4 How are megatrends transforming rural manufacturing?

This chapter examines challenges and opportunities that megatrends of globalisation, digitalisation, demographic and climate changes bring to rural manufacturing activities. Utilising more granular regional and sectoral data in 14 OECD countries, this chapter allows for deeper dives into the evolution of megatrends over time in the specific context of rural manufacturing. The chapter identifies some policy takeaways to help rural regions reap the benefits of each trend.

In Brief

How megatrends impact rural manufacturing

This chapter looks at several megatrends, including technology, digitalisation, demographic and climate change, and how they shape and transform manufacturing activities in rural regions. Megatrends are bringing both new challenges and opportunities. Technological upgrading is an important factor impacting rural areas with manufacturing hubs. Combining more granular data from selected OECD countries and data from the OECD regional database, the trends in technological intensity across types of regions reveal that:

- The employment share across TL3 region, as explained in Box 2.1 in Chapter 2, in 14 OECD countries is higher in rural regions in sectors that are considered less technically complex.
- The share of more technologically complex manufacturers in rural areas is growing. From 2008 to 2019, the average share of rural manufacturing employment in high-technology and medium-high technology industries increased from 5.7% to 6.4%.

Thus, the analysis confirms earlier results of a growing gap between high-technology firms advancing in productivity gains against the rest of the firms. This is also reflected spatially between metropolitan regions and rural ones, with metropolitan areas hosting more technologically intensive activities and showing higher productivity gains in these activities.

In terms of demographic challenges, the effects of population decline, and ageing are more pressing in rural regions. In this regard, automation may present opportunities to mitigate the effects of an ageing population and labour shortages. Increasing the participation of women in manufacturing activities can also alleviate the expected labour shortages foreseen.

In terms of the effects of climate change, more must be done to ensure that opportunities also emerge in rural areas across the manufacturing ecosystem. It will be necessary to close the digital gap that is currently present in rural regions.

Furthermore, rural economies disproportionally host some of the most carbon-intensive forms of manufacturing. In producing these materials, rural industries often contribute significant amounts of greenhouse gas (GHG) emissions. As such, rural regions are pivotal in the transition to a global net zero emissions economy and in building resilience to climate change. Rural manufacturers must find avenues to reduce their carbon footprint while maintaining efficient operations. Policy makers can provide targeted support to rural manufacturers to adapt and prepare for this transformational change by contemplating all aspects of the process, from inputs to operations and the products themselves.

Technology and rural manufacturing

A number of technological advances across a broad range of domains is changing the outlook of global manufacturing. International production fragmentation in manufacturing has led to a division of labour where OECD countries have become increasingly specialised in upstream activities like R&D, design, innovation, etc. while some emerging countries have become more specialised in manufacturing and assembly activities (De Backer, Desnoyers-James and Moussiegt, 2015[1]). Although certain manufacturing and assembly activities may result in a loss of innovative capabilities in the longer-term, OECD countries also face increasing competition from emerging economies in innovation, R&D, and higher value-added activities. Therefore, technological advances are becoming increasingly important to sustain competitiveness in manufacturing activities for OECD economies. Indeed, advancements in digital manufacturing, advanced robotics, bio- and nanotechnology, photonics, micro-and nano-electronics, new materials, amongst others are changing the industry and leading to a range of new business models for manufacturers.

As we look to the future of manufacturing, it becomes increasingly evident that the adoption of new technologies will play an even more vital role. For example, advanced manufacturing technologies allow for greater customisation, timeliness and opportunities for new innovation ecosystems (D'Aveni, 2015[2]). However, it is essential to recognise that this transformative trend is not currently being adopted uniformly across firms and regions across the OECD. In particular, there are disparities between rural and urban regions in their capacity to adapt and adopt technology, reflecting their different forms of innovation generation and absorption (OECD, 2022[3]). Improving the generation and adoption of technology in manufacturing activities will be critical to support productivity growth and competitiveness in rural regions over the long run, especially in those that are facing demographic challenges.

In this context, it is important to better understand the technological intensity of manufacturing activities in rural regions against their urban peers and how it has been evolving over time. The analysis, therefore, estimates the degree of technological intensity of manufacturing and two-digit manufacturing employment (see Annex 4.A) in Territorial Level 3 (TL3) small regions across regional types (see Box 2.1). Whilst this analysis is first and foremost carried out by grouping subsectors of manufacturing into technology groups, later aspects of the chapter examine the role of skills and climate change in rural manufacturing.

Technological intensity in manufacturing across OECD regions

Estimating technological intensity in manufacturing

As described in more detail in Box 4.1, we use a typology to categorise technology on the basis of research and development (R&D) expenditure as a share of the value-added incurred in the production of manufactured goods. Following this sectoral approach, manufacturing activities are grouped into "high-technology", "medium-high-technology", "medium-low-technology" and "low-technology". Whilst the OECD definition of technological intensity (OECD, 2003[4]) is similar, it requires access to more granular (three- and four-digit) industries, which was not available at the level of geography used in this report.

Box 4.1. Aggregation of manufacturing sub-industries according to technological intensity

Grouping of industries

Whilst numerous means of measuring technological intensity exist, this paper applies Eurostat's definition based on R&D expenditure.

Due to data limitations, the analysis does not employ more complex definitions based on resource use, labour intensity and degree of scale and differentiation (e.g. in Pavitt (1984[5])). We compare our methodology to an alternative method in Annex 4.B for the case of Norway where data are available at the three-digit industry level. The alternative methodology, Lall (2000[6]), considers a wide range of factors and takes account of product groups or clusters based on technological activity.

Mapping procedure

The body of the report categorises what is considered a technologically based on the two-digital level International Standard Industrial Classification (ISIC) Rev. 2 are related to four categories of technological intensity: high-technology, medium-high-technology, medium-low-technology and low-technology.

Following the Eurostat methodology, the manufacturing sub-industries are classified as below, fully expanded in Annex 4.A.2:

- High-technology: 21, 26.
- Medium-high technology: 20, 27-30.
- Medium-low-technology: 19, 22-25, 33.
- Low-technology: 10-18, 31, 32.

Source: Eurostat (2023[7]), *International Trade and Production of High-tech Products*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_trade_and_production_of_high-tech_products#Manufacturing_of_high-tech_products; United Nations Department of Economic and Social Affairs (United Nations Department of Economic and Social Affairs, 2008[8]) https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

Using this definition, we then assess the degree of technological intensity in manufacturing for each TL3 region using more granular data from the 12 OECD countries. This allows us to analyse how employment and gross value added (GVA) differ across these groups and to make comparisons between countries and regions within a country. Given data availability across the countries was not consistent, on some occasions, data were estimated. For more information on the detailed approach, see Box 4.2. The total sample of the estimate covers 914 regions across 12 countries[1] from 2000 to 2020.

Box 4.2. Data availability and approximation

Data collection process and description

Data on manufacturing employment and GVA for the manufacturing sector are composed at the TL3 level using the 2-digit level EU NACE and International Standard Industrial Classification of All Economic Activities (ISIC) Rev. 2), fully detailed in Annex 4.A. These data were collected directly from the national statistics offices in the following countries: Australia, Canada, Denmark, Finland, Germany, Ireland, Japan, Norway, Portugal, Slovenia, Sweden and Switzerland. For most, this took place over several years, which allows for a comprehensive analysis of change over time. A full breakdown can be found in Annex 4.A.

In cases where the industry categorisation did not clearly correspond to the ISIC Rev. 2 classification (e.g. Australia, Canada and Japan), the respective industries were mapped into the above-mentioned technological intensity classification based on three-digit ISIC categorisations and estimations.

On occasion, data were pre-aggregated by national statistics agencies for disclosure and confidentiality purposes. Whilst this does not impact the analysis of this report, it made it impossible to analyse each technology group's composition in these cases.

Establishment vs enterprise data

Given data were collected directly from National Statistics Offices, each country may differ in their definition of a "business unit". Statistically, what constitutes a business can fall into two broad categories, it can be an establishment or an enterprise. According to OECD/Eurostat (2007: 12), an enterprise (or firm) is defined as the "smallest combination of legal units […] producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more locations".

Local units (establishments), on the other hand, are enterprises or parts thereof (e.g., a workshop, factory, warehouse, office, mine or depot) situated in a geographically identified place. At or from this place economic activity is carried out for which – save for certain exceptions – one or more persons work (even if only part-time) for one and the same enterprise" (OECD/Eurostat, 2007: 86). This matters for regional statistics because it depicts where the activity of a business is taking place compared to where a company is registered. If the enterprise is used we may experience headquarter effects which may attribute employment and output to other regions where the headquarter is located.

In the sample of countries used in the analysis Switzerland provides data at both levels and the analysis uses establishment. We also use establishment data for the remaining countries. Data was provided by respective statistical offices broken down by TL3 and two-digit ISIC industry level.

Data approximation

In cases where some observations for some industries were missing but the data were available for neighbouring time periods, these observations were approximated. In total, the dataset comprises 66 503 observations (i.e. number of employed in a specific region, year and manufacturing sub-industry). Of these, 2 687 (4%) contained the value 0, and 10 117 (15.2%) were missing. The reason for the missing observations is that countries sometimes censor certain values due to data protection reasons. The distribution of missing observations in total number and relative share is as follows: Finland (731; 8.3%), Germany (4 324; 16.9%), Ireland (80; 22.7%), Portugal (3 455; 41.1%), Slovenia (1 280; 21.2%) and Switzerland (247; 4%).

Linear interpolations were utilised to approximate the missing values for three different cases: i) missing values in the first years; ii) missing values in the final years; and iii) missing values in the middle so that observations in the first and final years are available. In the fourth case, namely that all observations for a region and specific technological intensity are missing, analysis could not be carried out. As such, for each, the following process was undertaken:

- Case 1: The first available observation was taken and prior missing observations with this value replaced.
- Case 2: The last available observation was taken and the following missing observations with this value replaced.
- Case 3: The average of observations preceding and following missing observations was calculated, replacing the missing values.

This process resulted in:

- Finland: Reduction from 731 missing observations to 537 (8.3% to 6.1%). In 2020, this corresponds to 335 706 people employed across the country, compared to 337 110 according to OECD Regional Statistics (database), or 0.42% less.
- Germany: Reduction from 4 324 missing observations to 1 472 (16.9% to 5.8%). In 2020, this corresponds to 6 581 189 people employed across the country, compared to 7 342 000 according to the German Federal Statistics Office, or 10.36% less.
- Ireland: Reduction from 80 missing observations to 11 (22.7% to 3.1%). In 2020, this corresponds to 281 141 people employed across the country, compared to 261 740 according to OECD Regional Statistics (database), or 7.41% more.
- Portugal: Reduction from 3 455 missing observations to 308 (41.1% to 3.7%). In 2019, this corresponds to 745 505 people employed across the country, compared to 770 080 according to OECD Regional Statistics (database), or 3.19% less.
- Slovenia: Reduction from 1 280 missing observations to 672 (21.2% to 11.1%). In 2020, this corresponds to 204 493 people employed across the country, compared to 215 870 according to OECD Regional Statistics (database), or 5.27% less.
- Switzerland: Reduction from 247 missing observations to 50 (4% to 0.8%). In 2020, this corresponds to 679 919 people employed across the country, compared to 661 583 according to OECD Regional Statistics (database), or 2.77% more.

Overall, this resulted in a reduction from 10 117 missing observations to 3 050. Of these, almost half were in high-technology industries. This is due to confidentiality and low sample sizes. Because of this, there should be a slight downward bias for the share of high-technology employment in the countries with a large number of censored observations (e.g. Germany).

We measure this bias for the case of Germany by comparing the estimated figures in each of the four technology intensity groups, with the data provided by the Federal Statistical Office. The number of missing observations amount to 14.3% for high-technology manufacturing, 5% for medium-high technology, 1.8% for medium-low technology and 2% for low-technology manufacturing. Therefore, the data and indicators we estimated in Germany have a downward bias for high-technology manufacturing. This bias, however, is higher in non-metropolitan regions. The percentage of TL3 regions in Germany that are missing high-technology data amount to 1.6% in large metropolitan regions, 8.2% in metropolitan, 22.9% in non-metropolitan near a small city, 22.6% in non-metropolitan near a small city, and 25% in non-metropolitan remote regions. Therefore, the bias is more pronounced in non-metropolitan regions for the case of Germany, thus the results should be taken with caution. In order to mitigate this bias and the high number of small TL3 regions in Germany, the analysis applies a country-weight when calculating OECD averages of available data.

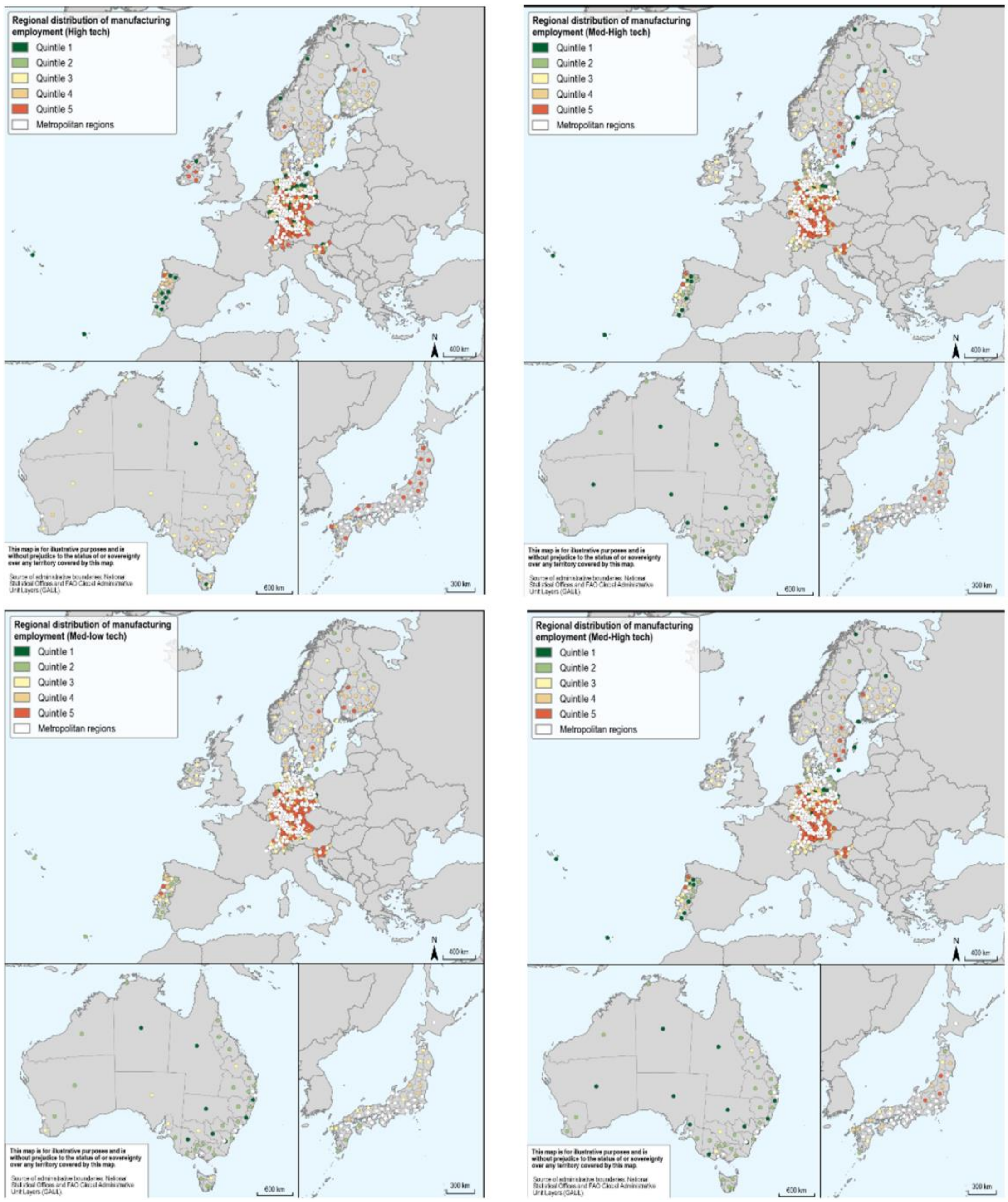
Source: Based on national statistics office data from Finland, Germany, Ireland, Portugal, Slovenia and Switzerland.

