trade	-47.8	-33.9	-39.4	-35.4
Consumption	36.9	39.6	59.3	37.0
Total	-4.0	6.1	1.8	11.9

d) Spain

	Fabrication	R&D	Management	Marketing
Technology	-25.3	3.4	-51.0	7.3
Trade	-37.2	-8.3	-17.8	-16.4
Consumption	36.1	46.2	36.6	44.9
Total	-26.5	41.3	-32.1	35.9

Source: World Input-Output Database, 2016 release and update of data from Timmer et al. (2019).

The bottom rows of the panels of Table 1 show that employment in the fabrication function declined in all four countries considered. In France and Italy, this decrease amounted to almost 20 per cent or more, while the reduction was much less marked in Italy (4 per cent). In the marketing and R&D functions, strong increases could be observed in all four countries considered. For management, the results do not reveal a uniform tendency. In Germany and Spain, labour demand for this function decreased considerably, while the changes for France and Italy are not very marked.

Growth of final demand (labelled as 'consumption' in the tables) clearly had a positive impact on employment of all functions, in all countries considered. This effect incorporates the positive labour demand effects of increasing purchasing power in emerging countries outside Europe, but also in Eastern Europe. The in our view most interesting results are those related to changes in technology and changes in patterns of international trade.

For fabrication, technological progress exerted a downward pressure on labour demand in these countries, except for Italy. Improvements in GVC technologies led to labour savings in all four countries, but Italy's weak productivity performance led to a net effect that is positive. Changes in trade patterns had negative impacts on demand for fabrication workers. For Germany, the negative effects of trade were of the same magnitude as those of technology (both at around -20 per cent), but for the other three countries considered trade had clearly more negative effects than labour-saving technological change.

If we consider the other three business functions, we note that technological change had negative employment impacts for workers in management, but that technological change for R&D workers and marketing employees tended to have either considerably smaller negative impacts (France and Germany) or positive impacts (Italy and Spain). For R&D, management and marketing, changes in international trade had structurally negative impacts, but the reductions in labour demand for these business functions were considerably smaller than those in demand for fabrication workers. Germany is a marked exception to this finding.

Table 2 presents results for Poland, the Czech Republic and Bulgaria. In Poland, the number of fabrication workers declined at about the same rate as in Germany, over the period 2000-2014. In the Czech Republic, however, the reduction was considerably smaller and Bulgaria even experienced an increase in demand for fabrication workers. Like for the West-European countries in Table 1, we find that marketing employment increased across the board, while we find varying results regarding the R&D and management functions.

Table 2: Source of change in labour demand by function (2000-2014, selected East-European EU countries; in percentages of 2000 employment by function)

a) Poland

	Fabrication	R&D	Management	Marketing
Technology	-47.5	-32.4	-43.3	-24.8
Trade	3.3	12.9	13.3	9.8
Consumption	32.5	38.9	35.6	38.5
Total	-11.7	19.4	5.6	23.5

b) Czech Republic

	Fabrication	R&D	Management	Marketing
Technology	-41.6	-31.0	-39.4	-11.7
Trade	1.6	-8.0	-2.6	-6.1
Consumption	34.5	38.1	34.7	38.8
Total	-5.5	-0.9	-7.3	20.9

c) Bulgaria

	Fabrication	R&D	Management	Marketing
Technology	-42.4	-46.4	-60.6	-29.1
Trade	6.8	-1.9	29.1	15.1
Consumption	37.0	31.4	42.8	42.5
Total	1.4	-16.9	11.3	28.5

Source: World Input-Output Database, 2016 release and update of data from Timmer et al. (2019).

Not surprisingly, increased consumption and investment demand had very positive effects on labour demand in all functions. Increasing domestic demand definitely played an important role in this. The effects of labour-saving technological change were clearly negative. Not only did production technologies in GVCs require less efficiency units of labour in 2014 than in 2000, Eastern European countries also managed to catch up dramatically in terms of labour productivity to other European countries and the United States.

As opposed to economies in Western Europe, changes in the location of activities within GVCs and changes in the relative importance of GVCs (i.e., changes in trade patterns) had positive effects or only mildly negative effects. In all three countries depicted, trade effects only would have increased labour demand for fabrication workers. In Bulgaria, demand for R&D workers would have decreased marginally if only trade changes would have taken place, while (like in Poland) the other business functions would have been in considerably higher demand. The results for the Czech Republic show that Eastern European countries should not be viewed as a set of economies that have identical characteristics. In this country, the employment effects of trade were only positive for fabrication workers, while workers in other functions experienced negative effects from trade.

