

Future of manufacturing

The future of manufacturing in Europe



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When citing this report, please use the following wording:

Eurofound (2019), *The future of manufacturing in Europe*, Publications Office of the European Union, Luxembourg.

Author: Donald Storrie

Eurofound project: Future of Manufacturing in Europe

Acknowledgements: Eurofound research staff and trainees involved in the Future of Manufacturing in Europe pilot project were: Martina Bisello, Enrique Fernández-Macías, Rebecca Florisson, John Hurley, Stefanie Ledermaier, Irene Mandl, Vincenzo Maccarrone, Massimiliano Mascherini, Alessandra Massaro, Claudia Metz-Ruffer, Valentina Patrini, Elisabeth Packalén, Eleonora Peruffo, Emma Pulkkinen, Sara Riso, Lea Schmidlechner and Donald Storrie.

The author acknowledges the contribution of the Finance, Operational Support and Information and Communication units for their extraordinary support during the project implementation.

Luxembourg: Publications Office of the European Union

Print: ISBN: 978-92-897-1858-5 doi:10.2806/912568 TJ-02-19-247-EN-C

PDF: ISBN: 978-92-897-1860-8 doi:10.2806/44491 TJ-02-19-247-EN-N

Web: <http://eurofound.link/fomeef18002>

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This is a publication from the Future of Manufacturing in Europe (FOME) project.

FOME is a Pilot Project proposed by the European Parliament and delegated to Eurofound by the European Commission (DG GROW).

More information on the FOME project, including available and forthcoming publications and events and relevant data, can be found on the FOME page of the Eurofound website.

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Country codes EU28

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Executive summary

Introduction

The Future of Manufacturing in Europe (FOME) is a pilot project proposed by the European Parliament and delegated to the European Foundation for the Improvement of Living and Working Conditions (Eurofound) by the European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. It is an explorative and future-oriented study, as reflected in the exploration of the future adoption of some key game-changing technologies and how this adoption can be promoted across the EU, even regionally. The implications for working life focuses primarily on tasks and skills, not only at the white-collar, tertiary-education level, but also for blue-collar occupations, including a focus on challenges facing national and company apprenticeship systems. The future orientation also includes quantitative estimates of the employment implications of the Paris Climate Agreement, of large increases in global tariffs and of radical automation.

Several studies emphasise the crucial global context for the future of manufacturing in Europe. The European Reshoring Monitor measures the return of previously offshored jobs to Europe. Other research examines how the deepening globalisation of recent decades has led to new opportunities for small companies to engage in international supply chains. This final report summarises the 10 project reports, which are complemented by 47 case studies, 27 policy instruments and 4 associated publications.

Policy context

The key industrial policy context lies in the nexus between emerging digital technologies and the challenges of new forms of international competition, not least from China. This is prominent in the gathering momentum for a more active European industrial policy as expressed, in February 2019, by both the German National Industrial Strategy 2030 and the Franco-German Manifesto for a European industrial policy fit for the 21st Century. The publicly funded promotion of European industrial champions inherent in such approaches must, of course, be tempered with due regard for the efficiency and innovation-enhancing benefits of fair and open competition. The large single market is a key asset for Europe and the basic rationale of European competition policy is to ensure the benefits of fair competition.

The policy perspective extends to other key European policy priorities, such as the Digital Agenda, climate change and trade policies. From an employment perspective, the most immediate policy context is the Skills Agenda for Europe. Action to promote the acquisition of relevant skills in Europe is key, both to foster a faster diffusion of digital technologies in the workplace and to ensure that the benefits of these new technologies are widely distributed.

Key findings

- Macroeconomic modelling of the implementation of the Paris Climate Agreement estimates that GDP in the EU will increase by 1.1% and employment by 0.5% up to 2030. Manufacturing employment is projected to increase by 0.7%. While this scenario implies more jobs, mainly in areas such as construction, many of them are at the bottom and the middle of the wage and skills distribution.
- Macroeconomic estimates indicate that a further increase in global tariffs will have a more severe impact for jobs in the EU than in other parts of the world. They lead to a 0.3% fall in employment in the EU by 2030. Of all sectors, manufacturing sees the largest percentage decline, of 1.1%.
- Currently, the commercial application of the technologies studied is limited and mainly in highly productive firms. However, they can have a game-changing impact. The commonality of data processing suggests both an application in many sectors and, at some critical juncture, an acceleration of synergetic diffusion all along the supply chain of manufacturing production.
- The diffusion of advanced technologies may accentuate regional disparities within Member States, due to economies of scale and the high investment costs in advanced manufacturing, together with the need for a highly skilled workforce.
- Europeans are concerned about the negative impact of these technologies and there are numerous estimates of huge potential job losses. However, these predictions take little account of the economic rationale of the substitution of workers by machines or of the macroeconomic feasibility of the scale of capital investment implied by the estimates of job loss.
- Historical evidence shows that employment growth goes together with technological progress. There are job creation effects when technology increases productivity. The more the productivity gains go to consumers and workers, the more positive are these effects.

- It is striking how perceptions of recent technological change are occurring when productivity growth in manufacturing is at an historical low. It may be that the productivity gains lie in the future as the technologies become more widespread.
- However, the productivity growth during the first ICT boom (associated with the rise of the big US tech companies) was small and short-lived. It is not improbable that a more widespread adoption of the new technologies will eventually boost manufacturing productivity but with a similar growth pattern – as in the first ICT boom.
- Nevertheless, the realities of international competition make the adoption of productivity-enhancing technologies in manufacturing an absolute imperative.
- Few jobs have been reshored back to Europe since 2014. However, very highly productive manufacturing may open up new options to reshore. Any significant job creation would, however, be in other more employment-intensive stages of the supply chain, such as R&D and marketing.
- A deeper globalisation, through the expansion of the market effectively available to companies, allows new opportunities for small companies to engage in global supply chains in niche markets. These are very active informal networkers and the building of trusting relationships with their partners is crucial for them.
- Since 2011, manufacturing employment growth has been in well-paid jobs requiring tertiary education. This trend will continue. The need for better literacy, information processing and problem-solving, even in blue-collar jobs, is driven not only by digitalisation but also by more quality control and standards. Despite a projected decline in physical tasks, dexterity will still be important, notably when operating machinery.
- New and higher skills are the most relevant labour market implication of advanced manufacturing. Newer skillsets, notably those of industrial data scientists, and data security analysts, will be in high demand. The most sought-after profile will be a combination of engineering and IT skills. Other often-mentioned skills include: creativity, communication, leadership and problem-solving.
- The focus on high-end skills tends to mask the challenges facing blue-collar occupations which will also change as traditional production is merged with ICT.

- Further automation will remove many arduous and potentially dangerous physical tasks. There are, however, several health and safety issues related to specific technologies. Moreover, the availability of data on individual employees can lead to unacceptable degrees of monitoring and control, both in terms of personal integrity and surveillance at the workplace.

Policy pointers

- Given the encompassing nature of digital technologies, their adoption can involve significant coordination issues. The systemic approach is best exemplified by the German Industrie 4.0 initiative. None of the other initiatives identified has the scope of the German model.
- A fundamental role for policy is to provide some certainty towards which companies can orient their investment strategy, such as industrial standards, future policy declarations and targets. Strategic public investment is generating much current policy discussion – where the importance of an initial leading position in strategic technologies is viewed in the context of global competition, especially from China.
- The three common features of strong regional industrial policy capacity to develop regions in Europe in light of the challenges of advanced manufacturing are: the existence of multilevel governance cooperation procedures and instruments, the widespread use of participatory methods in the agenda-setting process, and the development of strong policy implementation and executive agencies.
- The energy scenario is driven by policy measures aimed at reducing carbon emissions to a level compatible with the Paris Climate Agreement. These include carbon emission pricing, programmes to improve the efficiency of energy consumption, an aviation fuel mandate and various measures targeting the power generation and road transport sectors.
- There is little evidence of either a significant number of jobs being reshored to Europe or successful specific reshoring policies that include, for example, economic incentives. Reshoring can be best facilitated by improving the industrial infrastructure and hence is practically indistinguishable from other forms of industrial policy. However, as there is some future potential to reshore advanced manufacturing, the relevant jurisdictions could usefully engage in information campaigns and administrative facilitation of reshoring processes.

- When SMEs engage in global supply chains shortly after start-up, they need specialised assistance with legal and administrative issues in the foreign country. Their main policy needs are, however, the same as those entrepreneurial start-ups in general.
- The protectionism, climate change policy and radical automation scenarios all assumed no labour market frictions, for example as regards, skills and geographical mismatch. Any projected job creation will be diminished or delayed according to the extent of these frictions.
- The need for new and higher skills poses challenges for education policy at all levels. While some of the new skills are specific to the production process, the spread to and interaction with other stages of the manufacturing supply chain, not least in the context of increased servitisation, implies similar skill needs even in other economic sectors.
- New and higher skills, also for blue-collar workers, present a challenge to apprenticeship systems. The revision of existing occupational profiles, to incorporate compulsory basic ICT skills and optional specialisations, is preferable to the creation of new occupational profiles.
- Higher skills require more vocational training with tertiary education institutions. In contrast to the best designed initial apprenticeship systems, the lack of national frameworks and quality control is an issue, as is progression from initial apprenticeships to tertiary education.
- A crucial question is whether the productivity gains of new technologies lead to higher profits for companies, lower prices for consumers or higher wages for workers. If there are in fact highly significant productivity gains in the future, this will be the fundamental distribution policy issue.
- Previous experience of large-scale structural change shows that this change should be anticipated and managed. This is the most critical matter for social dialogue in the context of the future of manufacturing. It requires well-functioning social dialogue at company level as regards information and consultation and the active and responsible involvement of social partners in the strategic orientation of industrial policy.

Key messages

- The future of manufacturing must be in Europe.
- Europe will benefit more than other trading blocs from full implementation of the Paris Climate Agreement in terms of growth and jobs.
- Increased tariffs will lead to more jobs lost in Europe than in other parts of the world.
- Taking the lead in the commercial adoption of emerging technologies will give Europe a decisive competitive advantage over other trading blocs and will create more jobs.
- Europe will create more jobs from actively engaging in international production networks. Reshoring is not likely to lead to many more jobs.
- The future of manufacturing is expected to lead to better jobs, requiring new and higher skills.

Introduction

The Future of Manufacturing in Europe (FOME) is a pilot project proposed by the European Parliament and delegated to the European Foundation for the Improvement of Living and Working Conditions (Eurofound) by the European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. It is an explorative and future-oriented study employing many research methodologies, both quantitative and qualitative. In the course of the project, estimates have been generated from econometric forecasting models, expert opinions have been solicited, expert workshops have been attended and seminars have been held throughout Europe. In parts, the project compares aspects of European manufacturing in the 2000s with similar situations in the past to assess challenges and opportunities in the future. This overview report cannot do full justice to all the research conducted in this project. However, the annex represents a catalogue of all the topics analysed, the approaches taken, a brief summary of the results and a full list of the various publications: 10 project reports, 47 case studies, 27 policy instruments and 4 associated publications. All are available on the FOME page of Eurofound's website (<http://eurofound.link/fome>).

The project did not cover all aspects of the future of manufacturing in Europe. However, this final report does gather together the findings structured around what we believe to be the crucial issues for manufacturing in Europe in the next few decades. From an industrial policy perspective, the essentials are in the nexus between emerging advanced digital technologies and intense and new international competition. These are the subject of the first two chapters – 'Manufacturing in the era of globalisation' and 'Technological revolution or evolution?' – which examine the potential impact on employment levels in particular.

'Manufacturing in the era of globalisation' starts with an investigation of the most immediate global challenge for manufacturing in Europe – the threat of protectionism – and what impacts further tariff hikes might have for European manufacturing in general and for employment in particular. It continues with two topics related to a defining characteristic of the acceleration of globalisation since the mid-1990s: namely, the ever closer integration of global value chains in manufacturing. The European Reshoring Monitor charts the return of jobs to Europe from the previous bouts of offshoring. Also, the born global study is framed in integrated production networks and with a specific focus on the potential of companies that engage with these networks immediately upon start-up.

'Technological revolution or evolution?' explores five technologies that have the potential to radically change the way that manufacturing is organised. The chapter notes the relatively limited application of these technologies and discusses various means by which their diffusion can be fostered. It continues with a critical assessment of the dire predictions of potential job losses that may occur with a more widespread application of these technologies and examines how these predictions can be reconciled with the historical evidence that technological development has in fact gone hand in hand with employment growth. The chapter also presents the results of a highly explorative macroeconomic estimation of some of the job creation effects that can follow on from an initial round of radical labour-saving automation. The key issue here is the distribution of the productivity gains resulting from technological progress. However, the exceptionally low recent productivity growth seen in both Europe and in particular in the United States (US) suggests that the diffusion of technological innovation in companies is either much slower or less productivity enhancing than is commonly thought to be the case.

The view of a somewhat more modest or gradual impact of the emerging technologies does not imply any less urgency for the adoption of commercially viable innovations in European companies. In the highly competitive global markets for manufactured goods, the rewards of early market share can be both large and long-lasting, and tight profit margins mean that even rather modest productivity gains can prove to be significant. Given the key role of manufacturing in Europe, the stakes are high, and this report provides some discussion of some promising industrial policy developments in this context.

There is a further major challenge facing European manufacturing: namely, the transition to a low carbon economy, not least in the context of the circular economy. While this was not initially envisaged to be part of the pilot project, 'Technological revolution or evolution?' also contains an estimate of the global effects of full implementation of the Paris Climate Agreement on gross domestic product (GDP) and employment. The results indicate that this represents an opportunity for job creation in the EU.

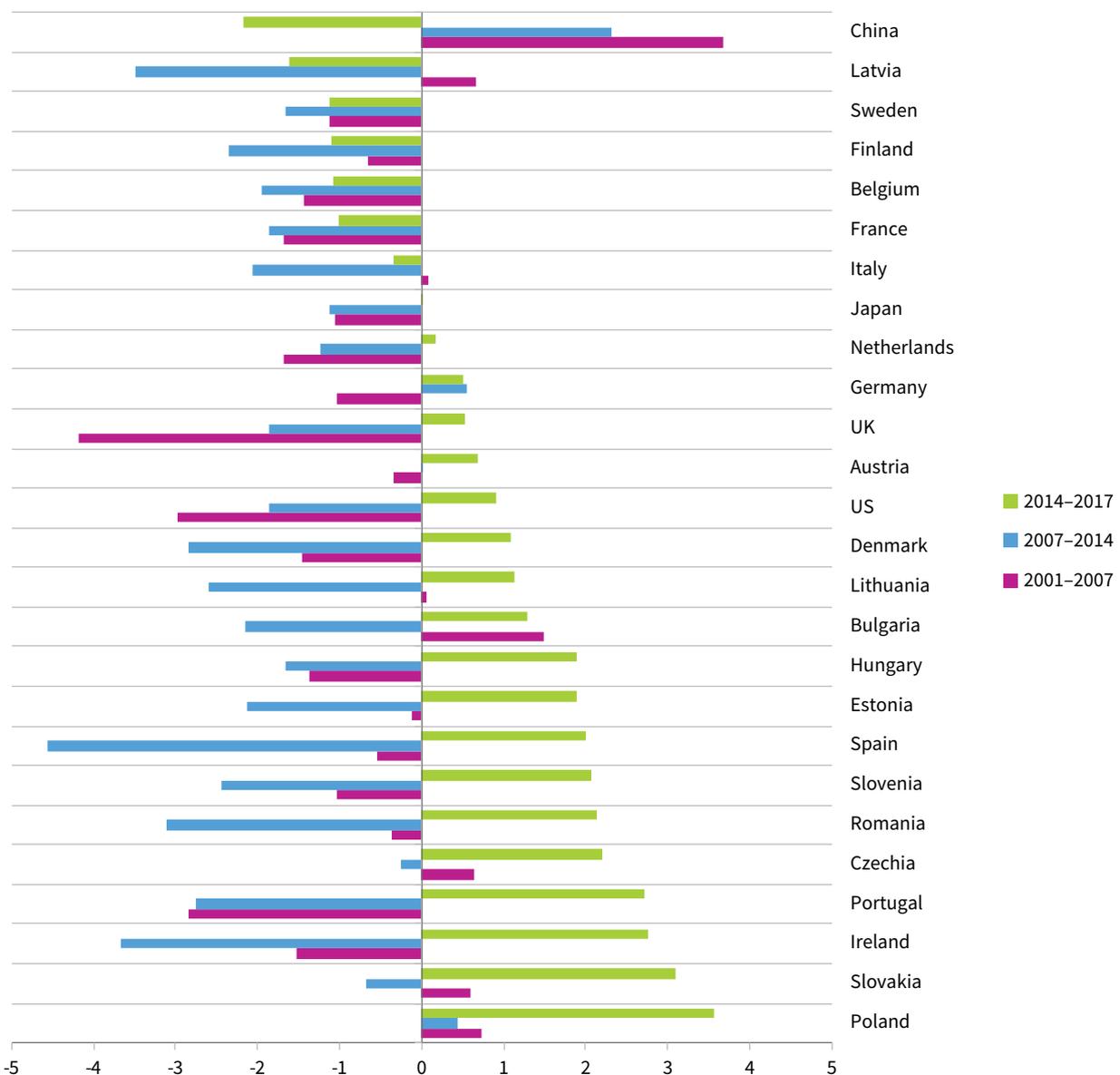
Both Chapters 1 and 2 examine various issues affecting levels of employment. Chapter 3, 'Other labour market implications', complements this with more qualitative aspects of manufacturing employment; it examines wages and changes in the tasks performed in manufacturing, both in the past and with a view to the

future. Many believe that a better-skilled workforce is the most important labour market policy issue arising from the emerging technologies. Much emphasis has been placed on very advanced skills, and these skills are also prominent in this report. However, it also focuses on how some more elementary manufacturing occupations are changing and examines the challenges facing the apprenticeship systems for the future of advanced manufacturing. While there is limited research evidence that could be used to envisage all future challenges for working conditions, this chapter draws a few general conclusions and suggests some

emerging risks on the back of new technologies. The principal challenge for industrial relations, however, is much clearer – how can social dialogue anticipate and manage the change that is coming?

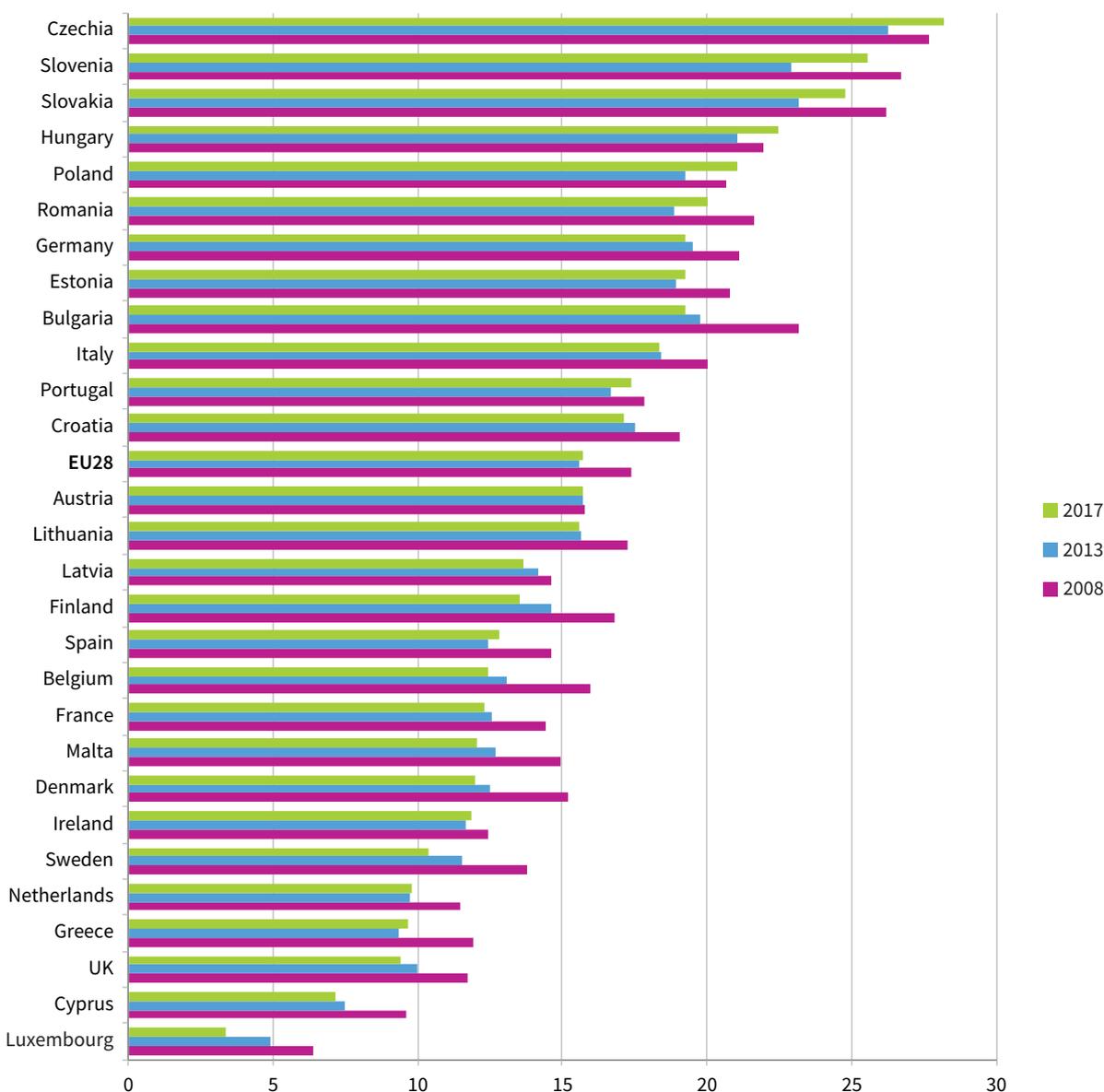
Employment issues are prominent in all three of the main chapters of this report. Figure 1 shows employment growth in manufacturing since the turn of the century. Up to the recession of 2008, when overall employment was increasing, manufacturing employment declined in most Member States. During the recession, employment declined even more but, notably, increased in Germany.

Figure 1: Average annual employment growth in manufacturing, some EU Member States, China, Japan and the US



Source: The Conference Board, International Labor Comparisons program, July 2018

Figure 2: Employment in manufacturing as a percentage of all employment (aged 20-64), 2008, 2013 and 2017



Source: EU Labour Force Survey

Since 2014, manufacturing employment has been increasing in most Member States, and in the EU28 by more than overall employment growth (see Figure 2), which is a welcome development in light of decades of employment decline, even if it is partly a cyclical rebound from the recession. Economic growth in the US in particular has attracted much attention together with some puzzlement: between 2010 and 2017 manufacturing grew by 7.6%, amounting to just under one million new jobs. This is not due to a strong post-recession rebound in manufacturing output, but rather the unprecedented decline in manufacturing productivity mentioned above.

These are turbulent times in manufacturing. There is an expectation of an imminent transformation in the industry, driven by new technologies, but this comes at a time when manufacturing productivity growth has hit an historical low in both Europe and the US. The stability of the post-war trade regime is under threat; China's industrial policy has both huge resources and a very focused direction and US-instigated trade protectionism seriously threatens manufacturing in Europe. Moreover, momentum appears to be building for a more ambitious European industrial policy. Just as this final project report was being drafted (February 2019), the German National Industrial

Strategy 2030 and the Franco–German Manifesto for a European industrial policy fit for the 21st century both recognised the importance of an active European industrial policy to foster global competitiveness in the

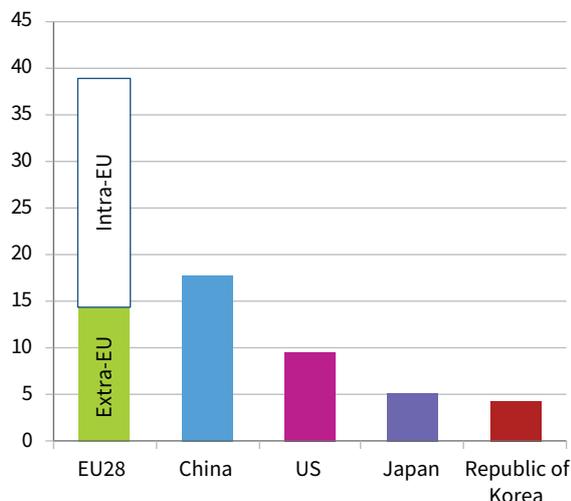
context of emerging game-changing technologies (Bundesministerium für Wirtschaft und Energie, 2019a, 2019b).

1 Manufacturing in the era of globalisation

Introduction

International markets are of fundamental importance for manufacturing in Europe. Despite some recent growth of trade in services, merchandise trade still dominates total global trade, with manufacturing accounting for 70% (WTO, 2018). While the value of extra-EU exports was surpassed by China (in 2010), they still constitute just under 15% of the global total (see Figure 3). With consumer demand expected to grow much faster in many parts of the world outside of Europe, the future of manufacturing – and therefore much of the material welfare enjoyed by Europeans – is highly dependent upon globally competitive European manufacturing with access to these markets.

Figure 3: Export share of the top five manufacturing exporters as a percentage of the global total, 2017



Source: World Trade Organisation (2018)

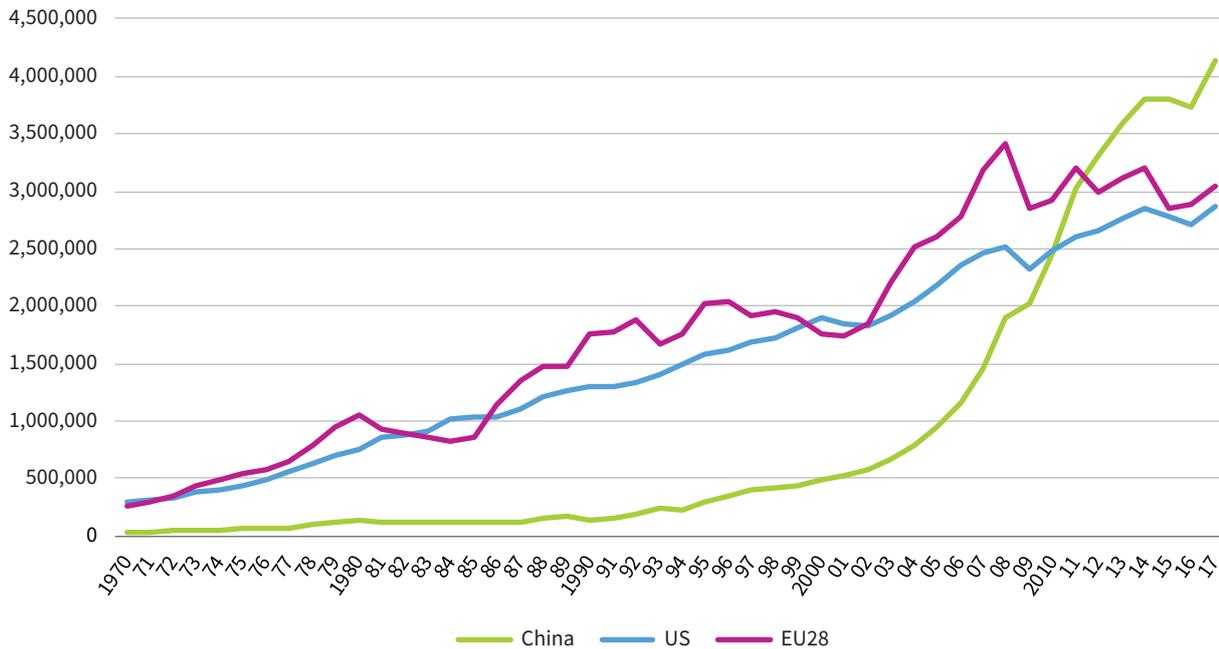
Between 1970 and 2017, the big three trading blocks of China, the EU28 and the US have together accounted for a stable 60% share of global valued added in mining, manufacturing and utilities. However, with the very

rapid growth of manufacturing in China, starting at the end of the last century, the distribution of global value added between the big three has changed dramatically, and since 2011 China has top position. (see Figure 4). Value added dipped significantly at the start of the Great Recession in both the EU and the US. While in Europe it subsequently grew again, it has yet to reach the peak of 2008. In the US, on the other hand, there has been a steady recovery of both value added and employment. This rather surprising surge in manufacturing employment in the US is examined in more detail in Chapter 2.