Technological intensity in manufacturing across OECD regions

Whilst there are variations amongst countries in their degree of technological intensity in manufacturing, there are also important variations inside countries between regions. Our sample of 914 OECD TL3 regions (based on the available more granular data) provides us with a basis to compare the degree of technological intensity across types of TL3 regions and measure trends over time. We first map the estimated levels of technological intensity in manufacturing to total employment in Figures 4.1 and 4.2 across 900 regions from Australia, Canada, the United States and across Europe. The maps reveal important variations that exist within countries in the share of employment in high-, medium-high-, medium-low- and low-technology manufacturing sectors to total employment.

Figure 4.1. Employment manufacturing by technology in Europe Australia and Japan, TL3 regions

Manufacturing employment in high, medium-high, medium-low and low-technology sectors to total employment in each TL3 region in selected OECD countries from Europe (2022), Australia (2016) and Japan (2016)

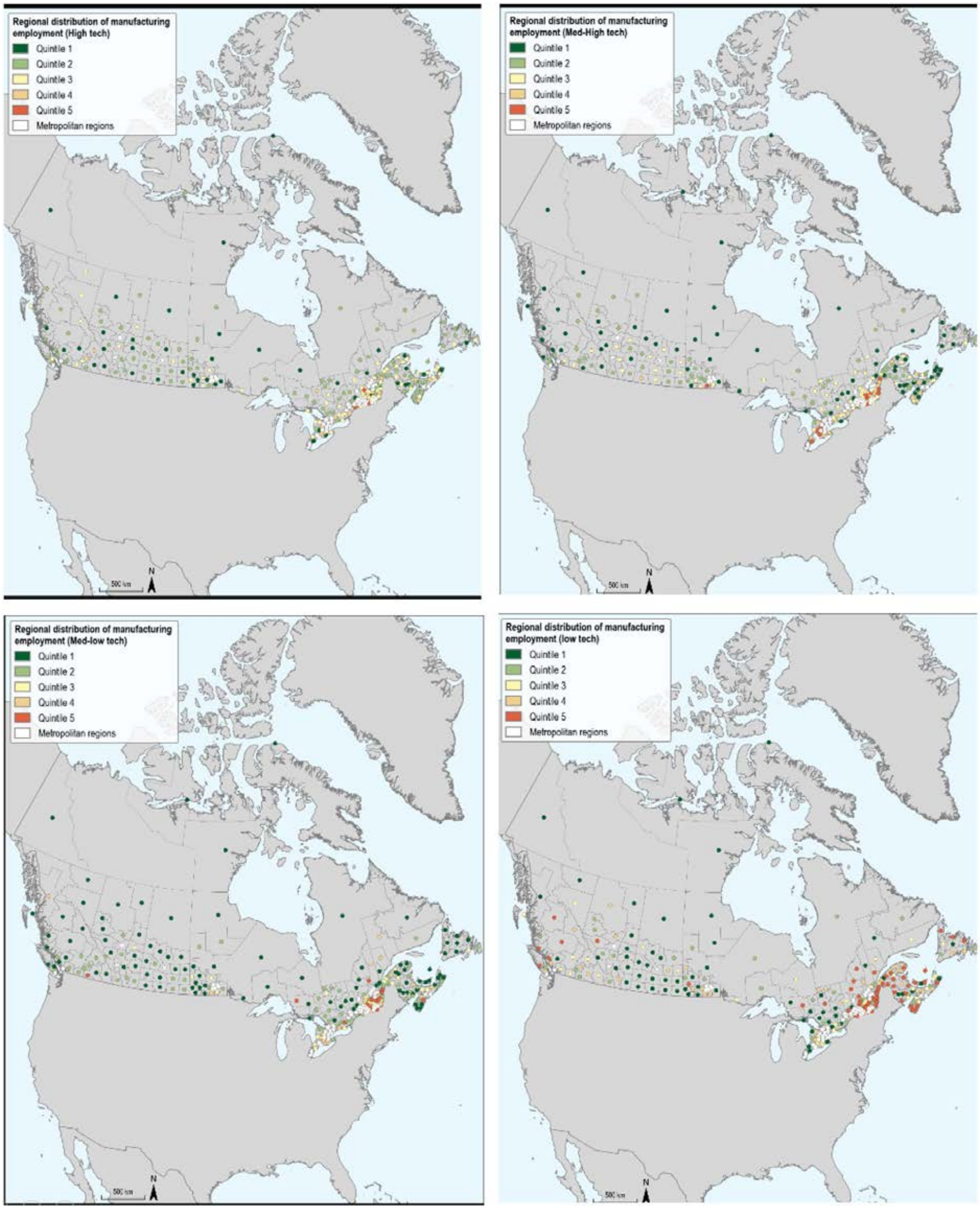


Note: The employment shares for each sub-industry in every country are calculated as the share of manufacturing each of the four technology intensity sectors to total employment in each TL3 region. Data from Australia, Canada, Japan are 2016. Switzerland, Germany, Finland, Denmark, Slovenia, Sweden, Portugal, Norway, Ireland data is 2020.
Source: Based on national agency statistics.

StatLink https://stat.link/ymhpfr

Figure 4.2. Employment manufacturing by technology in Canada, TL3 regions

Manufacturing employment in high, medium-high, medium-low and low-technology sectors to total employment in each TL3 region in Canada (2016)



Note: The employment shares for each sub-industry in every country are calculated as the share of manufacturing each of the four technology intensity sectors to total employment in each TL3 region.
Source: Based on national agency statistics.

StatLink https://stat.link/0dk2zt

As expected, the maps show high variation in their share of manufacturing technology to total employment across the sample of TL3 regions where data are available. Nonetheless, there are some interesting patterns emerging:

- Across Canada the average share of employment in low technology manufacturing is 4.6% as a share of total regional employment. Le Granit, QC and Maskinongé, QC were the regions with the highest share of low technology employment with almost 1 in 4 jobs (24%) in each region held here. Comparatively, the average share of employment in high technology manufacturing which is 0.06%. The region in fact with the highest share of high technology employment is the rural remote region of Brome-Missisquoi, QC with a share of 6.5% or 1740 people.
- In Australia, a range of clusters can also be partially identified, for example, medium high technology sectors are more prominent in northern and eastern territories than southern ones.
- More coastal regions of Japan have higher shares of low technology than more central regions but for high technology the patterns are more diverse.
- Amongst EU countries, the average regional employment in high technology manufacturing was 1.3% and closely aligned with the Swiss average of 1.6%. A notable exception can be made for Ireland where the average employment in high technology manufacturing was 3.3%.

Technological intensity in manufacturing inside OECD types of TL3 regions

The analysis next examines differences in technological intensity across different territories (e.g. between rural and urban). Differences can be driven by higher use of technology inside the firms or by overall higher technology in the region. Indeed, for the United States, there is evidence that the use of advanced technology is less prevalent in rural than in urban manufacturing plants. Still, plants of comparable size in the same industry use about the same level of technology. Some studies show that this gap was driven by a higher prevalence of low-technology firms in rural areas (Gale, 1997[9]). We next tested for differences in technological intensity across types of regions from our sample.

Our sample contains 914 regions, of which 115 are metropolitan large (MR-L), 230 metropolitan medium (MR-M), 199 non-metropolitan near a large city (NM-M), 79 non-metropolitan near a small city (NM-S) and the remaining 291 remote regions (NM-R). We tested for differences in technological intensity inside each of the five regional types and then compares them across regions. The analysis found the following:

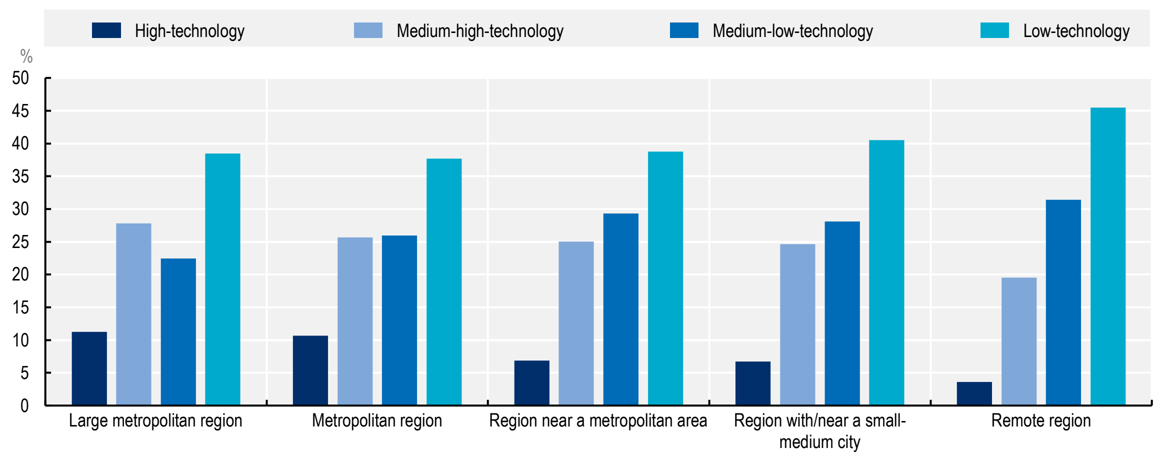
- The share of manufacturing employees in high technology is twice as high in metropolitan large (11.24%) and in metropolitan (10.65%) regions against the share in non-metropolitan regions (5.72%).
- The share of manufacturing employees in medium-high technology appears to be equally distributed in all types of regions except for remote regions, which appears lower (19.51%).
- The share of manufacturing employees in medium-low technology is lower in both metropolitan types of regions (22.46 and 25.97% respectively) than in the 3 non-metropolitan regions that held an average of 29.61%.
- Finally, the share of manufacturing employees in low-technology appears to be the same across all regional types except in remote regions, which is higher (45.49%).

In addition to this general finding, there are significant variations across countries that can somewhat be grouped based on their employment distribution characteristics (Figure 4.4). Ireland and Switzerland, for instance, consistently exhibit above-average levels of high-technology employment across all types of regions. Slovenia, on the other hand, shows below-average levels of low-technology employment across the board. The high-technology employment share tends to decline when considering the distribution from moderately rural to remote rural areas.

Interestingly, this lower share of high-technology sector employment does not necessarily correspond to a higher share in low-technology manufacturing employment. Instead, these regions demonstrate elevated levels of medium-high and medium-low-technology employment. It is important to note that having higher levels of high-technology employment does not necessarily mean that these countries have correspondingly higher levels of medium-high-technology or lower levels of medium-low-technology and low-technology employment. The overall employment picture varies considerably across countries and can allow for both high-technology and low-technology manufacturing simultaneously.

Figure 4.3. Share of manufacturing employment by technological complexity by TL3 region type

Share of manufacturing employment by five groups of technological intensity in each type of TL3 region, 2022 or the latest available year



Note: Geographical typology refers to OECD TL3 typology defining metropolitan (large MR-L and medium MR-M) and non-metropolitan regions (near a large city NMR-M, near a small city NMR-S and rural region NMR-R), for further details see Box 2.1.
Source: Based on information from national statistics offices from the following countries: Australia, Canada, Denmark, Finland, Germany, Ireland, Japan, Norway, Portugal, Slovenia, Sweden and Switzerland.

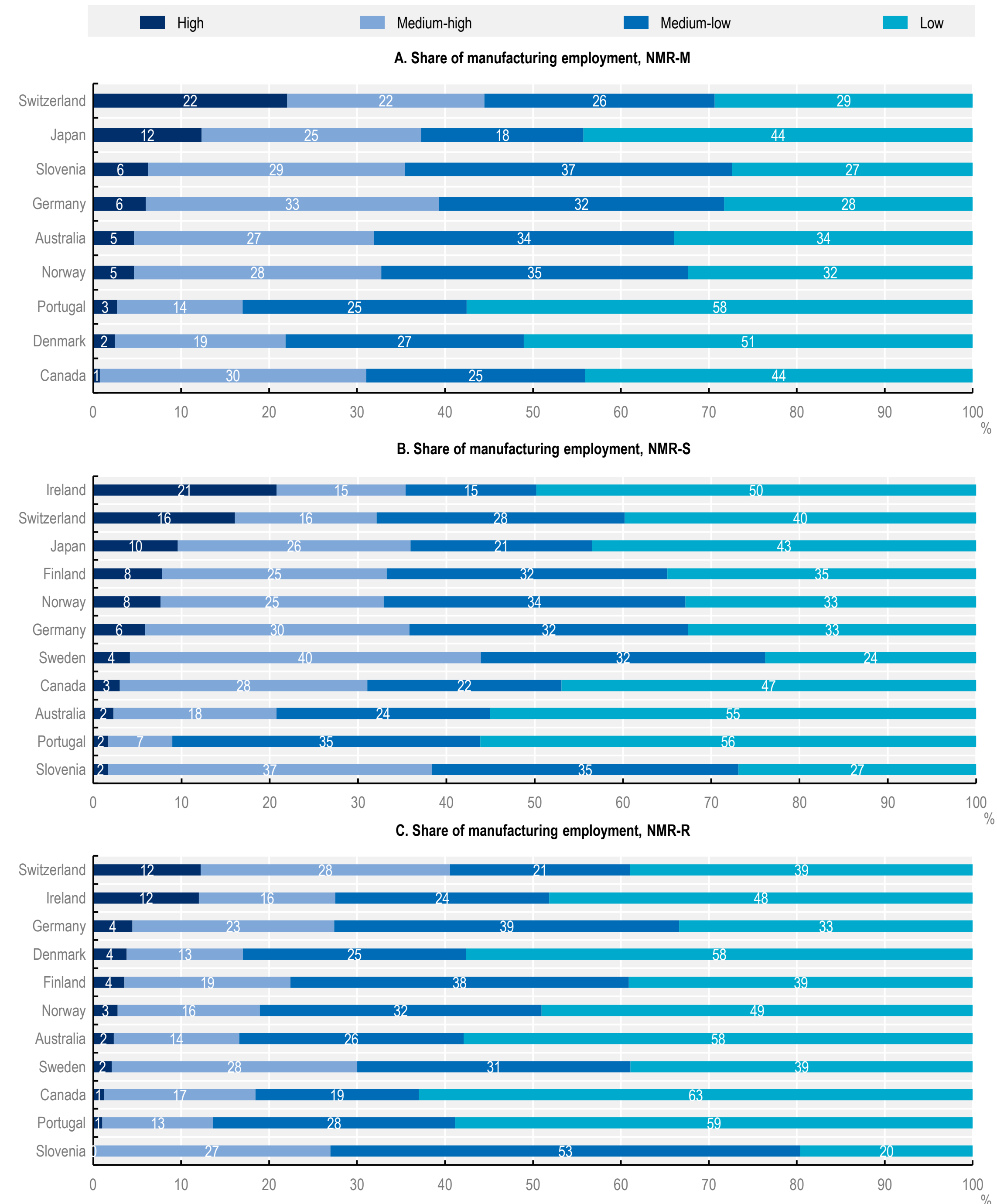
StatLink https://stat.link/gcmky4

Technological intensity in manufacturing inside OECD countries amongst TL3 regions

Utilising more granular data can help further explore the composition of industries across non-metro regions but also *within* technology groupings for a selected number of OECD countries (Figure 4.4). The case of Switzerland stands out, as it displays relatively high shares of workers employed in high-technology industries, highlighting the differences between countries in the scale of employment in each technology type.