Table 3 presents results for selected countries outside Europe, to provide a wider perspective. For the United States, we find increases in employment of non-fabrication workers, although the growth in marketing employment was limited. For fabrication workers, the reduction in demand was in between that of France and Germany. The contributions of changes in technology and changes in trade patterns were of the same magnitude for the fabrication function. Like for Germany, these results suggest that neither labour-saving technological change nor offshoring of fabrication activities can be seen as the sole culprit of increasing inequality in employment opportunities; both played an important role.

India and especially China benefitted from changes in trade patterns. The same holds for Turkey, although to a lesser extent. Technological change exerted a downward pressure on labour demand in China, because it managed to attain high labour productivity growth rates, increasing its efficiency relative to other countries. This downward pressure on labour demand came on top of the labour-saving technological change in GVCs in general. The large positive contributions of trade changes to employment in R&D and marketing in both China and India are reflections of the performance of these countries regarding upgrading within GVCs. We should be cautious, however, to view all R&D and marketing employment as "high-value added" activities. Sales workers, for example, are often not paid very well, but belong to the category of occupations within the marketing function.

Table 3: Source of change in labour demand by function (2000-2014, selected non-European countries; in percentages of 2000 employment by function)

a) United States

	Fabrication	R&D	Management	Marketing
Technology	-21.8	-7.0	-6.6	-19.6
Trade	-24.0	-7.3	-13.5	-14.1
Consumption	32.6	39.2	37.7	36.5
Total	-13.3	24.9	17.6	2.9

b) China

	Fabrication	R&D	Management	Marketing
Technology	-105.4	-75.3	-106.9	-90.8
Trade	60.6	96.2	94.3	130.5
Consumption	34.4	45.9	38.2	50.7
Total	-10.4	66.8	25.5	90.4

c) India

	Fabrication	R&D	Management	Marketing
Technology	-38.2	-4.3	86.4	-47.2
Trade	41.4	99.9	157.4	77.0
Consumption	40.0	51.0	69.9	43.1
Total	43.3	146.7	313.7	72.9

d) Turkey

	Fabrication	R&D	Management	Marketing
Technology	-26.6	2.4	-46.8	33.6
Trade	10.9	43.1	16.9	28.2
Consumption	33.1	44.3	37.3	44.0
Total	17.4	89.8	7.4	105.8

Source: World Input-Output Database, 2016 release and update of data from Timmer et al. (2019).

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 labor performing activities in four distinct business functions. Global input-output tables allow us to view the world economy as a network of GVCs. Technological change affects the labour requirements per unit of output of these chains, which by definition tend to span multiple countries. To pay justice to this view, we borrowed a new concept of technological change (from Reijnders and de Vries, 2018), which is not defined for national industries as is usually done (see, e.g., Goos et al., 2014), but for GVCs themselves. Furthermore, changes in the location of the production of raw materials, parts and components as well as final products have an impact on labour demand in countries. Finally, changes in the volume of national consumption bundles have effects on the relative sizes of GVCs and therefore on the amounts of labour by function demanded in countries contributing to GVCs.

Using our new decomposition method analysing the period 2000-2014, we find that fabrication workers in some of the largest economies of the 'old' EU suffered from a double blow. Although global demand for final products grew considerably, the effects of labour-saving technological change and changes in trade patterns ('offshoring') were both negative and sufficiently large to yield a negative net effect. The negative effects of trade appeared to be larger than those of technological change. For labour performing other functions (especially R&D and marketing), the negative effects of trade were also present, but they were considerably less pronounced.

For emerging countries in Europe's East, we found heterogeneous patterns. Trade increased demand for fabrication labour and labour-saving technological progress had a much larger negative effect in the three countries for which we present results. Regarding the other business functions, technological change exerted a clear downward pressure on labour demand, but the evidence regarding the impacts of trade is rather mixed.

The approach chosen in this paper might lead to further research. First, the identification of Global Value Chains based on 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) showed 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. In this sense, the availability of such tables in the OECD-ICIO database is promising. Tables in prices of the previous year are not yet available in this database, and compatible data on labour inputs classified by function are also lacking, which led us to use older WIOD-data.