International trade declined sharply at the start of the recession (in fact, evidence of a slowdown predates 2008) as would have been expected, but, perhaps more notably, it did not recover apace with the global rebound in GDP. However, between 2016 and 2017, the trade share of growth increased again, and although the World Trade Organization (WTO) forecasts the same level in 2018 – barring significant trade disputes (WTO, 2018) – it is far from clear that the previously long-standing stable global tariff regime will continue to hold. The next section uses a macroeconomic model to estimate the potential impact of significant tariff hikes, somewhat in excess of those as of February 2019, with a focus on the potential consequences for employment.

Economic globalisation is not just about international trade; it can be defined as an increase in the interdependency of national economies and the greater integration of goods, services, labour and capital markets. For companies, much focus since the 1990s has been on the potential of vertical differentiation and integration through international production networks. From an employment perspective, there has been concern that this may imply the offshoring of jobs from Europe (and the US) with alarming predictions of potential job loss (for example, OECD, 2006; Blinder, 2007). The discourse in the early 2000s was very similar to that seen some 10 years later, predicting significant potential job losses due to radical automation (see next section).

Figure 4: Value added in mining, manufacturing and utilities in China, the US and the EU, 1970–2017 (USD millions)



Source: UN Conference on Trade and development (UNCTAD), March 2019

Eurofound’s European Restructuring Monitor (ERM) has been quantifying offshoring on a continuous basis since 2003. Offshoring is most prevalent in manufacturing and accounted for around 12% of all announced job losses in the sector between 2003 and 2007, although this has subsequently declined to around 8%, with values for the whole economy being 7% and 3% respectively. Early in the recession there was much policy interest in the possible reshoring of these previously offshored activities. This was partly fuelled by an understanding that some companies had recognised quality and supply security issues with the offshored plants and a narrowing of global labour cost differentials. More recently, and of high relevance for the FOME project, it was thought that advanced automation could also shift locational preference towards Europe. Given the scarcity of evidence of the extent of reshoring, this project created a dedicated tool, the European Reshoring Monitor, to provide some indication of the scale of recent reshoring.

Adam Smith famously wrote in *The Wealth of Nations* that the division of labour is limited by the extent of the market. Globalisation trends since the 1990s have profoundly increased the effective size of potential markets for companies in Europe. This provides an increased opportunity for trade in narrowly specialised activities that can be performed by small firms. Born globals – that is, firms that have intense international activities from start-up – are of growing significance in European economies as a source of value and

employment creation. Under the heading ‘Born globals in international supply chains’ below, we explore how born globals can better engage in the international production networks within which most of them are embedded.

Employment implications of significant global tariff hikes

Introduction

Trade protectionism started to increase after the Great Recession of 2008. While in the first years of the recession outright tariff hikes were limited and rare, there are other means of restricting international trade. Georgiadis and Gräb (2013) identify a number of enacted policies that served to restrict trade, such as local clauses in stimulus and bailout packages. However, with the arrival of the Trump administration in the US, protectionist measures have been ramped up to levels unprecedented in living memory. The rules of global trade are being rewritten, and it is hard to identify a tariff regime that could be expected to prevail into the future. The research strategy adopted here is to construct a scenario assuming a very significant and specific global tariff hike in order to explore the implications of such developments for global growth and employment. The effects of the tariffs on growth and employment are estimated by the E3ME global macroeconomic model (see Box 1).

Box 1: The E3ME model

E3ME is a global macroeconomic model designed to address major economic and economy–environment policy challenges. Developed since 2000 by Cambridge Econometrics, it is one of the most advanced models of its type. Its strengths are listed below.

- It offers a high level of disaggregation, enabling detailed analysis of sectoral and country-level effects from a wide range of scenarios. Social impacts are important model outcomes.
- Its econometric specification addresses concerns about conventional macroeconomic models and provides a strong empirical basis for analysis. It can fully assess both short- and long-term impacts and is not limited by many of the restrictive assumptions common to computable general equilibrium models.
- It enables integrated treatment of the world’s economies, energy systems, emissions and material demands, allowing it to capture shared links and mutual feedback among the components.

E3ME covers 59 global regions, with a detailed sectoral disaggregation in each, and projects annually up to 2050. It is frequently applied at national level, in Europe and beyond, as well as for wider (European and global) policy analysis (Cambridge Econometrics, undated).

The baseline projection, to which the projections in this report are compared, incorporates the Eurostat population forecast available in 2017 and the short-term macroeconomic forecast produced by the European Commission’s Directorate-General for Economic and Financial Affairs in May 2017 (see Cedefop and Eurofound, 2018).

Construction of the protectionist scenario

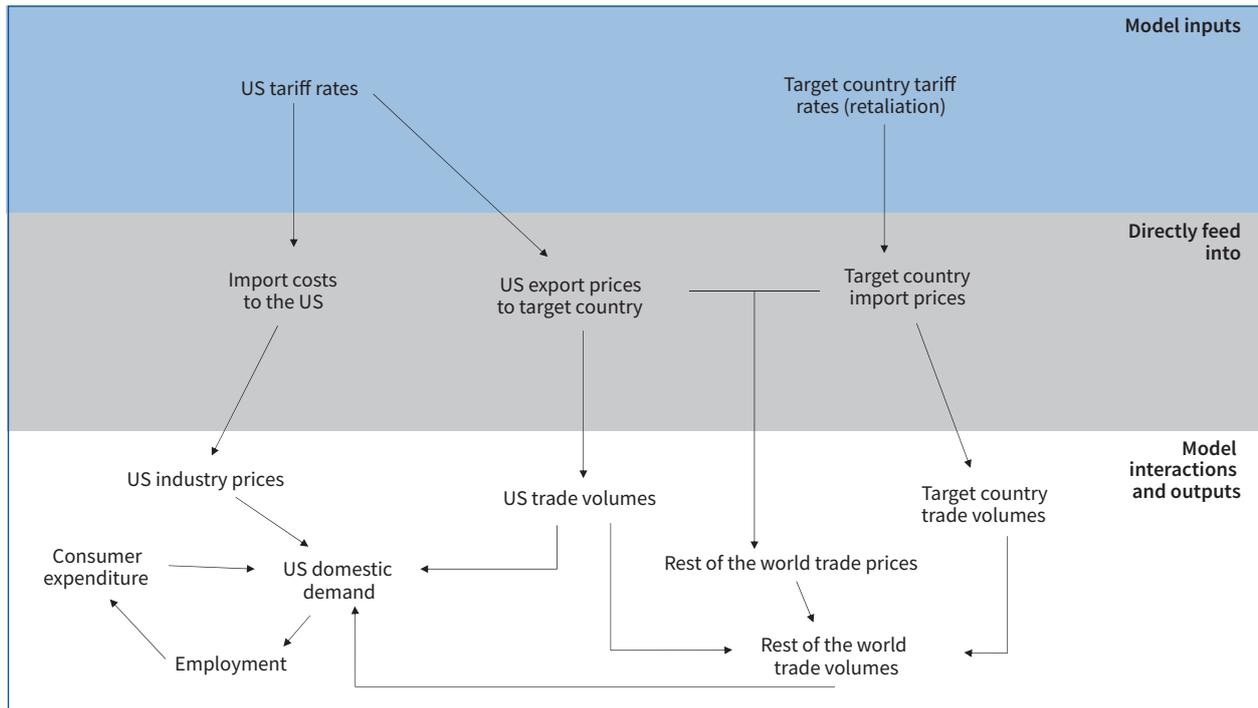
The main inputs to this scenario are assumptions for the changes in trade tariffs between the US and the EU, Canada, China and Mexico for each affected sector. These are implemented as a one-off, sustained change from 2019 and are as follows:

- the breakdown of the North American Free Trade Agreement (NAFTA), leading Canada, Mexico and the US to revert to tariff rates, as agreed by the WTO
- a 25-percentage-point increase in US tariffs on imports from China across all manufactured and agricultural goods
- the introduction of similar tariffs by China, adding 25 percentage points to tariffs on all manufactured and agricultural goods imports from the US in response
- the introduction of tariffs between the US and the EU, adding 25 percentage points to tariffs on all agricultural and manufactured goods

While the assumption of a breakdown of NAFTA has been superseded by the agreement announced at the start of October 2018, NAFTA has a limited impact on the EU. The assumptions for the US and China are roughly in line with developments since 2015, such as the levying of new tariffs announced in July 2018. As regards the US–EU trade barriers, the assumptions are more pessimistic than what has so far been implemented.

The new tariffs affect import prices, competitiveness and trade volumes. For example, in the model, tariffs introduced by the US on imports from China lead to the substitution of Chinese products with US products or imports from another country. In both cases, higher tariffs result in higher consumer prices, both directly and because increased costs for US firms are passed on to consumers. Generally, countries that are directly targeted by tariffs may be expected to see negative impacts on GDP, whereas tariffs may have beneficial effects for those that are not, as trade may be diverted towards such third countries.

Figure 5: Trade protectionism scenario inputs and model links for the US economy



Note: The same principal effects apply to the other regions of the world impacted by tariff increases.
Source: Eurofound: The Future of Manufacturing in Europe – Trade scenario

Figure 5 shows the model links illustrated for the case of the US. In the top-left corner, the introduction of tariffs on US imports leads to higher import prices for US purchasers, whether these are final consumers or US domestic industries. US domestic industries using imports therefore face higher costs, even if they mitigate the impact by switching to purchases from US-based producers or from a third country. These higher costs are ultimately passed through, at least in part, to final consumers, reflected in higher consumer prices and resulting in lower real disposable incomes (and real consumer expenditure). To the extent that there is a boost to purchases from domestic producers as a result of such a protectionist measure, there may be higher production and employment in some sectors, partly offsetting the consumer price effect on incomes and spending. The higher costs faced by US domestic producers affect export competitiveness, and this impact is exacerbated further as retaliatory tariffs are introduced in US export markets. The introduction of tariffs on Chinese imports to the US is expected to benefit producers in third countries such as India, which are not subject to additional tariffs and so increase their exports to the US to take up some of the market previously served by China.

The bottom-left corner of Figure 5 shows the link between reduced employment and consumer expenditure. When jobs are lost, some of the impact on formal unemployment is mitigated by a reduction in labour market participation, as some people are

discouraged from seeking employment. The reduction in gross wages leads to a reduction in income tax and social protection revenues to government and a reduction in post-tax incomes to households, mitigated in part by higher unemployment benefit payments in proportion to the rise in formal unemployment. The net reduction in household incomes then leads to a fall in consumer expenditure.

The same logic applies for any country that imposes a tariff: costs and prices are increased within the country, domestic producers and third countries gain market share at the expense of the targeted imports, and exporters suffer the impact of retaliatory action in their markets.

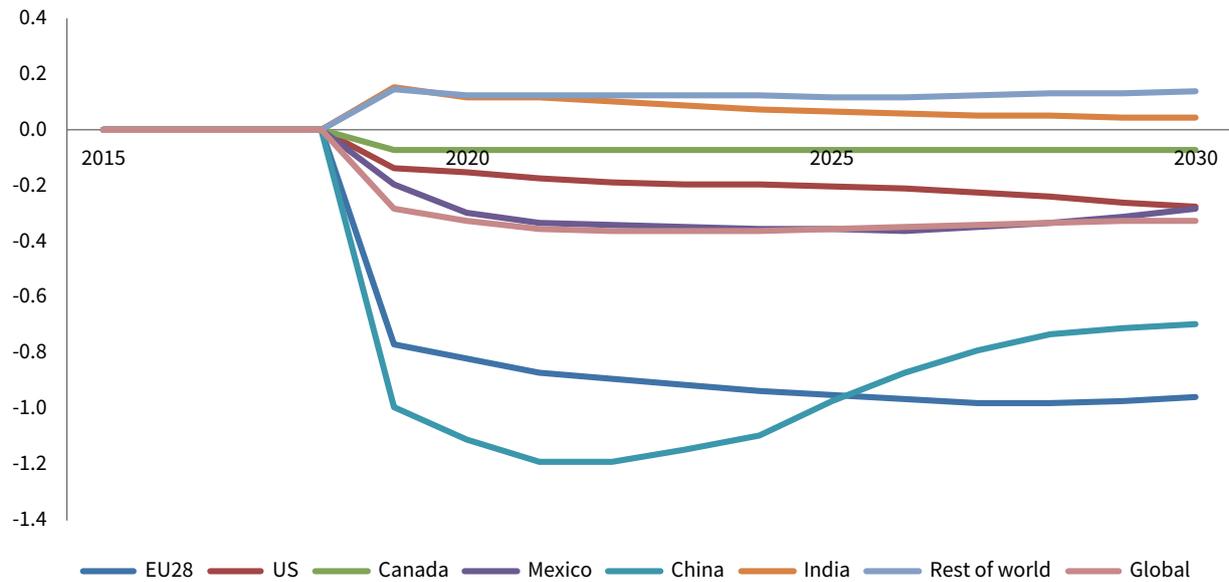
Scenario results

All the results are reported in terms of differences from a baseline projection (referred to in Box 1) that did not assume any changes in global tariff rates.

Overview of global impacts

Figure 6 shows the impacts on GDP relative to the baseline. In the US, the negative impact increases from 0.1% in the first year to 0.3% by 2030. Initially, the impact on China is larger with a 1% decrease in GDP, but China is predicted over time to increase exports to other markets and redirect its sourcing of imports to Asian countries at modest additional cost. Like China, the EU sees a large initial negative impact of 0.8% but only marginally recovers over time as China redirects its

Figure 6: GDP impacts by country/region, percentage difference from baseline in which tariffs are not raised



Source: Eurofound: The Future of Manufacturing in Europe – Trade scenario

exports to the EU; the model’s trade equations predict that the EU is less able to redirect its sourcing of imports to relatively low-cost alternatives. Exporters in India and elsewhere gain market share, so GDP is higher in these global regions.

Summary of EU results

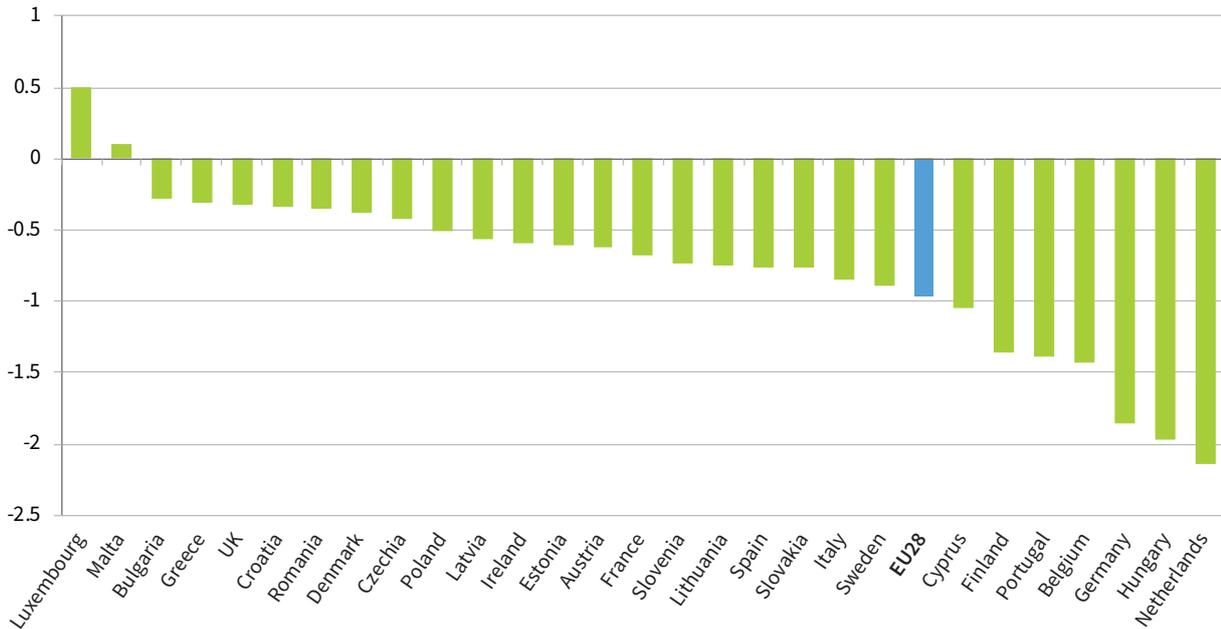
Table 1 shows the impact on key EU macroeconomic indicators. The 1% GDP decline in 2030 is driven by lower export volumes and higher prices. Employment is expected to be 0.3% lower in 2030. Imports are also expected to decrease by 1.1% as a result of lower economic activity.

Table 1: EU28 macroeconomic impacts, percentage difference from baseline

	2020	2025	2030
GDP	-0.8	-1.0	-1.0
Consumer spending	-0.4	-0.5	-0.5
Investment	-0.3	-0.5	-0.5
Exports	-3.8	-3.9	-3.9
Imports	-0.9	-1.1	-1.1
Employment	-0.2	-0.3	-0.3
Consumer prices	0.2	0.4	0.4

Source: Eurofound: The Future of Manufacturing in Europe – Trade scenario

Figure 7: Impact on GDP in 2030 by Member State, percentage difference from baseline



Source: Eurofound: The Future of Manufacturing in Europe – Trade scenario

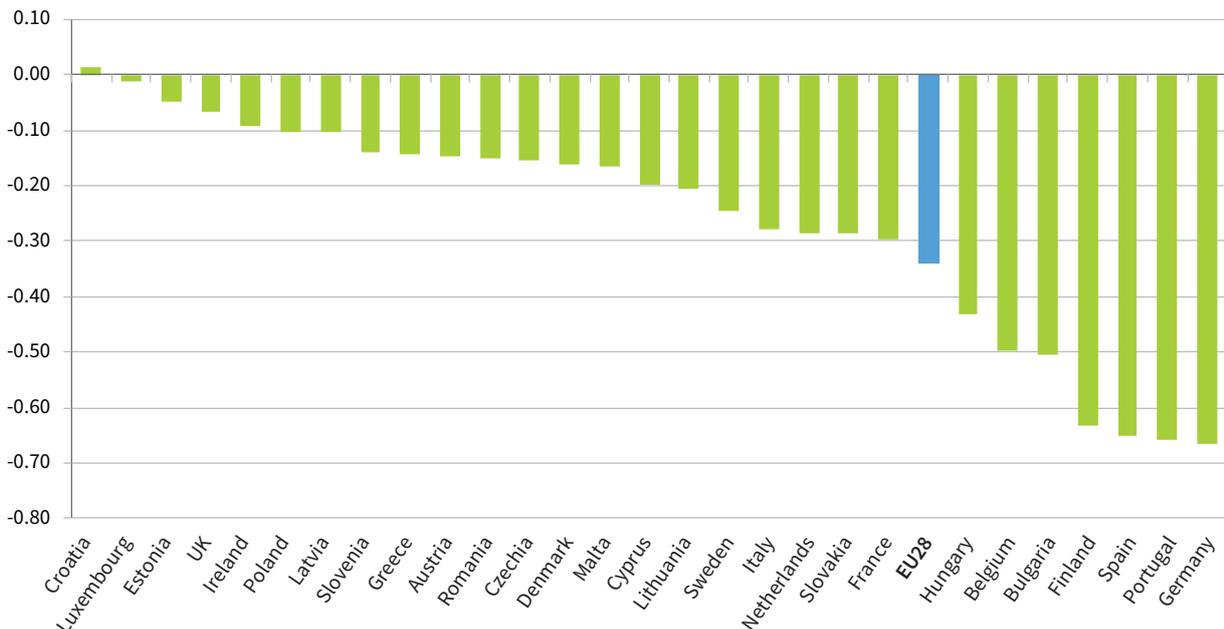
Among Member States, practically all countries show a decline in GDP in 2030 (Figure 7). The largest reductions are in the Netherlands, Hungary and Germany. Germany is Europe’s largest exporter to the US. The US market is also relatively important for Hungary. The Netherlands suffers from the direct impact of lower trade volumes to the US and also more generally from weaker economic activity in the EU, as it acts as one of the main ports for EU trade with destinations outside the bloc.

In the UK, manufactured exports to the US are of relatively less importance and UK exports are more service oriented, which means they are not directly affected by the tariffs.

Impact on employment

Figure 8 shows that the impacts on employment are negative in almost every Member State, albeit on a smaller scale than GDP impacts. There are some

Figure 8: Impact on employment in 2030 by Member State, percentage difference from baseline



Source: Eurofound: The Future of Manufacturing in Europe – Trade scenario

differences in the ranking of countries compared to the impact on GDP, reflecting the differences in sector effects by country and differences in sector intensities of employment. Generally, the impact on employment is roughly half that of the impact on GDP, but there are exceptions – notably the Netherlands, Luxembourg and Malta.

In the case of the Netherlands, the sectors most affected by trade are not the most labour intensive in the economy. Some sectors also see a decrease in average wages, which mitigates some of the impact on jobs from decreases in production. Spain and Bulgaria are among the countries experiencing the largest impacts. The result for Spain reflects slightly greater sensitivity to consumer spending and the importance of consumer services jobs in its economy. The result for Bulgaria reflects the sensitivity to the protectionist measures of the country’s significant textiles industry.

Most sectors within the manufacturing industry are expected to experience a decline, with the textiles and clothing, motor vehicle and chemicals sectors in particular expected to suffer the largest losses in absolute terms, reflecting both their size and the loss of the export market. The impact on food, drink and tobacco, pharmaceuticals and electrical equipment is modest by comparison. Business services are also affected by the higher tariffs as most sectors in this category are part of the supply chain within manufacturing. Higher prices and loss of wages mean less spending on household consumption, which affects

not only manufacturers of the goods but also producers of the services linked to distribution and, more broadly, of consumer services.

Sectoral results

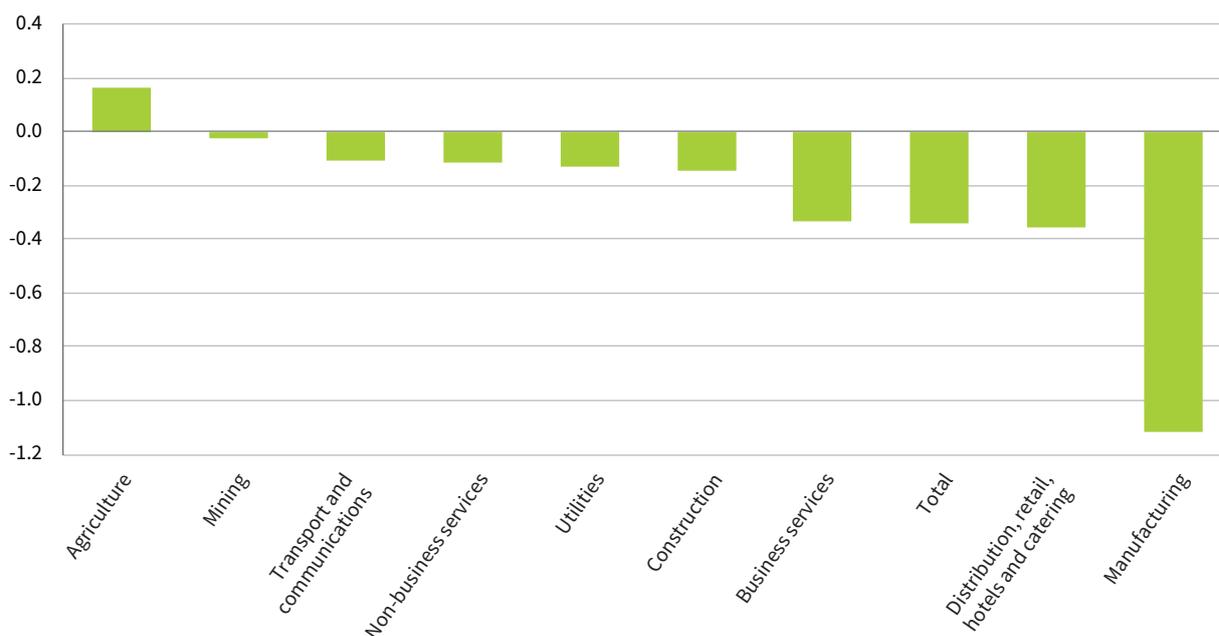
Figure 9 shows the impact on EU28 employment in 2030 by broad industry group. As manufacturing is directly affected by the tariffs, with a 1.1% decrease this sector shows the largest percentage impact of tariffs on employment. The impacts on services sectors reflect the second-round effects of lower economic activity and, in particular, lower consumer expenditure due to higher prices and loss of income from job losses in the sectors directly affected by the higher tariffs. Large employers such as distribution and retailing and business services are expected to see declines in the range of 0.3–0.4%.

Impact on the occupation and wage structure

The projected patterns of net change in employment by occupation are very similar to those in the baseline. The impact of the scenario on jobs in manufacturing is reflected in a loss of jobs relative to the baseline for science and engineering occupations and the various manufacturing trades. The knock-on effects operating through lower wage incomes and lower consumer spending are evident in occupations in hospitality and retailing, customer services and sales.

More details can be found by incorporating the employment projections into a classification of jobs as developed by Eurofound in the European Jobs Monitor (see Box 2 overleaf).

Figure 9: Impact on EU28 employment in 2030 by broad industry, percentage difference from baseline



Source: Eurofound: *The Future of Manufacturing in Europe – Trade scenario*

Box 2: The European Jobs Monitor

In the European Jobs Monitor, a job is defined as an occupation in a sector, as in the standard international classifications of occupation (ISCO-08) and sector (NACE, Rev 2.0) at two-digit level. The number of jobs so defined varies from 400 in the smaller Member States to just over 2,000 in the larger ones. As jobs are empirically defined by standard statistical classification, a further description of these jobs can be added using data from a variety of sources that follow these same classifications of occupations and sectors. The average wage in these jobs is a useful metric for capturing some of the characteristics and drivers of recent and future structural change in Europe. The wage data are compiled by combining data from the EU’s Labour Force Survey and Structure of Earnings Survey. The jobs are ranked from the highest to the lowest wage in each Member State. They are then allocated to quintiles based on the job–wage ranking for that Member State. Each quintile in each country represents 20% of employment at the starting period. The job-to-quintile assignments remain fixed over time so that the charts presented map the growth of jobs assigned to that quintile at the start of each period of observation (see also Eurofound, 2018a).

Source: Eurofound: *European Jobs Monitor*, <http://eurofound.link/ejm>

Figure 10: Job–wage quintiles in the baseline and trade scenarios, EU, 2015–2030 (thousands)



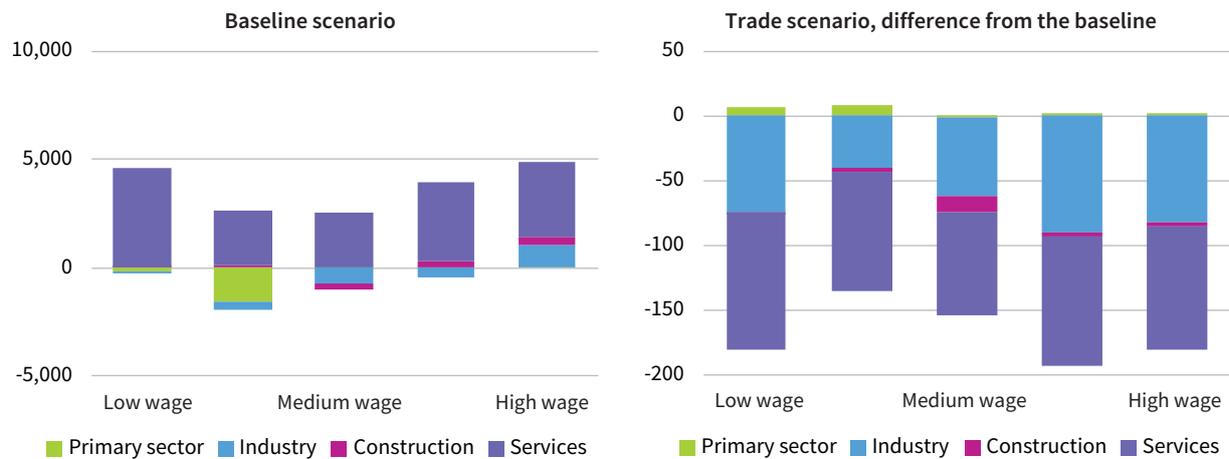
Source: Eurofound: *The Future of Manufacturing in Europe – Trade scenario and European Jobs Monitor*

The distribution of job–wage quintiles in the baseline scenario and the differences from the baseline of the trade scenario are presented in Figure 10.