Figure 4.4. Non-metropolitan regions display varying patterns in manufacturing composition

Share of employment in manufacturing sectors grouped by technology type across non-metropolitan region groupings for selected OECD countries



Note: Based on the latest available year for each country; see Annex 4.A for details. Geographical typology refers to OECD TL3 typology defining metropolitan (large MR-L and medium MR-M) and non-metropolitan regions (near a large city NMR-M, near a small city NMR-S and rural region NMR-R), for further details see Box 2.1.
Source: Based on data from country-specific national statistics agencies.

StatLink https://stat.link/7jkw4r

It is important to note that these statistics do not tell us if this is the role of a single large firm or whether distinct clusters of specific industries drive these trends. Detailed enterprise statistics at the subnational level could provide more insights into these circumstances.

Given the wide variations across countries, it is thus important to note that comparisons across region types for the basis of global value chain (GVC) assessments and technological intensity comparisons should take into account the notable impact of country-specific factors.

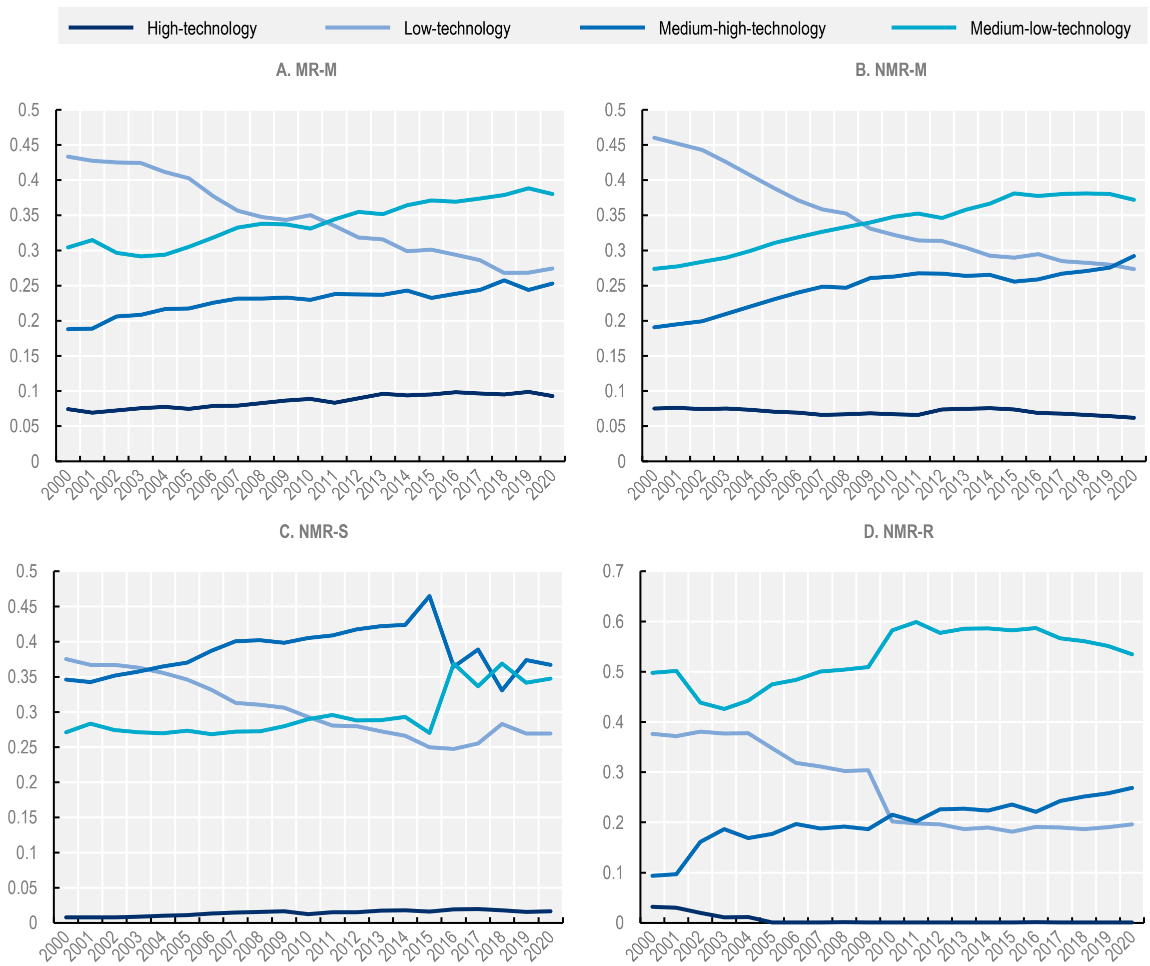
Differences in technological intensity in manufacturing across OECD regions over time

Whilst the data so far undertake a cross-sectional comparison, it is important to examine the dynamics over time. Indeed, many policies across OECD countries have targeted an increase in the share of higher technology products in their respective countries; thus, change over time can showcase whether progress has been attained. We first zoom on the case of Slovenia and examine the trends across the five regional types for the period 2000-2020 (Figure 4.5),which reveal the following trends:

- The shares of low-tech manufacturing employment to total employment decreased steadily during the two decades considered in all four regions.
- In all four regions the shares of low-tech manufacturing employment to total employment decreased steadily during the two decades considered.
- In contrast the employment share of medium-low technology manufacturing to total manufacturing increase in all four regional types. In remote regions it increased from 2003-2016 with a slight decrease from 2016-2020. In regions near a small FUA and medium city it increased from 2014-2020 and in regions near a midsize-large FUA and in metropolitan mid-size regions it steadily increased over the two decades considered.
- A steady increase is also present in the share of medium-high technology employment across all four regional types with steady and positive trends in metropolitan mid-size, in near a midsize/large FUA and in remote regions. In regions near a midsize and large FUA the share of high technology employment increased from 2000-2015 and declined over the last 5 years up to 2020.
- In high technology, the share has been relatively stable across all four regions displaying no clear pattern.

Figure 4.5. Composition of manufacturing employment over time in Slovenia

Regional employment share of manufacturing by technology group, 2000 to 2020



Note: Geographical typology refers to OECD TL3 typology defining metropolitan (large MR-L and medium MR-M) and non-metropolitan regions (near a large city NMR-M, near a small city NMR-S and rural region NMR-R), for further details see Box 2.1.
Source: Based on data from the Statistical Office of Slovenia (SURS).

StatLink https://stat.link/4i592w

Comparing employment and GVA trends in technological intensity across regions

When considering technology, employment statistics may not accurately reflect the size of the industry in the region, particularly if forms of high-technology sectors replace labour with capital, for example through automation of routine tasks. Therefore, looking at the GVA of the sectors could provide a better picture of the share of technology sectors in each region type as well as provide some insights into the degree of replacement.

As we do previously for employment in manufacturing, we conduct a similar analysis for GVA. Making use of more granular data from 112 regions in 4 countries, we utilise data between the years 2000 and 2020 with variations across countries. These are then grouped into the four technology groups based on the same categorisation of technological intensity sectors. Here, it is important to note that as the data come directly from national statistics offices, the degree to which they control, or even do not control, for headquarters effects is not identified in this analysis. See the Annex 4.A for more information.

Taking Sweden as an example, several things can be identified. The key finding is the presence of a notable correlation between manufacturing GVA shares and manufacturing employment shares. As with many of our previous examples, metropolitan regions in 2007 held a greater share of employment in high-technology sectors. By 2020, however, employment in high technology had fallen. At the same time, whilst over half of all metropolitan region GVA was derived from high-technology sectors, the decrease in GVA shares of these sectors by 2020 was less than the decrease in employment shares, indicating attempts to streamline efficiencies. Overall, there is an observable trend where higher technological intensity industries exhibit an upward trajectory in their GVA share. This implies that regions characterised by high- and medium-high-technology industries tend to have lower employment shares relative to their GVA share compared to other regions of the same type. At the other end of the equation, almost 40% of all manufacturing employment in remote rural areas in 2020 was in low-technology sectors, as with GVA, with little change over the decades.

Table 4.1. Sweden TL3 regions

Share of regional employment or GVA in manufacturing by technology type as a share of total regional manufacturing, 2007 and 2020

Year	Region type	Employment				GVA			
		High	Med-high	Med-low	Low	High	Med-high	Med-low	Low
2020	MR-L	0.18	0.40	0.15	0.28	0.44	0.26	0.10	0.20
	MR-M	0.14	0.35	0.24	0.27	0.19	0.37	0.19	0.24
	NMR-S	0.04	0.40	0.32	0.24	0.08	0.42	0.29	0.20
	NMR-R	0.02	0.28	0.31	0.39	0.02	0.29	0.31	0.39
2007	MR-L	0.34	0.25	0.12	0.29	0.56	0.21	0.07	0.16
	MR-M	0.08	0.33	0.26	0.33	0.14	0.39	0.21	0.26
	NMR-S	0.05	0.37	0.32	0.26	0.12	0.36	0.30	0.23
	NMR-R	0.04	0.26	0.29	0.41	0.05	0.26	0.30	0.39
Δ (2020-07)	MR-L	-0.16	0.15	0.03	-0.01	-0.12	0.04	0.04	0.04
	MR-M	0.05	0.02	-0.01	-0.06	0.05	-0.02	-0.02	-0.02
	NMR-S	-0.01	0.03	0.01	-0.02	-0.03	0.07	0.00	-0.03
	NMR-R	-0.01	0.02	0.02	-0.02	-0.03	0.03	0.01	0.00

Note: Geographical typology refers to OECD TL3 typology defining metropolitan (large MR-L and medium MR-M) and non-metropolitan regions (near a large city NMR-M, near a small city NMR-S and rural region NMR-R), for further details see Box 2.1.
: Based on data from Statistics Sweden. For ease of interpretation, colours indicate values from low- red, to high, green.

StatLink https://stat.link/es70fr

Subsequently, this analysis enables us to examine the ratio between manufacturing GVA and manufacturing employment shares for the sample of countries where data are available. We have data for GVA and employment at this level of granularity for four countries that include Finland, Japan, Portugal and Sweden. These four countries comprise 112 TL3 regions, where data are available for both employment and GVA technological intensity. We thus examine labour productivity based on the ratio between GVA and employment. The analysis takes an average of the values across the same regional types, selecting the earliest available year for each country and comparing it to the most recent available year for each country.

The results find that:

- As expected, productivity is highest in the high-technology category and lowest is the low-technology category.
- On average, high- and medium-high-technology industries demonstrate a slight increase in productivity over time, especially high for large metropolitan regions and non-metropolitan regions both close to large and small cities.
- There are no significant productivity gains in medium-low and low technology.

These results are consistent with the OECD analysis (Andrews, Criscuolo and Gal, 2015[10]) that show how firms at the global productivity frontier – defined as the most productive firms in each 2-digit industry across 23 countries – are typically larger, more profitable, younger and more likely to patent and be part of a multinational group than other firms. This analysis also showed the rising productivity gap between the global frontier and other firms over the last decades.

Table 4.2. GVA to Employment ratios over time by region and technology type

Averages from Japan, Sweden, Finland and Portugal

Year	Region type	High	Med-high	Med-low	Low
t2	MR-L	1.72	1.04	0.96	0.77
	MR-M	1.45	1.17	0.92	0.83
	NMR-M	1.11	1.25	1.15	0.83
	NMR-S	1.68	1.14	0.90	0.89
	NMR-R	1.13	1.09	0.96	0.98
t1	MR-L	1.46	1.03	1.00	0.75
	MR-M	1.86	1.08	0.91	0.80
	NMR-M	1.00	1.30	1.21	0.83
	NMR-S	1.48	1.10	0.95	0.90
	NMR-R	1.12	1.09	1.00	0.97
Δ (t2-t1)	MR-L	0.25	0.01	-0.04	0.01
	MR-M	-0.41	0.09	0.02	0.02
	NMR-M	0.10	-0.04	-0.06	0.00
	NMR-S	0.20	0.04	-0.04	-0.01
	NMR-R	0.02	0.00	-0.04	0.02

Note: The years covered as Time Periods 1 and 2 vary by country: Portugal 2008 and 2021, Sweden 2007 and 2020, Finland 2000 and 2020 and Japan 2012 and 2016. Geographical typology refers to OECD TL3 typology defining metropolitan (large MR-L and medium MR-M) and non-metropolitan regions (near a large city NMR-M, near a small city NMR-S and rural region NMR-R), for further details see Box 2.1. To derive the OECD average figures across regional types, the analysis assigns the same weight to each country to ensure that the large sample of rural regions in a given country does not bias the OECD average figures. Interpretation: A value of 1 means that the manufacturing industry of a certain technological intensity (e.g. high technology) contributes to the same share of employment as well as GVA in a certain region type (e.g. MR-L). Looking at the first cell (i.e. t2, MR-L, High), we see the value 1.72 – this means that manufacturing in this region type and technology type contributes to a higher share of total GVA than total employment, precisely 1.72 times more. In other words, a higher value indicates higher productivity (even though normally differently defined as GVA/worker).
Source: Based on data from national statistics offices of Finland, Japan, Portugal and Sweden. For ease of interpretation, colours indicate values from low- red, to high, green

StatLink https://stat.link/jzr5os

Beyond industrial composition

The analysis above defines the technological intensity of a region based on the share of employment in sectors that are defined as highly technologically advanced. However, this masks much of the nuances whereby it is possible, likely and encouraged for all firms to utilise advanced technologies in their manufacturing regardless of the complexity of the products that they are manufacturing. In addition, much of the literature points to the fact that firms within the same sector show vastly different levels of technology adoption. As part of their firm-level adoption of technology survey, Cirera et al. (2020[11]) found a greater variance across firms than across countries or regions.

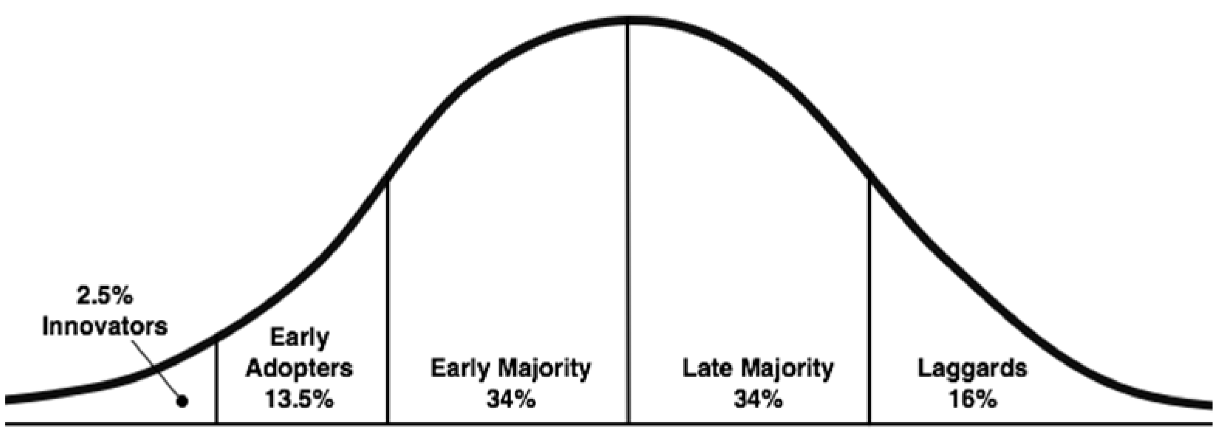
As such, the following section, based on existing literature, summarises bottlenecks and enablers to the adoption of advanced manufacturing technologies and specifically how these may play a role in rural manufacturers.

