Growing Inequality:
a Novel Integration of
transformations research

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D7.2 Report: WIOD-based scenario approach

WP7 Future scenarios: design, analysis and outcomes

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Summary

Inequalities on labour markets around the world are affected by three fundamental 'transformations': technological change that saves different types of labour to different degrees, globalisation and migration. Interactions between these three transformations shape both demand and supply of workers. It is unclear, however, to what extent the speed (or even the direction) of these transformations will deviate from rates in the recent past. In this report, we think in terms of scenarios.

To inform policy-makers of the changes that can be foreseen regarding inequalities between the employment opportunities of workers in eight macro-regions in the world, we develop eight scenarios. For each transformation, we choose parameter settings in line with "slow" and "fast" rates of change, relative to rates of change in the recent past. We then use a world input-output table to provide an internally consistent quantitative representation of the network of global value chains. This representation is then linked to data on the business function (fabrication or headquarter functions) workers perform, to obtain a benchmark outcome for 2014. This is the most recent year for which the required data are available. We divide the global economy into eight "macro-regions": Old-EU, New-EU, Other Europe, North America, East Asia, China, Russia and Rest of the World.

We then use a linear programming approach to model changes in employment structures and consumption levels. These changes are driven by changes in the numbers of workers in fabrication functions and in headquarter functions required to produce a given quantity of final output by a value chain. This can change the comparative advantages of macro-regions regarding the participation in (global) value chains. Mobility and migration of labour can have impacts on labour supply and therefore on how much output a macro-region can generate (given the production technologies in value chains). Finally, the extent to which international trade is more or less restricted by protectionist measures determines the extent to which comparative advantages determine the structure of world production. All three transformations interact, which is why it is worthwhile to analyse the eight scenarios.

It is not possible to summarise the results in a single paragraph, but one of the most important results is that decisions on policies regarding globalisation and migration might have very important consequences for New-EU, the macro-region that consists of the EU member states that joined the EU in 2004 or later. The results suggest that further opening up to trade and allowing inward labour mobility would give the economy of this region a boost. Still, given that the analysis has not been set up for this region in specific, additional analyses are needed to corroborate these findings.

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The Impact of Technological Progress, Globalisation and Labour Mobility on Employment Structures: Quantitative Scenario Analyses

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Abstract

Inequalities on labour markets around the world are affected by three fundamental 'transformations': technological change that saves different types of labour to different degrees, globalisation and migration. Interactions between these three transformations shape both demand and supply of workers. It is unclear, however, to what extent the speed (or even the direction) of these transformations will deviate from rates in the recent past. In this report, we think in terms of scenarios.

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1. Introduction

The world is a dynamic place, in which unpredictable events can have long-term consequences for well-being. Quite often, these effects do not only vary across regions in the world, but often also across segments of populations within these regions, such as different types of workers. Inequalities sometimes become more marked, and be reduced in other cases. Besides these unpredictable events, dynamism and changes in inequality are also due to transformations of a longer-term (and possibly more predictable) nature. Policymakers can influence the pace at which these transformations happen, and might take issues of inequality into account when considering their options. This study focuses on the effects of such structural transformations on inequality in what we would call the 'medium long-run', 2030.

We consider three such transformations: technological change, globalisation and migration. Our focus is on labour markets in eight regions in the world, including the 'Old EU' (the countries that became member states before 2004) and the 'New EU' (members states that joined the EU in 2004 or later). We consider two types of workers, those active in the business function 'fabrication' and those active in the 'headquarters' business function ('HQ'). Previous analyses of trends regarding the three transformations showed that these two broad types of workers in the two EU-regions were affected differently by the three transformations. Fabrication workers could be replaced more easily than HQ-workers by computers and robots, because of differences in skills needed for the activities they are involved in. For the same reason, fabrication workers tended to be affected differently by changes in trade patterns. The same holds for the effects of migration, because the supply of both types of workers of both types did not change to same extent, neither in the 'home' region nor in the 'host' region. Studying recent trends can provide very useful insights, but policymakers need indications of the implications of policy alternatives in the future. Especially if the transformations affect each other, it is not straightforward to get a good impression of what choices might entail.

What kind of decisions related to technological change, globalisation and migration are debated on an almost continuous basis at the moment and have effects on labour market inequalities? Regarding technology, recent rapid advances in Artificial Intelligence (AI) technology suggest that HQ-labour might be saved at a considerably faster pace than before (see Frank et al., 2019). At the same time, there are calls of various sorts to slow the diffusion of these technologies down. Regarding globalisation, the coordination costs associated with slicing up production processes into activities dispersed around various parts of the world continue to fall, allowing for new waves of globalisation. At the same time, however, mounting geopolitical tensions lead policymakers to introduce protectionist measures, reducing the opportunities of firms to trade and sometimes forcing firms to 'reshore' activities to their main bases. Regarding migration and labour mobility, demographic changes (ageing) might well lead to tight labour markets in several regions in the world. Sustaining recent rates of economic growth would be hard to achieve without labour migration from regions where labour is not scarce yet. At the same time, many policymakers are cautious in allowing more migrants to enter their countries, not only because of fears of loss of national identity, but also because of the notion that mobile workers compete with the current inhabitants for scarce resources such as housing.

With respect to all three transformations considered, a crystal ball would be needed to foresee what policies will have been adopted in the period up till 2030. This study provides quantitative indications of labour market outcomes for eight scenarios. For each transformation, we formulate a "slow" and a "fast" scenario. We define "slow" and "fast" as relative to what was observed for the period 2000-2014, which is the most recent period for which the required data are available. Scenario 1, for example, is the "slow-slow-slow" scenario, in which labour saving technological progress becomes even more biased against fabrication workers than in 2000-2014, in which the globalisation as observed for 2000-2014 turns into deglobalisation and labour mobility across regions is reduced, relative to 2000-2014. In Scenario 8 ("fast-fast-fast"), quick adoption of AI and related technologies is assumed to save HQ workers faster than fabrication workers, globalisation becomes stronger (i.e., opportunities to trade increase at a fast pace) and opportunities for worker mobility across global regions increase. In Scenarios 2-7, one or two transformations is/are assumed to be slow, while the other transformation(s) is/are assumed to be fast.

It is important to note explicitly that the quantitative results presented in this study should *not* be seen as predictions. The data on which we base the study are the best data available for this purpose, but are not good enough for predictions. One could also opt for other quantifications of the scenarios. If we choose an increase of 25% in e.g. HQ labour-saving technological progress over the rate for 2000-2014, a different scenario-constructor might say that 10% might be more reasonable, while someone else might argue in favour of 40%. Such opinions are highly subjective. Instead, our aim is to provide quantitative indications of the magnitude of effects, based on coherent and consistent quantitative descriptions of the global production structure and its links with consumers as users of the final products it produced (in the form of a series of global input-output tables). Moreover, the scenarios are linked in a transparent way to trends that can be observed for the 2000-2014 period, using the same set of global input-output tables and compatible data. Although we would need a crystal ball to have a good idea about the choices policymakers will make regarding the pace at which the transformations are allowed to take place, we are convinced that the results we present for the scenarios have much more to say than any numbers crystal ball gazers would come up with.

The rest of this report is structured as follows. First, in Section 2, we will provide a verbal explanation of the method that we used to analyse the labour market inequality effects of the (interaction between) the three transformations discussed above. The pros and cons of this method, which is based on linear programming, will be discussed. Section 3 is devoted to the specification of the scenarios. Which assumptions do we make, and how did we use data for 2000-2014 (and regarding a few variables more recent data) to specify these? Next, in Section 4, we first analyse the effects of the three transformations separately, to show how economic mechanisms drive the outcomes. The second part of this section then focuses on the interactions of "slow" and "fast" trajectories for each of the three transformations. Section 5 concludes.

2. Analysing the Global Economy using Linear Programming

Analysing labour market consequences of transformations like technological change, globalisation and labour mobility/migration in Europe implies that a global perspective should be adopted. In this section, we will outline our linear programming approach and explain what types of data we used to implement it. We will do this in verbal terms and provide a few diagrams. We provide the mathematical details in an appendix.

This section is divided into two subsections. We will first introduce the data and then explain the linear programming approach. This approach finds the maximum level of global consumption, given the state of technology (roughly, the numbers of fabrication workers and HQ workers required to produce a unit of each final product), the extent to which products can be traded internationally and the supplies of fabrication and HQ workers in regions. These levels of labour supply are affected by labour mobility across regions.

2.1 Data

2.1.a Global input-output tables

Macroeconomic studies of issues related to globalisation have received a major impetus from the relatively recent availability of global input-output tables. Input-output tables for single countries have been constructed by many national statistical institutes for a long time already. Such tables provide a structured and internally consistent quantitative description of the national production structure in a year. It also provides information on the economic linkages between final use categories (e.g. household consumption, capital formation and exports) and the productive sector, as well as between the productive sector and the use of production factors and imported products. Crucial is the characteristic that the national productive sector is split up into multiple industries, and that the values of transactions between firms in those industries are reported in the tables. Such transactions relate to the sales and purchases of materials, parts and components and various types of business services, together often labelled as 'intermediate inputs'. Such single country input-output tables have been used extensively to quantify the impact of changes in the consumption of specific products on GDP and employment, but also on pollution (see Miller and Blair, 2009, for extensive overviews of applications in several fields).

With the rapid increases in international trade and foreign direct investment following the North-American Free Trade Agreement, China's membership of the World Trade Organisation and the East-European enlargement of the EU (all in the 1990s and 2000s), many researchers and policy advisors felt that single country input-output tables had become less useful in explaining changes in the real world. Hence, it is no surprise that around 2010, several initiatives were launched to explore opportunities to construct global input-output tables, which expand the coverage of input-output tables to the global production structure to final use and production factors around the world. In such tables, the global production structure is split up into what Los et al. (2015) called 'country-industries'. Examples are the German transportation equipment manufacturing industry and the Japanese financial services industry. It is important to note that the country indicator refer to the location of the activities, rather than to the ownership. A car manufacturing plant in Hungary owned by German firm Volkswagen is thus viewed as part of the Hungarian transport equipment manufacturing industry.

As mentioned, several initiatives to construct such global input-output tables were started. Nowadays, international organisations like the OECD and Eurostat have published global input-output tables. Still, we decided to use older data from the 2016-release of the World Input-Output Database (WIOD; Timmer et al., 2015), because we need compatible data on employment by function to study labour market inequalities. WIOD is the only database for which this type of data is available. Below, we will discuss these employment data in more detail (see subsection 2.1.b, below).

The WIOD global input-output tables are available annually for the period 2000-2014. In the tables, the world is split into 43 countries for which publicly available official data of sufficient quality and detail could be obtained. The other countries were merged into a 'country' labelled "Rest of the World". In turn, the national economies of all 44 countries could be split into 56 industries. These tables have been widely used, not only in scientific studies, but also by international organisations and the corporate sector.