Job growth in the two scenarios is obviously very different as the baseline predicts significant job growth while the addition of the trade scenario leads to job loss. Moreover, the job growth pattern – the distribution

among the wage quintiles – is also very different. The baseline shows slower growth in the middle than in the top and bottom, while the trade scenario shows more modest decline in the middle with relatively more decline toward the two tails. A comparison of the two panels in Figure 11 shows that the trade scenario exhibits much more change in the industry sector, compared to other sectors, than in the baseline.

Figure 11: Job–wage quintiles in the baseline and trade scenarios by broad economic sector, EU, 2015–2030 (thousands)



Source: Eurofound: *The Future of Manufacturing in Europe – Trade scenario and European Jobs Monitor*

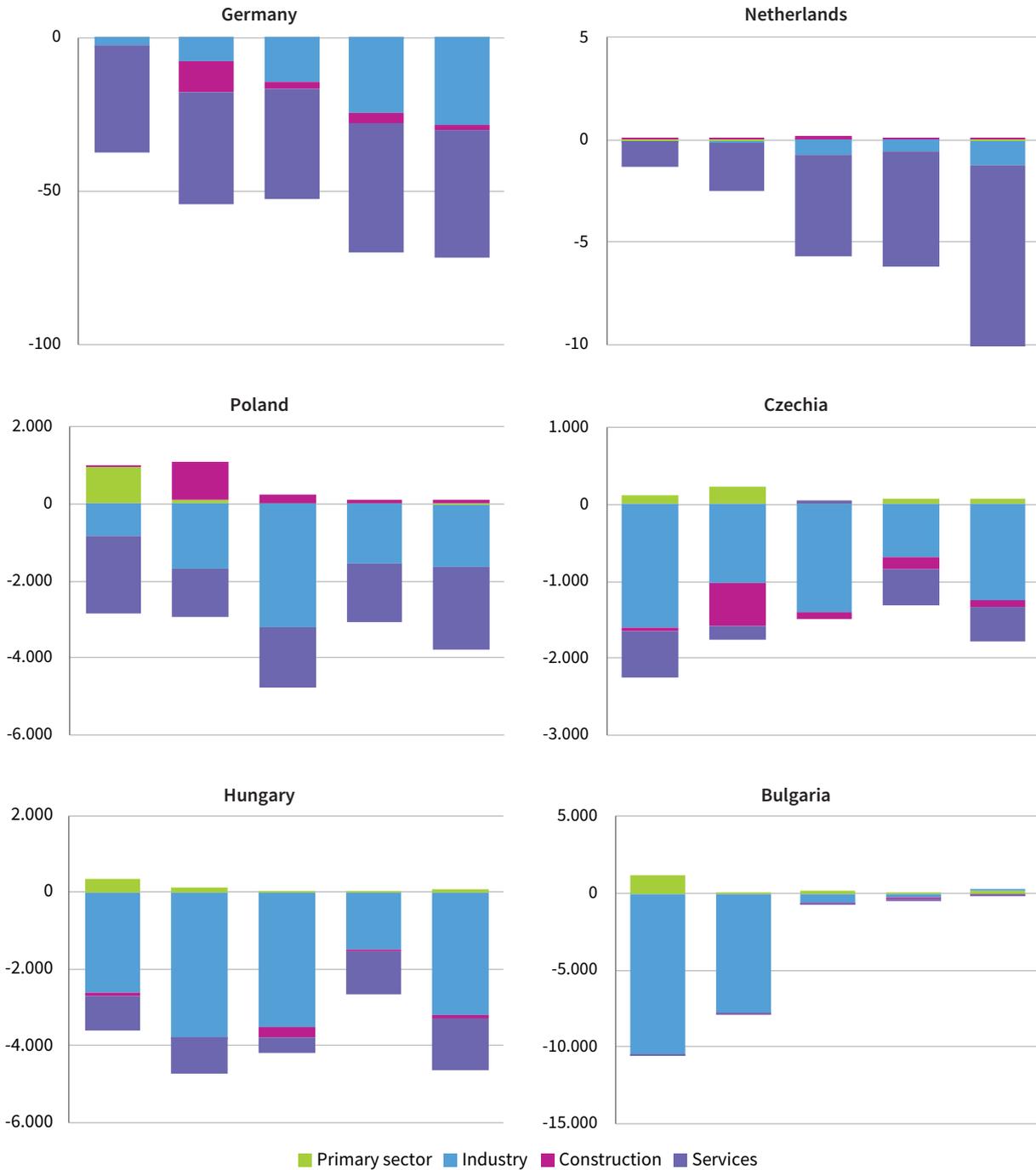
Some understanding of the types of jobs lost in the trade scenario can be read from a selection of country results presented in Figure 12. It shows that most job loss in Germany is in the higher wage quintiles, accompanied by considerable loss, also in the high quintiles, in associated business services. While Germany provides the clearest example of this, similar developments can be found in Austria, Finland and France.

The Netherlands, like Germany, also shows relatively extensive job loss, though primarily in services. This is in part related to the highly significant role that the Netherlands plays in the external trade of the EU. The role of Rotterdam in this context is well known, but there are a number of other Dutch logistic and distribution centres with other trade-related services. No other country in Europe shows a pattern anything like that in the Dutch results. This may also be

attributable to the fact that transit re-exporting activities in the Netherlands (*wederuitvoer*) account for 50% of all Dutch merchandise exports (De Kruijf, 2018). The Dutch industrial employment contribution to the value added of these goods is very limited. Czechia and Poland (both with much less job loss relative to total employment) show a much more even wage quintile distribution of job loss, with fewer jobs lost in services.

Bulgaria and Hungary are the central and eastern European countries with the largest overall job loss (see Figure 8 on p.14). The relative decline in the two bottom wage quintiles in Bulgaria is entirely attributable to the industrial sector and is the largest relative decline in any of the wage quintiles reported here. This is primarily attributable to some manufacturing subsectors being particularly exposed to tariff hikes, with the textiles subsector being a case in point.

Figure 12: Job–wage quintiles in the trade scenario (differences from the baseline), 2015–2030, by selected Member States and broad economic sector (thousands)



Source: Eurofound: *The Future of Manufacturing in Europe – Trade scenario and European Jobs Monitor*

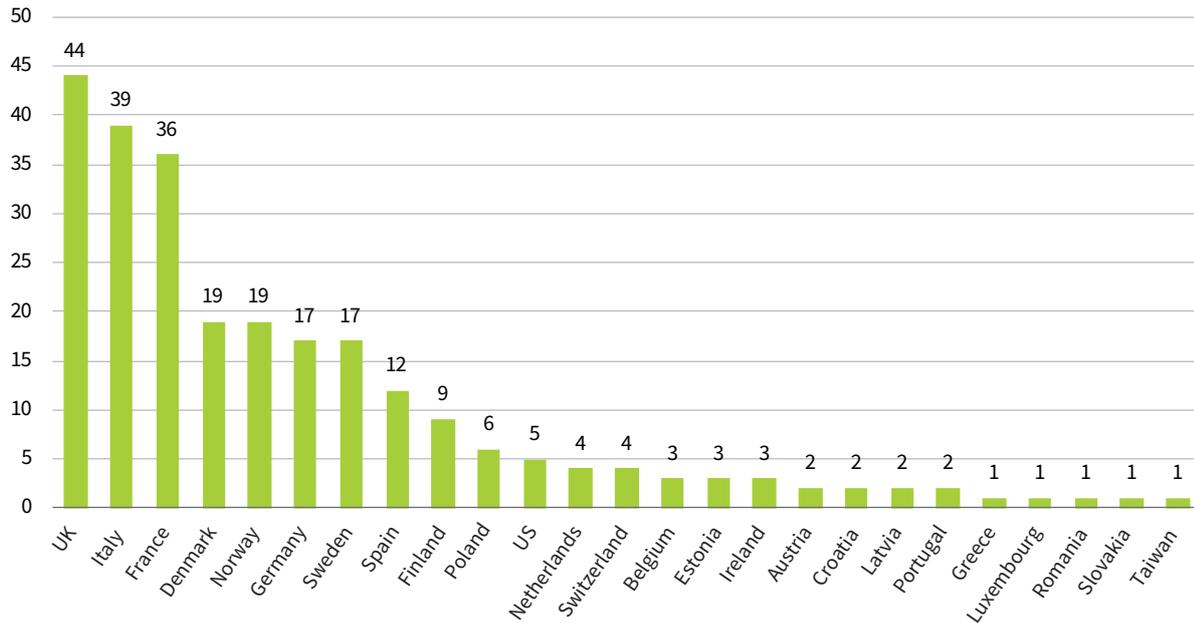
European Reshoring Monitor

Offshoring economic activities and employment has been one of the salient features of globalisation since the mid-1990s. The impact of offshoring on employment has been measured in the ERM (European Restructuring Monitor – see Box 3). Since 2010, political and economic changes globally, the thinning of location advantages in some offshore countries and growing awareness of the total cost of offshoring have driven some companies to

rethink the location of their international value chains and, hence, move their manufacturing activities back to their home country or to countries nearby. This phenomenon is often referred to as ‘reshoring’, although other labels have been used, such as ‘back-shoring’ and ‘in-shoring’.

The European Reshoring Monitor is a new tool, developed as part of this project, that collects information on individual reshoring cases from several media sources (newspapers, specialised press, scientific

Figure 13: Number of reshoring cases by country, 2014–2018



Note: US and Taiwanese data refer to the ‘Other reshoring’ category.

Source: Eurofound: The Future of Manufacturing in Europe – European Reshoring Monitor

Evidence from the European Reshoring Monitor 2014–2018

For each reshoring case the following data were collected:

- general company data such as location, employment levels, firm size and NACE sector code
- information on the reshoring initiative such as date, motivations, expected impact on employment and ownership of repatriated activities
- the previous offshoring initiative with regard to host country and ownership of offshore activities
- country of reshoring (home country or another EU country)

There were 253 cases recorded between 2014 and 2018. The majority of cases were of backshoring (92%), where previously offshored activity was reshored to the company’s home country. Figure 13 shows that the three largest reshoring nations were the UK, Italy and France. The numbers are low for Germany in relation to the size of its economy, and they were relatively high in Denmark, Norway and Sweden. While, historically, reshoring has been primarily back to developed western European countries (France, Germany, Italy and the UK), it has broadened more recently to encompass northern and eastern Europe, including Poland.

There are three other notable features.

- Half of all identified reshoring took place from China, followed by India, Poland and Germany.
- Around 59% of reshoring cases involved large companies (with more than 250 employees), while SMEs represented 41% of the collected cases.

- In 2014, 32 cases were reported, increasing to a peak of 74 in 2017 but declining to 46 in 2018. However, some 2018 cases may not yet have been reported.

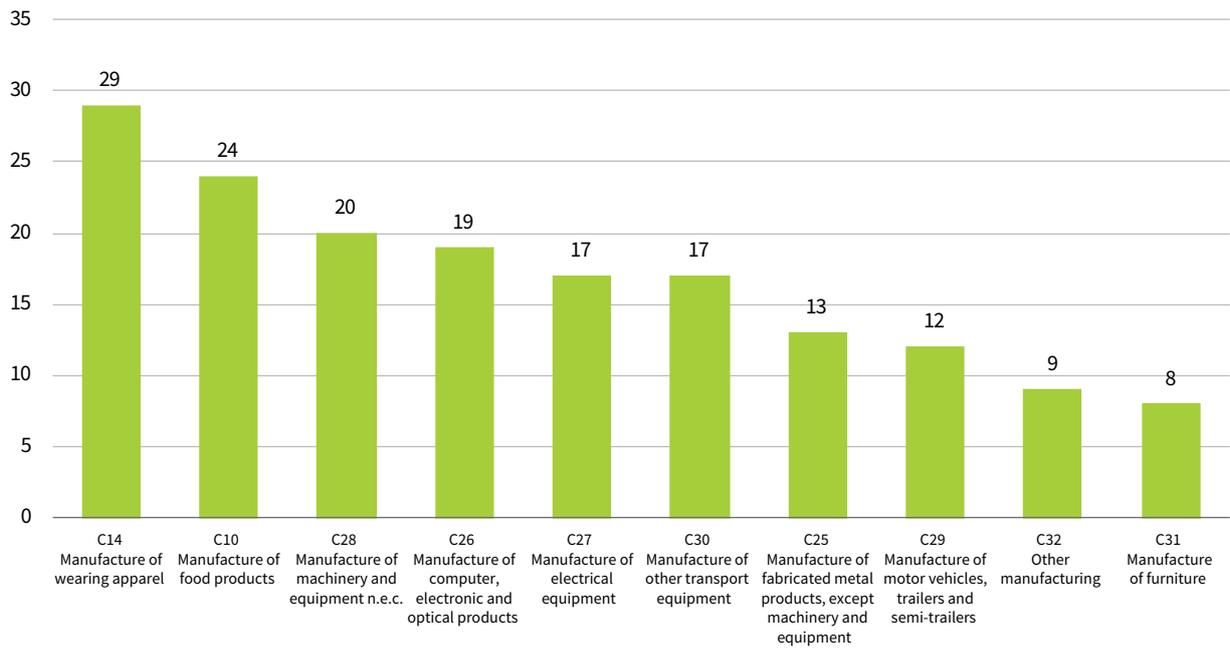
More than 85% of reshoring cases occurred in ‘Manufacturing’ (218), followed by ‘Information and communication’ (12) and ‘Financial and insurance activities’ (9). Despite the low number of reshoring cases in ‘Information and communication’, the latter sector enjoyed a significant increase in employment in the form of 2,411 jobs (19% of the total), most of which came from a single case where Vodafone reshored 2,100 call centre jobs to the UK.

The distribution among the main manufacturing sectors is presented in Figure 14. Within the manufacturing sector, the following six subsectors are the most relevant as regards reshoring activity:

- C14 – Manufacture of wearing apparel
- C10 – Manufacture of food products
- C28 – Manufacture of machinery and equipment n.e.c.
- C26 – Manufacture of computer, electronics and optical products
- C27 – Manufacture of electrical equipment
- C30 – Manufacture of other transport equipment

These sectors represent 47% of the cases and 43% of total manufacturing jobs gained. Manufacturing as a whole accounts for 79% of total job gains arising from reshoring. Since 2014, the concentration of reshoring effects in labour-intensive industries has diluted such that the range of industries affected has widened significantly.

Figure 14: Reshoring case frequency by industry (only for manufacturing companies)



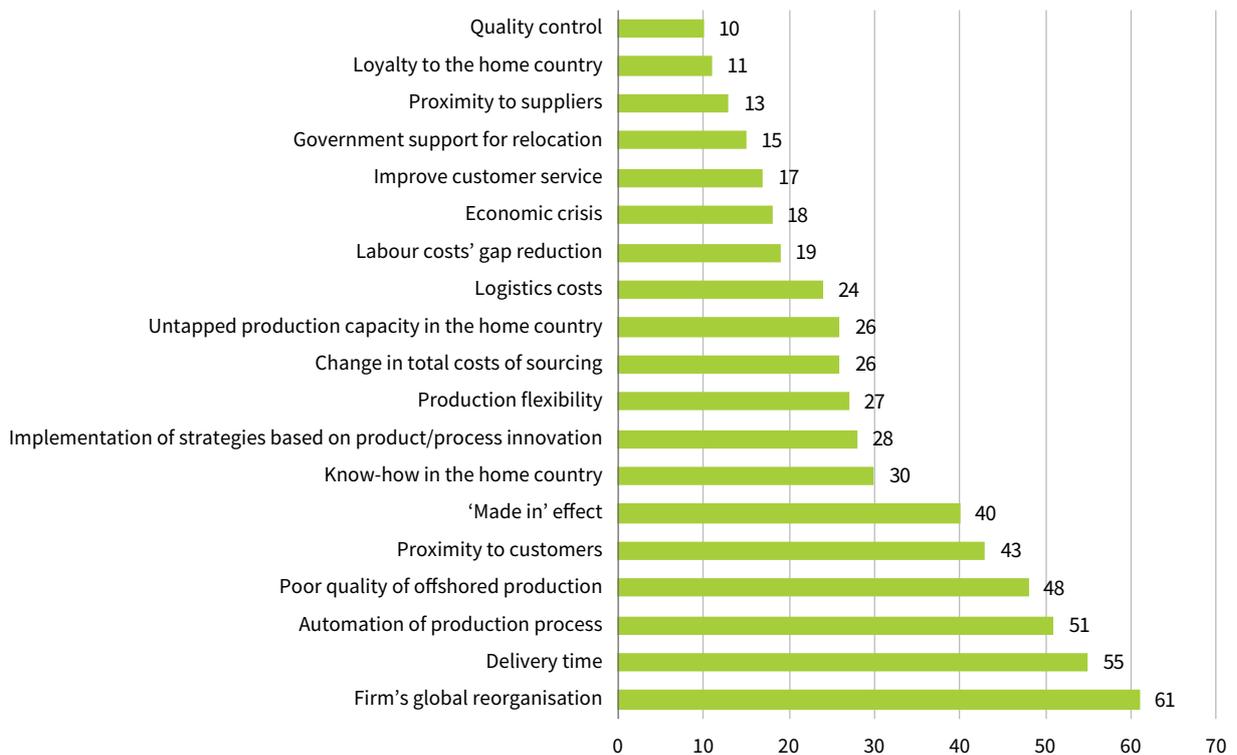
Note: Chart excludes sectors with fewer than eight reshoring cases

Source: Eurofound: The Future of Manufacturing in Europe – European Reshoring Monitor

A vast array of drivers or motivations has been identified in current reshoring literature (Fratocchi et al, 2016; Barbieri et al, 2018); for example, the European

Reshoring Monitor considered 56 reshoring motivations. Figure 15 presents the distribution of the most-cited motivations by number of cases.

Figure 15: Reshoring motivations (only those declared at least 10 times)



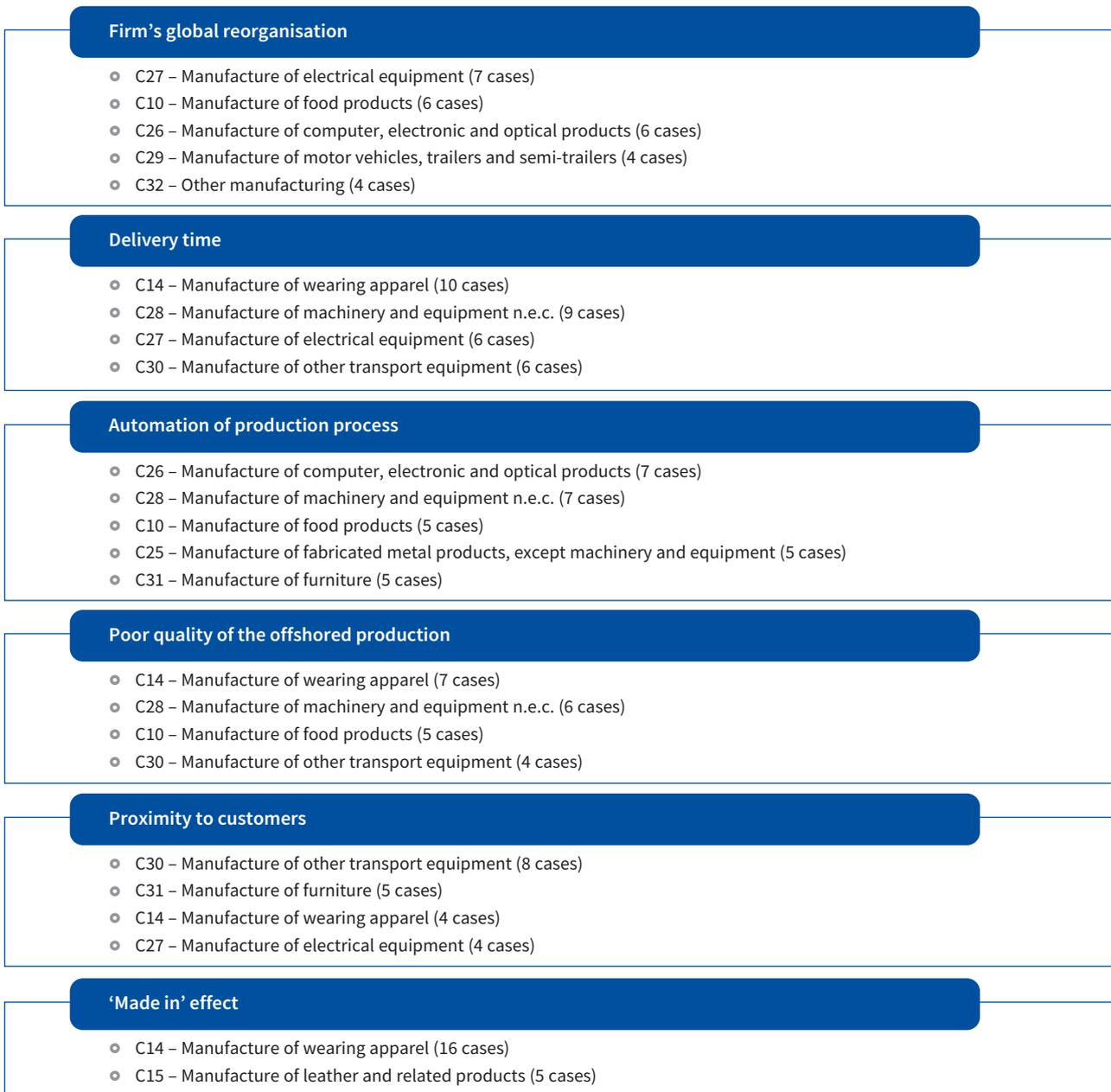
Note: Multiple motivations can be indicated for a single reshoring case.

Source: Eurofound: The Future of Manufacturing in Europe – European Reshoring Monitor

When breaking down reshoring drivers according to manufacturing subsector (Figure 16), it clearly emerges that only the ‘Made in’ motivation is strictly associated with a specific industry (the clothing sector with 16 out of 38 citations), while other drivers relate to a variety of different industries. Motivations for reshoring tend to vary also by country: for example, the ‘Made in’ effect is prominent in Italian cases; quality issues in offshored production are cited more often in Germany; and a

combination of delivery times, proximity to customers, product quality and the ‘Made in’ effect are the most frequently cited motivations in the UK cases. Cost factors, and even quality factors to some extent, which dominated the first wave of the phenomenon, have given way to factors linked to the global reorganisation of value chain activities, the need for customer responsiveness (delivery times) and new technological trajectories (automation and digitalisation).

Figure 16: Motivations for reshoring sorted by manufacturing sub-sector



Source: Eurofound: *The Future of Manufacturing in Europe – European Reshoring Monitor*

Information on employment is available only for less than half of the cases (99 or 41% of the sample). This finding may prompt the speculation that in the other 60% of analysed cases, the employment gains were totally absent or at least not relevant enough to be highlighted by the reshoring company when communicating its own decision or by the media in reporting the case.

A total of 12,840 new jobs were linked to these 99 initiatives between 2014 and 2018. In contrast to 2017, in 2018 the number of jobs greatly decreased both in total number (454 vs. 6,222) and in average job gains per case (86.4 vs. 11.3).

As far as reported job gains are concerned, two further issues emerge from the analysis of the case studies. First, the growing relevance of automation as a reshoring enabler, which implies limited employment creation. Second, companies sometimes implement reshoring decisions based on a 'defensive' approach, which is leveraging untapped production capacity available in the home country. Analyses conducted clearly show that, especially in Italy, firms may reshore in response to pressure from unions and local communities if in the home country there is otherwise a risk of plant closure and employee lay-offs.

Policies to promote reshoring

Reshoring initiatives have been called for in various resolutions adopted by the European Parliament, and often there are national-level initiatives in which reshoring policies are coupled with those aimed at attracting foreign direct investment. For example, in the UK, the Manufacturing Advisory Service (MAS) and UK Trade & Investment launched the Reshore UK service, which supported companies in evaluating their capabilities, tailoring their relocation strategies and finding national suppliers. However, the MAS programme formally came to an end on 31 March 2016. The British government has also contributed finance to the Advanced Manufacturing Supply Chain Initiative, which funded projects aimed at improving the competitiveness of UK supply chains and encouraging new suppliers to locate in the UK (AMSCI, undated).

France has been quite active in supporting firms' relocation strategies, as shown by a survey conducted in 2013 by the Ministry for Industrial Renewal which revealed that 60% of the companies that undertook reshoring initiatives received support from central government and/or the local authorities. Among other support services, the Ministry of Economics and Finance made available the Colbert 2.0 software tool, which helps companies self-evaluate their readiness for reshoring. However, data emerging from the reshoring monitor of France seems to show this service was not very supportive for local companies. Indeed, the service has been discontinued.

In Italy, there are various initiatives at the national and regional levels. One example is the Emilia-Romagna Regional Law 14/2014, which provides for 'Location and development agreements' among foreign companies aiming to invest within the region and Italian reshoring firms. Applicant companies – which are selected based on industry, technological innovation level and the environmental sustainability of their production processes – may receive benefits in terms of fiscal and financial incentives as well as reduced time for administrative authorisations.

The only ex post evaluation of reshoring incentives was of the Act on Assistance to Korean Off-shore Enterprises in Repatriation promoted by the South Korean government in 2013 (Moon, 2018). It was not particularly successful: analysts found that the main issues related to the restrictiveness of criteria for accessing aid (for example, the construction of a new manufacturing facility in Korea coupled with the total discontinuation of all manufacturing relationships with the host country) and an excessive focus on large enterprises despite greater interest being indicated by SMEs.

Born globals in international supply chains

Introduction

Small and medium-sized enterprises (SMEs), accounting for more than 99% of all European companies, are underrepresented in international trade: only about half of the SMEs in the EU are involved in international business. Among Member States, the smaller the country, the larger the share of SMEs with international activities (European Commission, 2015a; EIM Business & Policy Research, 2010). Internationalisation is increasingly much more than just trade and includes, for example, financial transactions (foreign direct investment, joint ventures), cross-border development activities (such as research and development (R&D) or product design) and cross-national distribution (including marketing and sales or promotion).

International engagement presents a number of challenges for SMEs, largely related to limitations in the finances and human resources required to conduct international transactions, not least in relation to the size of expected returns. Some of the issues relate to the target countries, such as local regulations and laws, special national certification and product or technical requirements and differences in payment practices. Additional difficulties when operating in non-EU Member States include customs issues and the lack of fair competition in some countries. External challenges are also related to the country of origin, such as difficulties in accessing external capital and finance on good terms, a poor national image and the national

support structure. These obstacles are not to be viewed as insurmountable, and many of the companies in this study were, together with their value chain partners, able to overcome them. However, while large companies are certainly better placed to resolve internationalisation issues, there is more of a role for public initiatives to assist smaller companies.

Born globals are companies engaged in intensive international activities immediately after start-up. Across Europe, about one-fifth of young enterprises are born globals, and despite much policy focus on both start-ups and internationalisation, these types of enterprise, which face these two challenges simultaneously, have received comparatively little policy attention as of March 2019 (see Eurofound, 2012). The research conducted in this project has focused on born globals in the context of their value chains, which are of fundamental importance for these firms given that they often occupy niches in bigger networks.