Adoption and diffusion of innovation for rural firms

To remain competitive, firms must adopt innovations from those external to the firm (Kristianto et al., 2012[12]). Decisions from the leadership of the companies often drive the adoption of these technologies. The least productive firms, however, often lack the capabilities and incentives to adopt new technologies (Berlingieri et al., 2020[13]).

The technology adoption curve (Figure 4.6), initially utilised to consider consumer behaviour, was extended to explain entrepreneurial mindsets in the adoption of technological products and processes within their businesses. The curve highlights the five types of innovators and their shares based on the features at each stage: innovators, early adopters, early majority, late majority and laggards. Note they are not stage for each firm to pass through but an outline of a distribution of all firms.

Figure 4.6. Innovation adoption curve



Source: Rogers, E. (1962[14]), *Diffusion of Innovations, Third Edition*, https://teddykw2.files.wordpress.com/2012/07/everett-m-rogers-diffusion-of-innovations.pdf.

Whilst there is no overarching empirical evidence so far, the literature does provide some case studies in Chile, the People's Republic of China (hereafter China) and England (United Kingdom), which suggest that firms located in rural regions tend to be more skewed to the right of the (innovation adoption) distribution curve:

- In the case of England, there is some evidence that rural firms are less likely to create new products (Phillipson et al., 2019[15]).
- In Chile, a past study found that entrepreneurial innovation is often not adopted in rural areas and small towns (Pedersen, 2010[16]).
- In China, a recent study finds that rural entrepreneurs show lower risk tolerance and, in more vulnerable rural communities, family-owned firms succeed over non-family-owned firms by prioritising longevity over growth ambitions (Sun et al., 2023[17]).

For policy makers, the theory and initial evidence can already provide insights into designing policy responses. The theory reveals the stages for which innovation is adopted and diffusion is accomplished. These include *awareness* of the need for an innovation, *decision to adopt* (or reject) the innovation, *initial use* of the innovation to test it, and *continued use* of the innovation. In addition, the theory also identifies five main factors that influence the adoption of an innovation (LaMorte, 2022[18]). These include:

1. **Relative advantage:** *The degree to which an innovation is seen as better than the idea, programme or product it replaces*. Due to their greater distances, rural regions may often not be aware of the latest technologies for their sector or indeed of the wide range of possible options and their full benefits and disadvantages. The role of links to universities and research institutes, as well as business networks, is therefore crucial to ensure the latest scientific knowledge and technical information is available to the decision makers within the firms. For example, McCain et al. (2011[19]) describe a successful co-operative venture between a state university and a federal agency to improve the new product development process of selected rural manufacturers by introducing them to leading-edge design automation technologies.
2. **Compatibility**: *How consistent the innovation is with the values, experiences and needs of the potential adopters*. Foreign direct investment (FDI) manufacturing firms in rural areas tend to outperform local firms (Damioli and Marin, 2020[20]) in part due to them bringing ideas and values from their host nation. These may be seen as external to those in the same sector and region. Opportunities for these frontier firms to highlight these benefits through knowledge-sharing networks may help locally owned businesses to see the benefits for them more clearly. Further research into corporate structure in rural areas within each region may provide further insights to produce more targeted options for policy officials.
3. **Complexity**: *How difficult the innovation is to understand and/or use.* Manufacturing technologies relate not just to products. They extend to design and engineering, planning and control, information management, as well as fabrication and assembly. As such, some technologies can be intimidating or poorly managed. Stornelli, Ozcan and Simms (2021[21]) highlight how advanced manufacturing technologies' complex and programmable nature makes these modern technology systems more subject to process flaws compared to mechanical models (Ettlie and Reza, 1992[22]) and they require generative learning for associated organisational adaptations (Bessant and Buckingham, 1993[23]). Indeed, Awano and Vyas (2018[24]) find that across United Kingdom businesses, productivity increases were only positive and significant when investment in capital was accompanied with investment in related skills, whether through internal staff training or outsourcing. Rural challenges regarding direct access to relevant skills (discussed in greater detail in the subsequent section) may also hinder adoption due to complexities. Therefore, amongst rural manufacturers, policies that aid in identifying significant complementarities in technologies can help make the integration of multiple technologies less complicated and more effective than stepwise adoptions. Robots' increasing variety and capabilities have reduced costs and allowed for a broad

range of specialisations and multiple possibilities within a single firm. DLG (2023[25]) identifies how additive manufacturing techniques can be used from the agricultural sector to the manufacturing sector and point at the same time to technologies that harness digitalisation as the new ways of doing business.

4. **Trialability**: *The extent to which the innovation can be tested or experimented with before a commitment to adopt is made*. In rural areas, the costs of trialability may be higher than in urban areas. This can be due to greater challenges in access to capital, particularly for small and medium-sized enterprises (SMEs) and may explain how Wojan and Parker (2017[26]) find that while large rural manufacturers had an innovation edge, that finding did not hold true for small and medium-sized rural manufacturers. A United States survey by Goldman Sachs (2023[27]) finds 86% of rural SMEs plan to grow, yet only 7% feel supported financially through private means. High costs of trial may off-put initial investments. Tello et al. (2017[28]) find in Peru that public financial support seemed to have a stronger effect in terms of investment inducement than in terms of investment intensity in services and low-technology manufacturing firms; as such financial support may greatly boost technology adoption in rural manufacturing SMEs. In addition, regulatory barriers may prevent trials of technologies. Allowing for regulatory sandboxes can aid innovative technology adoption (OECD, 2023[29]).
5. **Observability**: *The extent to which the innovation provides tangible results.* Not all technology adoption decisions are successful, which places firm performance and customer relationships at risk. This may be particularly cumbersome for rural manufacturing firms that face challenges in greater distances to their markets and networks. As such, finding a range of buyers and suppliers that can aid the success of their technological investment risk can be more challenging. Pivoting to alternates may require more work than for those in more urban, denser environments. At the same time, once established, relationships of rural manufacturing firms may be stronger and contractual agreements allow for greater agency in the development of their products and the ability to experiment for efficiency gains. At the same time, a policy that aids firms in identifying technology, market, product and environmental factors to aid adoption can also help firms effectively monitor the success of these (Graham and Moore, 2017[30]).

Policy response, therefore, may benefit from these measures at each of these stages and factors influencing the adoption of innovation. A number of policy takeaways are thus emerging:

- High-technology intensity within manufacturing is driving productivity gains, especially in large metropolitan region clusters, and R&D investments can further boost productivity; this matters for national growth. Nonetheless, policies should also encourage the adoption of advanced manufacturing techniques amongst existing firms, especially in rural regions, even those producing fewer complex products.
  - Pursue policies to help identify relevant technologies in addition to absorbing technology in rural regions, through the improvement links between universities and research institutes and the private sector.
  - Provide technical assistance on technology complementarities between forms of technological innovations (design and engineering, planning and control, information management, fabrication and assembly) to allow for cost and labour-effective adoptions.
  - Ensure good broadband access allows rural manufacturing firms to utilise the latest digital tools and remote labour.
  - Provide financial support for rural manufacturing SMEs to adopt technologies and regulatory sandboxes for firms to trial before commitment and space for generative learning.
  - Provide tools to help firms monitor the success of their technological adoption to spur on further investments.

The changing skills of rural manufacturing

With technological changes come changes to the skills demanded. In recent decades, the rapid advancement of automation technology has brought transformative changes to the manufacturing landscape worldwide. As industries strive for increased efficiency, reduced costs and heightened productivity, automation has emerged as a key enabler in meeting these objectives. This chapter explores the complex relationship between automation, digitalisation and other such manufacturing skills in rural areas, places where communities often rely heavily on industrial sectors as a vital source of employment and economic sustenance. By shedding light on the implications of automation on the workforce, evolving skill demands and population challenges faced by rural regions, we uncover insights some policy takeaways.

Rural areas are at a higher risk of automation

General increases in automation

Across OECD countries, nearly half of all jobs are facing some risks due to the tasks they encompass. A considerable 14% of these jobs are at high risk, indicating a likelihood of over 70% to be automated. Moreover, an additional 32% of jobs face a risk ranging between 50% and 70% to be automated, highlighting the potential for significant transformations in the execution of these roles due to automation's impact (Nedelkoska and Quintini, 2018[31]).

The impact of automation varies significantly across OECD countries, resulting in contrasting levels of job vulnerability. For example, the Slovak Republic faces a considerable risk, with 33% of its total jobs highly susceptible to automation, whilst Norway exhibits a much lower risk, with only 6% of its jobs falling into the highly automatable category (Nedelkoska and Quintini, 2018[31]). Moreover, the impact of automation is unevenly distributed among workers, with distinct implications across industries. As can be predicted, the manufacturing sector and agriculture are particularly vulnerable to automation (OECD, 2018[32]). According to McKinsey (2021[33]), 64% of the working time spent on manufacturing-related activities worldwide could be automated with currently demonstrated technology relating to a wide range of functions from physical, predictable tasks to processing and collecting data. Tasks relating to management, expertise and interface were occupations that currently held around half of United States jobs in the sector and were less likely to be largely automated.

Notably, occupations with the highest projected automatability are often characterised by minimal educational requirements, emphasising the necessity of targeted policy interventions to foster workforce adaptability and skill development (Nedelkoska and Quintini, 2018[31]; McKinsey, 2021[33]). The share of workers with tertiary education reveals that regions with higher percentages of jobs at risk of automation tend to have lower shares of workers with tertiary education (OECD, 2018[32]). Furthermore, when considering the occupational level, occupations at high risk of automation experienced significantly lower employment growth (6%) compared to occupations at low risk (18%) (Georgieff and Milanez, 2021[34]). This divergence in employment growth further underscores the urgency of reskilling and upskilling efforts and the need to strengthen adult learning policies to equip workers in high-risk occupations with the necessary tools to thrive in an increasingly automated labour market (Nedelkoska and Quintini, 2018[31]).

Characteristics specific to rural regions

The risk of job automation exhibits considerable variation across regions. For instance, in certain regions like West Slovakia the share of jobs at high risk reached nearly 40% in 2016, whereas in others like the region around Oslo, it can be as low as around 4%. These disparities highlight the importance of region-specific policy approaches to address the challenges posed by automation. In addition, the share of jobs at high risk of automation varies within countries. In Canada, for example, the difference between the best and worst-performing regions is only 1 percentage point, while in Spain, this gap expands to 12 percentage points (OECD, 2018[32]).

Rural regions have higher employment in low-technology manufacturing

In this overall context, we see that rural economies are especially at risk of automation (OECD, 2018, p. 54[32]). One reason for this is that rural economies display a lower share of service sector jobs, influenced by factors such as agglomeration effects and accessible infrastructure, which generally contribute to enhancing a region's resilience to automation. In contrast, rural regions rely more heavily on basic manufacturing, which is more likely to be affected by automation (OECD, 2019[35]; McKinsey, 2021[33]).

The aggregate share of medium-low- and low-technology employment in urban areas varies across countries. Nevertheless, employment in these industries is lower than in rural areas in each country, as was shown in Figure 4.4.

Lower density of markets

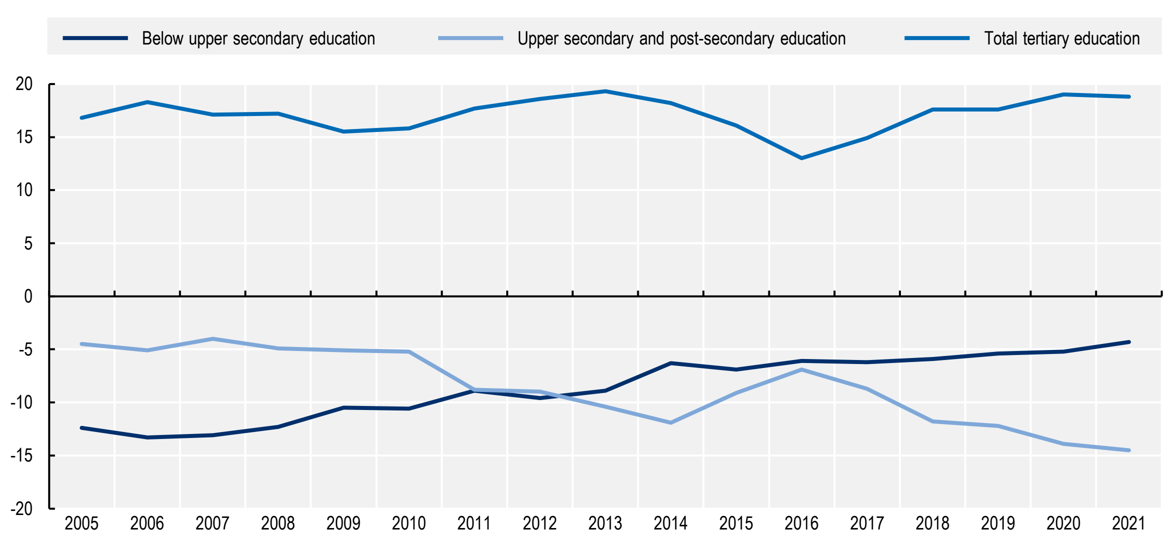
In addition, smaller towns and rural regions typically rely heavily on a limited number of employers or a single industry, leading to difficulties in reintegrating displaced workers when these employers adopt extensive automation (OECD, 2018[32]). Furthermore, rural regions encounter an elevated likelihood of job automation, particularly in economies heavily reliant on repetitive tasks and subject to a lack of diversification and outmigration of highly skilled workers (OECD, 2020[36]). Rural regions are also more likely to host carbon-intensive industries such as agriculture, mining and energy, the gradual phasing out of which can threaten local livelihoods and prosperity in these regions – discussed in further detail below.

Less tertiary-educated workers

This situation is compounded by the fact that rural regions typically have lower shares of tertiary-educated workers; see, for example, the case of Slovenia in Figure 4.7, which is positively correlated with a reduced risk of automation. Improving participation in tertiary education could, therefore, improve the resilience of rural areas to automation.

Figure 4.7. Rural-urban education attainment divide in Slovenia

Percentage difference in shares of employment (share in cities to share in rural)



Source: "The future of rural manufacturing: Slovenia case study", https://www.oecd.org/regional/rural-development/future-of-rural-manufacturing-case-study-slovenia.pdf; Slovenian statistics agency https://www.stat.si/statweb/en.

StatLink https://stat.link/gc0k47

Box 4.3. What jobs are at risk of automation?

Occupation-based vs. task-based approach

- **Occupation-based** indicators assess the automation risk based on the characteristics and requirements of entire occupations. This approach categorises jobs into broader occupation groups and estimates the overall risk of automation for each group. It considers factors such as the level of routine tasks, the complexity of job responsibilities, and the potential for technological substitution. Occupations with a higher concentration of routine and repetitive tasks are generally considered to be at greater risk of automation.
- **Task-based** indicators focus on analysing the specific tasks involved in individual jobs rather than the entire occupation as a whole. This approach breaks down job roles into various tasks and assesses the automation potential of each task. Some tasks within a job may be more susceptible to automation, while others may require uniquely human skills and are less likely to be automated.

Methodology

The study by Nedelkoska and Quintini (2018[31]) builds on work by Arntz, Gregory and Zierahn (2016[37]) and exploits the Programme for the International Assessment of Adult Competencies (the Survey of Adult Skills, PIAAC) to account for the variation in tasks within narrowly defined occupational groups.

The PIAAC survey is based on a questionnaire administered to individuals in households representing the population aged between 16 and 65. On average, 77.5% of participants across countries were assessed on a computer, while the rest took the paper-based assessment. It was designed to measure key cognitive and workplace skills and provides indicators of the proficiency of individuals in literacy, numeracy and problem solving in technology-rich environments, measured on a 500-point scale. PIAAC has extensive information on skill use at work and at home and background variables such as educational attainment, employment status, job, socio-economic background and personal characteristics. Most participating OECD countries, including Germany, conducted the survey in 2011-12. Further countries conducted the survey in 2014-15.