In next steps, which clearly fall outside the scope of this report, the most important ‘proximate sources of change’ identified in this analysis 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 effects of new technology and effects of changing trade patterns on the often very different wage rates of fabrication workers and workers in other (headquarters) functions.

References

Acemoglu, D. and D. Autor (2011) "Skills, Tasks and Technologies: Implications for Employment and Earnings", in: O. Ashenfelter and D.E. Card (eds.) *Handbook of Labor Economics*, Vol. 4B, Amsterdam: Elsevier, pp. 1043-1171.

Autor, D.H., D. Dorn and G.H. Hanson (2013) "The China Syndrome: Local Labor Market Effects of Import Competition in the United States", *American Economic Review*, vol. 103, pp. 2121-2168.

Autor, D.H. and L.F. Katz (1999), "Changes in the Wage Structure and Earnings Inequality", in: O. Ashenfelter and D.E. Card (eds.), *Handbook of Labor Economics*, Vol. 3A, Amsterdam: Elsevier, pp. 1463-1555.

Baldwin, R.E. (2006) "Globalisation: The Great Unbundling(s)", in *Globalisation Challenges for Europe*, Helsinki: Office of the Prime Minister of Finland.

Baldwin, R.E. (2016) *The Great Convergence*, Cambridge MA: The Belknap Press.

Baumol, W. (1967) "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis", *American Economic Review*, vol. 57, pp. 415-426.

Chen, X., L.K. Cheng, K.C. Fung, L.J. Lau, Y.-W. Sung, K. Zhu, C. Yang, J. Pei and Y. Duan (2012) "Domestic Value Added and Employment Generated by Chinese Exports: A Quantitative Estimation", *China Economic Review*, vol. 23, pp. 850–864.

Chenery, H.B. and P.G. Clark (1959) *Interindustry Economics*, Hoboken NJ: John Wiley and Sons.

Costinot, A., J. Vogel and S. Wang (2013) "An Elementary Theory of Global Supply Chains", *Review of Economic Studies*, vol. 80, pp. 109-144.

Dedrick, J., K.L. Kraemer and G. Linden (2010) "Who Profits from Innovation in Global Value Chains?: A Study of the iPod and Notebook PCs", *Industrial and Corporate Change*, vol. 19, pp. 81-116.

Dietzenbacher, E. and B. Los (1998) "Structural Decomposition Techniques: Sense and Sensitivity", *Economic Systems Research*, vol. 10, pp. 307-323.

Dietzenbacher, E., B. Los, R. Stehrer, M.P. Timmer and G.J. de Vries (2013) "The Construction of World Input-Output Tables in the WIOD Project", *Economic Systems Research*, vol. 25, pp. 71-98.

Feenstra, R. C. (2010), *Offshoring in the Global Economy. Microeconomic Structure and Macroeconomic Implications*, Cambridge MA: MIT Press.

Gollin, D., S. Parente and R. Rogerson (2002) "The Role of Agriculture in Development", *American Economic Review*, vol. 92, pp. 160-164.

Goos, M., A. Manning and A. Salomons (2014) "Explaining Job Polarization: Routine-Biased Technological Change and Offshoring", *American Economic Review*, vol. 104, pp. 2509-2526.

Inklaar, R., and M.P. Timmer (2014) "The Relative Price of Services", *Review of Income and Wealth*, vol. 60, pp. 727-746.

Johnson, R.C. and G. Noguera (2012) "Accounting for Intermediates: Production Sharing and Trade in Value Added", *Journal of International Economics*, vol. 86, pp. 224-236.

Leontief, W. (1936) "Quantitative Input-Output Relations in the Economic System of the United States", *Review of Economics and Statistics*, vol. 18, pp. 105-125.

Leontief, W. (1941) *The Structure of American Economy 1919-1939*, New York: Oxford University Press.

Los, B., M.P. Timmer and G.J. de Vries (2015) "How Global are Global Value Chains? A New Approach to Measure International Fragmentation", *Journal of Regional Science*, vol. 55, pp. 66-92.

Michaels, G., A. Natraj and J. Van Reenen (2014) "**Has ICT Polarized Skill Demand?: Evidence from Eleven Countries over 25 Years",** *Review of Economics and Statistics*, vol. 96, pp. 60-77.