Global value chains

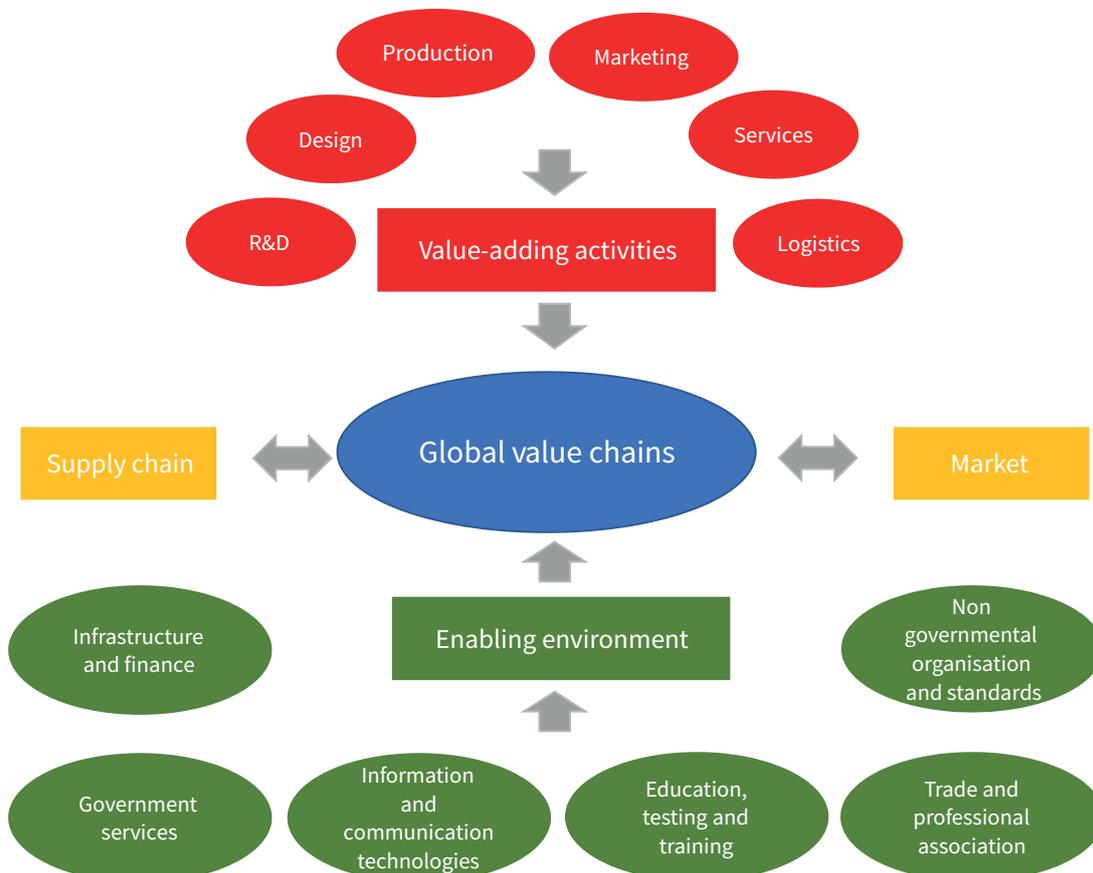
Since the mid-1990s globalisation has increasingly been characterised by international networks of companies covering the whole production process, from concept to delivery to the end user. Such a cross-national division of tasks is driven by the comparative advantage of different locations, improvements in

telecommunications technology, the reduction of transport costs, trade and investment liberalisation and the fall of political and economic barriers.

Global value chains entail the cross-national cooperation of specialised organisations, combining different internationalisation modes and collaboration models. From a manufacturing perspective, it is important to note that while the product as such could be viewed as the centre of the value chain, there are several closely related services that are crucial for the success of the overall value chain: for example, research, design, transport, marketing and sales or finance (see Figure 17).

The relationships among the firms along a global value chain can be formalised (for example, through cooperation agreements or contracts) or left as informal (that is, mainly based on individual contacts among staff members of the participating organisations) or take the form of a combination of both. Furthermore, the relationships can range from an almost hierarchical structure, in which one partner dictates the cooperation conditions and the value chain acts almost like an integrated firm, to market-like governance structures where the exchange of goods or services for money is the only interaction.

Figure 17: Building blocks of global value chains



Source: Barua et al (2015)

Box 4: What is a ‘born global’ enterprise?

There is no universal definition of born globals in the literature. Eurofound (2012) proposed a first approach towards a European definition of born globals, building on the different criteria mentioned in extant literature. Accordingly, a born global is an enterprise possessing all of the characteristics listed below.

- It is an independent, individual company.
- It has been started, is a spin-off or has been part of a business transfer (ownership and management) within the last five years.
- It has an active, strategic intention to internationalise.
- It has an export share of at least 25% of total sales during at least two of its first five years.
- It is active in at least two foreign countries, with ‘close markets’ (as regards geographic and cultural distance or language) also being considered as different markets (countries can be within Europe).
- It is active in any economic sector, but offers an innovative product or service with good market potential or uses new technology or design.
- Company size and market share are irrelevant.

Source: Eurofound (2018e)

Born global enterprises

Traditionally, firms start up locally, build up a solid home market and only then possibly reach out to foreign markets. However, the born global business model is characterised by very intensive internationalisation activity shortly after inception, and often without a solid home market and tested product/service (Bell et al, 2001, 2003; Cavusgil and Knight, 2009; Eurofound, 2012).

According to the Global Entrepreneurship Monitor data (GEM, 2011), born globals represent 2.5% of all SMEs and 12% of young enterprises (Eurofound, 2016b). Born global enterprises are confronted with important challenges related to the fact that they not only have to

undergo an internationalisation and innovation process simultaneously, but also at a very early phase in their life cycle. However, existing research also hints to the finding that – if they survive – they tend to perform better in terms of export speed, intensity and scope (Kuivalainen et al, 2007; Crick, 2009), growing faster than other young or international companies.

Born globals are found to be very innovative, quality oriented and agile, and they fill niches in global value chains that could not be filled otherwise. While many born globals are in future-oriented high-tech markets, they are also found in very traditional markets. Table 2 lists the company case studies with a brief description of their particular specialisation.

Table 2: Born global case study companies and their specialisation

Born global	Description
Blue Ocean Robotics (DK)	Development, creation and commercialisation of robotic solutions and services in various sectors, including manufacturing, healthcare and welfare, education, construction, agriculture and fisheries and offshore activities (wind, oil and gas).
Comodule (EE)	Development and production of information and communications technology- (ICT-) based monitoring platform solutions combining hardware and software for light electric vehicles (e-bikes and e-scooters) and for different applications, including control and collection of data on vehicles’ technical performance and user behaviour, management of warranties and direct engagement with customers via smartphone applications.
Frog Bikes (UK)	Design and manufacture of top-quality lightweight children’s bikes and accessories at affordable prices.
Graphenea (ES)	Production of high-quality graphene in different formats for R&D and industrial applications.
Khar & partners (RO)	Engineering and biology, including the development of several products, although only one (System Open Water Advanced Technology – SOWAT) is already in commercial phase. SOWAT is a water filtration system that can filter water from any natural source to produce drinking water for 500 to 5,000 people.
KristallTurm (DE)	Production and construction of highly customisable high ropes courses for leisure and sports purposes. The company also offers a complete service package for its high ropes courses (site analysis for project feasibility, financing and leasing options, project visualisation for presentation to sponsors and decision makers, delivery and assembly at the site of operation, training of on-site and maintenance personnel, delivery of safety equipment, inspection and maintenance activities and advice).
Reconnect (NL)	Production of interactive media walls combining specialised software and hardware for the healthcare sector, specifically psychiatry and mental healthcare, along with a number of related services.

Source: Eurofound: *The Future of Manufacturing in Europe – Born globals and their value chains*

Born globals follow a variety of internationalisation activities in parallel. Apart from imports and exports, international R&D and technological cooperation are particularly relevant, as is joint cross-border financial investment (see Table 3).

To fulfil this important role in global value chains, born globals rely heavily on networking activities. These tend to be rather informal and based on personal ties of the owner/manager or staff members. Born globals can be the initiator of global value chains or join existing ones. Furthermore, they can have different positions and roles within the value chain depending on their specific characteristics. Interestingly, and related to their above-mentioned multifaceted internationalisation activities, born globals can take on different roles for different partners in the same value chain, such as acting as supplier for one partner while acting as product development/research partner for another.

Mediating factors for successful international cooperation

Born global enterprises tend to be quite active in approaching potential cooperation partners due to their need to scale up internationally. This mindset and initiative need to be supported by good networking capabilities in order to be effective.

A second important mediating factor for successful international cooperation is the establishment and maintenance of a high level of mutual trust, accompanied by a joint commitment towards the product/service. Partners should respect and value each other's contributions and aim for a shared strategy benefiting all in equal measure, rather than following a competitive approach to generate the highest possible outcome just for themselves. While ICT plays an important role in global value chains, the usefulness of face-to-face meetings between individuals should not be underestimated.

Table 3: International activities of born globals

Born global	Type of internationalisation activities
Blue Ocean Robotics (DK)	International joint ventures International R&D and technical cooperation, usually EU-funded R&D projects International commercial cooperation (with a network of international sales partners, as a reseller of its partners' products to international customers and users)
Comodule (EE)	Exporting activities International subcontracting (components and hardware) International commercial cooperation with strategic partners International cooperation and partnerships (R&D activities, joint product development) International investors
Frog Bikes (UK)	Exporting activities International subcontracting (components and materials) International technical cooperation with suppliers and foreign manufacturers International commercial cooperation with international retailers
Graphenea (ES)	Exporting activities International subcontracting (components, materials and specialised equipment) International R&D and technical cooperation, often through EU programmes International commercial cooperation with a network of international distributors Foreign investment activities, via the opening of a branch abroad
Khar & partners (RO)	Exporting activities International subcontracting (components) International cooperation (R&D activities with international subcontractors) International commercial cooperation with a network of international distributors
KristallTurm (DE)	Exporting activities International licensing activities International commercial cooperation with a network of international sales agents and distributors
Recornect (NL)	Exporting activities International subcontracting (hardware) International R&D and technical cooperation International commercial cooperation with international distributor

Source: Eurofound: *The Future of Manufacturing in Europe – Born globals and their value chains*

Box 5: The role of trust in global value chains

According to the CEO of Khar & partners (Romanian born global), trust is decisive for sustaining successful cooperation among companies, since partnerships and cooperation agreements are often based on unwritten agreements that require time and face-to-face interaction to consolidate. Similarly, Graphenea (Spanish born global) stresses that strong trust and confidence is based on individuals. Indeed, the Graphenea interviewee suggested that if certain key people were to leave, the relationship between Graphenea and its international partners would be negatively affected (at least in the short term) due to the existing links of trust and confidence between these individuals.

Source: Eurofound (2018e)

The role of a well-balanced power relationship among the involved partners is also important. From the case studies conducted in this project on born globals' value chains, it appears that partnerships among 'peers' are easier to coordinate and more effective than those in which a stronger partner dominates and dictates the conditions of the cooperation. While SMEs and born globals may establish cooperation with a larger company to help bring a new product to market quickly – even though this may at first strengthen the smaller firm's position – the larger company may become more demanding over time and thereby either limit the potential of the smaller firm or even put it at economic risk: for example, by requesting production batches that are too large or too diversified considering the smaller scale of the SME/born global, or by requiring pre-finance.

Public support

The importance of internationalisation is mentioned in many high-level EU strategies, such as Europe 2020, the Small Business Act for Europe (SBA) and the EU Single Market Strategy (European Commission, 2008; 2010; 2014; 2015b).

Across the Member States there exists a wide range of public and social partner-based instruments aiming to enhance the international activities of enterprises, partly also with a specific focus on SMEs. They can broadly be categorised as follows:

- awareness raising to promote the benefits of internationalisation
- advice, including recommendations and information provision on target markets, public support and investors abroad as well as negotiation assistance
- information databases: portals, market intelligence and operational information on internationalisation processes, barriers and access to foreign markets
- one-stop shops for internationalisation: platforms combining information and/or providing an overview of all or the main support measures available for internationalisation
- networking: support in identifying and approaching potential business partners (including individual suppliers and customers, but also alliances and clusters) and investors abroad; providing contacts to exporters searching for business partners; other support for international collaborations
- international business incubators: organisations located abroad that provide a supporting environment for the development of new firms
- education and training for staff and management on internationalisation-related matters, promoting staff exchanges and experiences abroad and support related to international recruitment and human resource management
- trade missions: support for businesses participating in overseas trade missions
- certification: support in the process related to a product's certification abroad; legal or administrative procedures related to standardisation or product or service registration or recognition
- business registration: legal or administrative procedures related to registering a business, subsidiary or economic activity in another country
- image campaigns: enhancement of the reputation of national products, services or companies abroad
- legal or administrative initiatives related to, for example, the free movement of workers across borders and the removal or reduction of national tariff barriers where non-EU countries are involved
- protection of intellectual property rights including, for example, a reduction in registration and protection costs and/or the duration of procedures
- business environment and inter-country cooperation support: governmental and diplomatic support for businesses with international trade relations
- R&D, innovation and sectoral programmes: financial support and advice for innovative SMEs in their international expansion
- integrated support services: combining several of the above

Box 6: Born globals' general public support needs

Blue Ocean Robotics (Danish born global) stresses the need to raise capital to finance its business activities when developing a new robot for new markets, including the development stage, the commercialisation of the robot and the creation of a spin-off company. The company has been rather successful in seeking funds from different R&D funds at both national and EU levels.

Similarly, securing start-up capital was one of the main challenges faced by Recornect (Dutch born global) and Graphenea (Spanish born global); both companies received public support for research and product development.

According to AVS Electronics (HK), value chain partner of Comodule (Estonian born global), access to finance is the main problem for small companies, as banks tend to be reluctant to support start-ups and born globals. Comodule found a solution to this by applying for an innovation voucher from an Estonian public institution for conducting patent-related research.

Source: Eurofound (2018e)

In contrast to other SMEs, born global enterprises do not seem to request specialised internationalisation support. For them, more general support related to the business environment tends to be more important. This can be attributed to their multifaceted challenges of having to master start-up, innovation, scale-up and internationalisation all at the same time. Accordingly, traditional SME challenges, such as access to finance and specialised human resources or coping with the administrative burden, are more pressing and should be prioritised in public intervention to implicitly foster their international activities. However, the born globals analysed in this project show a high capacity for identifying and using different sources of external

support from private and public actors at different administrative levels.

In the context of internationalisation more explicitly, specialised assistance and advice related to legal and administrative issues in the target market are relevant to help SMEs/born globals overcome their liabilities related to their 'newness' in the host country and their allocation of limited resources. Here, national certification and product requirements, as well as intellectual property protection are important as these tend to be heterogeneous across the target market of SMEs/born globals and are expensive and time-consuming aspects of the internationalisation

Box 7: Born globals' internationalisation public support needs

Blue Ocean Robotics (Danish born global) regularly seeks legal advice to ensure its overseas activities are in line with national legislation, such as when establishing new companies abroad, including joint ventures and spin-offs, for instance.

Since 2016, KristallTurm (German born global) has been working with the German foreign trade chambers (*Außenhandelskammern*) to select interesting target markets, identify potential local business partners and obtain information on different legal regulations in the selected countries.

Recornect (Dutch born global) has successfully collaborated with its local chamber of commerce with support from the Enterprise Europe Network to start up and scale up (primarily via the development and updating of a detailed business plan). It has also benefited from a regional public 'knowledge voucher', used by the company to contract some external experts to map out the German market.

Khar & Partners (Romanian born global) actively participates in the Francophone Business Club in Sibiu, where participating companies exchange experience and knowledge with other entrepreneurs on various export markets, export requirements and business development strategies, sometimes resulting in new business opportunities.

The IP Attaché Network in the UK provides intellectual property awareness enhancement and support for internationalising. By creating different IP Attaché centres in Brazil, China, India and South East Asia, the network provides advice and information about intellectual property in those markets, networking opportunities with other members targeting the same market, and negotiates with foreign authorities to improve the intellectual property system.

Source: Eurofound (2018e)

process. Furthermore, and due to the importance of getting involved in global value chains, establishing support via international networking is a relevant factor.

This study identified five key areas in which support for public and social partner-based internationalisation efforts could be developed:

- broaden what is a narrow focus on exports to encompass a wider scope of internationalisation activities
- improve the transparency/visibility/promotion of the measures provided
- bundle together related aspects of support to provide more comprehensive packages covering, for example, access to finance, advice and networking rather than the rather isolated approach of offering specific aspects of support in isolation
- provide more general support rather than considering the specific needs of individual groups within the manufacturing or SME sector
- strengthen what is quite a weak evaluation culture which limits the effectiveness and efficiency of the instruments as well as further policy development

2 Technological revolution or evolution?

Introduction

Historically, technological development has primarily transformed material production, first in agriculture and then industry. While ICT has had some impact on certain services, it is still the case that it has mainly affected manufacturing. For example, most types of robots have industrial applications (primarily in the automotive sector but also in the electrical sector), and in 2017, industrial robot sales amounted to USD 16.2 billion globally. Service robots, with their main application in logistics, reached sales of USD 6.6 billion (IFR, 2018).

This chapter starts with a description of five emerging game-changing technologies and how they can transform production processes, with emphasis on the centrality of the digital analysis of data. It then explores the current extent of the application of these technologies, which varies greatly among technologies, sectors and Member States. This section concludes by emphasising the importance of future-oriented policy and targeting to promote the diffusion of these technologies throughout Europe.

The chapter continues with a critical evaluation of predictions of a strongly negative impact of these technologies on employment in the near future. It also elaborates a simple framework for how technology impacts employment levels and presents the results of a macroeconomic model to illustrate some possible compensatory knock-on effects of the initial substitution of labour by new technology. The chapter concludes by examining the apparent paradox between, on the one hand, the perception of widespread technological diffusion and, on the other hand, historically low levels of productivity growth and significant employment growth in manufacturing, particularly in the US.

Game-changing technologies

The five game-changing technologies

Eurofound (2018b) summarises the findings of reports prepared as part of this project on five game-changing technologies. The term ‘game changer’ reflects a belief that economically significant change comes in occasional bursts of innovation clustered around a core technology, with wide application throughout the economy. The game changers, described in Table 4 (overleaf), were explored with a view to possible developments up to 2025.

Artificial intelligence was not taken as a specific game-changing technology. Artificial intelligence is a very general concept – too broad, one might argue, for the type of study conducted here. However, artificial intelligence is an important feature of these technologies. One aspect of artificial intelligence, machine learning, which gives computers the ability to adjust data and to learn without being explicitly programmed to do so, is especially relevant for AIR and IIoT (see Table 4).

The three process technologies studied here (AIR, AM, IIoT) are all based on the microprocessor and the Internet. While EVs and IB are not strictly part of that family of technologies – the basic design of EVs is from the early 20th century, and IB is rooted in microbiology and fermentation techniques from the 19th century – their current development would have been impossible without digital technologies. All five technologies involve the increasing centrality of digital information, though in different ways.

Table 4: Description of the five game-changing technologies

Name and acronym	Type of internationalisation activities
Advanced industrial robotics (AIR)	Advanced industrial robotics is the branch of robotics dedicated to the development of robots which, through the use of sensors and high-level and dynamic programming, can perform tasks requiring more flexibility and accuracy than traditional industrial robots. Digitally enabled robots working within industrial environments are equipped with advanced functionality (for example, sensors detecting potential collisions and halting or performing a programmed motion with a very limited lag), allowing them to deal with less structured applications and to collaborate with humans.
Additive manufacturing (AM)	Additive manufacturing superimposes successive layers to build a product rather than it being cut out of existing materials (subtractive manufacturing). The key prerequisite of the AM process is that products can be digitally modelled before being physically generated. The 'revolution is ... the ability to turn data into things and things into data' (Gershenfeld, 2012, p. 2). AM is sometimes called 3D printing.
Industrial internet of things (IIoT)	Sensors applied in the manufacturing process create cyber-physical systems where the information collected from the sensors is fed, through the Internet, to computers in order to gather and analyse production data. In advanced cyber-physical systems, a whole factory can be digitally mapped and enabled using such sensors.
Electric vehicles (EVs)	Electric vehicles are vehicles for which the main system of propulsion depends on electricity. The vehicle relies on the storage of externally generated energy, generally in the form of rechargeable batteries.
Industrial biotechnology (IB)	Industrial biotechnology is the use of biotechnological science in industrial processes. Modern biotechnology is based on the most recent scientific insights into the specific mechanisms of biological processes within living organisms (for instance, through systems genomics and metabolomics research). These are used to design processes in industry using yeasts, bacteria, fungi and enzymes (biological catalysts that improve reaction processes and that are relatively easy to obtain) to produce biomaterials and biofuels.

Source: Eurofound: *The Future of Manufacturing in Europe – Game changing technologies*

The main difference between AIR robots and traditional industrial robots is that the former can autonomously process information from their environment and interact with it due to the presence of sensors and algorithmic control mechanisms. This gives them more flexibility and allows them to carry out tasks beyond the reach of traditional mechanical robots. AIR both needs and generates vast amounts of digital information and digital processing, and the information generated and processed is typically fed into the central information systems of the production process.

AM makes the design and testing of products a digital process in that it allows complex digital models to be directly materialised in a single step of 3D printing. AM could radically simplify the entire manufacturing process, transforming it into a sequence of processing, communicating and storing digital information (the 3D models of manufactured goods) with a single step for physical rendering.

IIoT is an information encoding, communicating and processing technology. By attaching interconnected sensors to objects in the production process, IIoT transforms the process into a system that is both physical and digital. As well as generating a detailed virtual model of the entire production process that can be optimised with the processing power of digital technologies, the technology turns the objects themselves into digital devices that can interact and can be algorithmically controlled.

The increased importance of ICT has led to the arrival of new players in many sectors, partly because of the lack of ICT skills and know-how in traditional manufacturing

and partly because of the very large investment needed for a full renewal of processes and players. For instance, the introduction of AIR and IIoT is often subcontracted to specialist companies in the ICT sector, which sometimes even provide the machines (robots, sensors) and people (experts) necessary within some kind of leasing or subcontracting agreement. This may be typical of the early adoption of promising but still immature technologies and may lead to a creeping colonisation of ICT companies into traditional manufacturing.

Potential impact on production processes

Flexible specialisation

Apart from the centrality of data, another important aspect of the technologies is that they open up the possibility of flexible specialisation or even mass customisation. Mass production is generally understood as the opposite of customised production: the latter is expensive, flexible and only suitable for small quantities, while the former is cheap (per unit), rigid and enormously scalable. According to the interviews carried out for this project, the three process technologies could remove this contradiction, thus allowing production that is cheap and flexible as well as highly scalable.

In traditional mass production, the production process is centrally controlled. Production workers tend to be relatively low skilled and have low levels of autonomy, while machines and robots generally serve a single purpose for which they were exclusively designed. Changing the process is very difficult and costly, since it requires a complete rearrangement of the entire

system. While this rather simplistic view of the labour process in manufacturing has been evolving for some time (Piori and Sabel, 1984), these three process technologies have the potential to radically increase flexible specialisation.

Firstly, in contrast to traditional robots, AIR robots are algorithmically controlled, general-purpose machines that can be easily reprogrammed to carry out different tasks in production. Indeed, with artificial intelligence, such robots would be able to interact and respond autonomously to changes in their environments. This obviously increases the flexibility of the production process. However, this flexibility does not necessarily come at the expense of standardisation. Although they can be easily reprogrammed and redeployed for different customised outputs, AIR robots are still robots that behave according to predefined rules, and thus their output will be standardised and consistent. This is crucial for mass customisation to be economically successful.

Secondly, by interconnecting all objects of the production process under centralised and algorithmic supervision, IIoT systems also increase the flexibility of the process. In the same way that digital robots are inherently more flexible than mechanical ones, cyber-physical production systems are inherently more flexible than traditional ones. Real-time centralised control and interconnectivity not only allow much faster reaction to problems, but also relatively fast reprogramming of production in response to changes in demand or other factors.

Finally, the relevance of AM for flexible specialisation is obvious. AM condenses the entire physical production process into a single step. The digital object can be easily reconfigured, and the different printed objects can have a consistent quality, provided the rendering process and materials used are the same. However, it might be unrealistic to believe that the scale of AM production could be termed 'mass customisation', and so 'flexible specialisation' is a more appropriate term in the case of this technology.

Servitisation

Another important potential effect of the studied game-changing technologies on the production process is the servitisation of manufacturing. Servitisation refers to the increasing importance in the added value of manufacturing companies of services attached to the product. Those services can be anything from maintenance to unrelated additional services.

This is most obvious in the case of IIoT. The connected digital devices embedded in products allow companies to maintain a line of communication with, and even control of, the product after the sale. This facilitates the provision of aftersales services such as predictive

maintenance and 'updates' that improve or even add functionality to the product, or additional services.

However, the servitisation trend can have a negative effect on the existing constellation of service providers around industrial products such as cars or household appliances. The reason is that servitisation enabled by IIoT makes it easier for producers to internalise maintenance and other services, thus eliminating the business of independent service providers. A car that is permanently connected to a manufacturer that can remotely and wirelessly control the functioning of its internal algorithms is much less likely to be maintained by a small independent workshop.

The same trend of servitisation can have positive implications for the environment. If products are a platform for long-term services, manufacturers have an incentive to make them more robust and enduring. In an economy driven by demand for mass-produced goods, it is in the interest of manufacturers to generate disposable goods with a short renewal cycle in order to sustain ever-expanding production. But for a servitised manufacturer, the ideal product is a long-lasting one that can make for sustained profitable service relationships with the client.

The relationship between AIR and servitisation is more tenuous, but still important. First of all, AIR contributes to servitisation by further reducing core manufacturing activities, which necessarily increases the relative importance of services. That is, after all, the main driver of servitisation: the need to generate new profit opportunities for products whose mere manufacture have a declining profitability. However, the technology studies also identified a trend towards the subcontracting or leasing of AIR by manufacturing companies, thereby contributing to a different type of servitisation of manufacturing. The core activities of manufacturing (logistics and production) could in practice become an externally provided service. In other words, specialised manufacturing services could take over the manufacturing sector. These manufacturing services might, for instance, be provided by upstream manufacturers of production systems.

Resource efficiency

Another effect on the production process of the studied game-changing technologies is the increase in resource efficiency. This is also related to the use of digital technologies. Much richer information at every step and in every aspect of the process along with the increased precision of algorithmic control enable a more efficient use of materials and energy in production. AIR can reduce errors and increase the precision of production operations. IIoT increases the knowledge available of the condition of products and materials throughout the production process and beyond, facilitating enduring products with more efficient maintenance.

Figure 18: Potential application of three game-changing technologies along the value chain

R&D	Design	Logistics (inward)	Production	Logistics (outward)	Marketing	Services
		Advanced industrial robotics				
		Industrial internet of things				
Additive manufacturing						

Source: Eurofound: *The Future of Manufacturing in Europe – Game changing technologies*, author’s elaboration

AM can significantly reduce manufacturing waste by using just the right amount of material needed in the additive layer-by-layer product creation. This obviously has significant environmental benefits, and in the context of growing environmental concerns and related policies, it was identified by several of those interviewed as a potential driver for the adoption of these technologies in Europe.

Diffusion of the game-changing technologies

Potential scope of the game-changing technologies

Three of the five technologies – AIR, IIoT and AM – are transversal technologies and so, unlike the other two, are not associated with particular products. Due to the generic nature of these technologies, both in isolation and in combination with each other, they have potential application in practically all types of manufacturing. Moreover, they are of possible relevance to many stages of the manufacturing supply chain (see Figure 18). Indeed, in some respects, they can transform the concept of a supply chain as distinct stages of economic activity. This is perhaps most obviously exemplified with AM where, in practice, the production process becomes almost indistinguishable from design and logistics.

These three technologies cover the core production process, which could potentially lead to very high levels of labour productivity and a minimum of labour input in this part of the supply chain. On the other hand, the potential for an increase in labour productivity may lie more in the other stages, which typically have lower levels of productivity.

Figure 18 also suggests the synergies that exist between these technologies – a crucial aspect. Combining two or more of these technologies can multiply their positive effects on the production process, and the use of one of these technologies makes the utilisation of others more likely. The key to these synergies is, of course, their basis in digital information and the potential for complete interconnectedness of various digitally based machines and systems.

AIR and IIoT are different technologies with different purposes, but each requires and produces a large amount of digital information and, ultimately, relies on digital algorithms to process and manage industrial processes. IIoT and AM can be considered as two sides of the same coin – the digitisation of production processes – since IIoT collects, encodes and processes digital information on the physical process, while AM transforms digital models into physical products. Together, these three technologies constitute the core elements of a cyber-physical model of the manufacturing process.