For the purposes of this study, this level of detail is not needed. We are not interested in scenario studies for specific countries, but in studies for relatively homogeneous blocs of countries. Hence, we aggregated the 44 countries into eight 'macro-regions' (see Table 1). Since we do not focus our analysis on specific industries either, we also aggregated the detailed 56 industries into 28 broader industries (see Table A1, in the appendix). We left detailed manufacturing industries untouched, because of the disproportionally important role the products of these industries play in the globalisation process. We also have pragmatic reasons to aggregate countries and industries. The linear programming approach would become computationally hard for the PCs on which we run the analysis (using the Matlab software package) and the measurement errors that occurred in the construction of the WIOD tables and associated data would yield implausible results in some scenarios. Such measurement errors are unavoidable in the construction of global input-output tables, since it involves the reconciliation of often inconsistent data from various sources. If more aggregate data are used, the impact of such measurement errors is much smaller, since errors for different countries tend to cancel each other out.

Table 1: Aggregation of countries into macro-regions

Macro-region	WIOD-Countries
Old-EU	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden
New-EU	Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, Slovakia
Other Europe	Norway, Switzerland, United Kingdom
North America	Canada, United States
East Asia	Japan, South Korea, Taiwan
China	China
Russia	Russia
Rest of the World	Australia, Brazil, India, Indonesia, Mexico, Turkey, Rest of the World

Figure 1 presents a schematic overview of the global input-output tables that we use as our point of departure. After having discussed other data requirements in the two following subsections (2.1.b and 2.1.c), we will discuss how the input-output tables matched to the associated data can be transformed into Global Value Chain tables, which play a crucial role in our scenario studies.

2.1.b Employment data by function

To study the impacts of the three transformations on labour market inequalities, we need to have information about the employment of both fabrication workers and HQ workers in each of the industries in each of the regions. For their study into functional specialisation in trade, Timmer et al. (2019) used harmonised data from national labour force surveys and population censuses to construct data on how many workers involved in four different business functions were involved in the operations of each industry. They matched data on the reported occupations of workers to four business functions, which have traditionally played an important role in the case-study based literature on upgrading in GVCs: R&D, fabrication, management and marketing. The Timmer et al. (2019) data were compatible with the industry classification used in the 2013-release of WIOD. For other tasks in the GI-NI project, these data were updated and reconciled with the more detailed 2016-release.

Figure 1: Schematic representation of an 8-region global input-output table

	Region	Old-EU	New-EU	Other Europe	N-America	East Asia	China	Russia	RoW	Old-EU	New-EU	Other Europe	N-America	East Asia	China	Russia	RoW	Total output
		1…28	1…28	1…28	1…28	1…28	1…28	1…28	1…28	C, I	C, I	C, I	C, I	C, I	C, I	C, I	C, I	
Region	Indust																	
Old-EU	1…28																	
New-EU	1…28																	
Oth Europe	1…28																	
N-America	1…28																	
East Asia	1…28																	
China	1…28																	
Russia	1…28																	
RoW	1…28																	
	Value added									X	X	X	X	X	X	X	X	X
	Total inputs									X	X	X	X	X	X	X	X	X

Note: The table contains 28 rows per region, corresponding to sales of the industries (in blue). They can sell to industries in each of the 28 regions (as intermediate inputs, industries in green), or to household consumption (C) or capital formation (investment, I) in each of the regions (in grey). All transaction values are recorded in the white-coloured cells. Besides intermediate inputs, industries in each region pay for the use of production factors (labour and capital). These payments are recorded in the row labelled Value added. The row Total inputs contains the sums of all payments by industries. Given that value added includes profits, the values in this row must be identical to those in the rightmost column (Total output), due to double-entry bookkeeping conventions. The cells marked with X are empty.

For the purpose of this study, we aggregated employment regarding the functions R&D, management and marketing into a single function, called the headquarter (HQ) function. Generally speaking, performing the HQ function requires creativity, interpersonal skills and or adaptability, whereas the fabrication function involves more routine-intensive activities. This is apparent from the occupations that Timmer et al. (2019) provide as examples: 'human resources managers', 'engineers and related professionals', and 'sales persons' fall under the heading of HQ workers, while 'assemblers' and 'machine operators' are presented as typical examples of fabrication workers. Although a one-to-one correspondence between function and skill level does not exist, HQ workers tend to be more highly-skilled than fabrication workers.

2.1.c Productivity data

In the next subsection, we will merge a global input-output table with employment data by function to arrive at indicators of the numbers of fabrication and HQ workers required to produce a dollar of a final product (e.g. German transport equipment). Decreasing labour requirements per dollar of final output would suggest labour-saving technological progress. There is one important caveat, though. Workers contributing to the production of a given final product can be employed anywhere in the world, given that production processes have become increasingly dispersed over countries and regions. If we would just consider the unweighted sum of all fabrication workers involved in such a GVC as an indicator of technology, we would implicitly assume that they are all equally productive. It is well-known, however, that e.g. Chinese workers are on average much less productive than e.g. German workers. If a German firm would increase its profits by relocating some of its activities to China, it would hence employ more Chinese workers (with low salaries) to make up for the German workers (with higher salaries). This would imply that a change in a trade pattern would cause an apparent regress in technology. To address problems like these, we express labour requirements in GVCs in terms of 'efficiency units of labour'. These are obtained by correcting labour requirements for differences in productivity.

Following Reijnders and de Vries (2018), we use data from the Penn World Tables (version 10.0, see Feenstra et al., 2015) on total factor productivity to apply this correction. Due to a lack of more detailed high-quality harmonised productivity data that span the global economy, we have to make two strong assumptions. The first one is that the productivity differences between *countries* are identical across industries at any point in time. The second one is that these differences are also identical for fabrication workers and HQ workers. Reijnders and de Vries (2018) experimented with alternative approaches to accounting for productivity for subsets of countries, and reported that their main conclusions remained unchanged. It is important to note that the productivity differences between two *macro-regions* as obtained in our are not completely identical, due to the fact that some countries in a macro-region have larger than average employment weights in either fabrication or HQ, and in one or more industries.

2.1.d Global Value Chain tables

As discussed, many production processes have become sliced up, with production activities taking place in various parts of the world. This implies that technological change should ideally not be considered at the level of industries in countries or macro-regions anymore. If a car-manufacturing firm in Germany would relocate its assembly activities to Hungary, while keeping its R&D and marketing activities in Germany, this would cause changes in the requirements of fabrication and HQ workers per unit of output, suggesting technological change in both the German and Hungarian car- manufacturing industries. In reality, technology did not change, but trade patterns did. To identify technological change, we need to take the GVC as the unit of analysis.

We follow Reijnders et al. (2021) by merging global input-output tables, employment data and productivity data into what we call 'GVC tables'. Figure 2 presents a stylised version of such a table. The columns refer to GVCs, of which the output is sold to final users, for consumption or investment purposes. Examples of such GVCs are "transport equipment from the Old EU" and "electronic equipment from China". The rows refer to industries in macro-regions that contribute to these value chains, such as the "financial service industry in the Old EU" and the "electronic equipment industry in North America". A cell in row *i* and column *j* provides an indication of the involvement of industry *i* in GVC *j*. It would reflect, for example, the contribution of the Old-EU's financial services industry to the GVC producing transport equipment finalised in the Old-EU, or the contribution of the North American electronic equipment industry to the GVC for Chinese electronic equipment.

Figure 2: Schematic representation of an 8-region GVC table

		Old-EU	New-EU	Other Europe	N-America	East Asia	China	Russia	RoW	Total number of efficiency units of labor per region-sector
	GVCs	1…28	1…28	1…28	1…28	1…28	1…28	1…28	1…28	
Regions	Ind									
Old-EU	1…28									
New-EU	1…28									
Other Europe	1…28									
North America	1…28									
East Asia	1…28									
China	1…28									
Russia	1…28									
RoW	1…28									
Total number of efficiency units of labor per GVC										
Final output per GVC										

Contributions by an industry to a GVC are measured in terms of efficiency units of labour. Since we consider two types of labour, we also construct two GVC tables. One refers to contributions in terms of fabrication labour, the second to what industries contribute in terms of HQ labour.

If the elements in the cells of a column in a GVC table are added, the number of efficiency workers in the GVC corresponding to that table is obtained. We can divide this by the value of the output of that GVC (in the bottom row), to know how much efficiency units of labour are needed per dollar of output. Comparing these outcomes over years (correcting for inflation) yields information about the rate of labour-saving technological progress in each GVC, for both types of labour separately.

The columns of GVC tables also provide information about the location of activities. If we add the labour contributions of the 28 industries in a region up, we find the total labour contributed by a region to that particular GVC. This can be divided by the global inputs of labour in that specific business function to get the share contributed to that region. We might, for example, find that 20% of the fabrication labour used in the GVC for Chinese electronics is contributed by North America, and 60% of the HQ labour (note that these percentages are hypothetical, just for exposition). These shares can change over time, reflecting changes in globalisation.

Obtaining these GVC tables from the global input-output tables, employment data by function and productivity data is relatively straightforward, using input-output techniques that were introduced by Wassily Leontief in the 1920s already. The main implicit assumption is that the production technology (the mix of intermediate inputs and use of both types of labour required to produce a unit of output) of an industry is assumed to be independent of the customer to which the output is sold. This is known to be strict assumption, because industries generally sell different products to consumers than to industries, and because exporting firms tend to use more productive production processes than firms in the same industry only selling to domestic clients. Still, given the current data situation, this assumption is unavoidable.

Figure 3: Schematic representation of an 8-region final goods trade table

		Old-EU	New-EU	Other Europe	North America	East Asia	China	Russia	RoW	Global consumption and investment demand per final product
Regions	Sect									
Old-EU	1…28									
New-EU	1…28									
Other Europe	1…28									
North America	1…28									
East Asia	1…28									
China	1…28									
Russia	1…28									
RoW	1…28									
Aggregate consumption and investment demand per region										

We should also take trade in final goods into account. We do this by means of tables as schematically presented in Figure 3. The rows indicate the industries selling final products, the columns refer to the regions that purchase the final products, for consumption and investment (gross fixed capital formation) demand. Final goods trade tables can be taken directly from global input-output tables, without any mathematical operations.

2.1.d Population and migration data

We assume that the numbers of HQ and fabrication workers in 2014 (taken from the employment data by function discussed above) per region equal supply of both types of labour in 2014. Next, we considered population growth (net of the effects of migration and mobility between macro-regions) from World Bank data (World Bank, 2023) as indicators of the growth of the labour force over the period 2014-2030. We considered the data related to the number of persons in the working age population. This yields an estimate of the availability of labour in both functions. In doing so, we assumed that the shares of fabrication workers and HQ workers remained identical over the period 2014-2030.