First, the survey asks workers whether they: i) think they have the needed skills to cope with tasks that are more demanding than the ones they are already performing; and ii) need further training to cope well with their duties. Second, exercises and simulations of basic literacy, numeracy and problem-solving skills in technology-rich environments are conducted to perform a direct evaluation. This latter serves to build a “skills score” for each participant. Workers who provide negative answers to the two previous questions provide scores that are used to create a quantitative scale of the skills needed to perform tasks for each occupation (single-digit International Standard Classification of Occupations). Third, this scale is used to establish minimum and maximum threshold values to quantitatively define well-matched workers. Hence, PIAAC defines mismatched skills as the respondents’ scores, which are situated below the minimum or above the maximum threshold. One of these methods’ limitations is that score variance in the same occupation does not necessarily indicate skills mismatch but can relate to differences in individual performances.

Hence, it follows a task-based approach. The reason for this is that using an occupation-based approach might lead to an overestimation of job automatability since occupations labelled as high-risk may still encompass a significant portion of tasks that are difficult to automate.

Source: Fuentes Hutfilter, A., S. Lehmann and E. Kim (2018[38]), “Improving skills and their use in Germany”, https://doi.org/10.1787/8a251b1f-en; Adalet McGowan, M. and D. Andrews (2017[39]), “Skills mismatch, productivity and policies: Evidence from the second wave of PIAAC”, https://doi.org/10.1787/65dab7c6-en; Nedelkoska, L. and G. Quintini , “Automation, skills use and training”, https://doi.org/10.1787/2e2f4eea-en; Arntz, M., T. Gregory and U. Zierahn (2016[37]), “The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis”, https://doi.org/10.1787/5jlz9h56dvq7-en.

Rural areas can benefit from automation

However, automation also presents significant opportunities for rural regions grappling with declining working-age populations. While over half of all OECD regions witnessed a decrease in their working-age population between 2010 and 2016, this was not evenly distributed.

Already, close to one-fifth of OECD countries (Estonia, Greece, Hungary, Japan, Latvia, Lithuania and Poland) are shrinking in their population between 2010 and 2021. Furthermore in 2021, there were about 13 working-age people (15-64 years old) for every elderly person (older than 80 years), in 2040 there will be only 7. These trends, however, have a strong territorial dimension, with several regions facing more severe patterns of depopulation and ageing, particularly rural regions. Within the OECD, 36% of remote regions witnessed a decrease (as shown in Table 4.3), with 26 regions experiencing a population drop of 1% or more (OECD, 2020[36])

- Over the last 20 years, the population in FUAs grew on average by 0.7% a year but by only 0.5% in areas outside FUAs (OECD, 2023[40]).
- In 13 OECD countries, remote regions have been losing population over the past decade and 44% of regions near a small-medium city have been losing population.
- Between 2001 and 2021, 38.3% of all OECD remote regions experienced population decline, 28 percentage points higher in remote regions compared to large metropolitan regions (OECD, 2023[40]).
- Remote regions – where the elderly dependency ratios stood at 31% in 2019 – experienced, on average, the largest increases in elderly dependency between 2003 and 2019 (a 0.9 percentage point increase)[2] (OECD, 2020[36]).
- By 2050, the population in towns and semi-dense areas is projected to increase from 2.1 billion to 2.3 billion worldwide, while the population in rural areas is expected to expand from 1.7 billion to 1.9 billion (OECD, 2023[40]).

Although there are green pockets of rural regions managing to repopulate and reverse the trend, these trends and projections imply that rural regions are likely to experience a decreasing workforce in the coming years. Against this backdrop, it will be important to transition towards more capital-intensive economic activities, including automation, to maintain well-being standards.

Table 4.3. One-third of rural regions experienced population decline in the last two decades, 2000-21

	Population growth	Population decline
Regions with a city >1M	239	37
Regions with a city >250K	416	110
Regions near a city >250K	269	132
Regions with/near a city <250K	214	116
Remote regions	394	220
Total	1 532	615

Note: Displays the number of regions that experienced population growth or decline broken down by region type.
Source: OECD (2020[36]), *Rural Well-being: Geography of Opportunities*, https://doi.org/10.1787/d25cef80-en.

StatLink https://stat.link/chx0ld

This at the same time as urban areas attract young and educated workers at the expense of rural areas, which are, therefore, more likely to suffer from labour shortages (OECD, 2018[32]). The declining proportion of young people in rural areas leads to labour market shortages but also reduces entrepreneurial activity and brings about a decline in local cultural vitality, building a negative downward circle. In addition to outmigration, the rapid ageing of the population is accelerating the decline of the rural labour force. In almost all OECD countries, the elderly dependency ratio is significantly higher in rural areas than in metropolitan areas (OECD, 2020[36]).

In Canada, for instance, rural regions experienced a 6% employment decline from 2011 to 2019, contrasting with continued growth in urban areas. By 2022, the average age in rural areas reached 43.8, in contrast to 41.3 in urban areas. Additionally, rural areas exhibited a 6% lower proportion of individuals in their prime working years (25 to 44 years) employed, alongside a nearly 6% higher share of individuals aged 55 and above engaged in employment, highlighting factors for skills and labour shortages in rural contexts (OECD, forthcoming[41]).

Box 4.4. Potential analysis to dive deeper into manufacturing industries at risk of automation

Utilising job posting data, one can analyse the evolving job demands within the manufacturing sector over time, with a specific focus on understanding the disparities between rural and urban areas. One potential data source for this is Lightcast, an automated web scraping database that enables collecting and analysing information from online job postings to study trends in labour market dynamics and skill demands. Its advantages lie in the richness, timeliness and granularity of data, providing the ability to track evolving skill demands up to recent months, examine cross-sectional variations in skill requirements within occupations where skill demands for the same occupation may vary depending on the geography analysed and explore specific knowledge domains such as Python programming or web design rather than generic concepts.

Utilising Lightcast data

The Lightcast data cover all six countries (Denmark, Finland, Norway, Portugal, Slovenia and Switzerland) for which we have disaggregated manufacturing employment data and provide detailed data on manufacturing occupations along the following dimensions:

- TL3 region.
- Two-digit ISIC industry code.
- Education level as well as job-related tasks.

Procedure

Based on these data, it is possible to categorise manufacturing jobs based on the two-digit industry code. Consequently, it becomes feasible to calculate the probability that a particular job will be automated. The next step is to determine the proportion of jobs in a given industry and region that are at risk of automation. In this way, it is possible to differentiate the level of skills in manufacturing between rural and urban areas and consequently measure where jobs are at greater risk of automation.

Correcting potential biases

As mentioned by Cammeraat and Squicciarini (2021[42]), using Lightcast data (formerly known as BGT) at face value to analyse aggregate skills and labour dynamics could lead to biased results, as high-skilled occupations are advertised on line more often than low-skilled occupations. In addition, certain occupations, such as construction worker, are severely underrepresented because recruitment processes are rarely conducted on line. To address this issue, we conducted a comparison with the European Union Labour Force Survey (LFS) data. Our preliminary analyses for the manufacturing sector covering Denmark, Finland, Norway, Portugal, Slovenia and Switzerland, where we compared employment by occupation (three-digit) between the two data sources, gave quite similar results, with differences of less than 5% in most cases. Nevertheless, further investigation using complementary data sources at the national level would be helpful to explore this more thoroughly.

Source: Based on Lightcast (2023[43]), *Homepage*, https://lightcast.io/ (accessed on 15 September 2023).

Embracing automation can help tackle these demographic challenges. While more than half of the regions have already managed to transition towards low-risk jobs in 2011-16, most countries still encounter challenges, including employment declines or a shift towards higher-risk jobs in some regions (OECD, 2019[35]).

As previously highlighted, the impact of automation goes beyond job losses, as it also leads to an increased demand for highly skilled workers capable of exploiting the potential of advanced technologies. This means tasks requiring human-centric skills like managing people, applying expertise and interpersonal communication will become more important. Consequently, workers will dedicate less time to routine physical activities and data processing, where machines excel. This shift will demand enhanced social, emotional, and cognitive skills like logical reasoning, creativity and advanced interpersonal abilities (McKinsey, 2017[44]), which can be an asset for rural areas. Indeed, Baù et al. (2018[45]) find rural manufacturing firms have a longevity particularly when family-owned due to their better integration into the local culture and greater emotional ties.

Furthermore, automation can unlock distance learning opportunities for rural areas that have shortages in education staff which are critical to then build the next generation of manufacturing employees. On average across OECD countries, shortages of education staff were more prevalent in rural schools than urban schools (OECD, 2018[46]). In developing skills capacity of rural areas, automated learning options can help deliver quality distance learning for remote communities. For example, the PLATO (Programmed Logic for Automated Teaching Operations) system, developed at the University of Illinois, was a mainframe/terminal-based e-learning tool that delivered automated classes in a variety of subjects to students from kindergarten through to university. From the 1960s through to the arrival of the personal computer in the 1980s, PLATO was used to educated tens of thousands of students across the US and internationally (OECD, 2021[47]).

The green and digital agendas

In the European Union, between 2000 and 2014, 1.4 million jobs were added to the green economy (ILO, 2017[48]). Trends such as this have caused a profound transformation of employment, with a distinct shift towards roles that demand proficiency in both green and digital skills. As all industries increasingly embrace sustainability, new opportunities are arising that require expertise in environmentally conscious practices. Simultaneously, the integration of digital technologies is reshaping job requirements, calling for individuals skilled in navigating the digital realm to drive innovation and efficiency. OECD rural manufacturing firms have an opportunity not only to embrace these changes but to provide world-leading expertise in essential niches.

However, rural areas currently fall behind, where the share of green jobs in remote rural regions can be as low as 5% compared to capital cities, where these can be as high as 30% (OECD, 2023[49]). Furthermore, green and digital transitions do not guarantee the creation of jobs in rural areas. There is increasing evidence that, without supportive policy, heavy hit regions will take a long time to offset job losses by local job creation (OECD, 2023[50]).

Additionally, local green employment opportunities within rural regions may be limited as the energy sector is more capital- than labour-intensive and installations could source labour and equipment from outside the region (OECD, 2020[36]). This requires local considerations to enable renewable energy and other green transition technologies to be an opportunity for rural areas that specialise in manufacturing. For instance, in Germany, a new Commission on Growth, Structural Change and Employment is taking steps to address the impact of the energy transition on mining communities (OECD, 2023[50]). This involved preparing a roadmap for the phase-out of coal, with a special focus on strengthening green skills for those living in affected regions.

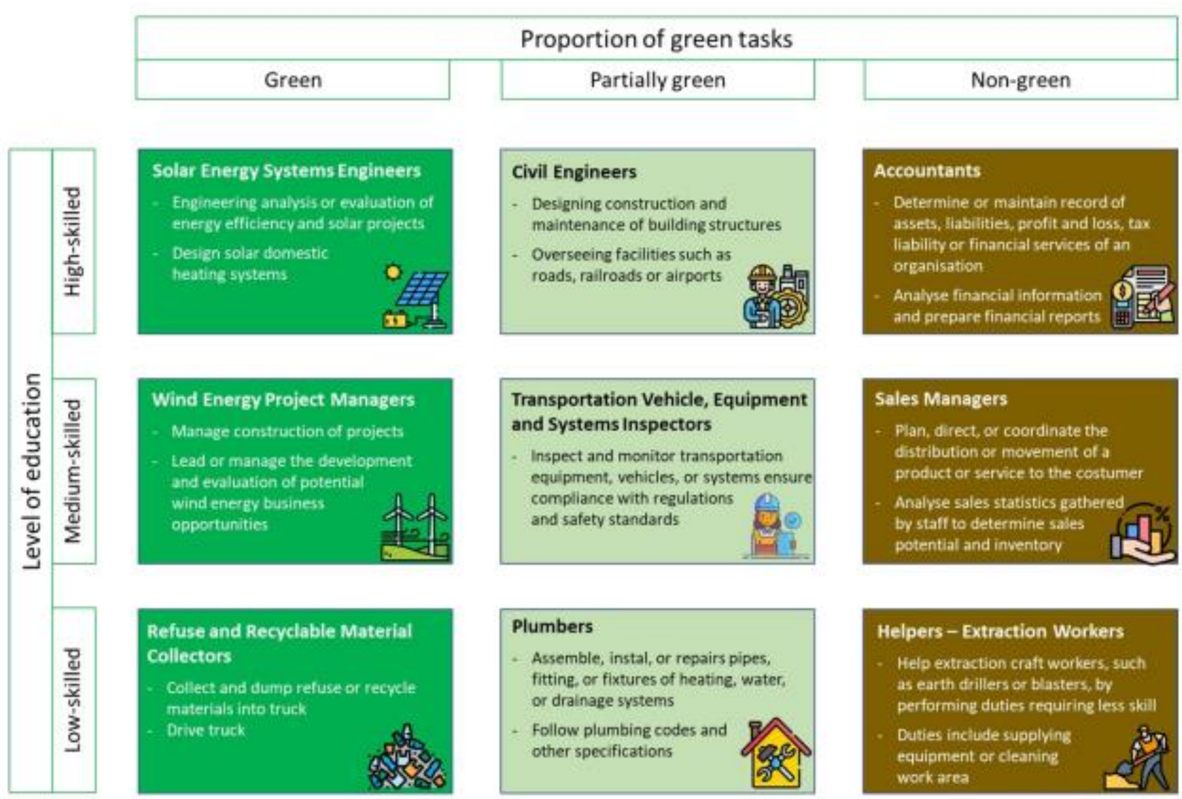
What skills are required for green and digital jobs?

In practical terms, digital and green jobs are often one and the same and, as such, the skills required largely overlap. For rural manufacturing firms, this further involves investing in a comprehensive skill set that encompasses digital proficiency, cognitive abilities (literacy, numeracy, problem solving), information and communication technology (ICT) and behavioural competencies. As such, rural areas could benefit from effective collaboration between education providers, employers and trade unions to provide training opportunities that are aligned with both the green and digital labour needs of each rural region, as well as workers' career development objectives. In this sense, occupational transitions can be streamlined whilst ensuring ongoing productivity of the rural workforce in required green and digital sectors.

Green skills requirements

Figure 4.8 highlights the skills required to carry out green-task jobs as corresponds to level of education and proportion of green tasks many of which are found within the manufacturing sector.