The two technologies that are a mix of product and process innovation (EVs and IB) are also strongly linked to the digitalisation of manufacturing and thus have strong synergies with the three process technologies, though in different ways. The EV is a new technology for the car industry. Well-known companies and industrialists from the ICT sector are among its key supporters and promoters, and it is likely to be a catalyst for the adoption of new technologies in production. Being radically new, the production of EVs requires the setting up of new factories and processes. This reduces the inertia caused by existing installations and practices and stimulates experimentation with new tools and methods. Some of the brand-new producers of EVs therefore provide the best example of several of the effects mentioned above (that is, information centrality, mass customisation, servitisation and increased resource efficiency). As such, these new entrants force established car manufacturers to innovate more quickly, and they encourage new and established companies to deploy EV charging stations.

Technological readiness and market size

These advanced technologies are far from widespread. When advanced ICT is used extensively, it tends to be significantly concentrated in highly productive firms (Gal et al, 2019); moreover, penetration rates vary widely among countries (Sorbe et al, 2019). Indeed, one of the possible explanations for the lack of significant productivity gains that can be attributed to these technologies is the very thinly spread take-up throughout the economy. Box 8 illustrates some of the issues related to the slow take-up of AIR in the textiles sector in France.

Box 8: Reality check on the adoption of AIR: The case of the textiles sector in northern France

The workshop (case study) on the adoption of AIR in the textiles sector in northern France provided insights into the actual level of uptake of AIR in a specific industrial setting. Despite the significant buzz and attention given to robotics, the level of uptake of AIR remains low, with only a handful of companies in the textiles sector having adopted this technology. This is mainly linked to the following points.

- AIR is still an emerging technology, with medium technology readiness levels.
- The regional industrial ecosystem is mostly composed of SMEs focused on traditional know-how. About 75% are not in a position (financially and in terms of skills) to implement automation for most tasks. Certain subsectors, such as high-quality lace production, still rely heavily on traditional manual labour and traditional tools/machines which cannot be automated.
- AIR requires high operational expenditure in addition to significant capital expenditure. This is linked to design, software, programming, testing and maintenance, which can have higher costs than traditional robots or machines and generally have to be outsourced.

In addition to this, for a vast majority of SMEs in the sector, purchasing robots is a very important decision with far-reaching financial, managerial, procedural and even spatial implications. This stems not only from the financial investment needed, but also the consequences of AIR for the rest of the production process. Integrating an advanced robot implies radically modifying existing processes and production line layout/organisation. For instance, some companies may be limited by the availability of free space in which to set up and run the robot. In other words, production line, infrastructure, process reconfiguration and the location/building may act as key barriers to any decision to invest in AIR.

Source: Eurofound (2018b)

This project examined the technology readiness level of the five technologies, based on literature reviews and expert interviews and workshops. These are presented in the project's five detailed technology reports. The technologies are at a relatively mature stage, ranging from testing in relevant environments to being fully technically operational. However, the degree of actual application, while increasing, varies considerably from sector to sector.

AIR is already used in sectors ranging from electronics assembly and automotive parts manufacturing to aerospace. However, the study identified potential immanent game-changing effects of AIR for two sectors in particular: food preparation – handling material of different textures and shapes, and replacing manual labour in fast turnaround tasks or in tasks where controlled conditions are needed for hygiene purposes; and craft and bespoke manufacturing where production needs to be closer to the market or batches have to be customised on demand, such as in the manufacturing of soft products like clothing and shoes.

In AM, operational maturity is high for domestic users where the equipment can be bought for a relatively low price (around €500 for a 3D printer) and small batches can be printed at household level. It is also having some impact in companies where prototyping and visual design are important, such as in the automotive and aerospace industries. The readiness of printers using plastic is at quite an advanced stage. It is less advanced for those using metal and ceramics, where quality standards are more difficult to achieve. Both General

Electric and Siemens are prototyping components for their energy turbines, and the latter is developing solutions for series production for manufacturing gas turbine burner nozzles and repairing burner heads. Another early adopter is the biomedical industry, as lightweight and customised design is particularly suited to the production of human prosthetics (such as hearing aids, dentistry and artificial limbs). Finally, creative industries related to jewellery, entertainment, fashion and shoes may find applications for AM based on its potential for customisation and producing complex shapes.

The capacity to process and store data combined with the development of 5G networks has changed the way manufacturing uses sensors. These are not new of course, but their widespread connectedness allows the creation of virtual simulacra of entire factories (WEF, undated). The potential of this technology has been recognised by the oil and gas and automotive industries, both of which have readiness at operational maturity level. IIoT also has wide applicability in the production of chemicals, motor vehicles, coke and refined petroleum products, food products and machine manufacturing as well as the repair and installation of machinery and equipment.

Technological maturity is relatively high for both IB and EVs. Many applications are already proven and commercialised. The readiness of EVs varies. Some technologies are still in the development phase (for example, extended-range EVs), while others are already on the market (for example, plug-in hybrids).

Table 5: Estimated potential market size of the five game-changing technologies

Technology	Estimates of potential market size
AIR	Impact on global market of between USD 1.9 trillion and USD 6.4 trillion (€1.61–5.42 trillion as of 15 December 2017) per year by 2025 (RAS 2020, 2014, p. 9)
AM	Estimates of the global AM industry vary from USD 1.7 billion (€1.44 billion) (Roland Berger, 2013) to as much as USD 500 billion (€423 billion) turnover per year (Manyika et al, 2013)
IloT	Deployment in the automotive industry only: valued between USD 210 billion to USD 740 billion (€170–626 billion) by 2025 (McKinsey Global Institute, 2015)
EVs	Electric car stocks at global level will be between 9 million and 20 million by 2020 (10% of the market).
IB	The EU market for IB-derived products is expected to increase from €8 billion in 2013 to €50 billion in 2030 (BIO-TIC, 2015)

Source: Eurofound: *The Future of Manufacturing in Europe – Game changing technologies*

IB can be found in the pharmaceutical industry (antibiotics), in the energy industry (biofuels), in the chemical industry (production of amino acids, biosurfactants or biolubricants) and in the materials industry (notably in the production of bioplastics and biopolymers).

Business analysis companies have made predictions of the potential market size for the five game-changing technologies. As shown in Table 5, these vary considerably.

It must be emphasised that there is much uncertainty in such forecasts. The practical application of these technologies does not depend only on technological readiness per se; the technologies also need to lead to innovations that generate profit for companies. AIR and IB in particular require substantial initial investment. Moreover, this requires sufficient cash flow to support the conversion of production processes and the training of workers in charge of monitoring robots. This may not be a speedy process throughout the economy. It takes time for companies to gather relevant information on, and come to an understanding of, how these technologies can generate profit. Investment can also be hindered by the many uncertainties related to radically new technologies: for example, as regards security, industrial standards and intellectual property rights.

Various digital monitoring tools have been developed by the European Commission's Directorate-General for Communications Networks, Content and Technology, such as the Digital Scoreboard and reports on the policy of Integration of Digital Technology by Enterprises. These generally do not involve the monitoring of the emerging advanced technologies. Of more relevance in this context is the Digital Transformation Scoreboard (with annual reporting) conducted by the Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, which does cover these emerging technologies more specifically. However, even in this case, it is difficult to provide concrete information on the scale of adoption.

Fostering the commercial adoption of game-changing technologies

Given the transformative potential of digital technologies, in the sense that the whole supply chain is to become digitally connected, significant issues arise around coordination. The systemic approach is best exemplified by Industrie 4.0, a German strategic initiative to promote the country's lead role in advanced manufacturing solutions. This has broad-based stakeholder and expert involvement and a broad remit with regional structures, and it integrates a number of wider policy fields, such as vocational education and training. There are a number of other overarching initiatives (10 others were identified), including Produktion2030 in Sweden and Connected Industry 4.0 in Spain. None of the others have the scope of the German initiative.

There are many policy initiatives aiming to spread information on the potential of digitalisation in companies. Certainly in many companies in Europe, not least in SMEs, there is still much unfulfilled potential in relation to items measured in the Digital Scoreboard – such as having a website, using social media, access to broadband, using ecommerce and using portable devices. However, policy issues for the game-changers are very different. The fundamental role for policymakers and other influential actors is the establishment of future frameworks that provide some degree of certainty around which companies can orient their investment strategy. There is also a role for significant publicly funded strategic investment, not least in light of the investment strategies of the main global competitors. Large companies, both by themselves and in partnership with others (such as suppliers), also have an important role to play.

Standards

One obvious framework condition is that of setting technical standards. This is not an issue that can be dealt with at national level. The European Commission's Rolling Plan for ICT standardisation recognises the relevance of standards. The Commission has identified

five priority domains: 5G, the cloud, cybersecurity, big data and the Internet of things. Indeed, a need for standards was identified for all five of the studied game-changing technologies. In particular, adoption of IIoT will rely on common protocols and standards for security and interoperability. Networks should be secure from external threats, and the various programming languages and platforms that are part of the cyber-physical factory should be able to communicate with each other. For IIoT to become a pervasive technology, it will also need to be adopted along the value chain, including by SMEs. Standards should also be developed by companies manufacturing EVs – especially standards for the treatment of batteries, which can cause work hazards due to chemical reactions. From the perspective of market expansion, standardisation and interoperability for European motorists, it is necessary to reassure consumers that they will have access to compatible networks of EV supply equipment when they drive from one country to another (IEA, 2013). For IB – particularly for biomaterials – uncertainties remain concerning the performance of bio-based products. Manufacturers will, therefore, demand products that comply with required specifications on safety, durability, elasticity and other quality dimensions.

Future policy and targets

Another strategic approach involves setting out the orientation of future policy. The recent announcements by some national governments that they intend to ban cars with combustion engines in the long term has provided an important push towards the adoption of EVs. In France and the UK, such cars will be banned by 2040 (The Guardian, 2017). The Netherlands wants only electric cars to be sold by 2025, Germany is considering a 2030 deadline (IEA, 2017) and Sweden is looking at a 2045 horizon. On the producer side, Volvo Cars has announced its intention to produce only electric or hybrid cars from 2019 onwards. Volkswagen has said that by 2026 it will have launched its last generation of cars using petrol or diesel engines.

Strategic public investment

There are numerous European funds promoting innovation and R&D. However, the technological and European competition law complexities, together with the size of investment required to generate the commercial application of game-changing technologies in close cooperation with European companies, requires new approaches. A highly prominent instrument for delivering such support is the Strategic Forum for Important Projects of Common European Interest (IPCEI). The first such IPCEI was announced in the Industrial Policy Strategy of September 2017. In December 2018, the European Commission approved €1.75 billion in public support from France, Germany, Italy and the UK to fund the joint European microelectronics project, which focuses on developing

the Internet of things and connected car technologies. The project involves 29 companies and research organisations from four EU Member States. In addition to the €1.75 billion in public support, the project expects to secure significant private investment, possibly up to €6 billion.

The importance of gaining an initial leading position in the commercial application of strategic technologies is heightened in view of global competition from China and the US. This was expressed in the February 2019 Franco-German Manifesto for a European industrial policy fit for the 21st century. The manifesto recognises that global competitiveness is crucially related to emerging game-changing technologies and calls for massive investment in disruptive innovation within the framework of the European Innovation Council, with the goal of supporting ‘very high-risk deep tech projects at the European level’. In concrete terms, it proposes to identify a consortium of firms, including car manufacturers, to establish a second IPCEI for a new generation of batteries for EVs. An even stronger expression of more active industrial policy, focusing on strategic technologies in the light of the industrial policy pursued in China, is found in the German National Industrial Strategy 2030, also announced in February 2019 (Bundesministerium für Wirtschaft und Energie, 2019b).

Regional perspectives

The adoption of advanced technologies is likely to accentuate the regional disparities within Member States. This is due to the economies of scale and the investment cost of these technologies, together with the need for access to a highly skilled workforce. The challenges to regional governance structures when tasked to conduct a more active regional policy, in for example the context of the Smart Specialisation Strategy, are considerable. The challenge is accentuated further with the uncertainties and complexities of advanced manufacturing.

FOME case studies explored regional industrial policy capacity and found three features which strongly stood out as common features of strong industrial policy governance: the existence of multilevel governance cooperation procedures and instruments, the widespread use of participatory methods in the agenda-setting process, and the development of strong policy implementation and executive agencies. In several of the regions, industrial policy is not specifically defined but assimilated in overall economic development policy. It is, however closely linked to regional innovation policy and overlaps and complements smart specialisation policy, which in several regions has had a clear impact on the conduct of regional policy, not least as regards broader stakeholder involvement, particularly with business. Smart Specialisation has also made the region’s industrial policy more region-specific.

A greater use of market and policy intelligence tools, to identify strengths and weaknesses of the region, were emphasised. However, despite the tendency to focus on fewer sectors, technologies and markets, many of the interviewed regions highlighted that further prioritisation is required to generate meaningful and sustainable change.

The nine case study regions were: Baden-Württemberg (Germany), Catalonia (Spain), Lombardy (Italy), North Brabant (the Netherlands), Pays de la Loire (France), Pirkanmaa (Finland), Pomorskie (Poland), Sardinia (Italy) and West Romania. The FOME Regional Report has many examples of how these regions, despite their different national regional policy governances and resources, have developed useful initiatives to better face the challenges of advanced manufacturing.

Digital technology and employment

There is much concern among Europeans about what these emerging technologies imply for job security. European Commission (2017) notes that three-quarters of Europeans thought that the use of robots and artificial intelligence will mean that more jobs will disappear than new ones created. These concerns may have been influenced by the dire predictions of huge potential job losses due to automation from academia, think tanks, business information and consultancy companies and international organisations, not least the Organisation for Economic Co-operation and Development (OECD). Predictions of job losses in the manufacturing sector are particularly high.

Predictions of potential job loss due to radical automation

The typical approach to predicting job losses has been to identify the tasks that are most vulnerable to automation enabled by digital technologies and then identify the occupations in which workers spend a substantial proportion of their time doing those tasks.

McKinsey Global Institute (2017) states that for the big EU5 (France, Germany, Italy, Spain and the UK), 54 million full-time equivalent jobs are associated with technically automatable activities, and the potential impact due to automation is 46% of work activities. Building on Frey and Osborne's original work (Frey and Osborne, 2013), data from the World Bank suggest that among the OECD countries, 57% of jobs are susceptible to automation on average (Citi, 2016). A more conservative estimate published by Arntz et al (2016) is that 9% of jobs across the 21 OECD countries are automatable. This estimate was revised upwards by a more recent OECD study by Nedelkoska and Quintini (2018), which found that about 14% of jobs in 32 OECD countries are 'highly automatable'; however, the figure

varies considerably across countries: from 33% in Slovakia to just 6% in Norway. The same study reported that a further 32% of jobs have a probability of automation above 50%.

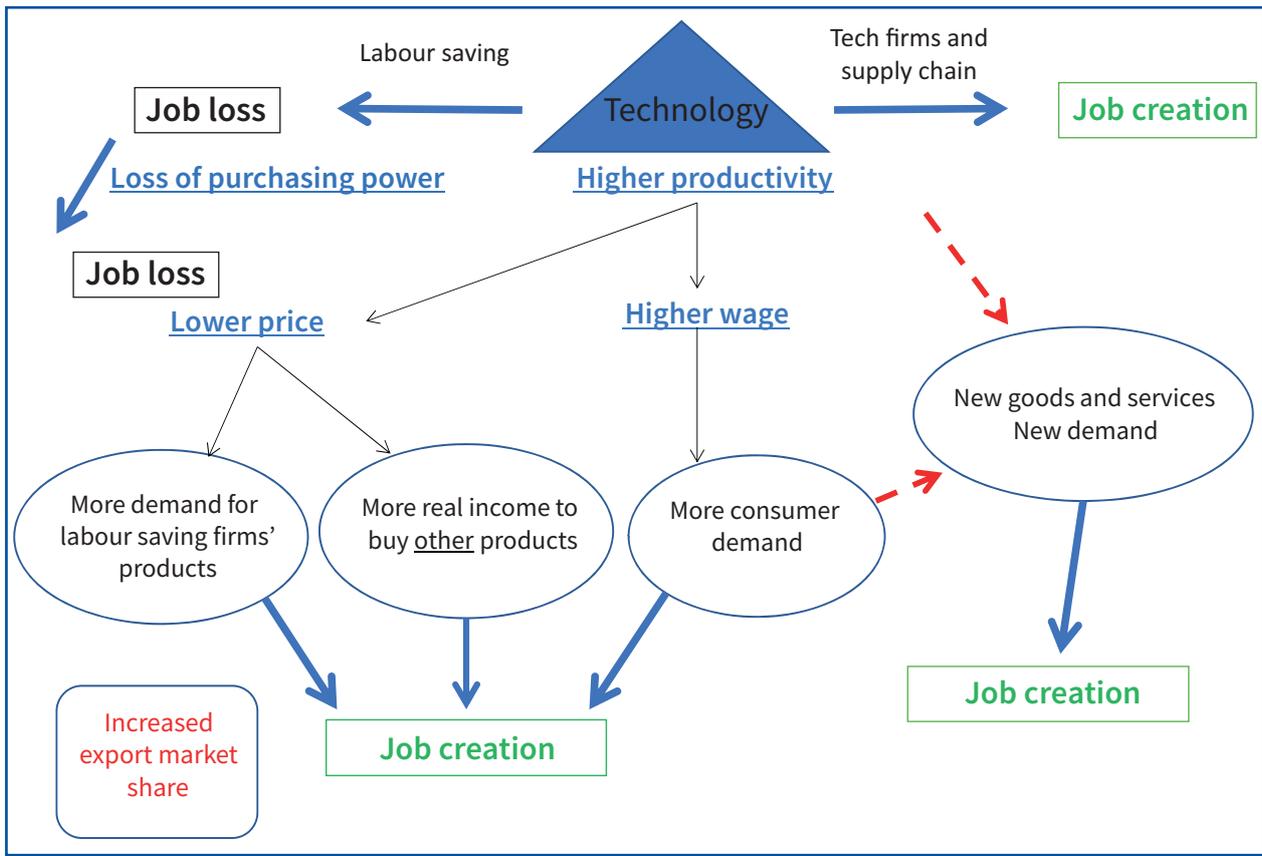
Others have attempted to go further and to gauge the likely extent of automation over a given time horizon. McKinsey Global Institute (2018) estimates that artificial intelligence will reduce the share of job profiles characterised by repetitive activities or requiring a low level of digital skills in total employment to around 30% by 2030; and increase the share of jobs characterised by non-repetitive activities and requiring high digital skills from roughly 40% to more than 50% over the same period. The World Economic Forum (WEF, undated) suggests that in 15 major developed and emerging economies, automation and technological advancements could lead to a net employment impact of more than 5.1 million jobs lost to disruptive labour market changes between 2015 and 2020. This net figure is made up of a loss of 7.1 million jobs, two-thirds of which are concentrated in the office and administrative job family, and a gain of 2 million jobs in several smaller job families.

The type of impact measured in these studies is probably very much in line with what public opinion considers to be the salient issue for employment. However, it is important to underline that these studies typically focus only on the labour process and the technical feasibility of substitution of workers by machines. There are many factors that might mean the predicted job losses do not materialise. The most obvious relates to whether what is technologically feasible is economically rational. From the company perspective, any decision to introduce new technology will hinge on the price of machinery relative to labour costs. Moreover, calculations made in this project, and reported below, show that if all the jobs susceptible to automation were in fact automated, the required investment would be of such a large share of GDP as to be simply unrealistic from a macroeconomic perspective. It is also important to realise that the substitution effects discussed here relate only to the first stage in a much larger macroeconomic context in which the distribution of productivity gains of technological progress and the role of demand are key.

Impact of radical automation on employment levels

Studies have examined the impact of radical new technologies on the labour market since as far back as the Industrial Revolution. Particularly when new technologies have had a pervasive effect, embracing the whole economy and society, it is difficult to identify the specific impact on employment of technology compared to other drivers of economic growth. However, whatever the short-run adjustment costs have been, the historical evidence suggests that employment

Figure 19: A simple stylised picture of how new technology impacts on employment levels



Source: Eurofound: *The Future of Manufacturing in Europe*, author's elaboration

growth goes hand in hand with technological development. How then to reconcile this historical experience with the dire predictions of potential net job losses in the literature, referred to above? Figure 19 provides a simple picture of how, in principle, the effects of new technology can ripple through the economy and how this can impact on employment.

The most immediate impact of new technology is the job losses when machines are substituted for labour in the workplace. However, this is only the first stage in a more complex process. The initial job losses have a knock-on effect due to the loss of purchasing power of the displaced workers. The impact depends on the re-employment rates of displaced workers and the income gaps between old and new jobs or, if no new jobs, the unemployment and other social protection systems.

However, new technology also implies job creation elsewhere in the economy. Firstly, it leads to an increase in the demand for the new technology, resulting in increased demand for labour in technology firms. New technology is introduced to increase productivity. Higher productivity can lead to lower prices and so to an increase in demand for the firm's product. Particularly in large global markets, this can be highly significant, not least for manufacturing. Moreover, lower prices mean more real income which may be spent on other

things, thereby boosting employment elsewhere in the economy. Consumer demand, and employment, will also increase if productivity gains lead to increased wages. Thus, the distribution of productivity gains is crucial. The income-induced job creation knock-on effects occur if the productivity gains lead to lower prices or higher wages. They do not materialise if all the gains are retained as profit.

New technology may give rise to completely new products and services. It is extremely difficult to predict the nature of these products and services and also what type of jobs and how many jobs will be created. However, the employment effects will depend upon the amount of consumer demand these products and services can generate and the total wage bill required to produce this demand: that is, the hours of employment multiplied by the wage rate.

This simple picture assumes that there are no frictions – for example, as regards labour mobility – in the implied structural change. With significant frictions, the indirect positive effects will take longer to occur. Moreover, it does not place the economy in a global competitive market. If it is primarily foreign firms that reap the benefits, then obviously domestic employment will not show appreciable gains. The main value of this simple picture is to indicate that the employment impact of new technology encompasses much more than the

initial substitution of workers by machines. It also suggests that, as has been the case historically, while initially net employment may fall when radically labour-saving technology is introduced, the longer-term effects are positive.

Speculative scenario of the employment implications of radical automation

A global macro-sectoral model – the E3ME model – is used to make a quantitative assessment of the potential employment impact of radically accelerated automation, primarily in light of digitalisation, that goes beyond the initial substitution effects. The model encompasses the major global regions but focuses mainly on the EU. While it covers the whole economy, it has particular relevance for the manufacturing sector. (See Box 1 on p. 11 for a brief description of the model.)

The first step is to take estimates from previous studies of the proportion of jobs that would be technically feasible to automate in each sector and country. For manufacturing in Europe at least, rates are typically very high, approaching and indeed sometimes exceeding 50%. These are then set in relation to estimates of the investment required to automate these jobs and serve as an upper limit on the additional investment that is regarded as plausible. This includes assumptions of the reduction in the cost of investment over time. The model also estimates the employment impact of changes in the supply chains to reflect the impact of digitisation on the material and transport intensity of production. These are applied to the model to find the economic consequences of the pass-through of lower unit costs and supply chain and income multiplier effects, distinguishing the initial assumptions for direct job losses due to automation from the final consequences for jobs once these wider economic transmission mechanisms are taken into account.

Because the future investment cost of automation is very uncertain, two cases are explored: a high-cost case, which implies slower uptake and hence fewer direct job losses; and a low-cost case in which uptake is faster and direct job losses are larger. Because the impacts depend crucially on how the benefits of greater automation are distributed in society, a variant of the low-cost case, in which workers enjoy a reduction in working hours while maintaining pay, is also modelled. This mitigates some of the shift in the share of national income from wages to profits that would otherwise occur.

In the past, the large-scale introduction of labour-saving technological progress has displaced jobs in the short term; but in the longer term, the income generated from lower production costs is spent on other goods and services, including products that did not previously exist, and new jobs are created elsewhere in the economy. In the scenarios modelled here, the jobs displacement effect still dominates results at the end of the forecasting period in 2030. There is a shift in the

distribution of income from wages to profits and a related shift in final expenditure from consumer spending to investment. The negative impact on real household disposable income and spending of the loss of wage income outweighs the positive impact of lower consumer prices. Although not explicitly modelled, the shift in the income shares of labour and capital would increase the inequality of income distribution and depress consumer spending because richer households spend a smaller proportion of their income. This shift is mitigated somewhat in the scenario, which assumes that workers enjoy a pay-compensated reduction in working hours, although whether this could be achieved by regulation, as is assumed, is a matter of political judgement.

The scale of job losses expected in 2030, as a proportion of the jobs projected for 2030 in a baseline scenario with no acceleration in automation, is highest in the EU (10% in the high-cost scenario; 16% in the low-cost scenario).

Within the EU, the sectors with the largest proportional job losses in all three scenarios are manufacturing, utilities, transport and communications. Employment in manufacturing and utilities is expected to be 20% lower than the baseline in the high-cost/low-uptake case, rising to 30–35% in the low-cost/high-uptake case. All sectors see a significant improvement relative to the low-cost case if the benefits of automation are shared among workers by raising the hourly wage while reducing hours worked; this is the case particularly for distribution, retail, hotels and catering, which is the sector most directly affected by household spending.

The first point to emphasise is the very high uncertainty of these projections. A notable uncertainty related to this potential technologically driven transformation is that, unlike previous ones, it will occur simultaneously throughout most of the world, rather than being led, as before, by Europe and the US. The contribution of this report is to extend the analysis beyond the basic calculation of the technologically feasible substitution of workers by machines by incorporating economics. This includes the macroeconomic feasibility of the investment cost of automation and the multiplier effects of loss of demand, not just due to the initial job loss but also from the shift away from other labour incomes and job creation in the supply chain emanating from the increased demand for ICT machinery. There is one major empirical result that should be deemed reasonably credible: while the net impact of the indirect employment effects is positive in Europe, it only marginally mitigates the radical rate of the direct job loss due to automation that was the basis of initial assumptions fed into the model. Net decline in employment is reduced by only a few percentage points – in the high-cost alternative from 12.6% to 10.0%, and in the low-cost alternative from 17.2% to 16.0%. However, distribution issues are critical in this respect as it is only in the scenario with some redistribution

from capital to labour that the demand effects lead to indirect effects that reduce net employment appreciably.

Technological revolution and slow productivity growth?

Technological change is only economically meaningful if it increases productivity and, indeed, is the reason why new technology is adopted. It is the link between technology and economic growth, and it is through productivity that the impact on employment is channelled. It is thus very striking that, now that there is a perception of transformative technological change, productivity in the developed world (developed east Asia, the US and western Europe) is at a historical low (see Table 6).

The broad-brush story of productivity in the post-war period was the rapid catch-up of both the now developed parts of east Asia and western Europe to the global leader, the US. Then from the mid-1990s, the US raced ahead again, with Europe diverging downwards – in some cases, for example, in Italy and Spain, quite dramatically (Cette et al, 2016). The strong US performance around the late 1990s was attributed to the gains from ICT and was driven by manufacturing, not least in the computer and electronic products sector (Houseman et al, 2011).

Recent developments in the US are highly significant in the discourse on the newer digital technologies such as advanced robotics, the Internet of things, 3D printing and artificial intelligence, as the US is still viewed as the global technological leader. Table 7 highlights the historically unique low labour productivity growth in US manufacturing in recent years (2010–2017).

Table 6: Annual growth rate of labour productivity, developed east Asia, western Europe and the US, 1950–2016, %

	1950–1970	1970–1996	1996–2006	2006–2016
Developed east Asia	6.71	3.47	2.47	1.45
Western Europe (EU15)	4.76	2.73	1.50	0.55
US	2.61	1.50	2.38	0.93

Note: Developed east Asia includes Hong Kong, Japan, Singapore, South Korea and Taiwan.

Source: Gordon (2018), Conference Board Total Economy Database

While not discernible from Table 7, it is important to note that productivity started to slow down in the US in 2004: that is, before the recession.