Miller, R.E. and P.D. Blair (2009) *Input-Output Analysis* (2nd ed.), Cambridge UK: Cambridge University Press.

Ngai, L.R. and C.A. Pissarides (2007) "Structural Change in a Multi-Sector Model of Growth", *American Economic Review*, vol. 97, 429-443.

Reijnders, L.S.M. and G.J. de Vries (2018) "Technology, Offshoring and the Rise of Non-Routine Jobs", *Journal of Development Economics*, vol. 135, pp. 412-432.

Timmer, M.P., B. Los, R. Stehrer and G.J. de Vries (2013) "Fragmentation, Incomes and Jobs. An Analysis of European Competitiveness**",** *Economic Policy*, vol. 28, pp. 613-661.

Timmer, M.P., A.A. Erumban, B. Los, R. Stehrer and G.J. de Vries (2014) "Slicing Up Global Value Chains", *Journal of Economic Perspectives*, vol. 28, pp. 99-118.

Timmer, M.P., E. Dietzenbacher, B. Los, R. Stehrer and G.J. de Vries (2015) "An Illustrated User Guide to the World Input-Output Database: The Case of Global Automotive Production", *Review of International Economics*, vol. 23, pp. 575-605.

Timmer, M.P., B. Los, R. Stehrer and G.J. de Vries (2016), "An Anatomy of the Global Trade Slowdown Based on the WIOD 2016 Release", GGDC Research Memorandum 162, University of Groningen.

Timmer, M.P., S. Miroudot and G.J. de Vries (2019) "Functional Specialisation in Trade", *Journal of Economic Geography*, vol. 19, pp. 1-30.

Timmer, M.P., B. Los, R. Stehrer and G.J. de Vries (2021) "Supply Chain Fragmentation and the Global Trade Elasticity: A New Accounting Framework", *IMF Economic Review*, vol. 69, pp. 656-680.

Wolff, E.N. (1985) "Industrial Composition, Interindustry Effects, and the U.S. Productivity Slowdown", *Review of Economics and Statistics*, vol. 67, pp. 268–277.

Appendix A: Mathematical exposition

We distinguish between fabrication workers, R&D workers, marketing workers and managers. We start by assuming that three factors drive changes in the demand for labor in each of these four functions. These factors are (1) 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), (2) 'function-biased' technological change, and (3) changes in the level and composition of global consumption. To disentangle these effects, we use "World Input-Output Tables" (WIOTs) and associated employment by function figures that were constructed in the WIOD project (see Timmer et al., 2015; 2019). 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).

Adopting the fundamental assumption of input-output models, 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 workers performing function i in the country considered) can be written as

$$x_i = \mathbf{u}_k' \hat{\mathbf{l}}_i \mathbf{q} \tag{1}$$

The diagonal matrix $\hat{\mathbf{l}}_i$ contains the labour requirements of function i per unit of (gross) output in each of the n industries in each of the m countries.[7] The mn-vector $\mathbf{q}$ stands for (gross) output levels in each of the industries in each of the countries. $\mathbf{u}_k$ is a mn-"selection vector". It contains ones in the cells associated with the industries in the focal country. All other elements of $\mathbf{u}_k$ 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. The global input-output tables in WIOD allow for a distinction between exports of final products (such as cars exported by Germany to Denmark) and exports of intermediate products (such as automotive components exported by Slovakia to be used in assembly activities in Germany). 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. In earlier contributions (see, e.g. Timmer et al., 2013, 2021; Los et al., 2015) we labelled this approach the "Global Value Chain perspective".

Denoting the number of countries in a WIOT by m, we define $\mathbf{Z}$ as the mnxmn-matrix that contains all domestic and international deliveries of intermediate inputs. The corresponding mnxmn-matrix $\mathbf{A}$ of intermediate inputs requirements per unit of gross output can be obtained as $\mathbf{A} = \mathbf{Z}\hat{\mathbf{q}}^{-1}$. We take the fact

[7] A hat (e.g. $\hat{\mathbf{y}}$) indicates a diagonal matrix, with the elements of the vector $\mathbf{y}$ on the diagonal.

that the production of intermediate inputs often requires intermediate inputs itself into account by using the so-called *mn*x*mn*-"Leontief inverse". The typical element b_{rs} of this matrix $\mathbf{B} \equiv (\mathbf{I} - \mathbf{A})^{-1}$, in which **I** stands for the *mn*x*mn*-identity matrix, indicates the output of each industry *r* required per unit of final demand for the products delivered by industry *s*. We can thus rewrite Equation (1) as

$$x_i = \mathbf{u}_k \hat{\mathbf{l}}_i \mathbf{B}\mathbf{f} \qquad (2)$$

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 x_i that affect the outcome of the multiplication $\hat{\mathbf{l}}_i\mathbf{B}$ 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 importance of each of the *mn* global value chains.