Figure 4.8. Green-task jobs can be found across the economy and skills spectrum

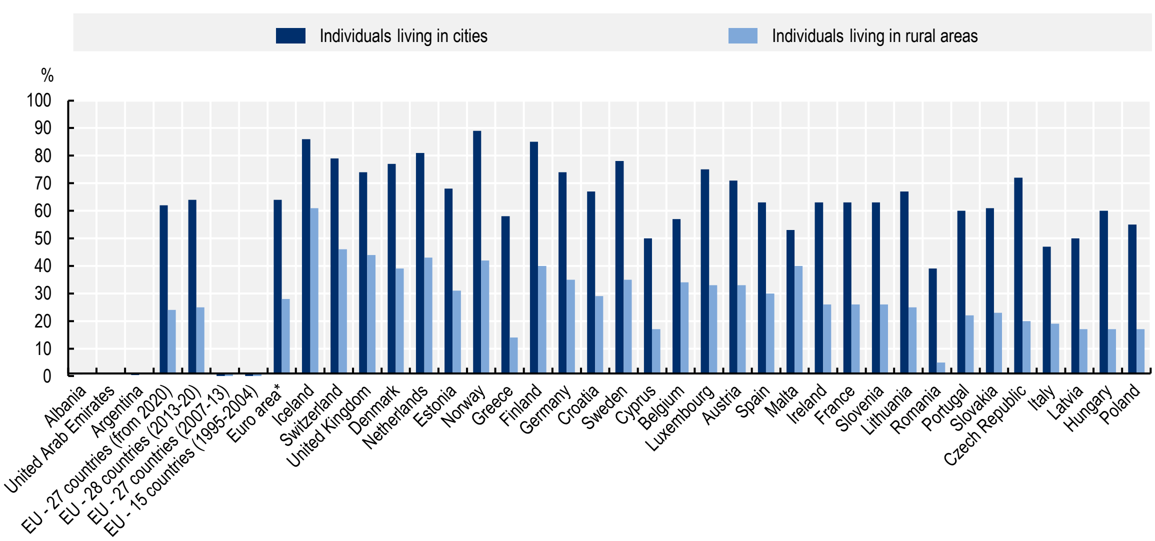


Note: The greenness of occupations is based on their task content and whether those tasks are green or not. The greenness score of an occupation ranges from 1 (all tasks are green) to 0 (all tasks are non-green). The classification of high-, medium-, and low-skilled occupations follows ISCO.
Source: (OECD, 2023[50])

Digital skills requirements

Digital skills required for employment are becoming increasingly more complex. High-skilled jobs that already require significant digital knowledge now require more complex skillsets. Additionally, many jobs in sectors that were previously not considered digital now require digital skills. This requirement has transformed the workplace, especially in low-skilled occupations (Muro et al., 2017[51]). Some workers also struggle to adapt to new digital work practices, with preliminary evidence suggesting that increased digitalisation is causing increased stress among workers (Haipeter, 2020[52]). Improving confidence and ability in digital skills in rural regions requires greater educational opportunities. Data available across European countries reveal that individuals living in rural regions strongly lag considerable behind their peers in cities in their level of digital skills (Figure 4.9) (OECD, 2020[36]). On average across Europe, the share of individuals living in rural areas with basic or above digital skills stood at 23% while the this share in cities was almost three times higher at 62%. Improving the level of digital skills in rural areas is critical to benefit from automation and make the most of future job opportunities in the green transition.

Figure 4.9. Individuals in rural areas and cities with basic or above digital skills, 2019



Note: Not all OECD countries are covered by the data source. For further information on the Eurostat classification of areas by degree of urbanisation, see https://ec.europa.eu/eurostat/web/degree-of-urbanisation/background.
Source: Eurostat (2020[53]), *The European Social Survey*, https://ec.europa.eu/eurostat/cros/content/european-social-survey_en.

StatLink https://stat.link/43xh5m

Untapped potentials in rural areas

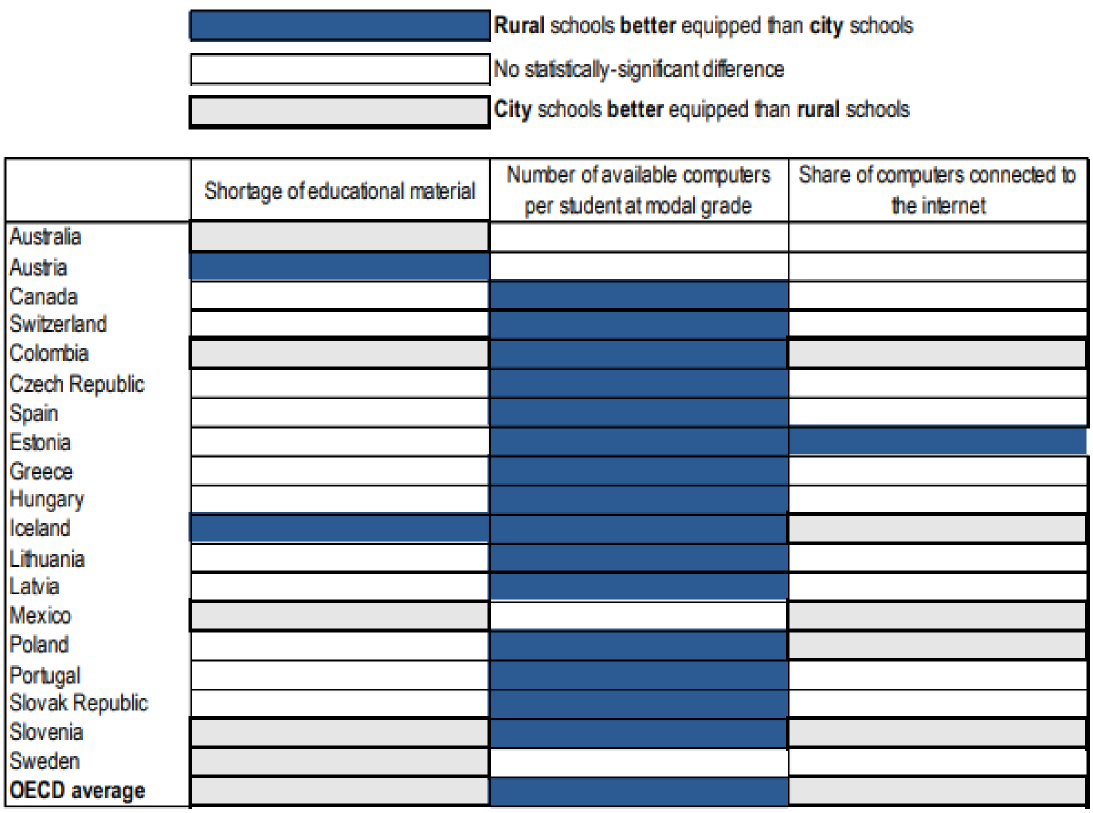
Distance learning to increase digital skills capabilities in rural areas

Distance learning is an important tool rural communities can utilise to provide access to digital skills education in remote areas. Some countries have developed specific frameworks to promote digital skills beyond the classroom and track progress in skill development. Digital provision allows decoupling service provision from specific locations, greatly improving access to services such as education. (OECD, 2021[47]) For instance, the Australian Curriculum, Assessment and Reporting Authority (ACARA) has a digital competency framework that moves beyond developing digital skills in stand along ICT classes, to a more comprehensive approach that fosters digital skills across learning areas. This includes organising student's ICT capacity development around several dimensions such as managing and operating ICT, communicating with ICT, and investigating with ICT and assessing their progress and proficiency across their schooling journey (OECD, 2021[47]).

While distance learning can be a tool to enhance digital skills in rural areas, there are rural-urban gaps in ICT resources in schools and beyond (OECD, 2021[47]). For instance, rural schools tend to have, on average, more computers per student than city schools, but they are less frequently connected to the internet across OECD countries. Local capacity in effectively scheduling and delivering distance courses to support all students is key to distance learning and increasing digital skills capabilities in rural areas (OECD, 2021[47]).

Figure 4.10. The rural-urban gap in schools' material resources

Based on school principals' 2018 reports



Note: Shortage of educational material is measured by an index based on school principals reports about the extent to which their school's capacity to provide instruction is hindered ("not at all", "very little", "to some extent", "a lot") by a shortage or inadequacy of physical infrastructure, such as school buildings, heating and cooling systems, and instructional space; and educational material, such as textbooks, laboratory equipment, instructional material and computers. No statistically significant differences in any category in Chile, Denmark, Finland, France, Ireland, Israel, Italy, Norway, New Zealand, the United Kingdom (UK) and the US. Source: OECD (2018[10]), PISA 2018 Database, https://www.oecd.org/pisa/data/2018database/ (accessed on 15 May 2020); adapted from Echazarra, A. and T. Radinger (2019[11]), "Learning in rural schools: Insights from PISA, TALIS and the literature", https://doi.org/10.1787/8b1a5cb9-en (accessed on 6 August 2019).

Boosting female participation

Leveraging female labour participation in the manufacturing sector represents a crucial avenue for skill augmentation. In most European countries, women form the majority of higher education students. However, substantial gender disparities persist in terms of field selection. Across all countries, female students are more inclined towards education and health-related disciplines than ICT, engineering, manufacturing and construction (Hauschildt et al., 2021[54]). In this context, the World Manufacturing Foundation, a non-profit organisation committed to spreading industrial culture worldwide, actively attempts to amplify female engagement in the sector. Rectifying this gender-specific gap not only bridges educational imbalances but boosts the manufacturing industry's capabilities by tapping into a pool of qualified talent.

Box 4.5. Policy examples to boost female manufacturers, Queensland, Australia

The Department of Regional Development, Manufacturing and Water in Queensland, Australia, developed a women-in-manufacturing strategy in 2023, recognising that increased diversity boosts productivity, fosters a more creative environment, can improve morale and employee retention and that encouraging more women to pursue a career in manufacturing is critical to the industry's continued growth.

As such, the policy focuses on four main priorities:

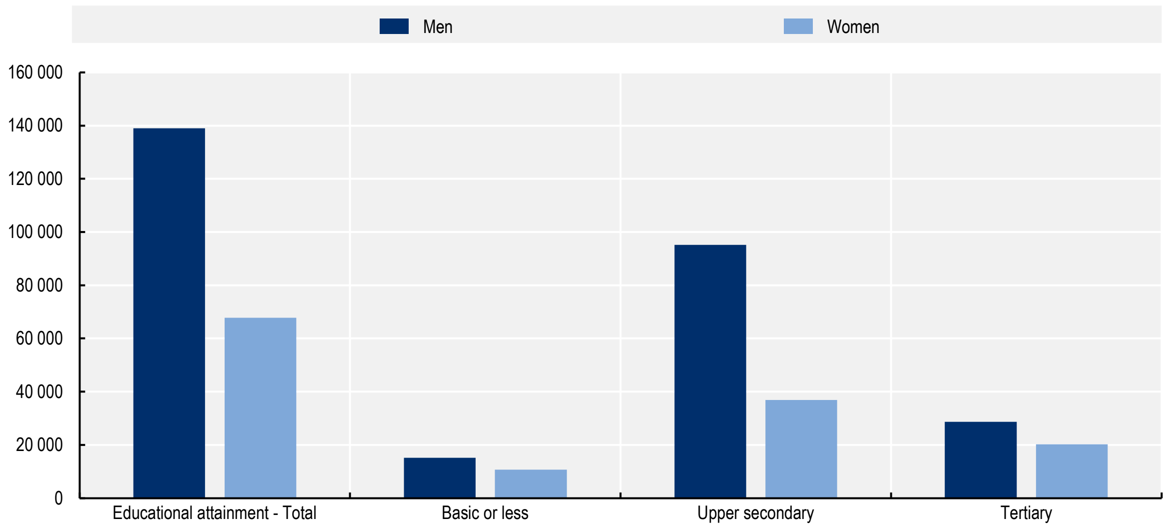
- Supporting diversity, equity and inclusion in the manufacturing industry.
- Building on our existing capabilities and skills to further women's leadership and development.
- Boosting women's participation in vocational education and training (VET), building the science, technology, engineering, and mathematics (STEM) pipeline and promoting advanced manufacturing capabilities throughout secondary and tertiary studies.
- Celebrating and showcasing the women in Queensland's manufacturing industry

These are achieved through holding a variety of manufacturing events with high-level panellists for information sharing, the development of a mentoring programme and a toolkit that all companies can utilise to aid them in boosting female participation.

Source: Queensland Government (2023[55]), *Women in Manufacturing*, https://www.rdmw.qld.gov.au/manufacturing/manufacturing-assistance-programs/women-in-manufacturing.

Figure 4.11. The manufacturing sectoral gender gap is smaller for higher-educated employees, Slovenia

Number of employees (thousands) in the manufacturing sector by gender, 2021



Source: "The future of rural manufacturing: Slovenia case study", https://www.oecd.org/regional/rural-development/future-of-rural-manufacturing-case-study-slovenia.pdf.

StatLink https://stat.link/dezhxv

Youth participation

In a similar way, better branding the image of the manufacturing sector, rural manufacturers may be able to attract young workers into the sector. This can be achieved by showcasing its technological advancements, innovation and diverse career opportunities, including its pivotal role in cutting-edge fields such as robotics, automation and sustainable practices. At the same time, regions can modernise and cultivate progressive education systems by closely connecting local universities with future-oriented skills required by the sector. Concise and customised courses directly linked to specific job openings can be a beneficial strategy for retraining workers and elevating skills during restructuring efforts (Strietska-Ilina et al., 2012[56]).

Consequently, rural regions should develop forward-looking strategies such as:

- Revising educational and training programmes to align with the changing skill and knowledge requirements of green jobs, encompassing activities from raising awareness to thorough transition-focused reskilling.
- Customising training opportunities for both upskilling and reskilling, placing particular emphasis on professions, industries and geographic areas that are significantly impacted by the shift towards green initiatives.
- Thinking beyond government and developing partnerships across sectors to substantially enhance the success of attracting relevant talent. For example, industry-level responses, facilitated by bodies like industry skills councils, yield significant outcomes, as seen with France's Qualit'EnR programme enhancing training standards for renewable energy installation in the construction sector.
- Public-private partnerships blending government resources with business expertise and effectively driving skill relevance and green transformation, often involving trade unions and employers'

associations. Denmark and Germany's tripartite vocational training governance ensures holistic curriculum updates, while Spain's Navarre region achieved a 65% increase in renewable electricity through a public-private skills initiative (CENIFER).

Policy takeaways to enhance skills amongst rural manufacturers

Encouraging firms to identify automation as an opportunity, not just a challenge for rural areas, through helping to overcome skills shortages based on population declines, is a crucial first step.

Identifying skills for the future will be based on the niches of specialisation identified through regional development plans such as smart specialisation strategies, which means reducing substantial future skills mismatches can begin.

Through local higher education and vocational training programmes and partnerships with educational institutions, the manufacturing sector can aim to equip young people with essential skills to attract young workers and females by challenging outdated perceptions of manufacturing.

Highlighting rural assets, such as relatively cheap land access to natural resources and local experience in circular economies, can help attract green jobs to the regions.

Climate change and rural manufacturing

This section identifies impacts on, and challenges and opportunities for, rural manufacturing based on climate change and the net zero emissions transition. One of the ways in which rural development challenges pertaining to climate change can be identified is through understanding rural exposure to employment and business activity in manufacturing sectors that are at risk of changes in employment and industrial comparative advantages. Beyond the sectors and sub-sectors themselves, impacts from climate change itself may be felt differently for areas that are more rural. At the same time, there will also be opportunities for rural development by working on climate solutions.

Noteworthy trends for rural manufacturing

Rural exposure to climate challenges

Natural hazard-induced disasters have significantly increased over the last 2 decades, from 4 212 events during the 1980-99 period to 7 348 events between 2000 and 2019 (RED/UNDRR, 2020[57]). Whilst ecosystem services and the potential of the renewable energy sector in rural regions are key to rural economic development and reducing emissions, rural areas are particularly vulnerable to climate change due to ageing, lower education levels and less diversified economic activity. Rural areas with carbon-intensive industries are also contributing higher emissions per capital than their metropolitan counterparts.

Rural regions are pivotal in the transition to a net zero emission economy and building resilience to climate change. Rural regions are home to around 30% of the OECD's population and cover approximately 80% of its territory, containing the vast majority of the land, water and other natural resources. OECD countries account for 27% of the world's forest areas (OECD, 2017[58]), many of which are in rural regions. These lands are needed for food and renewable production from wind, water and biomass. They are also where we find natural beauty, biodiversity and ecosystem services that produce clean air, detoxify waste, clear water, sequester carbon and allow for recreation.

However, at the same time, rural regions are themselves contributors to climate change. Rural economies produce almost all of the food, energy, timber, metals, minerals and other materials for society. Rural industries often contribute significant amounts of GHG emissions in producing these materials. Global population growth and increased living standards have raised the demand for many resources, products and materials. This has put strong pressure on extraction and production, often increasing emissions and depleting the earth's ability to absorb carbon dioxide (CO2). For example, the extraction and initial processing of metals, which largely happens in rural regions, is responsible for 26% of global CO2 emissions (IEA, 2017[59]).