The 2010–2017 productivity figures are without precedent in the post-war period, as is the growth in manufacturing employment of 7.6% (915,800 jobs). Between 1948 and 2008, manufacturing employment fell as a share of private non-farm employment by around 0.4 percentage points each year. Since January 2010, it has fallen by only 0.3 percentage points in total. There is no convincing explanation for this very surprising development.

The productivity figures for Europe are also low. In the euro zone, the European Central Bank (ECB) (2017) reports that between 2013 and 2016 productivity (labour productivity both per hour and per employee, and total factor productivity) averaged well under 1% and that in the depths of the recession, productivity growth was negative. The post-recession manufacturing productivity growth in Europe is also low (Van Ark and Jäger, 2017).

When these remarkably low US productivity figures began to emerge, some argued they could be due to measurement error, the key issue being how to determine the real value of product improvement in times of rapid product development. However, recent research suggests that this is simply not the case. Byrne et al (2016) show that it is unlikely that measurement errors are greater today than in the past. Syverson (2017) checked the robustness of the official statistics using various alternative approaches and data, concluding that they do in fact reflect a true reduction in the rate of adopted technological growth.

Table 7: Labour productivity growth in the US in the private economy and manufacturing, 1947–2017, average percentage

Period	Private economy	Manufacturing
1947–1980	1.72	2.64
1980–1990	1.37	3.85
1990–2000	1.75	4.54
1980–2000	1.56	4.20
2000–2010	1.86	5.3
2010–2017	0.18	-0.05

Source: Schmalensee (2018), compilation of data from the Bureau of Labour Statistics and the Bureau of Economic Analysis

Table 8: Regional summary, 2030, percentage difference from baseline

	Global	US	China	India	EU28
GDP	0.1	-3.4	4.7	0.6	1.1
CO ₂	-34.7	-45.5	-26.5	-53.2	-20.3
Employment	0.5	-1.6	2.3	0.1	0.5
Investment	1.0	-2.5	3.2	1.1	1.7
Consumption	0.4	-2.0	11.2	-1.1	0.7

Source: Eurofound: *The Future of Manufacturing in Europe – Energy scenario*

Others argue that the potential productivity gains are real but very unevenly spread across the economy due to large adjustment and adoption costs (Brynjolfsson et al, 2018) and that more is to come. However, even if this is the case, it is highly relevant to note that the ICT boom up to the mid-2000s was small and short. No doubt the robots of the future will be able to perform extraordinary tasks, but at the time of publishing their commercial application has been limited. This future is probably still some time away and will come gradually.

Nevertheless, even if this more evolutionary story is probably more credible than the revolutionary one, the realities of international competition, not least for sectors where Europe has currently a strong comparative advantage, make the adoption of productivity-enhancing technologies in manufacturing an absolute imperative.

Environmental technology and employment

The potential employment impacts of an implementation of the climate goals of the Paris Climate Agreement are also assessed. The analysis was carried out using the E3ME macroeconomic model (see Box 1 on p. 11). Further analysis of the employment developments in Europe is undertaken using Eurofound's European Jobs Monitor.

Table 8 shows that the transition to a low-carbon economy is positive for the EU as a whole. The positive impact on the number employed is largely due to the investment activity required to achieve such a transition, together with the impact of lower spending on the import of fossil fuels. The impacts vary considerably among sectors. For example, jobs are lost in fossil fuel extraction and processing but gained in the construction and manufacturing of renewable and energy-efficiency equipment, together with the associated supply chains.

This shift in production has implications for labour market demand. For example, the expected shift towards the production of capital goods, such as equipment, machinery and buildings, will result in an increased demand for construction and for labour from the associated occupations, as well as increased demand for metal and machinery and related labour.

The various estimates are compared to a largely 'business as usual' baseline forecast up to 2030. In the EU, the two headline measures of GDP and employment show growth of 1.1% and 0.5% respectively. The most positive results for both these measures are found in China and the EU. The US, however, experiences a drop in GDP of 3.4%, with employment falling by 1.6%.

While overall the energy scenario implies more employment in Europe, much of the employment created is at the bottom and the middle of the wage distribution. These jobs, to a greater extent than in the baseline forecast, are filled by lower-educated employees and involve performance of less advanced tasks.

Some of the key modelling assumptions have important policy implications. Firstly, the model assumes no labour market frictions. In particular, the labour force is assumed to adapt to the structural change in skill requirements associated with the transition to a low-carbon economy: the faster the change, the more likely it is that there may be frictions that leave some workers unemployed and some demands for new skills unmet, preventing the full potential benefits from being realised. Moreover, the appreciable investment required assumes that there are no barriers in accessing the finance necessary for investments needed in this transition. Finally, it is assumed that countries that currently have a lead in certain sectors are able to maintain this when switching to new technologies, for example, the main manufacturers of conventional cars and trucks become the main manufacturers of EVs and their components.

3 Other labour market implications

Introduction

The two preceding chapters were about globalisation and technology with a focus on the impacts on employment levels. This chapter takes up some qualitative aspects of manufacturing employment. It also examines some of the skills required for emerging digital technologies. In much of the extensive literature on skills in the digital age, the focus is placed on very high-end skills, often requiring third-level education. The skills implications of the five game-changing technologies are mainly of this type. However, even if many blue-collar jobs have been lost in recent years, these will still be very much needed in the manufacturing of the future, and this chapter reports on how some of these jobs are evolving. In this context, the research shows that despite the relatively low profile of apprenticeships in discussions about skills for new digital technologies, companies are in no doubt as to their key role in successfully adopting advanced manufacturing technologies and processes.

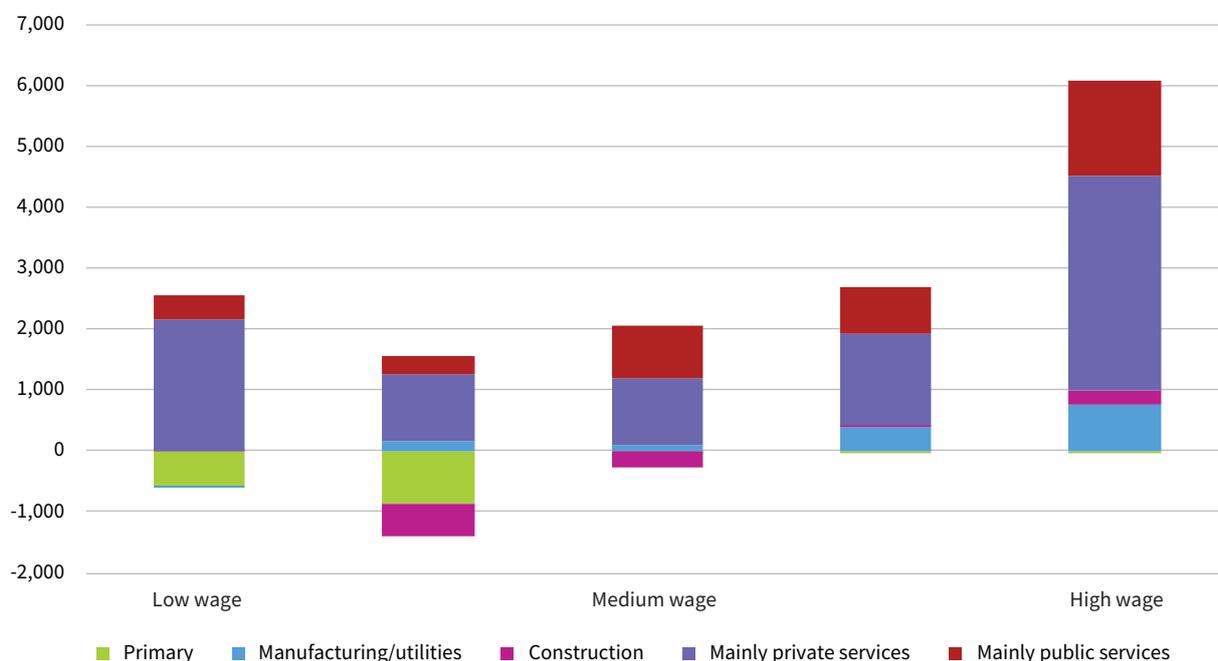
By way of an introduction, Eurofound’s European Jobs Monitor, which was used in previous chapters in the analysis of employment impacts in the trade and energy scenarios, can highlight possibly the most salient recent trend in manufacturing employment.

Figure 20 shows strong job growth in Europe in the top wage quintiles. Indeed, this has consistently been the case since the late 1990s. A comparison of broad economic sectors according to wage profiles shows that upgrading is much more pronounced in manufacturing and most net employment growth in manufacturing has been in better-paid jobs.

Table 9 provides some more detail on the occupations that are growing and declining at the fastest rates in Europe since 2011.

While most occupations in manufacturing are still of the blue-collar type, most of the fastest-growing are those with a managerial, engineering or ICT orientation. The four fastest-growing occupations are very well paid.

Figure 20: Employment change by wage quintile and broad sector, 2011–2018 (thousands)



Source: Eurofound: European Jobs Monitor, EU Labour Force Survey, EU Structure of Earnings Survey

Table 9: Employment in manufacturing and wage percentile in 2018 and growth since 2011 in Europe, by occupation

	Employment (millions)	Employment change, 2011-2018	Wage percentile
Largest 10 employing occupations			
Metal, machinery and related trades workers	4.88	-2	57
Stationary plant and machine operators	4.25	2	44
Science and engineering associate professionals	3.31	12	75
Food processing, wood working, garment & other craft and related trades workers	3.07	-2	27
Labourers in mining, construction, manufacturing and transport	1.98	3	30
Science and engineering professionals	1.95	16	93
Assemblers	1.69	12	42
Numerical and material recording clerks	1.62	6	61
Business and administration associate professionals	1.58	-3	77
Production and specialised services managers	1.09	17	96
10 fastest growing large-employing occupations			
Business and administration professionals	1.04	38	93
Production and specialised services managers	1.09	17	96
ICT professionals	0.41	16	94
Science and engineering professionals	1.95	16	93
Assemblers	1.69	12	42
Science and engineering associate professionals	3.31	12	75
Electrical and electronic trades workers	1.01	8	62
Numerical and material recording clerks	1.62	6	61
Building and related trades workers, excluding electricians	0.88	6	42
Labourers in mining, construction, manufacturing and transport	1.98	3	30
10 fastest declining large-employing occupations			
Handicraft and printing workers	0.88	-9	46
Administrative and commercial managers	0.56	-6	99
Business and administration associate professionals	1.58	-3	77
General and keyboard clerks	0.78	-2	52
Metal, machinery and related trades workers	4.88	-2	57
Food processing, wood working, garment & other craft and related trades workers	3.07	-2	27
Stationary plant and machine operators	4.25	2	44
Drivers and mobile plant operators	1.06	2	47
Sales workers	0.83	2	23
Labourers in mining, construction, manufacturing and transport	1.98	3	30

Note: Large-employing occupations are those with more than 400,000 employed in the EU28.

Source: Eurofound: European Jobs Monitor, EU Labour Force Survey, EU Structure of Earnings Survey

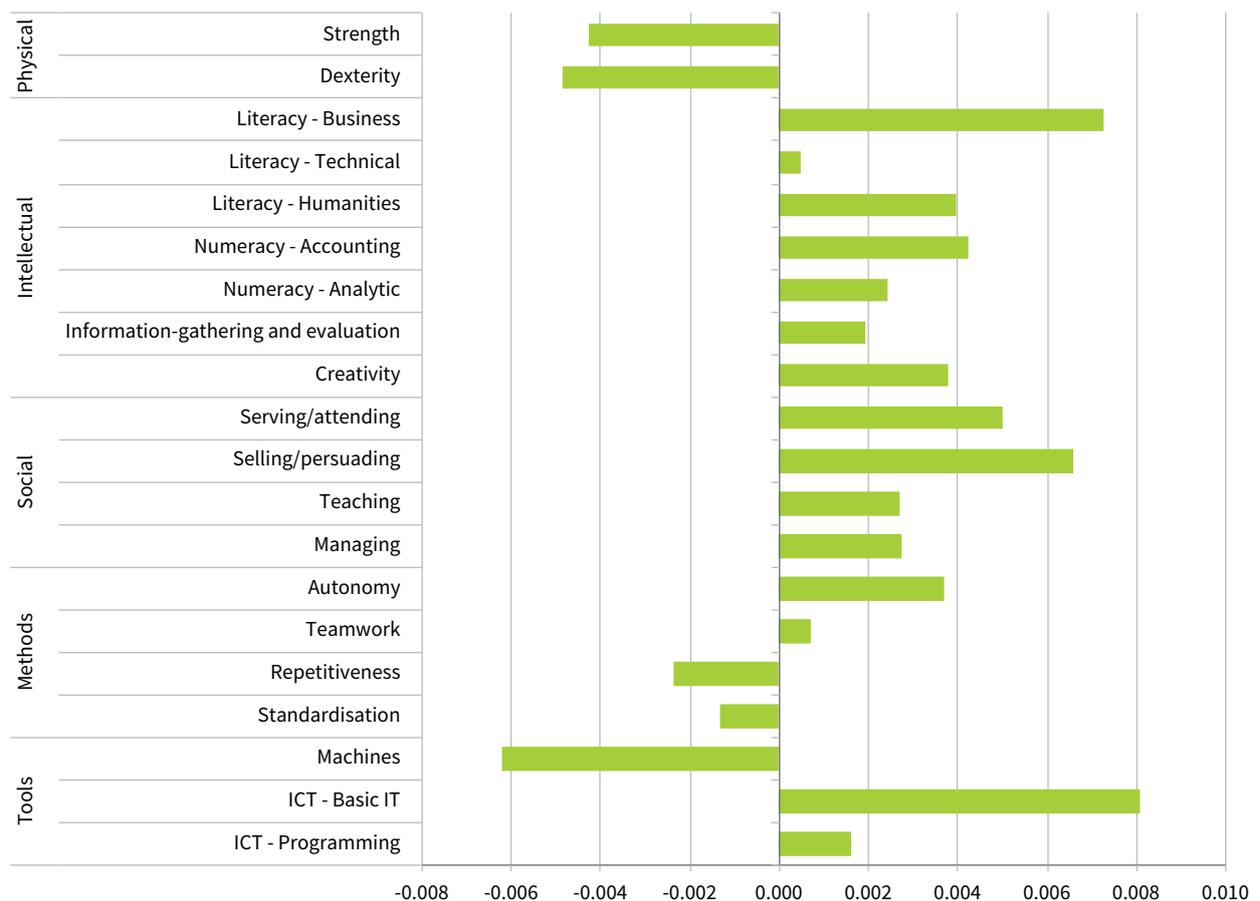
Changing task structure of manufacturing employment in Europe

Changes in task structure with an outlook to 2030

The baseline upon which the scenarios from the previous two chapters were based provided estimates of future employment by sector and occupation. It is useful to examine how these projections of the employment structure up to 2030 will affect the task content of employment in Europe. This task structure, as conceptualised by Eurofound (2016c), measures tasks performed at work along two main dimensions: the content of the tasks themselves and the methods and tools used to perform those tasks.

Figure 21 shows a decline in physical tasks, both those requiring physical strength and those requiring dexterity. These tasks are related mainly to agricultural and industrial occupations. Jobs with many tasks that are classified as routine are also projected to decline. This is, of course, not to say that tasks in existing jobs will not become more routine, and indeed there is some evidence that many jobs have in fact become more routine and standardised (Eurofound, 2016c). The largest projected decline is in tasks involving working with machines, which may appear puzzling. One should note, however, that this excludes working with ICT-related machinery. This projected decline may also reflect the shifting global division of labour where work with less advanced machinery moves to lower-wage countries. There is also a strong correlation between the occurrence of physical tasks, working with machines and routine tasks.

Figure 21: Changes in task indices in the EU, up to 2030



Source: Eurofound (2018a)

The projections suggest an increase in intellectual and social tasks. Indeed every type of task in these categories is projected to increase. In terms of what tasks are performed, two subcategories stand out: business literacy and selling/persuading. The business literacy task is the 'processing of verbal business information'. This includes tasks such as the reading and writing of letters and financial statements. The selling/persuading task is the second-most rapidly growing subcategory. This is closely related to business literacy.

In relation to methods that are applied in tasks, autonomy is projected to increase most. Overall, use of basic ICT – in the category of tools used in tasks – is projected to have the greatest increase. (See Eurofound, 2018a, an associated FOME publication, for a fuller description of these results.)

Changes within some manufacturing occupational classifications

Most statistical analysis of employment adjustment to structural change is based on changes over time in the numbers employed in sectors and occupations (compositional effects), and this approach does not allow for an examination of how the jobs themselves evolve over time.

The FOME project examined five occupations in manufacturing – car assembly worker, meat processing worker, chemical products machine operator, hand packer and inspection engineer – in six European countries to explore, mainly through expert interviews, how these jobs are evolving. The results, structured according to relevant categories of the Eurofound task classification used above, are summarised in Table 10.

Intellectual tasks involving information processing and problem-solving are becoming more common in manufacturing jobs, whereas previously physical tasks predominated. One reason for this is the increased use of digitally controlled equipment in production. This not only requires that workers in manual, semi-skilled occupations have more developed ICT skills, but also increases the literacy- and numeracy-related tasks they have to perform, such as reading technical documentation or dealing with numerical information. The spread of automation and the use of advanced machinery in production is also increasing the importance of problem-solving intellectual tasks, with workers on the shop floor increasingly being tasked with troubleshooting production lines and dealing with errors.

Another important driver of change in the nature of manufacturing work is the increasing use of quality control and standards in production. This is due to regulation, consumer demand and the increasing complexity of production processes. Quality standards impose a certain degree of formalisation in the production process with the use, for instance, of benchmarking, detailed planning and performance indicators. Many of these quality-control procedures are carried out, at least partly, by shop-floor operators, whose task set has broadened to include documenting problems, assessing progress toward targets, filling in forms and so on. The work of hand packers, for instance, has evolved in response to consumer demand for high-quality packing and delivery, particularly in relation to product traceability. The more experienced and qualified workers also have to be able to perform complex logistical and coordination tasks (for example, packing and shipping products on time to many different customers).

The importance of physical tasks is generally decreasing because of automation, although the extent to which this is happening depends on the comparative advantages and efficiency associated with manual vs. machine task performance. Tasks that require workers to exert physical strength, in particular, are in decline, but tasks that require physical dexterity remain an important part of some shop-floor jobs, notably in the context of operating machinery. Among the occupations studied, meat processing workers are the clearest exception to the declining trend in physical tasks, the reason for this being that the processing of meat is difficult to automate because of its inherent variability and so automation remains expensive relative to the cost of human labour.

Finally, with regard to social tasks, these are generally more important for services than for manufacturing. The occupations examined in this study had very little contact with customers or people beyond the shop floor, and social tasks were restricted to cooperation with co-workers and some coaching of new or less experienced colleagues. Both meat processing workers and chemical plant operators tend to work alone, so even cooperative task content is relatively limited within these roles.

Table 10: Summary of the main findings from the case studies in terms of task content, methods and tools

	Car assembler	Meat processing worker	Chemical products plant and machine operator	Hand-packer	Inspection engineer
Physical tasks	Declining because of digitalisation	Still very important Little automation yet (difficult and costly)	Declining because of automation and sensors	Declining because of automation, but very diverse and changing	Very minor role and declining with digitisation
Strength	Very minor role	Declining, but still important Increasing automation	Very minor role	Decreasing because of automation	Nothing
Dexterity	Declining, but still important (troubleshooting, customisation, etc.)	Very important Little automation	Declining, but still important (inspection, preparation, etc.)	Declining, but still important (machine operation)	Inspections and tests Declining because of digitalisation
Intellectual tasks	Increasing importance with digitalisation and standardisation	Remain secondary, but increasing importance Standardisation	Increasing importance with digitalisation and standardisation	Remain secondary, but increasing importance Standardisation	Core task category Increasingly digitised
Information processing	Quality control and documentation ICT tasks for digitally controlled equipment	Quality control and traceability Documentation standards	ICT tasks for digitally controlled equipment Quality control and documentation	Quality control and traceability Documentation standards In some cases, ICT tasks for digital control of machinery	Organising collection of quality data (increasingly digital) Analysing it and improving production processes
Problem solving	Troubleshooting production lines	Flexibility in production Troubleshooting	Error handling Troubleshooting production	Error handling Troubleshooting	Dealing with errors and complaints
Social tasks	Cooperation within team and supervision depending on position Coaching of new staff	Secondary, individual work Some coordination and coaching	Secondary, individual work Increasing cooperation Coaching	Cooperation within team and supervision depending on position	Cooperation with production workers and other departments Supervision of processes Dealing with customers
Work organisation	Routine work Teamwork increasingly important	Routine work Individual Little autonomy	Routine work Mostly individual Little autonomy	Routine work Teamwork Some autonomy	Some routine tasks, but not predominant High level of autonomy
Technology	Electronically controlled machinery Increasingly ICT-controlled	More traditional machinery, although increasingly ICT-controlled	Electronically controlled machinery Increasingly ICT-controlled	Electronically controlled machinery Increasingly ICT-controlled	Intensive use of ICT Some machinery for testing and quality control

Source: Eurofound: *The Future of Manufacturing in Europe – New tasks in old jobs*

Skills for advanced manufacturing

Skills for the five game-changing technologies

As traditional manufacturing jobs have declined in this decade, higher skills profiles (engineers and other professionals: see Table 9) have shown significant gains within manufacturing. This manufacturing-employment-skills upgrading is likely to intensify with the deployment of the five game-changing digital technologies (and other technologies). According to the experts interviewed, the dimension of working conditions most affected by the emerging technologies was training or professional development.

There will be an increased demand for higher-skilled workers. This includes those with a more traditional engineering profile – process engineers, quality control engineers, and chemical, electronic, mechanical or mechatronic engineers. However, due to the centrality of data and information on new technologies, there will also be demand for newer skill sets – notably those of designers, industrial data scientists, ‘big data’ statisticians/mathematicians and data security analysts – to deal with the increasing data-intensiveness of production processes. Once a component can be modelled digitally, its physical manifestation becomes secondary to its virtual representation, captured in bits and bytes. There is a rapidly growing demand for ‘symbolic analysts’ capable of processing and interpreting the large amounts of data in designing and producing things.

The most sought-after profile is likely to include some combination of engineering and ICT skills. Large companies like General Electric are increasingly making ICT skills training, including basic coding, mandatory for all new employees ‘from top floor to work floor’. The centrality of information processing and computer logic means that even more far-reaching reforms to educational curricula are envisaged, including programming skills tuition for primary school students, using products such as Raspberry Pi.

In addition to specific, high-skills occupational profiles, non-technical skills are also becoming increasingly relevant in manufacturing. Social and communication skills will become more important, as many of the game-changing technologies straddle different, quite specialised technical domains and require interdisciplinary collaboration between team members and departments as well as external service providers. Several of the technology reports from this project underline the importance of clear communication in complex environments. The capacity to work in teams will therefore be essential, as will adaptiveness, as individual specialists will be contributing to many different project teams.

Other skills frequently cited include independent decision-making and creativity. Decentralised production processes may require rapid intervention in cases of dysfunction or production ‘exceptions’. This is likely to require not only extensive knowledge of technical processes but also leadership skills and problem-solving capacity, as well as attributes related to temperament (‘grace under pressure’).

There will be keen competition among employers for the emerging skill sets, as indicated above. There is already a shortage of graduates in science, technology, engineering and mathematics (STEM). The ideal occupational profile will increasingly be some combination of the four prongs of STEM, especially together with skills in data processing. In practice, the combination of such advanced skill sets – as well as the indicated soft skills – in any one individual becomes less likely as projects become increasingly specialised. Projects will, of necessity, be team based.

Remote telework and telerobotics may offer one way of solving potential skills bottlenecks, as they enable individuals and companies in distant locations to provide services that are largely only offered locally. One example where this is already happening is telesurgery, but this approach could easily be applied to most of the game-changing technologies. For example, the work of an industrial data scientist is screen-based and computer-intensive and, as such, largely location independent. Labour cost arbitrage – especially for the higher-level professional skills – may make this remote working especially attractive in high-cost locations such as the EU and the US.

However, the importance of multidisciplinary teamwork and communication in many of the game-changing technologies may be a powerful factor against the physical dispersion of individual roles, especially given the extent to which time lags, time zone differences or any operational imperfections in the virtual workplace persist. However, these are likely to be eliminated in the medium term as technical advances make real-time virtualisation more or less seamless.

The five technology reports provide very rich descriptions of the skills required for each of the new technologies. Table 11 summarises the findings just for AIR. Given the cross-cutting nature of AIR, it is likely that widespread uptake of this technology in manufacturing will have at least some impact on the majority of production tasks. This involves production, logistics, supervision and management, administrative tasks and human-resource-related tasks. Robotics could also impact commercial and support tasks through, for example, the use of chat bots instead of sales staff and help desk attendants. Thus the range of skill sets to be affected by the uptake of AIR is very broad. Table 11 illustrates some of the main types of skills and relative impacts stemming from the use of AIR.

Table 11: Impact of advanced industrial robotics (AIR) on industrial manufacturing skills (non-exhaustive)

Skills	Impacts stemming from AIR
Engineering skills	Skills in advanced mechatronics and component design (sensors, actuators, power management, etc.) Skills in advanced robot dynamics and kinematics Skills in sensor development and integration
Data and mathematics skills	Skills to analyse data being collected by robots (big data) Skills to analyse and develop safer and more efficient robot trajectories and movements Skills in machine learning, including deep learning
Material/resource-specific skills	Skills in materials science and real-time simulation of material behaviour (for example, so that robots are prepared to work with soft materials)
Equipment and machinery operation skills	Skills for programming robots and robot maintenance Skills in automation and programming, robotic systems integration and robot maintenance Human-robot collaborative skills for workers
Packing-related skills	Human-robot collaborative skills for workers
ICT-related skills	Skills for programming robots and robot maintenance Skills in deploying and securing industrial communication networks Skills in virtual reality and virtual prototyping of production processes (together with engineers)
Communication skills	Skills for the design of human-machine interactions and interfaces Skills in data science and cognitive computing to ensure robots can communicate with workers in natural language
Organisational skills	Skills in industrial organisation that consider the role of AIR in the production process
Human resources skills	Integrating the presence and use of robots in human resources practices (for example, using robotics as a key recruitment selling point)
Legal skills	Skills allowing understanding and mitigation of the legal implications of using AIR in a manufacturing setting (for example, in relation to privacy and work-related accidents)
Thinking skills and competencies	Skills in systems thinking and systems design (as advanced robots automate more and more tasks, attention and thinking capacity of workers will be freed to work on higher-value activities)
Social skills and competencies	Human-robot collaborative skills for workers Skills to assess the social impact (and the impact on workers' lives) of advanced robots in the production environment

Source: Eurofound: *The Future of Manufacturing in Europe – Game changing technologies*

Skills for the adoption of AIR are also related to the use of new materials such as bio-based materials, carbon fibre, composites and various inputs for AM (3D printing). Because they are increasingly integrated into new products and technologies made by AIR, workers will need to understand these materials and how they perform. These developments will have subsequent impacts on the skills required in manufacturing: for example, skills related to mechatronics will be required within the car manufacturing process. The importance of such skills was highlighted by several interviewees.

Adapting apprenticeships for advanced manufacturing

The vocational training systems within which apprenticeship systems in Europe are embedded are exceptionally heterogeneous, so a structured and complete account of how they are adapting to new technological developments is very difficult to produce. This section focuses instead on what appears to be the

main issues based on the FOME apprenticeship research. The country studies and case studies were conducted in Denmark, France, Germany, Ireland and Italy, within Europe, and in Australia and the US.

It should be noted that in 2018 there was a highly significant reform of the national apprenticeship system in France, implementation of which occurred after the completion of the FOME research. The main elements of the reform include an increase in the age limit for starting an apprenticeship, new rules on the remuneration for apprentices and support for participating companies. However, possibly the most significant change is that curriculums will be defined by the state, together with the relevant professional organisations, who will draft the activity and the skills criteria for each diploma. It is thought that this will ensure the provision of skills needed by companies and lead to more efficient and relevant adaptation to change.

Creating new or adjusting existing occupational profiles

It is obvious that rapid technological change requires more urgency and effort to ensure the current relevance of apprenticeship skills. Adjustment can occur either by creating new occupation profiles or by adjusting existing ones.