We first look at demand for final products and trade in final products. We distinguish between 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 Poland grows faster than consumption demand in Belgium, it is likely that product-specific income elasticities will also imply that the Polish consumption bundle will change faster than its Belgian counterpart. Finally, market shares of countries in selling final products might change over time. Relocation of electronics assembly activities in France to China will imply that market shares of Chinese final electronics products will increase at the expense of market shares of French final electronics products will be reduced. These three factors can be incorporated into the analysis by expressing the final demand vector as[8]

$$\mathbf{f} = [\mathbf{T}^* \circ (\mathbf{S}^* \cdot \hat{\mathbf{c}})]\mathbf{u} \qquad (3)$$

c is an *m*-vector. It's typical element c_u contains total final demand exerted by country *u*. **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 $\mathbf{S}^*$ 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

[8] The symbol ◦ stands for the "Hadamard product", obtained by cell-by-cell multiplication (i.e., $\mathbf{W} = \mathbf{X} \circ \mathbf{Y}$ means that $w_{ij} = x_{ij}y_{ij}$, for all *i* and *j*).

constructed by stacking m nxm-matrices **T**, of which the typical element t_{ru} represents the share of the country considered in final demand for product r in country u. **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 (e.g. cars assembled in Germany). If function-specific labour requirements vary across global value chains, changes in relative importance of these chains could lead to changes in the relative demand for particular functions. We label these as changes *between* GVCs. *Within* such global value chains, however, (function-biased) technological change and changes in the type of activities countries specialize into can also lead to differences in the amounts of labour of functions that are employed in the focal country. If Italy would contribute substantially to the value chain that ultimately produces British food products and the fabrication requirements within this chain would decrease rapidly because of technological change, Italian employment of fabrication workers would decline, everything else 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 upgrade its activities in this chain, e.g. performing some of the food processing activities and marketing in a later period. Generally, such changes also lead to changes in the extent to which function-specific labour is employed in the country considered.

If the production of final products is a fragmented process organized in (global) value chains, the mn-vector $\mathbf{l}_i^{w\prime} \equiv \mathbf{l}_i'\mathbf{B}$ gives a more appropriate measure of the techniques used to produce final products. $\mathbf{l}_i^{w}$ gives the worldwide inputs of labour of function i used to produce one unit of each of the mn final products, irrespective of the location of the activities required. Changes in $\mathbf{l}_i^{w}$ would only reflect function-biased technological change correctly if workers performing a given function would be equally productive across countries. Loosely speaking, if the productivity of a fabrication worker in country A would be double that of a worker in country B and fabrication activities 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 $\boldsymbol{\pi}$, the typical element of which contains the industry-specific labour productivity levels of labour relative to levels in the US.[9] This allows us to specify a global value chain's technology in terms of labour measured in efficiency units, $\mathbf{l}_i^{*\prime} \equiv (\boldsymbol{\pi} \circ \mathbf{l}_i)'\mathbf{B}$.

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

[9] The elements of $\boldsymbol{\pi}$ can change over time, but are assumed to be identical across workers in the four business functions. This does not in line with reality, but our data do not allow for better quantifications. Econometric analyses based on microdata would be needed.

intermediate inputs delivered by each of the potential countries-of-origin. Consequently, some industries in some countries will employ more labour in a given function than expected on the basis of $\mathbf{l}_i$*****, whereas other 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 function *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:

$$\mathbf{R}_i = \{\hat{\boldsymbol{\pi}}\hat{\mathbf{l}}_i\mathbf{B}\}\hat{\mathbf{l}}_i^{*-1} \tag{4}$$

Finally, demand for labour classified by function 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 labour demand (everything else equal).