Migration and mobility data were also taken from World Bank sources (World Bank, 2023). These data do not provide information about the reason why persons moved from one macro-region to another. We assume that positive net immigration increases the size of the labour force of a macro-region, adding to the productive capacity of the destination region. The opposite, of course, holds for the macro-region where workers lived before they migrated. The data does not contain information about the origin and destination of migrants. For our purposes, this is not a downside, because we are just interested in the consequences for labour supply, so net migration figures suffice.

2.2 The linear programming approach

Linear programming is a mathematical technique to find an optimal solution given a set of constraints. In a macroeconomic context, it was introduced by Dorfman et al. (1958), using national input-output tables. Their lead was followed by several authors, among which Duchin's (2005) and Strømman and Duchin's (2006) contributions are notable, because they applied these techniques to policy questions that refer to technological change and international trade. In the discussion below, we introduce our application of these techniques in an intuitive way. Much more recently, Nii-Aponsah et al. (2023) also used linear programming techniques in analyses of the interplay between technological change and trade patterns.

In our study, the variable that is maximised is global consumption, as an indicator of global welfare. The main constraints relate to the limited availability of workers of both types. If labour would be available in infinite quantities, the level of consumption would also be unbounded. As long as labour of at least one type (fabrication or HQ) is needed in all GVCs, limits to available labour supply imply limits to global consumption exist. Given constraints, the optimal solution could be attained by a 'social planner', but as Ricardo's classical trade theory shows, markets with profit-maximising firms and utility-maximising consumers can also yield solutions to linear programming models related to macro-economic phenomena based on comparative advantage. Still, the use of this approach is one of the reasons why our results should be seen as indications of outcomes of a number of broadly defined scenarios, and definitely not as predictions.

More constraints are needed to apply this technique in a sensible way. Some simple examples can illustrate this. First, if labour would be fully mobile across regions and trade would be without any friction, all workers in the world might move to the most productive region, from where the entire world would be served. All other macro-regions would be unpopulated, which is clearly not a realistic situation in 2030. Second, if households could choose the mix of their consumption basket freely and would only be concerned about the total value of that basket, they would only buy the final products of the GVC that requires the least efficiency units of labour. This might, for example, imply that they would only purchase real estate services. This is not a realistic situation either.

To preclude unrealistic outcomes like those discussed above (so-called 'corner solutions'), we included constraints in our linear programme. One set of constraints refer to the extent to which location patterns of functions in GVCs could change between 2014 and 2030 and the extent to which patterns of trade in final products could change in that period. The specific formulations of these constraints reflect policy options and will be discussed in more detail in the next section, on scenarios. The other set of constraints refers to the degree to which workers are mobile across regions in the period up to 2030. Also in this case, the specific constraints reflect policy options. Hence, we will discuss the exact way in which these constraints are formulated in the scenarios in the next section. As we will mention in that section, we will assume that the shares of all consumer products in the total consumption bundle remains unchanged in 2014-2030.

The optimal solution to the linear programme not only gives the global consumption level that can be attained given the production technologies and the constraints. It also provides information about employment of fabrication workers and HQ workers in each of the macro-regions. This provides us with indications of the evolution labour market inequalities in several parts of the world, in cases in which the three major transformations central to the GI-NI project interact. In interpreting the outcomes, it is important that it does not consider prices (such as wage rates) as a mechanism that can lead to quantity adjustments. In reality, workers who fear to get unemployed might settle for a lower wage rate and continue to be employed. The absence of such mechanisms in our modelling approach means that the employment and unemployment rates as reported by us should mainly be seen as indicators of the unequal labour market effects of the transformation on fabrication and HQ workers.

3. Scenarios

In this section, we discuss the scenarios. The magnitude and the distribution over macro-regions of global demand for labour performing specific functions depend on many factors. As explained in the introduction, we focus on three of these: labour-saving technological change, migration and mobility, and changes in patterns of international trade. For each transformation, we will define a "slow" trajectory and a "fast" trajectory, leading to a total of eight scenarios, summarized in Table 2 below. The numbers that we attach to the terms "slow" and "fast" in our scenario analyses are based on historical data, in most cases for the period 2000-2014. For many of the variables that we need, more recent data are not available. It is important to note that we focused on setting parameters for the long run, and therefore not specifically identify the effects of crises and other sources of structural breaks. We first consider the long-run evolution over 2000-2014 and extrapolate the observed values of key variables until 2030 in our 'business-as-usual' scenario. Next, we assume slower or faster evolution of these variables for the "slow" and "fast" scenarios, for each of the transformations. The only important exception is globalisation, since global trade to global GDP statistics show that the degree of globalisation has more or less remained stable after 2014, while it increased dramatically before the 2008 global financial crisis. Hence, we take the 2014-situation as the 'business-as-usual' situation in 2030, regarding patterns of international trade.

The specific assumptions made for scenarios regarding these three transformations will be discussed in subsections 3.2-3.4, below. The choice for these three transformations is not only in line with the lens through which all research in the GI-NI project is looking at inequality in labour markets, but it also keeps the analysis tractable. A downside is that we have to make a number of assumptions, some of which are strict. These apply to all scenarios. We discuss them one-by-one in subsection 3.1.

Table 2: Scenarios regarding the three transformations

	Techn. Change	Globalisation	Migration
Scenario 1	slow	slow	slow
Scenario 2	slow	slow	fast
Scenario 3	slow	fast	slow
Scenario 4	slow	fast	fast
Scenario 5	fast	slow	slow
Scenario 6	fast	slow	fast
Scenario 7	fast	fast	slow
Scenario 8	fast	fast	fast

3.1 Assumptions pertaining to all scenarios

The evolution of the world production structure (or, in other words, the network of GVCs) and its links to end users of its outputs is driven by a multitude of factors. In order to keep the analysis tractable and to keep the number of scenarios reasonable, we had to make some choices. These resulted in a number of assumptions common to the eight scenarios that are central to this study. We discuss these below.

3.1.1. Options for workers to adapt to changes

The first set of assumptions relates to the flexibility of workers in adapting to changes. First, we assume that workers performing a *function* (fabrication or HQ) are not able to perform the other function. We thus assume that the capability sets required to perform either of the two functions are not sufficiently overlapping to allow for function switching and that retraining is not possible within a reasonable number of years.

We assume that switching from a job in a function in one *industry* to a job in the same function in a different industry is possible instantaneously, at no cost.

Furthermore, we assume that the extent to which workers can move from one *macro-region* to a different one is unrelated to any mismatches between the capabilities workers have and the capabilities that are required to work in a different region. Even more so, we assume that workers who move between regions attain the productivity level of workers in the same function as workers in the same function who worked in that region much longer already. This seems a strong assumption, but given that we assume that workers can migrate between 2014 and 2030, the majority of mobile workers would have multiple years to reach higher productivity levels, becoming as productive as others in the same industry and same region by 2030 (the year for which we analyse the scenario outcomes). This implies that we assume that mobility of workers is fully determined by mobility/migration regimes discussed in subsection 3.2 below, and by opportunities to get a job. If fabrication workers, for example, are unemployed in a macro-region, immigration of fabrication workers into this region is assumed to be zero. This implies that we only consider labour migration, and that other reasons to be geographically mobile are not taken into account in our scenarios.

3.1.2 Production factors: labour and capital

The production factors of central interest in our analysis are fabrication labour and HQ labour. We assume that the numbers of workers in the eight macro-regions in 2014 represented a situation of full employment, up to the extent that no involuntary unemployment existed. We then applied projected rates of population change (net of migration flows; we will label this as 'autonomous' population change) up till 2030 to these 2014 levels, to arrive at 'autonomous' labour supply for the regions in 2030. The projected rates of population change were taken from World Bank (2023). In view of our data, we could not take any changes in the age distributions of the population in regions into account. We also had to assume that the shares of labour *supply* with the skills to do fabrication activities and those with the skills required for HQ functions in the regions remains constant between 2014 and 2030 (the numbers of workers of both types who are actually employed can and will change, due to differences in labour *demand* across scenarios). Hence, changes in education policies are disregarded in this study.

Physical capital (machinery, transportation equipment, computers, etc.) is needed to produce, but only plays an implicit role. We assume that the ratios between investment and GDP remain fixed at their 2014 levels in all eight macro-regions. This implies that part of the world's productive resources have to be used to produce investment goods, and cannot be used to produce products available for consumption. We furthermore assume that the composition of investment remain unchanged over the 2014-2030 period.

This approach implies that we assume that capital and the two types of labour cannot be substituted for each other at a given point in time. As we will discuss in section 3.2, technological change is assumed to be purely labour-saving, implying that capital intensities (the ratios between capital and fabrication labour and between capital and HQ labour) increase over time. We assume that this technological progress is exogenous, i.e. that it does not depend on the scale of production (no 'learning-by-doing') or on purposeful investments in innovation. The numbers of HQ workers used by us to calibrate our scenarios include workers active in R&D activities, but we implicitly assume that these numbers do not affect the rate of technological change.

In some productivity studies, additional production factors such as land are considered as well (e.g., Smulders and Gradus, 1996). This is beyond the scope of our study, we implicitly assume that it is not a scarce production factor. The same goes for environmental stressors (e.g. greenhouse gas emissions). These can also be seen as production factors and there is sufficient evidence that these have become scarce, but including these would make the analysis considerably less tractable and distract from the focal point of our study, the interplay of technological change, globalisation and mobility/migration.

3.1.3 Consumption

As discussed before, the global linear programming problem that is central to our approach revolves around the idea that household consumption is maximised, given the GVC technologies used to produce final products, the extent to which productive locations can be used and the availability of labour of both types in these locations. These determinants together yield the maximum level of consumption, given the composition of the consumption bundle.

In the real world, relative prices play a role in the consumption decisions made by households. In general, if the price of one product goes up relative to that of another product, the purchased quantity of the first product will be reduced. It is less clear what happens to the purchased quantity of the second product, since the outcome depends on the interplay of price elasticities and substitution elasticities. If decisions at different points in time are considered, income elasticities ('Engel curves') would also become relevant. Since prices are not explicit in our approach and because we want to focus on the three transformations, we decided in favour of a rather simple approach and assume that the relative quantities consumed by households in each of the eight macro-regions does not change after 2014, the most recent year for which all required data are available.