Certainly in Germany, the continuous adjustment approach continues to prevail. It would appear that the actors and structures of the German system, not least the cooperative and influential role of social partnerships within national qualification frameworks, allow for relatively quick and relevant updates – an ‘agile procedure’ (Gesamtmetall et al, 2017). This approach often entails the introduction of new transversal skills. For example, in metalworking and electronics occupations, these include online communication skills, data analysis, data transfer, online search and online learning skills. These occupations also offer optional additional skills. For metalworking only, these include system integration, process integration and AM (3D printing). In electronics only, options include digital networking, programming and digital security.

For new profiles, the production technologist (*Produktionstechnologe*) was established in 2008 in Germany. This followed a request by the engineering employers’ organisation with direct reference to the increased role of advanced manufacturing technologies, particularly the use of ICT in automation technologies. However, very few new apprenticeship contracts have been concluded by enterprises (only 123 in 2015). Both companies and applicants still choose more established occupations, such as mechatronics (with 26,400 newly concluded apprenticeship contracts). The traditional apprenticeship occupation of industrial mechanics is still the most widespread apprenticeship programme (46,000 in 2015). Overall, according to the BIBB database Dazubi, newly concluded vocational education and training (VET) contracts in Germany continue to decline.

Similarly, the Danish VET system is continuously adjusted to adapt curricula to changes in the labour market. Trade committees monitor and report annually to the Ministry of Education on emerging new technologies and changes in work organisation. Apprenticeships are adjusted by offering options to specialise as well as making non-mandatory modules available, which can be shared between different programmes. The flexibility inherent in this modular approach makes it possible for apprentices (and enterprises) to put together customised curricula that take into account specific requirements: thus, there is little requirement to develop entirely new occupations or programmes.

Ireland has introduced more new occupational profiles, partly due to a recent overhaul of the apprenticeship system. They include mechanical automation and maintenance fitting, and training to become polymer processing engineers and manufacturing technicians. However, the take-up rate of these opportunities has been low.

In general, the Industry 4.0 process is best defined in terms of the merging of traditional industry with the existing and emerging digital technologies. Thus the adaptation of existing profiles with some digitally related focus does appear to be the most sensible approach. This has a particularly strong logic in a transition phase with the coexistence of the old and the new and when the occupational requirements of advanced manufacturing may, in many cases, still be somewhat unclear.

Deeper knowledge with further or higher apprenticeships

A ‘further apprenticeship’ is taken to mean one that builds upon an initial apprenticeship within the institutional and regulatory framework of the initial apprenticeship system. For the new occupation of production technologist mentioned above, established in 2008 in Germany, a further qualification certificate for process manager production technology (*Prozessmanger Produktionstechnologie*) was created.

The emerging advanced digital technologies require not only new skills but significantly deeper or advanced skills. The obvious provider of such technical skills are the third-level education institutions. However, these institutions typically have a very limited role in the provision of training for apprenticeships at the initial level.

While not a precise or universally used term, ‘higher apprenticeships’ are taken to mean dual study programmes where the degree is awarded by a tertiary education body (for example, a university) with some involvement from companies. This involvement varies greatly regarding financing, the curricula and the relationship between the company and the apprentice or student. While in some of the acknowledged best practice initial apprenticeship systems, the involvement of social partners is seen to be a key element, it is mostly absent.

These higher apprenticeships are becoming increasingly prevalent in France, Germany, Ireland and Italy, and the project reports have numerous examples where either a single company or a cluster of companies are involved. Many of them have an orientation towards advanced manufacturing. More formalised dual academic programmes in Germany combine vocational training and degree programmes. The trainee is employed by

the company financing the course and obtains both practical knowledge within the company and an academic degree (bachelor's or master's, European Qualifications Framework level 6). Dual academic programmes are expanding in terms of both the number of programmes and the number of students participating. By 2017, in Germany there were almost 1,600 dual study courses, mainly offered by technical colleges in economics and engineering sciences. However, according to the FOME expert and stakeholder interviews, the role of dual study courses in the manufacturing sector should not be overestimated. Though detailed figures on the number of dual students in the manufacturing sector are not available, the total number is very modest when compared to the number of apprentices in the sector.

Recent decades have seen a very strong 'vocationalisation' of third-level educational institutions, and undoubtedly much of the positive future of vocational training and education rests with these institutions. There is, however, an obvious fundamental tension between the needs of educational institutions and those of industry, not least when industry is a significant financial contributor.

Box 9 describes a relevant initiative, the Jules Verne Manufacturing Academy in France. The co-location and institutional integration of initial and higher apprentices as part of this initiative may have potential in reconciling further and higher apprenticeships.

A clear advantage of the well-designed further (or initial) systems (like, for example, in Germany and Denmark) is that the national qualification framework is a well-recognised certificate that enables labour mobility within this occupational segment. Such accepted and recognised certification (and quality control) does not generally feature in the higher apprenticeship programmes. However, a commonly cited disadvantage of traditional apprenticeships is their rather limited options for upward occupational mobility through higher-level education. Indeed, this is commonly perceived to be a significant factor for the continued problems of enrolment in even the best of the traditional systems. Many of the experts interviewed for this project underlined that the lack of mobility from initial apprenticeship to higher education is a significant unresolved issue.

Finally, most of the focus in this section has been on hard or technical skills. However, in the skills for advanced manufacturing literature much mention is made of the importance of soft skills. An often underappreciated feature of apprenticeships is their role in facilitating the socialisation of young people into the world of work. This includes not only issues of particular relevance during the school-to-work transition period, such as attitudes and punctuality, but also those of central importance throughout the working life, such as teamwork and problem-solving.

Box 9: New approaches to apprenticeship training in advanced manufacturing in France

In 2015, the Technological Research Institute (*Institut de Recherche Technologique*) launched the Jules Verne Manufacturing Academy in Nantes. It aims to train apprentices in advanced technologies from 2019 onwards. The school will have a capacity of 1,000 training places, half of which will be reserved for apprentices from local schools, with the other half for students pursuing university curricula. The school aims to pool the technological equipment of the high-level Technological Research Institute with a dozen dual training institutions. These institutions will be able to relocate their training within this school to benefit from its technological equipment. The new school and the collaboration between the Technological Research Institute and the training institutions aim to improve the attractiveness of occupations within manufacturing.

'Job and qualification campuses' (*Les Campus des métiers et qualifications*) is a national label awarded to secondary and higher education institutions that provide either initial or continuous training. These campuses form part of a national policy initiated by the Ministry of Education in 2013. They aim to improve the coordination between training offer and demand and to adapt vocational training to the needs of companies. In practice, each campus targets a specific economic sector, generally at the level of an employment area. So far, 78 campuses have been launched in France, among them the Campus of the rail and automobile industry (*FIAEM Campus or Campus des métiers et des qualifications du ferroviaire, de l'industrie automobile et de l'ecomobilité*) in the Hauts-de-France region, which has been analysed in the context of the Eurofound research. One of the main reasons for establishing this campus is to better link secondary education, apprenticeship, higher education and research in order to improve the attractiveness of apprenticeships among young people.

Source: Eurofound (2019c)

Working conditions and industrial relations

Table 9 (p. 44) shows that it is the relatively high-skilled, white-collar and well-paid occupations that have grown fastest between 2011 and 2018, and most predictions about jobs in the advanced manufacturing future suggest an acceleration of this trend. It is highly likely that these jobs, particularly as applicants may be in short supply, are also likely to have good working conditions in most other respects.

The case studies of changing tasks in some manufacturing jobs indicate that the decline in physical tasks, combined with more restrictive safety regulations limiting direct contact with machinery, has the benefit of reducing physical workplace risks for some manual occupations. This, together with the upgrading of work in terms of intellectual tasks, has contributed to job quality improvements even in traditional manual occupations in manufacturing. Some indication of more problematic aspects of working conditions for future-oriented game-changing technology are summarised below.

Health and safety

For AM (3D printing technologies), the incorporation of the entire production process in one printer lessens the dangers from moving mechanical parts. However, the presence of high voltage arcs and high-temperature printer nozzles, as well as the toxicity of small particles of material, all represent significant new sources of physical risk.

For IIoT applications, a McKinsey study estimates that insurance costs may be reduced by 10–20% ‘by preventing accidents and injuries with sensors and tags on employees and equipment’ (McKinsey Global Institute, 2015). More generally, robots will increasingly take over hazardous jobs formerly performed by humans, including the handling of hazardous materials or operating in dangerous environments (for example, underwater welding).

In AIR developments, there has been a trend to clearly demarcate and separate human and robot spaces in order to avoid industrial accidents. In their current phase of development, deployed industrial robots still tend to be largely pre-programmed and only partially sensitive to changing ambient circumstances, including the presence of human workers. With the rapid developments in artificial intelligence, these shortcomings will increasingly be addressed. However, protection has not always proved successful. For instance, there may still be the requirement for repair or maintenance personnel to enter caged robot enclosures. There were two reported incidents in auto sector plants in 2015 – one in the US and one in

Germany (McAlone, 2015) – in which unforeseen robot–human interactions in such circumstances resulted in the deaths of workers. The first industrial robot-related death occurred in 1979. While such incidents have been characterised as ‘rogue robot-related deaths’, in practice they arise largely as a result of human error in the installation, programming or supervision of pre-programmed machines. Taking a longer-term perspective, the prospect of artificially intelligent, self-learning robots with enhanced sensors and real-time decision-making capacity raises the potential for genuinely rogue robots. These could actively subvert the wishes of human supervisors or contain algorithms covertly altered by a hostile human agency with similar outcomes.

Such disruptive possibilities highlight the high priority attached to the training and recruitment of data security experts, especially in IIoT and AIR applications. This is all the more pressing as weak digital security is a common vulnerability of all network data systems. At the time of publishing, security considerations have tended to be secondary to the imperatives of product rollout: for example, in personal computer operating systems and software.

More generally, there is a need to invest in safety in situations where robots cooperate with human workers. The FOME project technology reports refer to emergency break buttons and improved visual and auditory sensors, as well as natural language systems that allow workers to interact directly with robots and give them instructions that can be processed in real time. The development of ‘cobots’ – smaller robots designed to co-work with humans, increasingly endowed with artificial intelligence – implies an ongoing desegregation of robots and human workers. EU research projects such as the Horizon 2020 project, Inclusive, is investigating the implications for manufacturing work of these advances in the design of human–machine interfaces.

There are also more mundane concerns about the job quality implications of the virtualisation of work. One concern relates to the psychological effects of machine control of work processes. The increasingly secondary role of human intervention – confined to tasks such as supervising robots or machines or exception handling – may result in workers experiencing a loss of control and a sense of alienation from their work, feeling that they are increasingly appendages to a machine. With technical advances, the algorithms become self-improving and smarter, potentially eliminating swathes of better-quality, higher-paid jobs. At the same time, lower production-line employee levels may weaken the social context of work. The capacity of work to forge a positive social identity – at individual and collective levels – as well as personal self-worth and meaning may be jeopardised as algorithms supplant human agency.

Personal data protection

One important potentially negative job quality dimension of the game-changing technologies relates to personal data privacy. The digitalisation of production processes is the fundamental basis of AIR, AM and IIoT, while it is also important for both IB and EVs. This means that all production processes involve large amounts of data processing, including data about individual workers. This can amount to a form of ‘digital panopticon’ in which an individual’s rate of work, rate of task completion, work presence and absence, and potentially even physical measurements such as heart rate and blood pressure, are capable of being actively monitored by employers.

The negative implications of such surveillance for working conditions have already been signalled in the highly automated warehouses operated by the online retailer Amazon. So-called ‘pickers’ have handheld scanners that are used ostensibly to record task completion and to coordinate work organisation. These may also be used to monitor individual performance in relation to production targets (distance walked, objects delivered or packed) or employee behaviours such as taking toilet breaks. They can provide data for potential disciplinary actions. While tracking technologies (for example, wearable sensors monitoring air quality or physical indicators) could be deployed to benign effect by responsible employers, concern remains that any existing power asymmetries in the employer–worker relationship are likely to be exacerbated by the wealth of additional data about individual worker performance that the new technologies generate.

Working time arrangements

In principle, new digital technologies offer more scope for remote working – including teleworking – and flexible working time arrangements. The digitalisation of work processes and the use of remote sensors and virtual screen interfaces mean that more work is theoretically location independent. However, those interviewed in the project considered it more likely that more automation may result in a reduction of flexibility. Production – especially in AIR applications – is likely to be carried out in single production facilities. Given the capital investment involved, these are likely to operate around the clock. A small complement of specialised staff may serve as a constraint on scheduling flexibility, while overnight orders or machine failure may

necessitate a constant staff presence or on-call availability. In this way, game-changing technologies are likely to quicken the erosion of traditional and predictable working time schedules.

Implications for social dialogue

The implications of the game-changing technologies for social dialogue and formal employer–worker relationships have received very limited attention. In part, this relates to a lack of clarity about how the game-changing technologies will affect workplaces. They are all emerging technologies with many unforeseeable implications for workplace relations. One noted exception is Germany, where the Industry 4.0 debate has engaged all sides of industry in a discussion about how the strong national manufacturing sector will absorb these changes. It has also spawned multistakeholder reflection on how the new manufacturing will affect work (Work 4.0).

Trade unions tend to be rather cautious about the implications of the impending change. One reason for this is that the companies championing new technologies have proven less amenable to collective representation. Unionisation is very low in many high-tech companies. Automation via AIR or IIoT tends to be viewed with concern by trade unions, given their potential to displace members’ jobs. In addition, to the extent that all of the game-changing technologies affect labour demand, they tend to favour higher occupational profiles where the level of worker representation has tended to be lower, while jeopardising the types of blue-collar production jobs that traditionally have been highly unionised.

Another concern on the part of trade unions is the capacity of digital technologies to increase the surveillance and monitoring of workers. This is considered a risk in terms of making it easier to intensify work or breach privacy.

While this chapter considered the predictions of potential mass job loss as rather unlikely, and the impacts of technological change are uncertain and somewhat speculative, it is reasonably safe to assume that new technologies will lead to significant structural change in the economy and changes in the organisation of work within the workplace. Thus, the most immediate issue in terms of social dialogue is the anticipation and management of this change.

4 Summary and conclusions

Trade protectionism scenario

The headline finding of the trade protectionism scenario is that while China, the EU and the US lose GDP from increased tariffs, the US loses much less than the others. The obvious explanation for this is the trade surplus – primarily attributable to manufacturing – in China and the EU and the large trade deficit in the US. Most other parts of the world see a GDP increase due to trade diversion effects.

The negative effects occur very quickly after tariff hikes, particularly for China and the EU. However, recovery in China is quicker than in Europe, as the model predicts that China is able to increase exports to other markets, including the EU, and redirect its sourcing of imports to Asian countries at modest additional cost. The EU is less able to redirect its sourcing of imports to relatively low-cost alternatives. The EU GDP effects are primarily driven by lower export volumes, mainly to the US, and higher consumer prices. The largest negative impacts are in the Netherlands (2.1% less than the baseline GDP), Hungary (2.0%) and Germany (1.9%). This leads to a 0.3% fall in employment in the EU28 by 2030 compared to the baseline. The impact on employment in the Member States by 2030 is similar to the GDP effect and is negative in almost every country, albeit on a smaller scale.

Manufacturing sees the largest percentage decrease in employment (-1.1%). The impacts on services sectors reflect the second-round effects of lower economic activity and, in particular, lower consumer expenditure due to higher prices and loss of income from job loss in the sectors directly affected. Large employers such as distribution and retailing and business services are expected to see impacts in the range of 0.3–0.4%.

While the baseline predicts a polarised picture of employment by wage class, with growth at the top and bottom of the occupational wage structure, the job loss in the trade scenario shows a more significant decline at the tails than in the middle. In Germany, much of the job loss is in the top two wage quintiles. While the impact on the industrial sector is of course large, many associated services jobs are also lost. In some of the less developed economies, Bulgaria being a prominent example, the relatively large decline in low-wage jobs occurs overwhelmingly in industry. In more developed economies, the decline in low-wage jobs is due more to losses in services, which are particularly sensitive to falls in consumer demand.

European Reshoring Monitor

Numerically, reshoring is a relatively minor phenomenon. While it is certainly the case that the methodology of the monitor may miss a number of cases, it is highly unlikely that a more comprehensive coverage would much alter the assessment of direct employment impacts of reshoring in the manufacturing sector. Both the relatively low number of reshoring cases and the limited number of jobs created in Europe from these cases suggest that reshoring has not significantly boosted employment in manufacturing. Significant indirect employment creation arising from reshoring – in R&D, management and engineering functions – may have occurred but is, by its nature, much more difficult to identify.

However, it has been argued that the application of highly labour-saving innovations, as in the game-changing technologies examined in Chapter 2, may open new possibilities for reshoring. The technological infrastructure and skills required to operate extremely automated factories may only be readily available in developed economies, as in Europe. Moreover, the very limited amount of labour required in heavily automated plants may, almost regardless of wage levels, lead to a relatively small total wage bill. Thus, the cost of labour may become a much less significant factor in firms' location decisions. The location of highly automated manufacturing plants in Europe will obviously not lead to many new manufacturing production jobs. However, it still may be a significant development when the high innovation link in the value chain is in the manufacturing production process itself, as this may require R&D activities to be in close geographical proximity to the production process. R&D and other stages in the value chain are more employment intensive. The European Reshoring Monitor data do show that 'automation' is quite often cited as a reason to reshore and has shown some modest increase in recent years.

The policy review indicates that there are very few reshoring policy initiatives in the Member States. Even fewer have been evaluated, and some have been discontinued. One might suppose that a dedicated policy to promote the relocation of companies back to Europe that is based on specific economic incentives for firms would encounter many design and implementation difficulties. Indeed, the experience of such policies in the regional contexts in Member States is hardly encouraging (Devereux et al, 2007), and with firms located in more than one economic jurisdiction, the matter is bound to be even more problematic. It is likely that the best policy to promote reshoring is the improvement of national industrial infrastructure, an

approach that is practically indistinguishable from other forms of industrial policy and more general economic framework conditions. Notwithstanding these policies, there is, of course, a role for information campaigns and some administrative facilitation of the reshoring process.

Born globals in international supply chains

While small and medium-sized enterprises (SMEs) generally engage less than large companies in international activities, the expansion of the international market provides more opportunities than was previously the case. Born globals, which upon start-up very quickly become global, are not an insignificant phenomenon, representing 2.5% of all SMEs and 12% of young enterprises. They are found to be highly innovative, quality oriented and agile, often filling key niches in global value chains. They are confronted with important challenges related to the fact that they have to undergo start-up and internationalisation at the same time and at a very early phase in their life cycles. Given their limited resources, there is scope for significant policy input into their development processes.

Born globals appear to be highly active in informal networking activities, and indeed the building of trusting relationships with their partners is of fundamental importance to them. They find that relationships are easier to build with other smaller firms, and they recognise the lock-in vulnerabilities with larger ones. In terms of processes of internationalisation, their main need is for specialised assistance in legal and administrative issues in foreign countries. Their other needs, however, are more directly related to the start-up aspect of their activities, though they appear to be better equipped to access such support than is the case for most other SMEs.

Game-changing technologies

The five game-changing technologies studied are: advanced industrial robotics (AIR), additive manufacturing (AM), industrial Internet of things (IIoT), electric vehicles (EVs) and industrial biotechnology (IB). The first three, but also to a lesser extent the other two, are potentially transformative, mainly due to the centrality of data. Other relevant aspects are the acceleration of flexible specialisation and servitisation in manufacturing. All of these technologies have some existing commercial application, but the degree of technological readiness varies among both the technologies and their adoption in sectors. While there is limited concrete information on their use in practice, much less on projections of potential market size, it would appear that their use is not currently widespread and is concentrated in highly productive firms. However, for various reasons – not least the digital commonality of these technologies that allows their wide synergetic application both along the supply chain

and in various sectors – one might expect that when adoption starts in earnest, it will advance rapidly, and indeed this may just be the case currently.

Given the transformative potential of digital technologies, their adoption in companies generates significant coordination issues. The systemic approach is best exemplified by the German Industrie 4.0 strategy. This has a very broad-based stakeholder and expert involvement with a broad remit with regional structures, and it integrates a number of wider policy fields such as vocational education and training. None of the other overarching initiatives identified in this research have the scope of the German one. The fundamental role for policy is the establishment of various future frameworks to provide some degree of certainty to which companies can orient their investment strategy. These include issues such as standards, future policy declarations and targets, and strategic public investment. The latter is viewed as particularly important and is generating much current policy discussion where the importance of gaining an initial leading position in the commercial application of strategic technologies is seen in light of global competition from the US and especially China.

This was expressed in the February 2019 Franco-German Manifesto for a European industrial policy fit for the 21st century (Bundesministerium für Wirtschaft und Energie, 2019a). The manifesto recognises that global competitiveness is crucially related to the emerging game-changing technologies and calls for massive investment in ‘disruptive innovation’ within the framework of the European Innovation Council, with the goal of supporting ‘very high-risk deep tech projects at the European level’. In concrete terms, it proposes identifying a consortium of firms, including car manufacturers, to establish a second IPCEI for a new generation of batteries for EVs. This is also reflected in the German National Industrial Strategy 2030, announced also in February 2019 (Bundesministerium für Wirtschaft und Energie, 2019b).

Digital technologies and employment

There is widespread concern among Europeans about job losses resulting from the emerging digital technologies, and there have been numerous forecasts of massive job losses, not least in manufacturing. Taking a narrow technical approach to the substitution of workers by machines should raise doubts about the predictions of net employment effects in the next decade. The job loss estimates take little account of the economic rationale for the substitution at firm level or the macroeconomic feasibility of the scale of capital investment that would be required to replace workers by machines to an extent consistent with the estimates of job loss. Moreover, the historical evidence suggests that employment growth goes hand in hand with technological development. There are many potential job creation effects when technology increases

productivity. Most obviously, this leads to an increase in the demand for this new technology and, in turn, to an increase in the demand for labour in technology firms. The really significant job creation effects, however, depend upon how the productivity gains of new technology are distributed. The more they lead to lower prices or higher wages, the more demand is enabled and the more positive are the employment effects. They do not materialise to the same extent if the gains are retained as profit. This is not to say that the wider effects are necessarily all positive. For example, with considerable labour market frictions, the positive effects take longer to materialise. Also, the global competitive position is crucial. If it is primarily foreign firms that reap the benefits, then obviously domestic employment will not show appreciable gains. A global macroeconomic model used to estimate the effects of radical automation indicates that without some redistribution of profits, the positive employment effects only very marginally mitigate the massive initial job losses when machines replace workers.

Technological revolution and slow productivity growth?

It is indeed highly striking that perceptions of recent and impending technological change are occurring at a time when productivity growth, not least in manufacturing, is at a historical low point and with manufacturing productivity in the US declining – see Table 7 (p. 41). Although it was argued initially that various measurement errors, related to the measurement of the value of new products, led to underestimation of growth and productivity, there is a growing consensus this was not the case. It may be that productivity gains lie in the future as the game-changing technologies become more widespread. However, even if this is the case, it is highly relevant to note that the productivity growth that occurred with the first ICT boom (associated with the rise of the big US tech companies) up to the mid-2000s was small and short-lived. No doubt the robots of the future will be able to perform extraordinary tasks, but currently their commercial application appears limited.

Nevertheless, even if this more *evolutionary* story is probably more credible than the *revolutionary* one, the realities of international competition, not least for sectors where Europe has currently a strong comparative advantage, make the adoption of productivity-enhancing technologies in manufacturing an absolute imperative.

Environmental technology and employment

The macroeconomic model finds that a full implementation of the Paris Climate Agreement in Europe is projected to increase GDP by 1.1% and employment by 0.5% by 2030. The most positive results for both these measures are found in China and the EU.

The US, however, experiences negative effects. While overall the energy scenario implies more employment in Europe, much of the employment created is at the bottom and the middle of the wage distribution. These jobs, to a greater extent than in the baseline forecast, are filled by lower-educated employees and involve performance of less advanced tasks.

Some of the key modelling assumptions have important policy implications. Firstly, the model assumes no labour market frictions. In particular, the labour force is assumed to adapt to the structural change in skill requirements associated with the transition to a low-carbon economy: the faster the change, the more likely it is that there may be frictions that leave some workers unemployed and some demands for new skills unmet, preventing the full potential benefits from being realised. Moreover, the appreciable investment required assumes that there are no barriers in accessing the finance necessary for investments needed in this transition. Finally, it is assumed that countries which currently have a lead in certain sectors are able to maintain this when switching to new technologies, for example, the main manufacturers of conventional cars and trucks become the main manufacturers of EVs and their components.

Changing task structure of manufacturing employment

A very striking feature of manufacturing employment since 2011 is the growth of well-paid, mainly white-collar, jobs. A study of how quantitative estimates of compositional changes in employment in sectors and occupations up to 2030 will impact on the tasks performed in all jobs in Europe shows a decline in physical and routine tasks as well as working with (non-ICT-related) machines. All social and intellectual tasks are expected to be more prevalent. Working with (particularly basic) ICT and tasks involving business literacy and those related to selling and persuading are expected to increase. All these trends are attributable to the projected sectoral shifts and not to changes within occupations themselves.

Case study evidence of change within some blue-collar manufacturing occupations suggests that the trends attributable to compositional changes will be accentuated due to similar trends within occupations. The case studies highlight a move towards intellectual tasks involving information processing and problem-solving. While digitalisation is seen to be one major driver of these trends, the increasing prevalence of quality control and standards is emphasised as another significant factor. This requires, in particular, better numerical and literacy skills. This is attributed not only to regulation but also to consumer demand and the increased complexity and integration of production systems. Despite quantitative projections indicating a decline in the dexterity dimension of

physical tasks, these case studies suggest this is still an important part of work, notably when operating machinery.

Skills for advanced manufacturing

Many believe that facilitating the creation of a better-skilled workforce is the most important labour market policy issue arising from the emerging technologies. The skills predicted to be in demand in the future include those with the traditional engineering profile – process engineers, quality control engineers and chemical, electronic, mechanical or mechatronic engineers. Newer skill sets – notably those of industrial data scientists, ‘big data’ statisticians/mathematicians and data security analysts – are also expected to be in high demand due to the increasing data-intensiveness of production processes. The centrality of data and information in production is at the heart of the paradigm change embodied by the game-changing technologies, and so the most sought-after general profile is likely to include some combination of engineering and ICT skills. The required technical skills vary considerably among the technologies, and interested readers should consult the five published technology working papers for a wealth of detail (see Annex, p. 65).

Other skills frequently cited include independent decision-making and creativity, as decentralised production processes may require rapid intervention in cases of malfunction and will require not only extensive knowledge of technical processes but also leadership and problem-solving skills. Social and communication skills are also expected to be more important as many of the game-changing technologies straddle different, quite specialised technical domains, necessitating interdisciplinary collaboration between team members and departments as well as external service providers. The research also emphasises the importance of clear communication in ever more complex production environments. The capacity to work in teams will, therefore, be essential, as will adaptiveness, as individual specialists will be contributing to many different project teams.

The high-end technical skills mentioned above dominate the discussion on future skills for advanced manufacturing. However, almost 60% of employment in manufacturing is still in occupations that could be classified as blue-collar. While of course blue-collar work has developed for decades to be more like white-collar work, many of the high-end technical skills envisaged do not have the same relevance for the majority of employees in manufacturing. It is generally acknowledged that dual apprenticeship systems have been the best means of providing highly relevant skills for blue-collar occupations in manufacturing.

The predicted acceleration of new and higher skills needs, also for blue-collar workers, sets new challenges for even the best-performing apprenticeship systems. The apprenticeship country studies show that the approach taken (for example, in Denmark and Germany) has not been the adoption of new occupational profiles but rather the adaptation of existing ones, mainly by introducing basic ICT skills in all existing occupational profiles and by providing optional specialisations within various initial apprenticeship profiles. When new occupational profiles have been introduced, the take-up rates have been low.

Given that the emerging technologies require not just new skills but significantly deeper or advanced skills, there is potentially a greater role for third-level education institutions focusing on vocational skills in general. There are moves towards more dual study programmes where a degree is awarded by a tertiary education body with some involvement of companies. However, these do not have some of the features that are seen to be important factors for success in the best-designed initial apprenticeships, not least the lack of national frameworks and quality control and the involvement of social partners. The country studies also show that the issue of progression from initial apprenticeships to higher education is still largely unresolved.