Consequently, many rural communities feel left behind and face a number of challenges in reducing their carbon footprint while maintaining efficient operations. Rural regions and their workers specialised in economic activities, which would need to be phased out in the transition to net zero emissions, need targeted support with regard to climate change. As non-renewable resources run out, rural economies will suffer significant losses as they rely on the direct extraction of resources from forests, agricultural land and oceans or the provision of ecosystem services such as healthy soils, clean water, pollination and a stable climate.

Many rural economies (e.g. fisheries, mining, energy, etc.) are already suffering from the increased frequency and intensity of extreme weather events such as storms, floods, droughts and landslides, which can jeopardise the safety of production sites. In many rural regions across the world, increasing heatwaves will contribute to water scarcity, with risks to food production. Rural communities also often confront natural disasters with limited resources, expertise and capacity to adequately prepare for extreme weather events. As previously mentioned rural areas will face higher demographic challenges such as concentrations of elderly, increases rural areas' vulnerability to natural disasters. For instance, by 2050, nearly 20% of the population in European regions outside of metropolitan areas are expected to be 65 years or older (OECD, 2020[36]). Geographical distance to services and less developed transportation services in rural regions amplify these challenges.

Rural communities often struggle to adapt and prepare for the transformational challenges required to move to net zero emissions. The benefits of globalisation and technological change have not reached many rural places in the past few decades and regional inequalities have increased. Population ageing, limited economic diversity, limited capacity and dependence on external markets and transport often accelerate their vulnerability.

Furthermore, rural regions are highly dependent on transport to move and export the tradeable products they produce. Thus, the sector faces the challenges of reducing its environmental footprint in production and the movement of goods while maintaining efficient operations and dealing with the penalty of distance. Consequently, many rural communities feel left behind and face a number of challenges to overcome. Rural regions and their workers that are specialised in economic activities, which would need to be phased out in the transition to net zero emissions, need targeted support with regard to climate change.

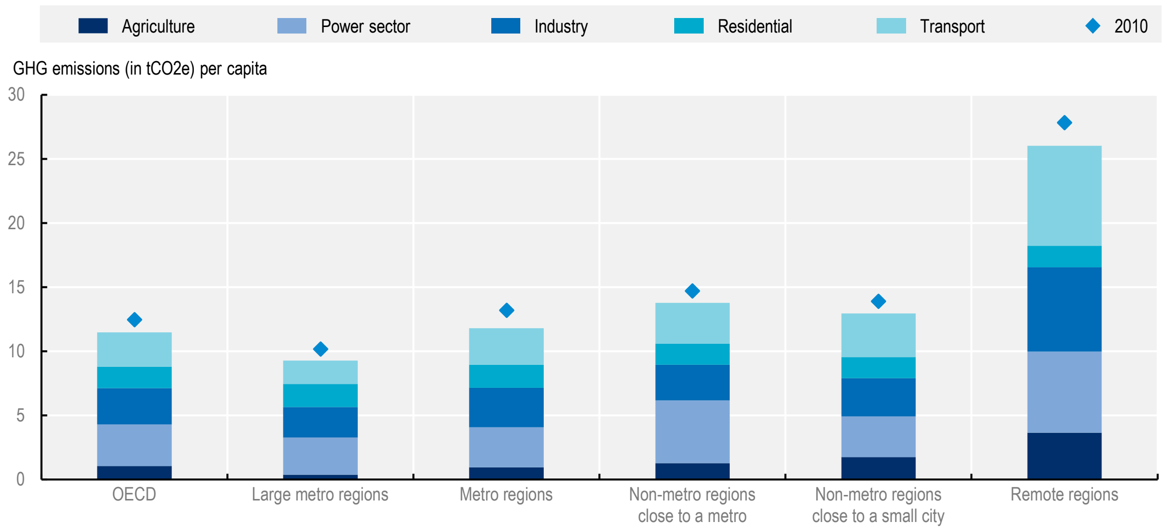
Emissions from manufacturing

Industry is one of the most polluting sectors, contributing a quarter of direct global GHG emissions (not taking into account indirect emissions from electricity and heat production) (Dhakal et al., 2022[60]). This points to the challenges in transitioning towards a net zero emissions economy. The manufacturing sector also tends to be more energy-intensive compared to other sectors. In 2021, the industrial sector accounted for 38% of the total global final energy consumption (IEA, 2017[61]).

Furthermore, while metropolitan regions contribute more to cross-sector emissions and industrial emissions in absolute production-based terms, rural regions have higher emissions per capita, both across sectors and for industry specifically (Figure 4.12).

Figure 4.12. Greenhouse gas emissions per capita are highest in remote regions

Production-based GHG emissions per capita by type of region, 2018



Note: OECD countries, plus Bulgaria and Romania. GHG emissions, excluding emissions from land use and land use change. Geographical typology refers to OECD TL3 typology defining metropolitan (large MR-L and medium MR-M) and non-metropolitan regions (near a large city NMR-M, near a small city NMR-S and rural region NMR-R), for further details see Box 2.1.
Source: Calculations based on EC (2023[62]), *EDGAR - Emissions Database for Global Atmospheric Research*, https://edgar.jrc.ec.europa.eu/; last accessed April 2021, OECD (2021[63]), *OECD Regional Outlook 2021: Addressing COVID-19 and Moving to Net Zero Greenhouse Gas Emissions*, https://doi.org/10.1787/17017efe-en.

StatLink https://stat.link/79ewtk

High industrial emissions per capita exemplify the economic importance of (emissions-intensive) industries, such as the manufacture of steel and cement, in rural regions (OECD, 2021[63]). Moreover, while manufacturing emissions decreased in metropolitan regions across the OECD, they increased by 9% in remote regions since 1970 (OECD, 2022[64]).

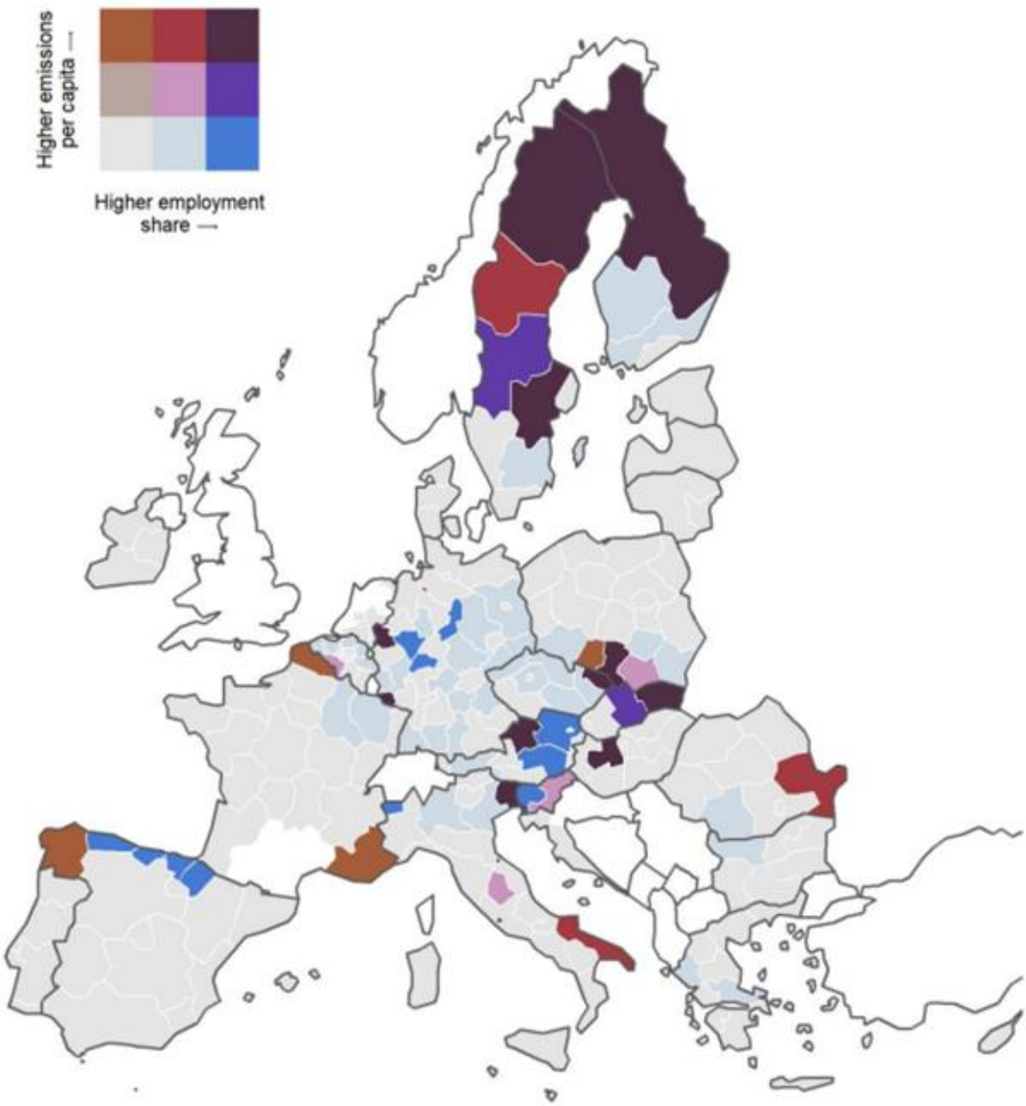
Some types of manufacturing are more polluting than others. Following the ISIC classification, the manufacture of coke and refined petroleum products, of basic metals (which includes steel), of other non-metallic mineral products (which includes cement) and of chemicals and chemical products are the most emissions-intensive. The manufacture of motor vehicles has high indirect emissions from product use.

Combining the sectoral and regional approach

Manufacturing activities are regionally concentrated, posing challenges for economic growth that also reduces regional inequalities (a just transition). The local exposure to the transition of manufacturing to climate neutrality can be measured by simultaneously assessing local employment in the manufacturing sector and manufacturing-related emissions per capita (OECD, 2023[65]). Such data are more available for large regions (TL2 – see box 2.1 in chapter 2 for more detail). Figure 4.13 takes the example of the manufacture of basic metals and estimates find that manufacturing activity and emissions are further concentrated in small regions (TL3), including rural regions.

Figure 4.13. Regional employment and emissions in the manufacture of basic metals, TL2 regions

Emissions per capita from the manufacture of basic iron and steel and of ferroalloys (ISIC 241) and aluminium production (ISIC 2442), and employment shares in the manufacture of basic metals (ISIS 24)



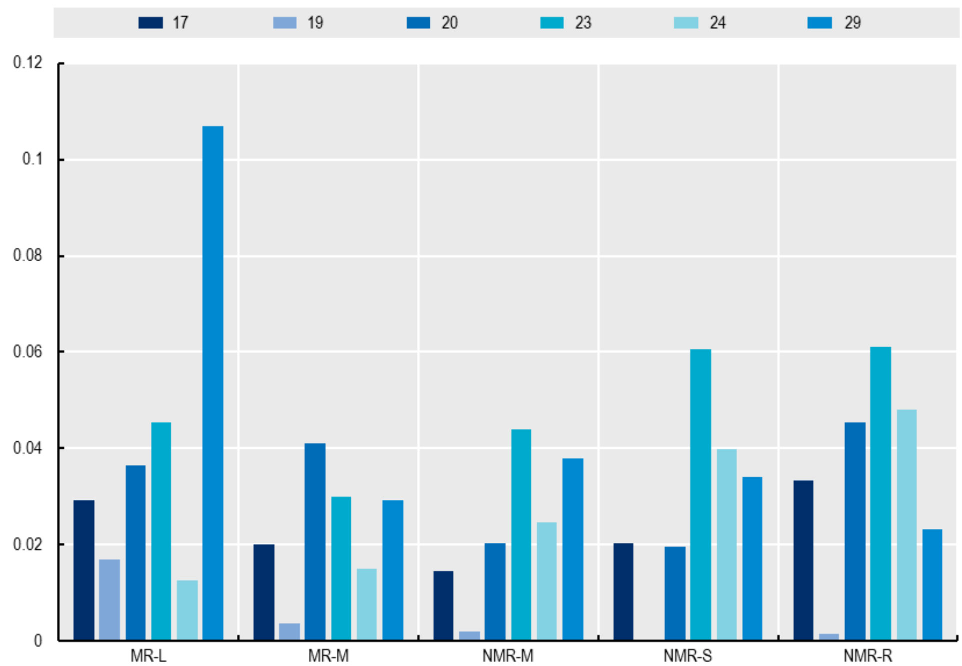
Note: Breaks in employment shares are at 0.5% and 1%. Breaks in emissions per capita are at 0.25 and 0.5 tonnes of CO_2 equivalent per capita. White areas represent missing data. North Holland has high emissions but does not provide employment data. Emissions per capita are calculated as emissions from European Union Emissions Trading System (EU ETS) installations of businesses whose main activity is in the manufacture of basic iron and steel and of ferroalloys (ISIC 241) and aluminium production (ISIC 2442) divided by population in TL 2 regions. Employment shares are calculated as employment in the manufacture of basic metals (ISIC 24) as a share of total employment in TL 2 regions.
Source: Fuentes, A., J. Noels and D. Derecichei (forthcoming[66]), "Regional industrial transitions to net climate neutrality: Identifying most affected", OECD Publications, Paris.

StatLink https://stat.link/ajg6zr

Utilising more granular data from 6 OECD countries, Figure 4.14 highlights some of these hard-to-abate/emissions-intensive sectors highlighted above by region type. Here it can be seen that many of these subsectors host a relatively higher share of employment in non-metropolitan regions. For example, employment in the manufacture of other non-metallic mineral products is, on average, twice as high in non-metropolitan than metropolitan regions. And so, in turn, these regions are more exposed to potential transitions towards net zero.

Figure 4.14. Manufacturing employment in emission-intensive sectors by region type

Share of total regional employment by region type, 2020



Note: Industries are categorised as follows: 17 - Manufacture of paper and paper products; 19 - Manufacture of coke and refined petroleum products; 20 - Manufacture of chemicals and chemical products; 23 - Manufacture of other non-metallic mineral products; 24 - Manufacture of basic metals; 29 - Manufacture of motor vehicles, trailers and semi-trailers. Geographical typology refers to OECD TL3 typology defining metropolitan (large MR-L and medium MR-M) and non-metropolitan regions (near a large city NMR-M, near a small city NMR-S and rural region NMR-R), for further details see Box 2.1.
Source: Based on national statistics agency data from Finland, Norway, Portugal, Slovenia, Sweden and Switzerland for which two-digit manufacturing employment data at the TL3 level was unaggregated.

StatLink https://stat.link/rs92go

Challenges and opportunities for rural manufacturing related to climate change

Challenges

The vulnerability of rural regions exposed to manufacturing transitions can be measured across multiple dimensions, namely local employment and worker characteristics, firm competitiveness and existing regional development challenges (OECD, 2023[65]). A fairer net zero transition should consider the local labour market and help firms remain competitive.

- **Jobs**: As noted in earlier sections of the report, the net zero emissions transition will bring both employment losses in high-carbon jobs and gains in low-carbon jobs. However, the geographic overlap between low- and high-carbon jobs may be limited (Saussay et al., 2022[67]). Hence, rural regions with more activity in emissions-intensive industrial sectors may initially struggle to absorb employment losses in those sectors. Moreover, low-carbon jobs require different skills. Over time, local labour markets will need to reskill to approach low-carbon-based job tasks. While only a limited number of measures are currently directed at areas that will support the development of such skills, demand for them has been growing (OECD, 2023[50]). Furthermore, a shift from high-carbon to low-carbon labour markets may have other negative distributional effects. For example, so far, high-skilled and educated workers have predominantly captured employment opportunities from the transition (OECD, 2023[50]). However, workers with lower educational attainment and in medium-skilled occupations are at higher risk of displacement. Individuals at high risk of displacement are predominantly male and have lower educational attainment and medium-skill levels. They also tend to have lower training participation rates than other workers (OECD, 2023[50]).