3.2. Technological Change

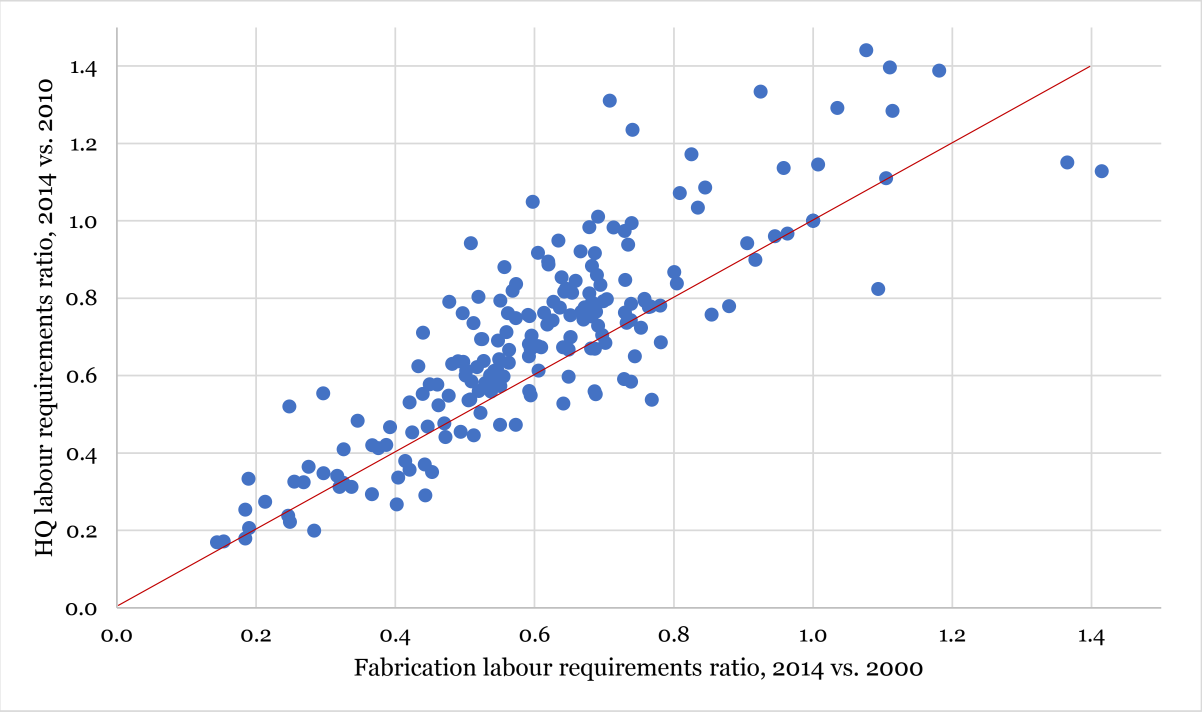
The scenarios regarding technological change include assumptions about the values of two sets of variables in 2030. The first set relates to the requirements of fabrication and HQ labour in each of the GVCs. The second set consists of assumptions about the speed with which the productivity levels of workers in the eight macro-regions converge with those in the region with the highest productivity, North America.

3.2.1 GVC-specific changes in labour requirements

As we discussed in Section 2, the number of efficiency units of fabrication labour and HQ labour required per dollar of final output provides a measure of the state of technology in a GVC in a given year. Comparing the GVC table derived from the global input-output table for year *t* expressed in prices of year *t*-1 to the the GVC table derived from the global input-output table of year t-1 expressed in current prices (that is, also prices in *t*-1), we can quantify labour-saving technological change in GVCs between *t*-1 and *t*. Unlike most global input-output databases available, WIOD provides global input-output tables expressed in previous year's prices, for the period 2000-2014. Chaining the rates of technological change (both for fabrication workers and for HQ workers), we thus identified average annual rates of labour-saving technological change over that period, for all 28x8 GVCs. We extrapolated these rates till 2030, assuming that the average annual rates of progress would apply to the period 2014-2030 as well. This yielded numbers of efficiency units of fabrication labour and HQ labour for each GVC in what could be called the 'business as usual' (bau) scenario.

Figure 4 shows that technological progress over 2000—2014 has been biased against fabrication workers. A ratio smaller than 1.0 indicates that less labour of the types considered was needed per unit of final output of a GVC in 2014 than in 2000, for fabrication labour and HQ labour along the vertical axis, respectively. The figure clearly shows that for the vast majority of GVCs, technological progress saved both types of labour. We also observe, though, that most GVCs were characterized by ratios that were smaller for fabrication labour than for HQ labour: the fact that most dots are located above the 45-degrees line means that the fabrication labour requirements decreased more rapidly than the HQ labour requirements. Apparently, innovations in ICT and robots (and the diffusion of these types of capital) replaced fabrication labour more rapidly than HQ labour. In some cases, reductions in fabrication labour requirements were even accompanied by (modest) increases in HQ labour requirements, which is a phenomenon emphasised in e.g. Acemoglu and Restrepo (2018).

Figure 4: Function-biased labour-saving technological change (2000-2014)



Note: Source authors' computations based on WIOD (2016-release, Timmer et al., 2015) and updated occupations database (Timmer et al., 2019). Each dot represents a GVC. Ratios between fabrication requirements (in efficiency units) per unit of GVC output in 2014 and 2000 are plotted along the horizontal axis. Ratios between HQ requirements (in efficiency units) per unit of GVC output in 2014 and 2000 are plotted along the vertical axis. The red 45-degrees line indicates unbiased technological change.

In our scenarios with "slow" labour-saving technological progress, we assume that technological change regarding the fabrication labour requirements slowed down by 25% in 2014-2030 in comparison to the rate of progress in 2000-2014 (in each GVC), while the rate of progress regarding HQ labour requirements remains unchanged. This scenario can be viewed as a reflection of a situation in which the low-hanging fruits of ICT and robot technology had been reaped already in 2014, and no new major technologies would emerge until our projection year 2030.

Our scenarios with "fast" labour-saving technological progress are characterised by the assumption that the fabrication labour requirements continued to decrease at the same paces as in 2000-2014 (again, in each of the GVCs), while the HQ labour requirements decrease in 2014-2030 at paces 10% faster than in 2000-2014. This scenario can be viewed as a reflection of a situation in which new types of innovations appear and diffuse rapidly. Relative to the period 2000-2014, these innovations replace HQ workers more than fabrication workers. According to many commentators, this is a distinctive feature of many innovations in the field of Artificial Intelligence.

In both scenarios, the bias in technological change against fabrication work is weaker than observed in 2000-2014, but for different reasons. Changes in the relative requirements of fabrication and HQ labour will have implications for comparative advantages driving changes in trade patterns in scenarios in which international trade is relatively free. In the scenarios with fast technological progress, the differences in the rates of population growth will be less of a factor determining migration than in scenarios with slow technological progress, because demographic decline will be compensated by increased productivity of the labour force.

3.2.2 Relative productivity levels in the eight macro-regions

The GVC-specific technologies, trade patterns and demand for final products together determine the number of efficiency units of labour (of both types) employed in a macro-region. This quantity of labour is converted into numbers of jobs via differences in labour productivity.

The leftmost columns of Table 2 shows how the productivity levels compared in 2014. All levels are relative to the United States, which means that an efficiency unit of labour is equal to one worker in the US. Given that the macro-region North America consists of the US and Canada, it is no surprise that the productivity levels of this region are always close to one. Workers in Old-EU and Other Europe were about 14% less productive in 2014, while workers in New-EU and East Asia were more than 25% less productive. The gaps between labour productivity in China and Rest of the World were exceeding 50%. The productivity levels for fabrication and HQ workers differ slightly, because the weights of the countries of which macro-regions are composed varies. Canada, for example, has a larger share of fabrication workers than the US. Hence, the fact that Canada's productivity level was lower than the level in the US implies that North America's relative productivity level of fabrication workers is lower than that of HQ workers.

Table 3: Productivity levels (relative to the USA), 2014 and 2030-scenarios

	2014		2030-bau		2030-slow		2030-fast	
	Fab	HQ	Fab	HQ	Fab	HQ	Fab	HQ
Old-EU	0.850	0.863	0.878	0.889	0.872	0.883	0.885	0.895
New-EU	0.718	0.720	0.767	0.769	0.756	0.758	0.779	0.781
Other Europe	0.850	0.845	0.879	0.874	0.872	0.867	0.885	0.881
North America	0.984	0.987	0.987	0.990	0.986	0.989	0.988	0.990
East Asia	0.714	0.711	0.764	0.762	0.752	0.750	0.775	0.774
China	0.425	0.425	0.505	0.505	0.485	0.485	0.524	0.524
Russia	0.589	0.589	0.655	0.655	0.639	0.639	0.671	0.671
RoW	0.513	0.536	0.587	0.608	0.569	0.590	0.604	0.625

Note: Authors' computations based on Penn World Tables 10.0 (Feenstra et al., 2015). USA=1.

Productivity gaps across regions are not stable over time, which implies that it would be naïve to assume that the gaps as measured in 2014 will also apply in 2030. A panel data regression for 2000-2014 in which we assume that all regions converge or diverge equally quickly in terms of productivity levels yielded an average rate of catch-up equal to 1.40% per year. That is, every year, the productivity gap of each region shrank by 1.40% of the existing gap to the United States. Assuming that this rate of catch-up would continue to prevail in the period 2014-2030 yields the relative productivity levels in the columns 2030-bau ('business as usual') in Table 3.

In the scenarios with "slow" technological change, we will assume that the rate of productivity catch-up will be 25% lower than in bau, at a rate of 1.05% per year. For the scenarios with "fast" technological progress, we assume that the productivity convergence is 25% faster than in bau. The resulting relative productivity levels for each of the macro-regions in these scenarios can be found in the columns in the parts on the right of Table 3.

3.3. Migration and Mobility

If no constraints regarding labour mobility across macro-regions are included in the linear programme for our scenario study, by far the most economic activity cluster in the regions where productivity levels are highest (unless opportunities to trade are restricted to very low levels). This is a phenomenon that can also be observed in reality, but it is also clear that labour mobility is in many cases restricted by governments. To formulate sensible scenarios regarding the rate of migration, we used population and migration data from the World Bank (2023). This migration part has the advantage that it covers the entire world, but the disadvantage is that it does not provide information about the reasons why people move from one region to another. In our scenarios, we assume that everyone who moves will work.

We first used the data on net migration to compute the 'autonomous' growth rate of the regional populations aged 20-64. We then computed how large the cumulative net inflow of migrants since 2000 was, relative to the autonomous population. The values for 2014 are given in the leftmost part of Table 4. Not surprisingly, the New-EU, China and the Rest of the World experienced net outmigration, while in particular the Old-EU, Other Europe and North America welcomed more people than left.