Working conditions and industrial relations

There is appreciably less evidence available on the possible implications of new technologies for working conditions and industrial relations. However, there is much to suggest many beneficial consequences of automation for working conditions, essentially by removing arduous and potentially dangerous physical tasks. There are, however, a number of health and safety issues related to specific technologies. Another concern arises from the amount of highly detailed data on the work of individual employees generated by new technology, which could lead to unacceptable degrees of monitoring and control, both in terms of personal integrity and surveillance in the workplace.

While this report suggests that the impact of new technologies on employment levels may not be as great as many have predicted, there will be some loss of jobs. In addition, there will certainly be highly significant implications for work organisation and skills needs. Previous experience of large-scale structural change shows that this should be anticipated and managed. This is the most critical issue for social dialogue in the context of the future of manufacturing. It requires well-functioning social dialogue at the firm level in terms of information and consultation, as well as the active and responsible involvement of social partners in the strategic orientation of industrial policy at all levels.

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Annex: Project summaries and publications

This annex provides a brief summary of all the modules studied as part of the pilot project on the Future of Manufacturing in Europe. A complete list of publications is included for each module. Further details are available at the pilot project website: www.eurofound.link/fome

Mapping of regional industrial policy capacity

Project managers: Irene Mandl and Stefanie Ledermaier

Background

Manufacturing is much more regionally concentrated than other economic activities. Thus, it is important to examine the effects of developments in the manufacturing sector on regional economic areas and labour markets in order to design and implement suitable regional policies.

Previous research highlights that successful approaches to local economic and employment development, including structural change and restructuring, are characterised by: the involvement of a wide range of (regional) actors; a variety of measures; and coordinated implementation that takes into consideration the particularities of the region. This points to the challenges involved in designing and realising future-oriented regional policies. While it certainly is the case that some regions do have the knowledge and institutional capacity to orient their policy strategies and instruments towards sustainable economic structures and labour markets, taking into account their core industrial activities, this is by no means the case throughout Europe.

Objectives

The aim of this research is to map the existing industrial policy capacity in selected EU regions, identifying elements and processes of regional policy design and implementation as well as pinpointing good practices.

In this context, 'regional industrial policy' refers to the set of strategic measures targeted at improving the competitiveness of the regional economy, taking into consideration the specific characteristics of the region. It addresses the institutional and business environments, the structure of economic activity and the labour market to prepare the region for future developments so that economic growth and societal

welfare can be realised. Regional industrial policy capacity is the combination of the actors involved (and the coordination/cooperation among them) and the applied strategies and instruments in various policy fields that might be relevant in individual cases.

Methods

The study is based on an analysis of eight European regions characterised by the high importance of manufacturing. In addition, to enrich the information gathered, a non-manufacturing region was explored. For each of these regions, the study explored the scope and objectives of the regional industrial policy, the related policy governance, implementation and monitoring/evaluation practices. This was done via a qualitative approach that involved document and data review as well as regional stakeholder interviews. This information was supplemented by information gathered in a more general (that is, not specific to the selected regions) literature review. Following on from that review, and based on a predefined set of 'good practice criteria', success factors for sound regional industrial policy were identified, including the preconditions that needed to be in place to allow for transferability.

Main findings

Although the term 'industrial policy' is widely recognised and acknowledged in Europe, it is not explicitly defined in regional policy documents. In general, regional industrial policy consists of a range of policy areas and takes into account the policy challenges specific to the region. Innovation, clusters, SMEs and entrepreneurship are referred to most commonly, while, notably, higher education and vocational training are not directly addressed. The design and implementation of regional industrial policy is characterised by a multistakeholder approach. High levels of joint understanding and buy-in by local stakeholders are increasingly facilitated by broad and open consultation processes as well as strong coordination mechanisms. The 'good practice elements' identified in regional industrial policy include: clear and transparent setting of objectives, multistakeholder activation and cooperation (including industry dialogue), mechanisms for rapid development of advanced manufacturing technologies, effective use of policy intelligence and policy learning approaches beyond the region.

Publications

Overview report:

[Developing regional industrial policy capacity](#)

Related working papers:

Baden-Württemberg case study

Catalonia case study

Lombardy case study

North-Brabant case study

Pays de la Loire case study

Pirkanmaa case study

Pomorskie case study

Sardinia case study

West Romania case study

Literature review

Additional material on case studies and selection criteria

Impact of new game-changing technologies

Project manager: Enrique Fernández-Macías

Background

Digital technology is changing manufacturing. Changes falling under the heading of ‘Industry 4.0’ describe a set of technologies which are likely to bring about deep transformations in the production process. Advanced robots, networked machines and artificial intelligence will be combined to generate new products and new ways of making products. This will have consequences for work organisation and for employment at establishment level as well as in terms of skills demands. It will also impact on the structures that regulate relationships between social partners in specific sectors.

Objectives

The project aims to examine the potential impact of new technologies – the ‘game changers’, or disruptors – on manufacturing in Europe, focusing on the period from 2017 to 2025. Case studies of game-changing technologies were carried out to allow stakeholders to anticipate and address the impact of these technologies on production processes, working conditions and social dialogue. Five technologies were examined: advanced industrial robotics (AIR), additive manufacturing (AM), the industrial Internet of things (IIoT), electric vehicles (EVs) and industrial biotechnology (IB).

Methods

Each of the five case studies started with a literature review. Because the phenomena in question are quite recent, the reviews relied on academic articles together with other literature such as reports prepared for policymakers and industry associations and reports prepared by consultants. The Scopus database and Google Scholar were used to identify articles and reports containing relevant keywords, with an emphasis on material published from 2013 to 2016. Subsequently, interviews were conducted with 30 leading experts, covering each of the game-changing technologies from a variety of perspectives (industry, research and policy). A detailed interview guide was used to ensure that the three main parts of the study (technology, production process and work/employment) were covered. The third and final step consisted of five regional workshops (one for each technology) with representatives from companies and cluster organisations as well as researchers and other stakeholders.

Main findings

A number of (tentative) conclusions can be derived from this analysis of the likely impacts of game-changing technologies on production and employment in the manufacturing sector in Europe up to 2025. Perhaps most importantly, production processes will become increasingly digital and less mechanical. All the game-changing technologies studied rely on a huge expansion of data flows and have particular requirements for data manipulation and analysis. Digitisation is expanding possibilities to: design and test products or processes virtually (simulation); repair industrial apparatus remotely; and automate the constant fine-tuning of processes. These changes are likely to accentuate an existing trend which has seen value added in manufacturing expand at either end of the product life cycle – initial design and R&D at one end and marketing and post-sales service at the other – rather than during the physical mass production process itself. They also imply a further shift in employment demand in manufacturing away from traditional production line work to increasingly higher skills profiles, including specialisations such as industrial data scientists, encryption experts and network security analysts. Demand for the combination of engineering and data/statistical skills is especially likely to grow strongly. The specialist nature of many of the game-changing technologies will, however, increase the importance of project work or teamwork as well as good management, implying a growing need for ‘soft’ communication skills.

Competitiveness in manufacturing will probably be based less on the cost of the labour force and more on the capacity to automate and control production processes (that is, AIR, AM and IIoT; although this is also relevant for EVs and IB). This sets the scene for some reshoring to Europe of production previously offshored

on labour cost grounds, although the direct employment benefits from such reshoring is likely to be modest. Overall, the impact on employment levels is uncertain: there will be considerable replacement of labour by technology; however, as has been the case in previous experiences of significant technological innovation, the net effect can be positive. The potential for job creation is closely related to the distributional outcomes of the productivity gains and the demand generated for the new products and services.

The data-intensive nature of production entails new sets of risks at both company and employee levels. For companies, managing data – and, in particular, data security vulnerabilities – will become much more important (and potentially business threatening if not done correctly). Meanwhile, expanded data flows on individual employee performance raise the spectre of intrusive monitoring, surveillance and breach of privacy – concerns that have been noted by worker representatives. Potentially, many of the game-changing technologies will have positive impacts on the working environment (for example, more automation of ‘dirty’ processes) and environmental benefits in terms of greater material efficiency and reduced emissions. In the context of global environmental and energy sourcing challenges, this will provide additional impetus to invest in such technologies (including public investment), most obviously in the case of EVs. Sectors that are currently at the forefront in terms of adoption of the game-changing technologies studied here tend to be highly capitalised and already technology rich. However, applications are increasingly being identified in comparatively low-technology sectors, including clothing and food manufacture. The challenge remains to broaden the potential benefits across value chains, including to SMEs. The adoption and observance of industry standards and protocols will be essential to ensure interoperability across production units, whatever their size.

Publications

Overview report:

[Game-changing technologies: Exploring the impact on production processes and work](#)

Related working papers:

Additive manufacturing: A layered revolution

Advanced industrial robotics: Taking human-robot collaboration to the next level

Electric vehicles: Shifting gear or changing direction?

Industrial biotechnology: Changes in supply chains and skills needs

Industrial internet of things: Digitisation, value networks and changes in work

Associated publications

Social dialogue and game-changing technologies in manufacturing, in *All Tomorrow's Jobs: How robotics and new technology can create better work*.

Analysis of the task content of significant manufacturing jobs

Project manager: Enrique Fernández-Macías

Background

The task content of occupations is continuously changing, reflecting the introduction of new technologies in production and new forms of work organisation. Such changes in the task content of occupations pose important challenges for societies: many workers whose skills have become obsolete may find it difficult to update them and, as a result, face unemployment or downward mobility; education systems may struggle to keep up with the changing requirements of the economy; and existing employment regulations and industrial relations systems may be less effective or not as well adapted to the new working environments and conditions. For these reasons, it is critical to monitor and to understand changes in the task content of occupations. While a quantitative approach is useful to provide broad overviews of the task content of occupations across Europe, this does not allow for the consideration of context, which is necessary to understand the process of change in the task content of occupations and its drivers and implications. A way to try to cover at least some of the gaps in the existing quantitative information is to complement it with a qualitative approach.

Objectives

This project aims to provide better understanding of changes in the nature of key manufacturing occupations in Europe in recent years as a result of factors such as technology, market changes, policy and regulation, as well as their implications for employment, tasks and skills, job quality and industrial relations. The study provides a qualitative perspective on recent changes in Europe in the content and nature of five manufacturing occupations: meat processing workers, hand packers, car assemblers, chemical plant machine operators and inspection engineers. It explores these occupations across four countries (Germany, Italy, Sweden and the UK) covering different European regions, and tries to identify interactions between the task content of occupations and contextual aspects, such as policies and regulations, market structures and industrial relations systems.

Methods

The five occupations were analysed in the four target countries via selected companies. A total of 20 occupational case studies were produced, each based upon extensive desk research and in-depth interviews with workers, line managers, trade association representatives and trade union representatives. Each occupational case study includes analysis of the contextual factors affecting the task content of the occupation in the specific country along with analysis at company level.

Main findings

The overview report summarises findings from the 20 case studies looking at recent changes in the task content of the five selected manufacturing occupations as a result of factors such as digital transformations, globalisation and offshoring, increasing demand for high quality standards and sustainability. It also discusses some implications in terms of job quality and working life.

Tasks in all five occupations studied have evolved quite significantly in recent years, whether in response to technological change, market forces and consumer needs, or regulations. The study reveals that: the importance of physical tasks in manufacturing is generally declining due to automation; the more intensive use of digitally controlled equipment, together with increasing importance of quality standards, involves a growth in intellectual tasks among manual industrial workers; and the amount of routine task content is still high in the four manual occupations studied, both in terms of repetitiveness and standardisation, despite the argument often found in the literature that computers are increasingly replacing these tasks.

Publications

Overview report:

[New tasks in old jobs: Drivers of change and implications for job quality](#)

Related working papers:

Car assemblers: Occupational report

Chemical products plant and machine operators: Occupational report

Hand packers: Occupational report

Meat processing workers: Occupational report

Inspection engineers: Occupational report

Associated publications

[Are blue-collar jobs turning white?](#)

Review of dual apprenticeship programmes

Project manager: Massimiliano Mascherini

Background

This research on apprenticeships in manufacturing and advanced manufacturing was carried out in response to the increasing interest of EU and national policymakers in apprenticeships as a way to tackle the generally high levels of youth unemployment and to integrate young people into the labour market. It is, however, essential to ensure that any initiatives undertaken in relation to apprenticeships correspond to the needs of the labour market and the ways in which new technologies are transforming work organisation and production processes across all sectors, particularly manufacturing. Five EU Member States (Denmark, France, Germany, Ireland and Italy) and two non-EU countries (Australia and the US) are included in this research. These countries were selected due to the importance of advanced and high-tech manufacturing for their national economies and labour markets and because of the prominent role of apprenticeships within their vocational education and training (VET) systems.

Objectives

This research is divided into two projects, each with specific objectives. The main objectives of the first project are to provide an overview of apprenticeship systems in the selected countries and to review policy developments in response to labour market shifts, changes in employment, career and mobility patterns and technological and structural changes. The main objective of the second project is to investigate the actual implementation and adaptation of apprenticeship programmes, particularly in advanced manufacturing, at the level of company, industrial district or regional cluster. The aim is to identify innovative practices but also to assess the resilience and flexibility of the prevailing national apprenticeship models in the sector, which is challenged by the fast pace of technological change and requirements for new skills.

Methods

The research draws from an extensive review of a range of sources including policy documents, academic studies and policy research carried out by national experts in the selected countries. This desk research was underpinned by between four and eight in-depth interviews per country with key stakeholders representing public authorities, employer organisations, trade union organisations, training providers and research institutes. Company practices were selected and studied by means of qualitative interviews with company representatives, VET researchers and training institutions.

Main findings

Apprenticeships are long established in manufacturing and are attractive for both employers and young people because of the balance between theoretical and practical education that they offer.

The first project finds, however, that in several of the countries studied, apprenticeships are lagging behind changes in manufacturing, and the full potential of good-quality apprenticeships is not being realised by either industry or the labour market. With the exception of Germany and Denmark, the link between industrial policy initiatives and initial vocational education and training and apprenticeship policies is relatively weak. The approach to modernising and adjusting apprenticeship training to new skills requirements in manufacturing varies between countries. In some countries, however, this is hampered by the absence of national governance structures or weak involvement of social partners.

The second project confirms the variety of national apprenticeship contexts analysed in the first project, but also identifies some similarities, such as the urgency for adjustments to existing curricula and programmes resulting from new disruptive technologies (except in Ireland, where new apprenticeship programmes have been created) and the need for ‘higher’ apprenticeship and VET programmes able to compete with academic pathways. Proactive local and regional industrial policies aiming at strengthening the new technologies have been key promoters of new initiatives and good practice among companies and VET institutions (as shown by the French, German and Italian cases). Such regional and local networks have been much weaker in Australia and the US, where individual companies in close cooperation with VET institutions have been the main promoters of innovative and new practices. A firm commitment from the key actors involved, including top management of companies, to invest in VET systems and apprenticeships emerges as one of the key success factors for adjusting and modernising apprenticeship programmes in advanced manufacturing.

Publications

FIRST PROJECT

Overview report:

[Adaptation of national apprenticeship systems to advanced manufacturing](#)

Related working papers:

Australia: Policy developments on apprenticeship
Denmark: Policy developments on apprenticeship
France: Policy developments on apprenticeship
Germany: Policy developments on apprenticeship
Ireland: Policy developments on apprenticeship

Italy: Policy developments on apprenticeship

United States: Policy developments on apprenticeship

SECOND PROJECT

Overview report:

[Company initiatives to align apprenticeships to advanced manufacturing](#)

Related working papers:

Modernisation of dual apprenticeship training at ABB – Germany

Innovative practices at Airbus Operations in Hamburg – Germany

Talent Tracks for gifted industrial apprentices – Denmark

Knowledge centres for robot technology and automation – Denmark

Jules Verne Manufacturing Academy – France

Job and Qualification Campus in transport – France

‘New’ apprenticeships in the light of technological change – Ireland

Modernisation of a designated craft apprenticeship – Ireland

Bosch Industry 4.0 Talent Program – Italy

Higher Apprenticeship in Advanced manufacturing – Italy

Siemens higher apprenticeship pilot programme – Australia

Varley Group: Modernising apprenticeships – Australia

Adjusting apprenticeship at Oberg Industries – United States

Mechatronics Apprenticeship Program of Festo Didactic – United States

Born globals and international supply chains

Project managers: Irene Mandl and Valentina Patrini

Background

Small and medium-sized enterprises (SMEs) are widely acknowledged as the ‘backbone of the European economy’, providing an important contribution to GDP and employment. In spite of the fact that international activity is, in general, positively related to firm performance, the share of SMEs engaged in international activities is limited compared to the share of large companies. Also, there is considerable heterogeneity among SMEs regarding their internationalisation intensity, modes and target markets.

Objectives

This research focuses on a subgroup of internationally active SMEs: born globals. These companies, which engage intensively in international activities soon after start-up, have been found to outperform other young firms in economic and employment terms. Furthermore, as they tend to be involved in international business networks, their success might have knock-on effects for other businesses. As there is little information on their specific roles in global supply chains and the effects of this cooperation, this is the main research question for this project. Furthermore, the factors driving and hindering the international activities of born globals, along with potential support needs, are investigated.

Methods

The study is based on a combination of three methodological approaches: a literature review covering the engagement of SMEs, and specifically born globals, in internationalisation (for example, extent, modes, influence factors, outcomes), the relevance of global value chains in the context of globalisation and the EU policy approach towards internationalisation by SMEs; seven in-depth case studies of one born global enterprise and at least two of their global value chain partners, investigating the characteristics, drivers and barriers and effects of this cooperation; an analysis of 28 internationalisation support instruments from 16 countries in Europe and beyond, illustrating delivery mechanisms and the effectiveness of such interventions.

Main findings

The study finds a broad diversity of international engagement in global value chains among born globals and significant impact of cross-border cooperation on the performance of the firms involved. Among the identified challenges for internationalisation are the complexity of regulations and administrative burdens, national differences in product certification, differences in institutional settings and business practices, difficulties in managing international partnership relations and lack of financial and human resources. In response to these challenges, European policymakers are offering a wide range of support measures for internationalisation in SMEs. The main factors associated with policy success are related to flexibility and comprehensiveness of interventions, tailor-made approaches to business needs and low administrative requirements. Networking facilitation and access to finance are in high demand. The lack of robust evidence on the effectiveness of available support is a fundamental weakness as this hinders further measures for development in the light of experience and learning.

Publications

Overview report:

[Born globals and their value chains](#)

Related working papers:

Blue Ocean Robotics – Value chain case study

Comodule – Value chain case study

Frog Bikes – Value chain case study

Graphenea – Value chain case study

Khar & partners – Value chain case study

KristallTurm – Value chain case study

Recornect – Value chain case study

Related policy measures:

Incubator Support – Internationalisation policy measure (Australia)

Go Silicon Valley – Internationalisation policy measure (Austria)

Communication Support – Internationalisation policy measure (Belgium)

Global Growth Competencies – Internationalisation policy measure (Denmark)

Innovation Centre Denmark – Internationalisation policy measure

VITUS – Internationalisation policy measure (Denmark)

Development of Clusters – Internationalisation policy measure (Estonia)

Startup Estonia – Internationalisation policy measure

BMW-Markterschließungsprogramm – Internationalisation policy measure (Germany)

Start Alliance – Internationalisation policy measure (Germany)

100% Made in Italy certificate – Internationalisation policy measure

FINEST SpA – Internationalisation policy measure (Italy)

Regional Industry Tie-up Programme – Internationalisation policy measure (Japan)

SMEs CEO Network Enhancing Project – Internationalisation policy measure (Japan)

Foreign Investment Ombudsman – Internationalisation policy measure (Korea)

Grant scheme DHI – Internationalisation policy measure (Netherlands)

Matchmaking Facility – Internationalisation policy measure (Netherlands)

- Chamber of Commerce and Industry – Internationalisation policy measure (Romania)
- Global Lehian – Internationalisation policy measure (Spain)
- ICEX-Next – Internationalisation policy measure (Spain)
- International Mobility Law – Internationalisation policy measure (Spain)
- Spain Tech Centre – Internationalisation policy measure
- Born Global – Internationalisation policy measure (Sweden)
- High Value Opportunities – Internationalisation policy measure (UK)
- IP Attaché Network – Internationalisation policy measure (UK)
- Open To Export – Internationalisation policy measure (UK)
- Startup Global – Internationalisation policy measure (United States)
- Born globals and their value chains: Literature review

European Reshoring Monitor

Project manager: John Hurley

Background

Reshoring is the relocation of previously offshored value chain activities (particularly production, sourcing, R&D and services) back to the EU. It may represent a key trigger to revamp the EU's manufacturing industry over the coming years, restoring the EU as a global location of excellence in manufacturing. The European Reshoring Monitor project team consists of a network of Italian university researchers with an established record in reshoring research (Uni-CLUB MoRe), supported by the media monitoring company M-brain.

Objectives

The main objective of the project is to monitor the evolution, magnitude and motivations of reshoring. This is of paramount importance in understanding the drivers of reshoring decisions, learning how reshoring is implemented and evaluating the role of policy in encouraging the phenomenon.

Methods

The European Reshoring Monitor relies on media monitoring as well as screening of relevant policy and academic literature to identify and describe (in summary) reshoring cases. It also identifies reference materials, including relevant research articles and reports and policy initiatives. The cases collected include: companies that reshore to their home country (within the EU) value chain activities previously offshored to another country; and companies that reshore to any EU/European Free Trade Association (EFTA) country value chain activities previously offshored to a non-EU country. Reshoring cases and relevant research were edited and published directly to a Eurofound-hosted website.

Main findings

In total, the monitor recorded 253 cases of reshoring over the period from 2015 to 2018. The employment effects of reshoring were indicated in only around 40% of cases due to limited media reporting on this aspect. In aggregate, the cases involved the creation of 12,840 new jobs. Manufacturing cases predominated (85% of the total) with especially high frequencies in relatively low-tech manufacturing sectors (29% in clothing/apparel, 24% in food products). Large companies accounted for the majority of cases (around 60%). An increasing range of sectors experienced some form of reshoring over the period.

The incidence of reshoring increased from 2015 to 2017 before declining in 2018 – though this may be due, in part, to lags in reporting. The three Member States with the highest number of reported cases were France, Italy and the UK, but case numbers picked up notably over the period of analysis in the Nordic countries and in eastern Europe. By some margin, the biggest country from which reshoring to Europe took place was China, though Poland and India accounted for a growing share of cases in 2017–2018.

As far as the motivations for reshoring decisions are concerned, the two most frequent reasons cited were 'global reorganisation of the company' and 'delivery times'. Cost and quality factors, which were the dominant factors in the first wave of reshoring, have given way to factors linked to the global reorganisation of value chain activities, the need for customer responsiveness (delivery times) and new technological developments (automation and digitalisation).

Publication

Report:

[Reshoring in Europe: Overview 2015–2018](#)

Associated resources

A website with details of the project and a database of reshoring cases as well as relevant policy and academic references.

Scenarios for the future of manufacturing

Project manager: Donald Storrie

Background

The main challenges to manufacturing and employment in Europe are related to climate change, global protectionism and the possible radical automation of work due to the emergence of game-changing digital technologies. While all forecasts are associated with much uncertainty, the technology forecast in particular is rather speculative. Its value is that it outlines many of the factors that should be considered when evaluating the final effects of a large initial displacement of employees by technological change and makes an attempt to both quantify and model these factors. Moreover, it indicates that the somewhat dire assumptions of potential job loss from the mass introduction of digital technologies are somewhat mitigated when a fuller economic analysis comes into play.

Objectives

For all three scenarios – energy, trade and technology – the objective is to estimate the impact of the above-mentioned challenges to growth and employment in Europe. The focus is predominantly on employment levels. The disaggregation of results by country, sector, occupation and task structure of employment varies among the scenarios. The data for the energy scenario provide the highest degree of disaggregation, while data for the technology scenario are the most aggregated.

Methods

The E3ME model was used to estimate the effects of the three scenarios. This is a global macroeconomic model designed to address major economic and economy–environment policy challenges. Developed over the last 20 years by Cambridge Econometrics, it is one of the most advanced models of its type. It covers 59 global regions and includes a detailed sectoral disaggregation in each one. It is frequently applied at national level, in Europe and beyond, as well as in wider

(European and global) policy analysis. A further labour market analysis of the trade and energy scenarios was conducted using Eurofound’s European Jobs Monitor. Details of this can be found in Eurofound (2018a).

The assumptions used to generate the energy scenario are rather complex and detailed (see the Energy scenario report referenced below). The main modelling assumption of the trade scenario is a 25% increase in tariffs in agricultural and manufacturing goods between China, the EU and the US. These are implemented as a one-off, sustained change from 2019. In the technology scenario, the driving assumption is that of a large initial job loss amounting to, in one case, 17.2% and, in the other, 12.6% of all employment in Europe.

Main findings

The energy scenario shows that the transition to a low-carbon economy is positive for the EU as a whole, both in terms of GDP and employment growth. This is mainly attributable to the investment activity required to achieve such a transition, together with the impact of lower spending on the import of fossil fuels. The shift towards production of capital goods, such as equipment, machinery and buildings, results in an increased demand for construction and for labour from the associated occupations as well as increased demand for metal and machinery and related labour. The various estimates were presented in comparison to a largely ‘business as usual’ baseline forecast up to 2030. In the EU, GDP and employment show growth of 1.1% and 0.5% respectively. The most positive results in both these respects are found in China and Europe. The US, however, experiences a drop in GDP of 3.4%, with employment falling by 1.6%.

In the trade scenario, the headline finding is that while all the big three lose GDP from increased tariffs, the US loses much less than China and the EU. The obvious explanation for this is the trade surplus – primarily attributable to manufacturing – in China and the EU and the large deficit in the US. Other parts of the world see a GDP increase due to trade diversion effects. The EU-wide decline in GDP translates to a 0.3% fall in employment in the EU28 by 2030 compared to the baseline. Imports are also expected to decrease by 1.1% as a result of lower economic activity and, as a result, lower demand for goods. The impact on employment in the Member States by 2030 is similar to the GDP effect and is negative in almost every country, albeit on a smaller scale.

The technology scenario, which is somewhat speculative, shows one major empirical result that should be deemed reasonably credible, namely that while the net impact of the indirect employment effects is positive in Europe, it only marginally mitigates the

radical rate of the direct job loss due to automation that was the initial assumption fed into the model. It reduces net decline in employment by only a few percentage points: in the high-cost alternative, from 12.6% to 10.0%, and in the low-cost alternative, from 17.2% to 16.0%. However, distribution issues are critical in this respect as it is only in the scenario with some redistribution from capital to labour that the demand effects lead to indirect effects that reduce the net employment appreciably.

Publications

Reports:

Energy scenario: Employment implications of the Paris Climate Agreement

Trade scenario: Employment implications in Europe of a large increase in global tariffs

Technology scenario: Employment implications of radical automation

Associated publications

Skills forecast: trends and challenges to 2030 (in collaboration with Cedefop – European Centre for the Development of Vocational Training)

Wage and task profiles of employment in Europe in 2030

The pilot project The Future of Manufacturing in Europe is an explorative and future-oriented study. It explores the future adoption of some key game-changing technologies and how this adoption can be promoted, even regionally. The analysis of implications for working life focuses primarily on tasks and skills, not only at the white-collar, tertiary-education level, but also for blue-collar occupations, including a focus on challenges facing national and company apprenticeship systems. The future orientation also includes quantitative estimates of the employment implications of the Paris Climate Agreement, of large increases in global tariffs and of radical automation. It also measures the return of previously offshored jobs to Europe.

Other research examines how the deepening globalisation provides opportunities for small companies to engage in international supply chains. This final report summarises the 10 project reports, which are complemented by 47 case studies, 27 policy instruments and 4 associated publications.

The European Foundation for the Improvement of Living and Working Conditions (Eurofound) is a tripartite European Union Agency established in 1975. Its role is to provide knowledge in the area of social, employment and work-related policies according to Regulation (EU) 2019/127.