Writing $\hat{\mathbf{l}}_i\mathbf{B} = \hat{\boldsymbol{\pi}}^{-1}\mathbf{R}_i\hat{\mathbf{l}}_i^*$ and substituting Equation (3) into Equation (2), we can express the employment of labour in function *i* in period 0 in the focal country as[10]

$$x_{i0} = \mathbf{u}_k'\hat{\boldsymbol{\pi}}_0^{-1}\mathbf{R}_{i0}\hat{\mathbf{l}}_{i0}^*[\mathbf{T}_0^*\circ(\mathbf{S}_0^*\cdot\hat{\mathbf{c}}_0)]\mathbf{u} \tag{5}$$

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

$$x_{i1} - x_{i0} = \mathbf{u}_k'\hat{\boldsymbol{\pi}}_1^{-1}\mathbf{R}_{i1}\hat{\mathbf{l}}_{i1}^*[\mathbf{T}_1^*\circ(\mathbf{S}_1^*\cdot\hat{\mathbf{c}}_1)]\mathbf{u} - \mathbf{u}_k\hat{\boldsymbol{\pi}}_0^{-1}\mathbf{R}_{i0}\hat{\mathbf{l}}_{i0}^*[\mathbf{T}_0^*\circ(\mathbf{S}_0^*\cdot\hat{\mathbf{c}}_0)]\mathbf{u} =$$

$$\mathbf{u}_k'\langle\hat{\boldsymbol{\pi}}_1^{-1} - \hat{\boldsymbol{\pi}}_0^{-1}\rangle\mathbf{R}_{i1}\hat{\mathbf{l}}_{i1}^*[\mathbf{T}_1^*\circ(\mathbf{S}_1^*\cdot\hat{\mathbf{c}}_1)]\mathbf{u}\ + \tag{6a}$$

$$\mathbf{u}_k'\hat{\boldsymbol{\pi}}_0^{-1}\langle\mathbf{R}_{i1} - \mathbf{R}_{i0}\rangle\hat{\mathbf{l}}_{i1}^*[\mathbf{T}_1^*\circ(\mathbf{S}_1^*\cdot\hat{\mathbf{c}}_1)]\mathbf{u}\ + \tag{6b}$$

$$\mathbf{u}_k'\hat{\boldsymbol{\pi}}_0^{-1}\mathbf{R}_{i0}\langle\hat{\mathbf{l}}_{i1}^* - \hat{\mathbf{l}}_{i0}^*\rangle[\mathbf{T}_1^*\circ(\mathbf{S}_1^*\cdot\hat{\mathbf{c}}_1)]\mathbf{u}\ + \tag{6c}$$

$$\mathbf{u}_k'\hat{\boldsymbol{\pi}}_0^{-1}\mathbf{R}_{i0}\hat{\mathbf{l}}_{i0}^*[\langle\mathbf{T}_1^* - \mathbf{T}_0^*\rangle\circ(\mathbf{S}_1^*\cdot\hat{\mathbf{c}}_1)]\mathbf{u}\ + \tag{6d}$$

[10] For ease of exposition, we did not include indices for time periods in the matrix algebra above.

$$\mathbf{u}_k'\widehat{\boldsymbol{\pi}}_0^{-1}\mathbf{R}_{i0}\hat{\mathbf{l}}_{i0}^*[\mathbf{T}_0^*\circ(\langle\mathbf{S}_1^*-\mathbf{S}_0^*\rangle\cdot\hat{\mathbf{c}}_1)]\mathbf{u}\ + \tag{6e}$$

$$\mathbf{u}_k'\widehat{\boldsymbol{\pi}}_0^{-1}\mathbf{R}_{i0}\hat{\mathbf{l}}_{i0}^*[\mathbf{T}_0^*\circ(\mathbf{S}_0^*\cdot\langle\hat{\mathbf{c}}_1-\hat{\mathbf{c}}_0\rangle)]\mathbf{u} \tag{6f}$$

As mentioned above, we identified six determinants of changes between initial period 0 and final period 1 in the domestic demand for labour of function *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 in function *i* that can be attributed to productivity catch-up to the United States (*changes in efficiency*). Equation (6b) gives the employment of worker in function *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 only technological change within global value chains would have been the only source of change (*changes in GVC 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*).[11] The changes regarding the composition and levels of consumption also include the effects of changing patterns and levels of investment demand.

[11] 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.

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