Migrants working in the macro-regions in 2014 are already included in the employment figures for both functions. Hence, in order to arrive at meaningful scenarios for 2030, we have to consider the differences in population between 2014 and 2030. We thus took the ratios between the cumulative net migrants since 2000 and our estimate of the autonomous population, for all years between 2000 and 2019 (the most recent year for which reliable data not affected by the Covid-pandemic is available) and drew a trendline through these. Assuming that these trendlines would be followed between 2014 and 2030 we arrived at the shares in the columns labelled '2030-bau'. Because we do not know whether migrants have the skills to work in fabrication or in the HQ function, we assume that both shares are identical. The percentage 6.45 in the first row, for example, indicates that in the business-as-usual scenario, the labour supply for fabrication and HQ would be 6.45% higher than in the absence of migration. The last row (for the Rest of the World) is left empty for the scenarios, because the net migration of the other seven macro-regions determine the net migration in RoW.

Table 4: Interregional migration (in %), 2014 and in scenarios for 2030

	2014		2030-bau		2030-slow				2030-fast			
	FAB	HQ	FAB	HQ	FAB lower	FAB upper	HQ lower	HQ upper	FAB lower	FAB upper	HQ lower	HQ upper
Old-EU	5.05	5.05	6.45	6.45	-4.84	4.84	-6.45	6.45	-8.06	8.06	-8.06	8.06
New-EU	-5.80	-5.80	-7.15	-7.15	-5.36	5.36	-7.15	7.15	-8.94	8.94	-8.94	8.94
Other Europe	5.64	5.64	6.08	6.08	-4.56	4.56	-6.08	6.08	-7.60	7.60	-7.60	7.60
North America	5.65	5.65	6.29	6.29	-4.72	4.72	-6.29	6.29	-7.86	7.86	-7.86	7.86
East Asia	0.53	0.53	0.62	0.62	-0.47	0.47	-0.62	0.62	-0.78	0.78	-0.78	0.78
China	-0.34	-0.34	-0.37	-0.37	-0.28	0.28	-0.37	0.37	-0.46	0.46	-0.46	0.46
Russia	0.46	0.46	0.29	0.29	-0.22	0.22	-0.46	0.46	-0.36	0.36	-0.36	0.36
RoW	-0.71	-0.71										

Note: Authors' computations, based on World Bank (2023). Positive percentages refer to net immigration and are expressed as ratios to the estimated 'autonomous' population levels. Columns labelled 'lower' refer to the minimum migration level in the corresponding scenario, columns labelled 'upper' refer to the maximum level in that scenario.

For the scenarios in which migration is “slow”, we assume that policymakers will reduce the maximum ratio of the number of incoming fabrication workers to the autonomous population by 25% (as compared to 2030-bau. In the case of macro-regions with net outmigration, they reduce the maximum share of leaving fabrication workers by 25% in comparison to the bau-scenario. In the scenarios in which migration is “slow”, the maximum migration rates of HQ workers are assumed to be as in the bau-scenario.

In the scenarios in which migration is “fast”, our assumption is that the maximum rates of migration are higher than in the business-as-usual scenario, both for fabrication workers and for HQ workers. The maximum difference between the bau-scenario and the “fast” scenarios is 25%.

It might be argued that labour mobility between Old-EU and New-EU should not be bounded from above, given the freedom for EU citizens of one member state to get a job in another member state. Still, workers face several types of barriers when doing so. Examples are differences in pension systems, problems in finding accommodation, differences in qualifications required to do specific types of jobs, language problems and leaving relatives and friends behind (see, e.g. Baldwin and Wyplosz, 2020, Ch. 8). In view of such barriers, we treat Old-EU and New-EU as a regular ‘pair’ of macro-regions in this respect.

It should be noted that we set lower and upper bounds in the “slow” and “fast” scenarios. The actual magnitudes of the inflow and outflow of workers depends on the evolution of GVC-technologies, on the pace of productivity convergence between regions and the extent to which globalisation is restricted. The solution to the linear programming problem with the highest global consumption level also implies how many workers entered or left each of the macro-regions.

3.4. Globalisation

The widespread organisation of production processes in global value chains (GVCs) can be used as a good illustration of the trade-offs between (i) reaping the benefits of differences in comparative advantages of locations and (ii) incurring the costs involved with being active in multiple countries that are often distant from each other. The outcomes of such trade-offs determine trade patterns, both regarding the location of activities within GVCs and the trade in final goods.

From the perspective of firms, comparative advantages are just cost differentials between locations. If the productivity of low-skilled workers is equal in two places, but their wages are higher at home than elsewhere, it might be profitable for a firm to relocate low-skilled labour-intensive activities away from home. The main reasons why wage levels of low-skilled workers might be lower in one place than another are differences in technology and differences in the availability of low-skilled labour. These two determinants of comparative advantage are explicitly present in our linear programming framework. Given that production factors (fabrication workers and HQ workers) can be scarce, the maximisation of global final consumption will ensure that the activities will take place according to comparative advantages (see ten Raa and Mohnen, 2001), as long as trade costs are zero.

How about these costs, related to organising production processes in GVCs and/or producing final products in places far away from where large populations of consumers are located? First, *transportation* costs definitely play a role, but for some type of products more than for others. Especially products with a high ‘value-to-size ratio’ (such as many types of electronic products) can be transported cheaply. Disruptions related to natural disasters and accidents require the consideration of a certain degree of risk, but over the long run transportation costs have been falling (Hummels, 2007). Secondly, *coordination* costs should be considered. If some activities depend very strongly on each other (e.g. because of the need of face-to face communication, or because the manufacture of final products requires sufficient availability of components while inventories of components are expensive), coordinating them over long distances can be problematic. With the rapid emergence and diffusion of internet-based ICT, coordination costs have been falling substantially, although they are still sizable for some pairs of activities (Baldwin and Venables, 2013). Continued innovations in digital technology will most probably bring the costs of coordination further down, as stressed by Baldwin (2016). Finally, firms face what we label *trade policy* costs. National governments and supranational governments (think of the European Commission) can liberalise trade by abolishing quotas and tariffs. They can also facilitate foreign direct investment. These are policies that reduce trade policy costs. Alternatively, governments can raise such costs, e.g. by introducing export bans or by implementing strict legislation on standards applying to imported products. Examples of the latter types of protectionist measures are regulations regarding environmental aspects of production processes and/or the conditions under which workers are employed.

If the sum of transportation costs, coordination costs and trade policy costs increase, the profitability for firms of relocating activities to benefit optimally from differences in comparative advantages is reduced. As e.g. Timmer et al. (2021) show, GVCs tended to continue becoming more fragmented after the global financial crisis of 2008/2009, but at a slower pace than between 2000 and 2008. In this 2009-1014 period, the trade policy costs did not increase yet, and the slower slicing up process thus suggests that the lowest-hanging fruits regarding gains from using comparative advantages had been reaped already, and/or that coordination costs did not fall much further. The period for which Timmer et al. obtained their results preceded the period in which geopolitical tensions started to grow. These led to the trade war between the United States and China and the sanctions against Russia adopted by many countries following the start of the war in Ukraine. Trade policy costs thus soared recently and it is only natural that several multinational firms started to consider reversing offshoring decisions, contemplating ‘reshoring’ (bringing activities back to the home country) or 'friendshoring' (relocating activities to countries belonging to the same trade bloc) (see, e.g., Delis et al., 2019; Kamakura, 2022; Javorcik et al., 2022).

Table 5a: Minimum changes in regional labour shares in "slow" globalisation scenarios (2014-2030)

from \ to	Old-EU	New-EU	Oth Eur	N-Am	E-Asia	China	Russia	RoW
Old-EU	1.0	1.0	0.2	0.2	0.2	0.2	0.2	0.2
New-EU	1.0	1.0	0.2	0.2	0.2	0.2	0.2	0.2
Other Europe	0.2	0.2	1.0	0.2	0.2	0.2	0.2	0.2
North America	0.2	0.2	0.2	1.0	0.2	0.2	0.2	0.2
East Asia	0.2	0.2	0.2	0.2	1.0	0.2	0.2	0.2
China	0.2	0.2	0.2	0.2	0.2	1.0	0.2	0.2
Russia	0.2	0.2	0.2	0.2	0.2	0.2	1.0	0.2
RoW	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.0

Note: Values represent ratios to the shares in 2014. A value of 1.0 indicates that the share of the region in the row in labour inputs required by the GVCs of the region in the column is not allowed to decrease between 2014 and 2030. A value of 0.0 indicates that such a share is allowed to become zero. Shares are expressed in efficiency units of labour, and apply to fabrication and HQ labour. These lower bounds are also assumed for shares in final products trade.

We use stability of the shares of macro-regions in the use of both fabrication and HQ labour (measured in efficiency units) in each GVC in 2014 as the business-as-usual scenario. Ideally, we would have used recent values for these shares, but a lack of data prevents us from doing this. The scenarios with "slow" globalisation are represented by the bounds around the 2014 shares as given by Tables 5a-b. Table 5a gives the minimum ratios between the shares of locations in the total inputs of labour in each of the GVCs in 2030 and in 2014, while Table 5b presents the maximum ratios for these.

Table 5b: Maximum changes in regional labour shares in "slow" globalisation scenarios (2014-2030)

from \ to	Old-EU	New-EU	Oth Eur	N-Am	E-Asia	China	Russia	RoW
Old-EU	3.0	3.0	0.8	0.8	0.8	0.8	0.8	0.8
New-EU	3.0	3.0	0.8	0.8	0.8	0.8	0.8	0.8
Other Europe	0.8	0.8	3.0	0.8	0.8	0.8	0.8	0.8
North America	0.8	0.8	0.8	3.0	0.8	0.8	0.8	0.8
East Asia	0.8	0.8	0.8	0.8	3.0	0.8	0.8	0.8
China	0.8	0.8	0.8	0.8	0.8	3.0	0.8	0.8
Russia	0.8	0.8	0.8	0.8	0.8	0.8	3.0	0.8
RoW	0.8	0.8	0.8	0.8	0.8	0.8	0.8	3.0

Note: Values represent ratios to the shares in 2014. A value of 1.5 indicates that the share of the region in the row in labour inputs required by the GVCs of the region in the column is not allowed to grow by more than 50% between 2014 and 2030. A value of 0.8 indicates that such a share must decrease by at least 20%. Shares are expressed in efficiency units of labour, and apply to fabrication and HQ labour. These upper bounds are also assumed for shares in final products trade.

The values 1.0 and 3.0 in the upper left cells of the two tables imply that the shares of both types of Old-EU's labour in the total labour inputs in GVCs for its own final products should in 2030 be at least as high as they were in 2014, and at most three times as large. A value larger than one implies that reshoring takes place. Given the EU Single Market, we set the same values for labour contributions from the New-EU to Old-EU GVCs, and vice versa. All other labour shares (associated to labour contributions by regions to the GVCs of other macro-regions) are forced to be between 20% and 80% of the 2014 shares, implying that substantial reshoring has to take place. Please note that all macro-regions are treated symmetrically (with the exception of Old-EU/New-EU pair). We do not assume, for example, that the EU restricts imports from China or Russia, but does not adopt such policies with respect to the United States. We use the same values as reported in Tables 5a and 5b regarding trade in final products, too. This implies that we assume a scenario in which e.g. the imports from Chinese clothing in total clothing consumed by consumers in Old-EU has to decrease by at least 20%, in the scenarios featuring "slow" globalisation. In a small number of GVCs and regarding the final demand for a few products, tripling the domestic share is not sufficient to accommodate reductions in the import shares of at least 20%, because the region was too small a player in 2014. In these cases, we assumed that the 2014 trade shares do still prevail in 2030.

Table 6a: Minimum changes in regional labour shares in "fast" globalisation scenarios (2014-2030)

from \ to	Old-EU	New-EU	Oth Eur	N-Am	E-Asia	China	Russia	RoW
Old-EU	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
New-EU	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Other Europe	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
North America	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
East Asia	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
China	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Russia	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
RoW	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Note: Values represent ratios to the shares in 2014. A value of 0.8 indicates that the share of the region in the row in labour inputs required by the GVCs of the region in the column is not allowed to decrease by more than 20% between 2014 and 2030. Shares are expressed in efficiency units of labour, and apply to fabrication and HQ labour. These lower bounds are also assumed for shares in final products trade.

Table 6b: Maximum changes in regional labour shares in "fast" globalisation scenarios (2014-2030)

from \ to	Old-EU	New-EU	Oth Eur	N-Am	E-Asia	China	Russia	RoW
Old-EU	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
New-EU	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Other Europe	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
North America	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
East Asia	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
China	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Russia	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
RoW	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

Note: Values represent ratios to the shares in 2014. A value of 1.2 indicates that the share of the region in the row in labour inputs required by the GVCs of the region in the column is not allowed to grow by more than 20% between 2014 and 2030. Shares are expressed in efficiency units of labour, and apply to fabrication and HQ labour. These upper bounds are also assumed for shares in final products trade.

The scenarios that feature "fast" globalisation are characterised by similar sets of tables, but with different values. These values are given in Tables 6a and 6b. In this case, all changes in shares of labour contributions between 2014 and 2030 are bounded by the same values. The shares of contributions to GVCs of the own macro-region can decrease by 20% or increase by 20%, and the same holds for contributions to GVCs of other regions, and for shares in the use of final products. If trade would not be completely frictionless (i.e., transportation costs, coordination costs and trade policy costs would all be zero), the bounds to these shares would be -100% and infinity. As discussed before, policymakers can only directly affect the trade policy costs. Given that the other two types of costs associated with dispersing production processes geographically and trading final products remain positive, setting bounds to the extent in which comparative advantages affect trade patterns is a sensible approach, in our view.

4. Scenario outcomes

This section consists of two parts. In the first subsection, we will compare outcomes regarding employment of fabrication and HQ workers and consumption levels for each of the eight macro-regions between the 'business-as-usual' scenario and scenarios in which a single transformation (i.e. either globalisation, or migration or technological change) will follow the "fast" scenario, while the remaining two are assumed to track the 'business-as-usual' scenario. We include this subsection to build intuition. Which mechanisms drive the results? The second subsection is then devoted to the eight scenarios derived using the 2x2x2 approach: how do the outcome variables regarding the labour market and consumption vary across scenarios in which the paces of globalisation, migration and technological progress interact?

4.1. The effects of the transformations considered one-by-one

The top panel presents the values of the variables that are of central interest for this study for the 'business-as-usual' scenario, for all three transformations. In 2030, global final output has a value of almost 118 trillion US dollars. Prices do not play a role in our scenario analysis, so this value can be seen as measured in constant, dollars of 2014. Next, the value of consumption in each of the eight macro-regions is presented, followed by the numbers of jobs in fabrication and HQ functions. Consumption per worker (which can be seen as a measure of productivity in a region: how much consumption can a given number of workers sustain in a region, using imports to complement their own inputs) turns out to be highest in Other Europe and in North America, followed by Old-EU. New-EU is lagging considerably, but still much more productive than China and the Rest of the World. The top panel also contains information on unemployment rates, for both types of workers. At first sight, negative unemployment rates (mainly observed for HQ workers in a number of regions) might seem strange. This is because we expressed unemployment rates as the percentage of the 'autonomous' population that would be unemployed. A negative percentage therefore shows that the region considered is depending on inward labour mobility (or immigration) in the optimal solution, because the 'autonomous' population is too small. The conventional unemployment rate (defined as a fraction of the workers of a given type present in the region, irrespective of whether they have moved or not) is zero in these cases.

Table 7: Effects of changes regarding a single transformation

Business-as-usual								
Global final output	117,739,396							
	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
Consumption	12,618,583	828,554	4,618,772	20,797,103	5,078,905	10,729,475	484,192	29,198,815
Fabrication employment	34,062	12,244	7,661	32,523	21,828	278,228	18,661	1,429,678
HQ employment	113,344	20,864	32,809	150,362	68,873	414,922	37,349	1,197,443
Fab unemployment	0.9%	22.0%	-3.0%	4.9%	19.3%	32.9%	31.0%	13.7%
HQ unemployment	-6.4%	7.2%	-6.1%	-6.3%	-0.6%	0.4%	-0.3%	1.2%
Consumption/worker	85.6	25.0	114.1	113.7	56.0	15.5	8.6	11.1
Fast globalisation								
ΔGlobal final output	1.5							
	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	5.0	-1.2	6.7	2.4	5.5	0.3	-3.1	-1.1
ΔFabrication employment	1.0	4.1	2.4	2.0	2.6	2.5	-4.3	-1.1
ΔHQ employment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ΔFab unemployment	-1.0%	-3.2%	-2.5%	-1.9%	-2.1%	-1.7%	3.0%	0.9%
ΔHQ unemployment	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ΔConsumption/worker	4.8	-2.7	6.2	2.0	4.8	-0.7	-1.7	-0.6
Fast migration								
ΔGlobal final output	0.7							
	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	1.6	26.0	1.6	1.6	0.2	1.0	-1.0	-1.1
ΔFabrication employment	1.5	12.6	1.4	1.4	0.2	0.8	-0.5	-0.9
ΔHQ employment	1.5	17.3	1.4	1.5	0.2	0.8	-0.6	-0.9
ΔFab unemployment	-1.5%	-9.8%	-1.4%	-1.3%	-0.1%	-0.5%	0.3%	0.8%
ΔHQ unemployment	-1.6%	-16.1%	-1.5%	-1.6%	-0.2%	-0.8%	0.6%	0.9%
ΔConsumption/worker	0.1	9.1	0.2	0.1	0.0	0.1	-0.4	-0.2
Fast technological change								
ΔGlobal final output	12.2							
	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	7.0	14.1	1.1	11.1	12.6	15.7	14.1	14.5
ΔFabrication employment	7.5	10.3	3.0	11.2	11.2	10.9	11.0	10.8
ΔHQ employment	-3.5	0.0	-7.8	0.0	0.0	0.0	0.0	0.0
ΔFab unemployment	-7.4%	-8.0%	-3.1%	-10.6%	-9.0%	-7.3%	-7.6%	-9.3%
ΔHQ unemployment	3.7%	0.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%
ΔConsumption/worker	8.0	9.9	7.3	8.9	9.7	10.9	10.1	8.1

Notes: Global final output in millions of US dollars (in constant 2014 prices); Fabrication and HQ employment in thousands of workers; Fab unemployment and HQ unemployment in percentages; Consumption per worker in thousands of US dollars (in constant 2014 prices); Unemployment rates computed as relative to autonomous labour supply: negative rates indicate the dependence on mobile labour; ΔGlobal final output, ΔFabrication employment, ΔHQ employment and ΔConsumption/worker expressed as percentage difference relative to business-as-usual scenario; ΔFab unemployment and ΔHQ unemployment expressed as difference in percentage points relative to business-as-usual scenario.

We see that fabrication unemployment rates are particularly high in the regions that specialised in fabrication-intensive activities, such as New-EU and China. In the 'business-as-usual' (bau) scenario, technological progress remains biased, saving fabrication labour ate a faster pace than HQ labour. Furthermore, productivity levels keep catching-up to those of the regions that were more productive in 2014. Part of the scarce-HQ workers also move to regions in which they are more productive, leaving fewer activities for complementary fabrication workers.

The second, third and fourth panel present differences between scenarios in which globalisation, migration and technological change, respectively, are "fast", as described in section 3. The differences regarding global final output, consumption per region, employment of both types and consumption per worker are expressed as percentage differences relative to the bau-scenario. For the unemployment rates, we express differences in percentage points relative to the bau-scenario.

As we discussed already, the "fast" globalisation scenario allows for increased exploitation of differences in comparative advantages across regions. We find that this has positive effects on global output indeed. It is 1.5% higher than in the bau-scenario. For consumption levels, we find heterogeneous results. Fabrication employment is larger in all regions, apart from Russia and RoW, while HQ employment is identical across the two scenarios. Productivity differences are more marked, with richer regions gaining in consumption per worker.

"Fast" migration also causes an increase in final output at the global level, of 0.7% relative to the bau-scenario. Especially New-EU attracts a lot of HQ-workers, which also allows in the bau-scenario unemployed fabrication workers to get employed and to contribute to consumption growth. The vast majority of these workers would come from the RoW-region. The cause of the strong positive effect for New-EU is that in the bau-scenario, workers from East-European countries would continue to move to Old-EU, without attracting workers from other regions. Given catch-up and a productivity level in 2014 that was already higher in New-EU than in many other parts of the world, opening up to labour migration from outside Europe would allow firms to relocate also more HQ-intensive activities to New-EU. New-EU would hence become a region with a net migration surplus. For the other regions, the effects are much less pronounced.

Not surprisingly, fast technological change has strong positive impacts on global welfare. While allowing for more trade or more labour reallocation through migration has once-and-for-all impacts, faster technological change leads to freeing up labour each and ever year. Global final output is more than 12% higher than in the 'business-as-usual' scenario, and consumption levels are higher in each and ever region. The fact that especially HQ-labour is saved in the "fast" technological change scenarios is reflected in the employment levels for HQ-workers in Old-EU and Other Europe. Given that trade patterns are not allowed to change in this comparison, output growth is not strong enough to compensate for the lower HQ-labour requirements per unit of output and unemployment among these workers rises. Fabrication workers do not experience such fast rates of labour-saving and just benefit from output growth, leading to lower unemployment regarding this type of labour. Actually, in this scenario, Old-EU, Other Europe and North-America become destinations of fabrication workers moving from other regions. This leads to lower unemployment rates in China, Russia and RoW. China, Russia and RoW also benefit from catch-up that is more rapid than in the bau-scenario, allowing them to attain large positive consumption differences relative to the bau-scenario. A similar effect can be observed for New-EU.

4.2. The effects of interacting transformations

In reality, the three transformations are taking place simultaneously and are affecting each other. Technological change can cause scarcities and surpluses in segments of labour markets, and thus trigger migration. Technological change can change comparative advantages and could therefore have implications for specialisation patterns (see, e.g. De Backer et al., 2018; Krenz et al., 2021). The same goes for migration: if regional supply of one type of labour increases faster than supply of the other type, trade specialisations can change, implying changes in the intensity of globalisation. In this section, we will compare the impacts of such interactions and again focus on the implications for global production, consumption per region and employment of fabrication and HQ workers. We will analyse eight scenarios, in which each of the transformations can follow the "slow" or the "fast" trajectory described in section 3. This yields the eight scenarios in Table 2. Once more, we use the 'business-as-usual' scenario as the benchmark to which we compare scenario results.

We document the results in Table 8. Not surprisingly, global final output (an indicator of how well the global economy performs in converting the availability of labour resources into output that can be consumed or used for investment) is lowest in Scenario 1 ("slow-slow-slow") and highest in Scenario 8 ("fast-fast-fast"). In the first scenario, global final output in 2030 is about 7% lower than in the bau scenario, while it is close to 16% higher in the most favourable scenario. In this scenario, productivity is not just growing faster than in the bau-scenario, but reallocation of labour across regions and trade specialisation (both regarding activities within GVCs and regarding trade in final products) add to the positive effects.

The rate and bias of labour-saving technological change appears to be the most important driver of these differences, although we should be somewhat careful in making strong claims about this, given that the differences between the "slow" and the "fast" scenarios for each of the three transformations are to some extent arbitrary. If, for instance, we would not have assumed a 10% more rapid decline in HQ labour requirements per unit of final output in the "fast" scenarios regarding technological change (relative to the bau-scenario), but a 5% more rapid decline, the impact of technological change would have been more modest). Still, technological change has continued effects that accumulate over time, while the geographical reallocation of activities (globalisation) and labour (migration) have a one-off nature. When considering the relative importance of the other two transformations, we see that globalisation appears a bit more important in a "slow" technological change environment (see the differences in global final output in scenarios 2 and 3, relative to the bau-scenario), while the differences are negligible if technological change is "fast" (see scenarios 6 and 7).

If technological change is "slow", "fast" globalisation has a small negative effect on consumption per worker in Old-EU, while this has a very strong positive effect on New-EU. "Slow" technological change is biased towards saving fabrication labour, the production factor that is abundantly available in New-EU. Hence, it has a comparative advantage in fabrication-intensive activities, which plays out much more prominently if trade is less restricted.

Table 8: Scenarios with interacting transformations (2030)

Business-as-usual
Global final output 117,739,396

	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
Consumption	12,618,583	828,554	4,618,772	20,797,103	5,078,905	10,729,475	484,192	29,198,815
Fabrication employment	34,062	12,244	7,661	32,523	21,828	278,228	18,661	1,429,678
HQ employment	113,344	20,864	32,809	150,362	68,873	414,922	37,349	1,197,443
Fab unemployment	0.9%	22.0%	-3.0%	4.9%	19.3%	32.9%	31.0%	13.7%
HQ unemployment	-6.4%	7.2%	-6.1%	-6.3%	-0.6%	0.4%	-0.3%	1.2%
Consumption/worker	85.6	25.0	114.1	113.7	56.0	15.5	8.6	11.1

Scenario 1: slow technological change; slow globalisation; slow migration
ΔGlobal final output -7.1

	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	-1.5	-31.7	-21.6	-12.5	7.6	2.7	10.9	-10.8
ΔFabrication employment	5.8	35.0	1.5	10.2	24.4	39.5	45.2	15.7
ΔHQ employment	-4.8	-11.3	-18.6	-10.5	0.0	0.7	0.2	-3.4
ΔFab unemployment	-5.8%	-27.3%	-1.5%	-9.7%	-19.7%	-26.5%	-31.2%	-13.5%
ΔHQ unemployment	5.1%	10.5%	19.8%	11.1%	0.0%	-0.7%	-0.2%	3.4%
ΔConsumption/worker	0.8	-35.4	-8.0	-6.1	1.6	-11.7	-3.7	-16.6

Scenario 2: slow technological change; slow globalisation; fast migration
ΔGlobal final output -6.0

	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	1.7	-28.6	-19.2	-9.8	7.7	2.8	10.7	-11.1
ΔFabrication employment	9.1	39.6	4.4	13.5	24.8	39.7	45.4	15.5
ΔHQ employment	-1.9	-8.6	-16.5	-7.8	0.2	0.8	0.1	-3.6
ΔFab unemployment	-9.0%	-30.9%	-4.6%	-12.8%	-20.0%	-26.7%	-31.3%	-13.4%
ΔHQ unemployment	2.0%	8.0%	17.5%	8.3%	-0.2%	-0.8%	-0.1%	3.5%
ΔConsumption/worker	1.0	-34.7	-7.7	-6.0	1.6	-11.8	-3.9	-16.7

Scenario 3: slow technological change; fast globalisation; slow migration
ΔGlobal final output -4.1

	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	-1.5	25.1	-5.3	-0.9	7.4	-0.7	2.7	-11.6
ΔFabrication employment	5.8	35.0	1.5	10.2	24.4	34.7	36.7	15.7
ΔHQ employment	-2.0	15.2	-4.8	-1.5	0.0	0.7	0.2	-6.4
ΔFab unemployment	-5.8%	-27.3%	-1.5%	-9.7%	-19.7%	-23.2%	-25.4%	-13.5%
ΔHQ unemployment	2.1%	-14.1%	5.0%	1.6%	0.0%	-0.7%	-0.2%	6.3%
ΔConsumption/worker	-1.3	2.1	-1.8	-1.5	1.4	-13.2	-8.6	-16.3

Scenario 4: slow technological change; fast globalisation; fast migration
ΔGlobal final output -2.9

	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	2.1	30.6	-2.2	2.4	7.5	-0.7	2.3	-12.0
ΔFabrication employment	9.1	39.6	4.4	13.5	24.8	34.9	36.9	15.5
ΔHQ employment	0.9	17.3	-1.5	1.3	0.2	0.8	0.1	-6.5
ΔFab unemployment	-9.0%	-30.9%	-4.6%	-12.8%	-20.0%	-23.4%	-25.5%	-13.4%
ΔHQ unemployment	-1.0%	-16.1%	1.6%	-1.4%	-0.2%	-0.8%	-0.1%	6.4%
ΔConsumption/worker	-0.7	4.0	-1.8	-1.1	1.3	-13.3	-8.9	-16.6

Notes: Global final output in millions of US dollars (in constant 2014 prices); Fabrication and HQ employment in thousands of workers; Fab unemployment and HQ unemployment in percentages; Consumption per worker in thousands of US dollars (in constant 2014 prices); Unemployment rates computed as relative to autonomous labour supply: negative rates indicate the dependence on mobile labour; ΔGlobal final output, ΔFabrication employment, ΔHQ employment and ΔConsumption/worker expressed as percentage difference relative to business-as-usual scenario; ΔFab unemployment and ΔHQ unemployment expressed as difference in percentage points relative to business-as-usual scenario.

Like we observed when considering "fast" migration in isolation, we also observe that the activities in New-EU depend heavily on migrant workers: In the scenarios, the differences in unemployment are more negative than the positive unemployment rates in the bau-scenario. If globalisation is "slow" this remains limited to fabrication workers, but if it is "fast" also HQ-workers from other macro-regions move to jobs in New-EU. At first sight, it might seem strange that this also happens (although to a lesser extent) in cases with "slow" migration, given that a lot of workers left the region between 2000 and 2014 (see Table 4).

Table 8 (cont'd): Scenarios with interacting transformations (2030)

Scenario 5: fast technological change; slow globalisation; slow migration

ΔGlobal final output	14.1							
	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	25.8	-10.3	2.9	9.1	23.7	21.2	15.4	9.7
ΔFabrication employment	5.8	35.0	1.5	10.2	24.0	18.5	8.6	8.3
ΔHQ employment	0.0	12.8	0.0	0.0	0.0	0.7	-0.7	-0.5
ΔFab unemployment	-5.8%	-27.3%	-1.5%	-9.7%	-19.4%	-12.4%	-5.9%	-7.1%
ΔHQ unemployment	0.0%	-11.9%	0.0%	0.0%	0.0%	-0.7%	0.7%	0.5%
ΔConsumption/worker	24.1	-25.8	2.6	7.2	16.9	12.4	12.7	5.2

Scenario 6: fast technological change; slow globalisation; fast migration

ΔGlobal final output	15.1							
	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	29.1	-4.1	6.8	12.6	23.8	20.6	15.4	8.6
ΔFabrication employment	9.1	39.6	4.4	13.5	24.3	18.1	8.6	7.4
ΔHQ employment	1.5	17.3	1.4	1.5	0.2	0.8	-0.6	-0.9
ΔFab unemployment	-9.0%	-30.9%	-4.6%	-12.8%	-19.6%	-12.1%	-6.0%	-6.4%
ΔHQ unemployment	-1.6%	-16.1%	-1.5%	-1.6%	-0.2%	-0.8%	0.6%	0.9%
ΔConsumption/worker	25.1	-23.6	4.7	8.7	16.9	12.0	12.6	4.8

Scenario 7: fast technological change; fast globalisation; slow migration

ΔGlobal final output	15.0							
	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	16.9	37.9	19.9	13.7	18.7	16.9	9.0	12.4
ΔFabrication employment	5.5	29.0	1.5	9.5	14.6	14.8	5.8	9.6
ΔHQ employment	0.0	15.4	0.0	0.0	0.0	0.7	-0.7	-0.5
ΔFab unemployment	-5.5%	-22.6%	-1.5%	-9.1%	-11.8%	-10.0%	-4.0%	-8.3%
ΔHQ unemployment	0.0%	-14.3%	0.0%	0.0%	0.0%	-0.7%	0.7%	0.5%
ΔConsumption/worker	15.4	14.5	19.5	11.8	14.7	9.9	7.4	7.0

Scenario 8: fast technological change; fast globalisation; fast migration

ΔGlobal final output	15.6							
	Old-EU	New-EU	Oth Europe	N-America	East Asia	China	Russia	RoW
ΔConsumption	19.1	40.7	21.1	15.4	19.0	17.0	9.1	11.7
ΔFabrication employment	8.5	30.3	4.4	12.2	14.4	14.9	5.9	9.0
ΔHQ employment	1.5	17.3	1.4	1.5	0.2	0.8	-0.6	-0.9
ΔFab unemployment	-8.4%	-23.7%	-4.6%	-11.6%	-11.6%	-10.0%	-4.1%	-7.8%
ΔHQ unemployment	-1.6%	-16.1%	-1.5%	-1.6%	-0.2%	-0.8%	0.6%	0.9%
ΔConsumption/worker	15.5	15.2	18.8	11.7	14.9	9.9	7.4	7.0

Notes: see above.

The explanation is in the fact that we assume 'symmetric' migration policies, implying that it is as easy or hard to move to a region as it is to leave that region. In reality, it has been relatively easy for workers from New-EU to move to Old-EU (where they could be more productive, often implying a higher wage rate), but much more difficult for workers from non-EU regions to move to New-EU (where they could be more productive than in their home region). In the scenarios with "slow" migration, we restrict the extent to which workers from New-EU can leave the region to work in Old-EU, but the symmetry implies that it is also easier to come into the region than in the bau-scenario.

For Old-EU, we observed already that the bau-scenario leads to some unemployment of fabrication workers. In other scenarios, we do not see this. The negative and sizable differences reported for ΔFab unemployment show that inward mobility of fabrication workers is required in the situation in which global consumption is maximised. In scenarios with "slow" technological change, this is due to the fact that fabrication labour is saved at a slower pace than in bau, leading to a situation that in order to produce a given quantity of output more fabrication workers are needed. In the scenarios with "fast" technological change, HQ-labour requirements per unit of output are reduced more rapidly than in the bau-scenario. This implies that HQ-labour is 'freed up' to produce more. Because fabrication workers and HQ-workers are complementary, demand for fabrication workers increases. The actual number of fabrication workers that moves into Old-EU is then dependent on whether the "slow" or the "fast" migration scenario is considered.

In the bau-scenario, all HQ-workers in Old-EU are employed, and this workforce consists partly of workers who moved in from other regions (HQ unemployment is negative, -6.4%). Unemployment of these workers in Old-EU is zero across all scenarios, as is reflected in the fact that the reported differences compared to the bau-scenario are never as large as +6.4%. Still, the extent to which the economy of Old-EU depends on HQ-workers who migrated from other macro-regions varies considerably. If technological change and globalisation are slow (scenarios 1 and 2) less migration of HQ-workers happens, irrespective of whether the migration scenario is "slow" or "fast". If technological change is "slow", but globalisation is "fast", the reliance on migrant HQ-workers depends on what migration policies allow for (compare scenarios 3 and 4). In all other scenarios, the extent to which the HQ-workforce consists is either as high as in bau (the "slow" migration scenarios 5 and 7) or higher than in bau (the "fast" migration scenarios 4, 6 and 8).

Finally, we would like to emphasise the importance of "fast" globalisation for New-EU. Irrespective of whether technological change and migration are "slow" or "fast", the economic performance of this region is much better in the "fast" globalisation scenarios 3, 4, 7 and 8 than in the other scenarios. It is essential to note that we specified the globalisation scenarios such that de-globalisation would not affect trade between New-EU and Old-EU negatively. Still, being less able to import from other macro-regions implies that scarce domestic resources have to be used in relatively unproductive ways.

In this discussion of the results of the eight scenarios, we mainly focus on differences observed for Old-EU and New-EU. Much more could be said about results for other macro-regions, but we focus on the results for the EU macro-regions to show what types of interactions should be considered if macro-economic consequences of the three transformations are considered.

5. Conclusions

In this report, we introduced a quantitative framework to analyse the effects of differences in the rate and direction of three major transformations that are affecting the global economy: labour-saving technological change, globalisation and international mobility of workers (migration). We focused on consumption as an indicator of welfare, and considered the employment inequalities of two types of workers, workers who are employed in jobs related to the fabrication business function and those who perform activities related to 'headquarters' (HQ) business functions, such as positions in R&D, marketing and management.

The workhorse is a linear programming model of the global economy. It maximises the global output of products ready for consumption, given constraints. These constraints relate to the available factors of production in regions (supply of fabrication workers and HQ-workers), the production technologies (how much labour of both types is needed to produce a unit of final product), the extent to which the output of activities and final products can be traded across regions, the composition of consumption baskets, etc. We did the analysis for 2030, adopting the perspective that developments regarding the three transformations affect the constraints under which global consumption can be maximised. The availability of the required data led us to formulate a 'business-as-usual' scenario based on long-run developments over 2000-2014, and then extrapolating these to 2030. For each of the three transformations, we then formulated a "slow" and a "fast" scenario, in which essential features of the transformations would happen over 2014-2030 at a lower or higher pace, respectively, than over 2000-2014. This yielded eight (2x2x2) scenarios, which we analysed. We presented the results for eight macro-regions, which together constitute the global economy.

The outcomes suggest that the interaction of the three transformations is important. To give some examples: technological change that is biased towards one type of workers can yield changes in comparative advantages of regions and can therefore affect trade specialisations. Migration can affect the supply of labour in regions, and can therefore affect the productive capacities of regions to different extents. The effects of such change in productive capacity on consumption and employment depend on the extent to which products can be traded between macro-regions.

The results presented in this report should not be viewed as predictions. Instead, they should be seen as indications of how the transformations interact. This is important for policy-makers, since the effectiveness of policies with respect to transformation depends on tendencies regarding other transformations. The analytical framework proposed in this report is sufficiently flexible to formulate more specific scenarios. In the scenarios presented in this report, we assume symmetry of policies. To give an example, we assumed that in the "slow" globalisation scenarios, all macro-regions adopt policy measures that stimulate reshoring of activities. For policy-makers in the EU, however, geopolitical considerations might make it much more important to promote reshoring from some countries or regions, but much less so from other. Scenarios taking such considerations can be formulated and analysed.

References

Acemoglu, D., and Restrepo, P. (2018). Automation and new tasks: How technology displaces and reinstates labor. Journal of Economic Perspectives 33(2), 3-30.

Baldwin, R.E. (2016). *The Great Convergence; Information Technology and the New Globalization*. Cambridge MA: Harvard University Press.

Baldwin, R.E., and Venables, A.J. (2013). Spiders and snakes: Offshoring and agglomeration in the global economy. Journal of International Economics 90(2), 245-254.

Baldwin, R.E., and Wyplosz, C. (2020). *The Economics of European Integration* (sixth edition). London: McGraw-Hill.

De Backer, K., DeStefano, T., Menon, C., and Suh J.R. (2018). *Industrial robotics and the global organisation of production*. OECD STI Working Papers 2018/03, OECD Publishing, Paris.

Delis, A., Driffield, N., and Temouri, Y. (2019). The global recession and the shift to reshoring: Myth or reality? Journal of Business Research 103, 632–643.

Dorfman, R., Samuelson, P.A., and Solow, R.M., (1958). *Linear Programming and Economic Analysis*, McGraw-Hill, New York.

Duchin, F. (2005). A world trade model based on comparative advantage with m regions, n goods, and k factors. Economic Systems Research, 17, pp. 141–162.

Feenstra, R.C., Inklaar, R., and Timmer, M.P. (2015), The next generation of the Penn World Table. American Economic Review 105(10), 3150-3182, available for download at www.ggdc.net/pwt.

Frank, M., Autor, D., Bessen, J.E., and others (2019). Towards understanding the impact of artificial intelligence on labor. Proceedings of the National Academy of Sciences 116(14), 6531-6539.

Hummels, D., (2007). Transportation costs and international trade in the second era of globalization. Journal of Economic Perspectives 21(3), 131-154.

Javorcik, B.S., Kitzmueller, L, Schweiger, H., and Yildirim, M.A. (2022). Economic costs of friend-shoring. EBRD Working Paper No. 274. London: European Bank for Reconstruction and Development.

Kamakura, N., (2022). From globalizing to regionalizing to reshoring value chains? The case of Japan's semiconductor industry. Cambridge Journal of Regions, Economy and Society 15(2), 261-277.

Krenz, A., Prettner, K., and Strulik, H. (2021). Robots, reshoring, and the lot of low-skilled workers. European Economic Review 136, 103744.

Los, B., Timmer, M.P., and de Vries, G.J. (2015), How global are global value chains? A new approach to measure international fragmentation. Journal of Regional Science 55, 66-92.

Miller, R.E., and Blair, P.D. (2009), Input-Output Analysis (second edition), Cambridge: Cambridge University Press.

Nii-Aponsah, H., Verspagen, B., and Mohnen, P. (2023). *Automation-induced reshoring and potential implications for developing economies*. UNU-MERIT. UNU-MERIT Working Papers No. 018.

Reijnders, L.S., Timmer, M.P., and Ye, X. (2021) Labour demand in global value chains: Is there a bias against unskilled work? The World Economy 44(9), 2547-2571.

Reijnders, L.S., and de Vries, G.J. (2018). Technology, offshoring and the rise of non-routine jobs. Journal of Development Economics, 135, 412-432.

Smulders, S., and Gradus, R. (1996), Pollution abatement and long-term growth. European Journal of Political Economy, 12(3), 505-532.

Strømman, A. H. and Duchin, F. (2006). A world trade model with bilateral trade based on comparative advantage. Economic Systems Research, 18(3), 281-297.

Ten Raa, T., and Mohnen, P. (2001). The location of comparative advantages on the basis of fundamentals only. Economic Systems Research 13(1), 93-108.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., and de Vries, G. J. (2015). An illustrated user guide to the World Input–Output Database: the case of global automotive production. Review of International Economics 23(3), 575–605.

Timmer, M.P., Miroudot, S., and de Vries, G.J. (2019). Functional specialisation in trade. Journal of Economic Geography 19(1), 1-30.

Timmer, M.P., Los, B., Stehrer, R., and de Vries, G.J. (2021). Supply chain fragmentation and the global trade elasticity: A new accounting framework. IMF Economic Review 69, 656-680.

World Bank (2023), Population estimates and projections, Data downloaded from https://databank.worldbank.org/source/population-estimates-and-projections.

Appendix

Table A1: Industry classification

1	Agriculture, forestry and fishing	15	Computers / electronic products
2	Mining	16	Electrical equipment
3	Food, beverages and tobacco	17	Other machinery and equipment
4	Textiles, apparel and leather	18	Motor vehicles and trailers
5	Wood and wood products	19	Other transport equipment
6	Paper and paper products	20	Furniture and other manufactures
7	Printing	21	Repair/installation of machinery
8	Coke and refined petroleum products	22	Utilities (electricity and water supply; waste collection)
9	Chemicals and chemical products	23	Construction
10	Pharmaceutical products	24	Trade and transportation services
11	Rubber and plastic products	25	Retail trade, hotels and restaurants
12	Other non-metallic mineral products	26	Professional and business services (non-financial)
13	Basic metals	27	Financial and real estate services
14	Fabricated metal products	28	Public services

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