- **Productivity**: At the company level, there is fear that climate-related action will bring cost implications. However, increasing evidence shows climate policy does not necessarily negatively affect firm competitiveness. Indeed, research found that the EU Emissions Trading System (EU ETS) had no significant impact on firm profits and employment and even increased regulated firms' revenues and fixed assets (Dechezleprêtre, Nachtigall and Venmans, 2023[68]). However, the OECD (2023[65]) found that European regions that are most vulnerable to the transition to climate neutrality in heavy industry can host low-productivity firms, posing challenges to a fairer transition. Low-productive firms may find it harder to adopt new clean technologies. Hence, as sectors transition, these firms may struggle to keep up and may need to exit the market. Therefore, rural regions with less productive firms and their workers in industrial sectors may be more vulnerable.
- **Diversification**: Finally, regions underperforming on socio-economic characteristics compared to the national or macro-regional average may be less willing to undertake transitions and need more policy attention to ensure a fairer transition (OECD, 2023[65]). For example, regions with lower gross domestic product (GDP) per capita will have fewer public and private resources to provide services, infrastructure and other forms of support to firms and individuals involved in the transformations. They may also be less able to offer attractive alternatives for economic activity or employment, leading to wider issues relating to locating in a rural area. Rural regions can ensure they examine if the necessary infrastructure and institutions (e.g. schools) are in place to support the green transition. One way of doing this is through creating coalitions to co-ordinate diversification at the local level. For instance, the Oulu Innovation Alliance, created in 2009, functioned as an informal discussion platform for relevant stakeholders and resulted in business development being reorganised into Business Oulu, a strategic hub for boosting start-up ecosystems in the area. All coalitions showed a willingness to take risks. This facilitated a start-up boom, in which over 600 start-ups were created.
- **Climate hazards**: While manufacturing may be less impacted than more weather-reliant sectors, such as agriculture, climate change will directly affect manufacturing companies and employees. Climate-induced weather events may cause significant losses and damage to rural manufacturing.[3] In addition, deteriorating climatic conditions are generally associated with more urbanisation (Castells-Quintana, Krause and McDermott, 2020[69]), leading to a particular challenge for rural manufacturers and communities.

  Climate hazards can affect local manufacturing activity either directly at the local establishment level or indirectly through disruptions in the supply chain. Floods can damage facilities, complicate the transportation of material inputs and final goods, and reduce production outputs as a result. For example, a severe flood close to a car assembly site can reduce the production facility's output by a third (Castro-Vincenzi, 2022[70]). Indaco, Ortega and Taşpınar (2020[71]) find persistent declines in employment and wages in businesses affected by Hurricane Sandy.

  Linking to an earlier challenge, climate-induced hazards can affect workers and reduce the productivity of local labour markets. For example, labour exposure to heat stress driven by climate change will increase significantly with the rising global temperatures (Szewczyk, Mongelli and Ciscar, 2021[72]). Under heat stress, workers must reduce work intensity and take longer breaks from work to prevent occupational illness and injuries. Regions where the dominant occupations have relatively lower earnings would also experience higher productivity losses. In addition, growing evidence shows that climate change impacts the distribution of economic activity across regions (Desmet and Rossi-Hansberg, 2015[73]).

Opportunities

Whilst climate change poses both transition and physical risks to rural manufacturing, there are also opportunities that rural regions can grasp. Rural manufacturers that are proactive about building climate solutions can benefit from both a climate change mitigation and adaptation perspective.

Most production outputs of manufacturing firms will continue to be needed in a climate-neutral economy. Rather than phasing out activities, manufacturing subsectors need to transform the way they produce products. However, many net zero technologies that transform these production processes are in their infancy.

Some decarbonisation approaches can be used across most manufacturing subsectors. These include shifting to zero-carbon energy sources, reducing energy consumption through increased energy efficiency and improving material circularity. The manufacture of steel, cement and chemical products is particularly hard to abate. Transformation levers in the chemical sector include the use of green hydrogen and biofuels as feedstock. Steel manufacturing can decarbonise through hydrogen-based production. Decarbonising manufacturing of cement requires the use of carbon capture and storage to remove process emissions.

There are sustainable growth opportunities from developing new technologies such as carbon capture, utilisation and storage-related technologies, products and services (Andres et al., 2021[74]) and manufacture of zero-emission passenger vehicles (Unsworth, Martin and Verhoeven, 2020[75]). Evidence suggests that investments in the development and diffusion of infrastructure and human capital for such technologies can generate job opportunities in the short and longer run (Stern and Valero, 2021[76]).

Policy makers can encourage investment in clean technology innovation by providing direct grants for R&D, skilled immigration and improving human capital (Bloom, Van Reenen and Williams, 2019[77]). This may lead to local knowledge spillovers, which can boost rural economic growth. In fact, evidence suggests that clean technologies generate more spillovers than more emissions-intensive counterparts (Dechezleprêtre, Martin and Mohnen, 2014[78]), also providing a more welcome environment to green start-ups (Colombelli and Quatraro, 2017[79]).

The focus on green growth opportunities for local economies has been on technologies that support the net zero emissions transition. Indeed, finding ways to use less energy and material does not just benefit the climate; it helps manufacturers lower their costs and become more competitive. There will also be opportunities for developing and implementing climate change adaptation solutions and innovations. Investment in adaptation solutions can either create new industrial activities or maintain the competitiveness of existing manufacturing activities. However, if rural regions want to capture those opportunities, they will have to train or attract workers with relevant skills.

While climate hazards make firms and workers vulnerable, there is growing evidence of adaptation solutions that build resilience. For example, Fatica, Kátay and Rancan (2022[80]) find that manufacturing firms located in more flood-prone areas are able to better withstand flood damages over time than firms in less flood-prone areas, likely through updates in their capital stock and adoption of new technologies.

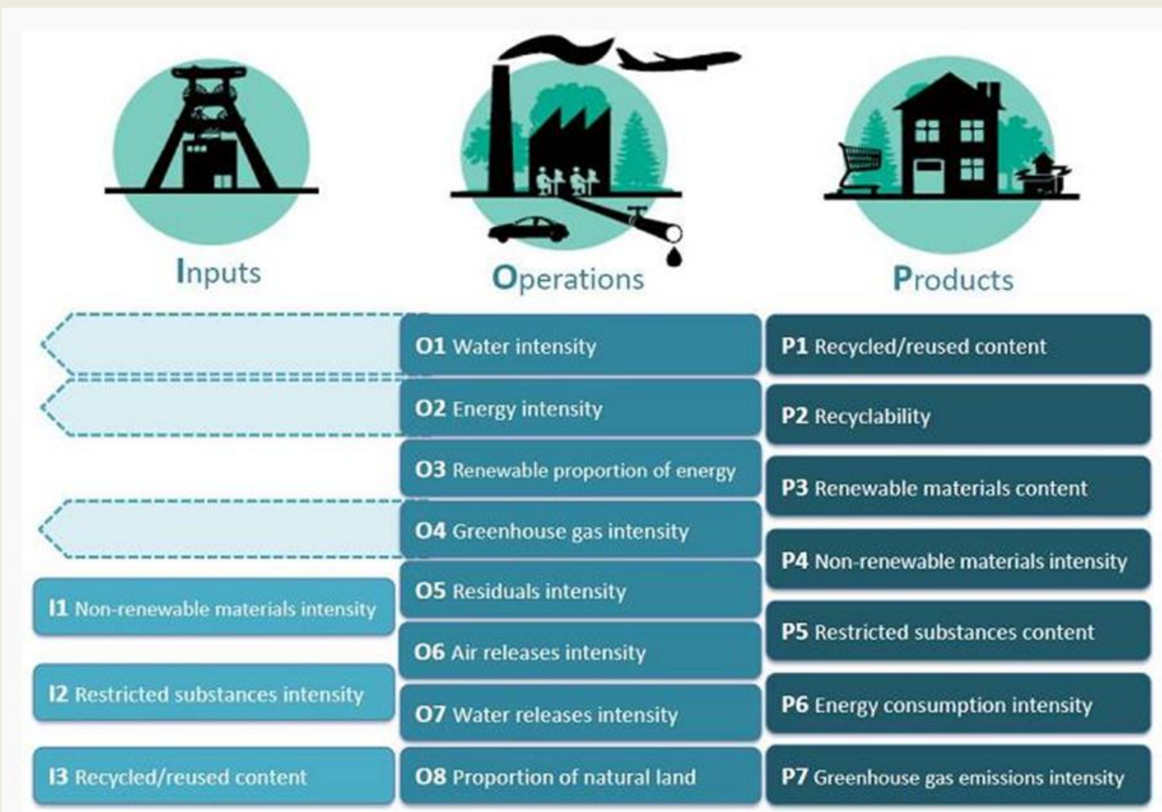
Rural regions may also have a range of competitive advantages to grasp opportunities. For example, remote regions may have an advantage in providing renewable energy and sequestering carbon from the atmosphere through sustainable land use. Already, rural regions are hosting more electricity from renewable sources (OECD, 2022[64]).

Box 4.6. The green transition of manufacturing must consider all aspects of the production process

Overview of the OECD sustainable manufacturing indicators

Managing operations in an environmentally and socially responsible manner – "sustainable manufacturing" – is no longer just nice-to-have but a business imperative. Companies across the world face increased costs in materials, energy and compliance coupled with higher expectations of customers, investors and local communities. As such, the OECD has developed a toolkit that highlights areas of development along the production process to facilitate businesses and support governments in the transition within the manufacturing sector. The area covers inputs, outputs and products, as illustrated below.

Figure 4.15. Overview of the OECD Sustainable Manufacturing Indicators



Note: Indicators O1, O2 and O4 can be extended to measure the impact associated with the supply chain as well as the facility, namely water and energy consumed and GHG emissions caused during the production of inputs.
Source: OECD (2023[81]), *OECD Sustainable Manufacturing Indicators*, https://www.oecd.org/innovation/green/toolkit/oecdsustainablemanufacturingindicators.htm.

Policy takeaways to harness the opportunities and overcome challenges of climate change for rural manufacturing

- Policy makers can encourage the greening of the entire production process, from inputs to operations, by facilitating access to financial capital and the development of regional development agencies to search for innovations and adjustments across the production process.
- Provide regional support in shifting the manufacturing sector towards decarbonisation approaches through direct grants in R&D and other policies. The strategies most applicable across most manufacturing sectors include zero-carbon energy sources, reducing energy consumption through increased energy efficiency and improving material circularity.
- Help accelerate the green transition in rural regions towards green technology industries by ensuring necessary infrastructure, institutions, support networks and policy incentives. Helping existing manufacturing firms utilise their current assets to effectively transition their supply chains to greener inputs can also accelerate the transition.
- Invest in reskilling the local labour market to low-carbon-based job tasks to limit displacement effects through reducing the production of manufacturing of high-carbon-intensive products.

Adding value to production

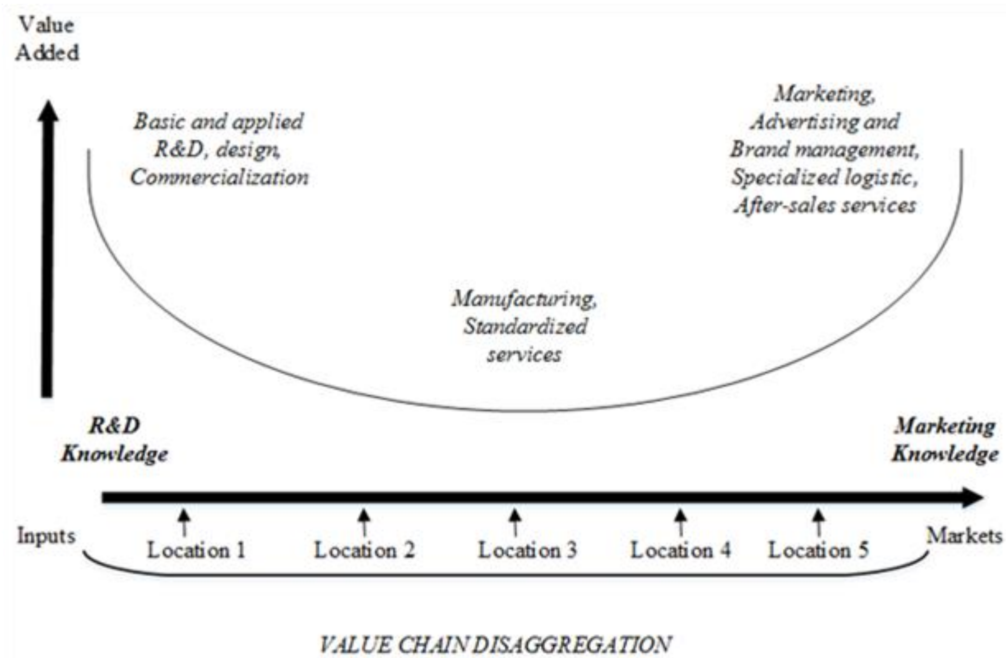
As noted in the technology section of the report, productivity and value-added are not solely defined by the sector or subsector of manufacturing but take into account differences within sectors. In this section, we note that, in fact, differences exist within a single product, driven by what part of the production process a firm is involved in.

In today's global market economy, world production lines are increasingly fragmented. Information and communication technology and automation made it possible to slice up the supply chain. Activities are, therefore, de-localised, especially in countries that could guarantee a relatively lower labour cost or relatively less stringent standards of production. These decades of decoupling different stages of the manufacturing product life cycle have meant that firms can, at least theoretically, locate anywhere (Navaretti et al., 2020[82]).

Increased competition in low-wage jurisdictions suggests that value-added in manufacturing across OECD countries will need to come from R&D and commercialisation of products. Production has become a low-value-added stage in the life cycle of some products in recent decades (Ding et al., 2022[83]). At the same time, the need to innovate and differentiate the products has made some service functions associated with manufacturing – product research, development and design, sales, marketing and branding, and after-sales service – all the more important, thereby raising the value-added of these activities. The result has been to raise the relative value of these activities relative to production, a pattern first described as a "smile curve" (Figure 4.16).

The physical decoupling of these higher value-added functions from the production process is now coming under scrutiny, giving room for rural areas to benefit. This, in practice, often meant that production was outsourced to emerging markets. The physical fragmentation of production put an end to the large-factory era and many manufacturing towns that traditionally specialised in low-cost production have lost their competitiveness. Free trade agreements have further accelerated the globalisation of manufacturing supply chains. Routine and less complex activities have been located in more remote and cheaper locations, while more complex and innovative activities have been concentrated more fully in urban areas to benefit from agglomeration advantages (Anas, Arnott and Small, 1998[84]; Balland and Rigby, 2016[85]). However, in these circumstances, room remains for rural areas to benefit from these fragmented products by understanding the tasks in GVCs and identifying their niche value-added to these chains.

Figure 4.16. Smile curve of value-added in the production line



Source: Mudambi, R. (2008[86]), "Location, control and innovation in knowledge-intensive industries", https://doi.org/10.1093/jeg/lbn024.

Disruptions of value chains during the pandemic and rises in transportation costs due to the Russian war of aggression against Ukraine have revived the debates of re-coupling and building more resilience. Since the COVID-19 pandemic, several OECD countries have experienced a lack of domestic production capacity in several suddenly critical sectors. At the same time, research that had previously indicated that the high value-added functions might follow suit to relocate to emerging markets (Bailey and De Propris, 2016[87]) was gaining traction. Transportation cost rises have also contributed to reconsidering the re-coupling of economic activity in closer locations. Whilst production costs may be cheaper offshore, transportation costs have accelerated, driven further by the rise in gas prices following the Russian war in Ukraine. These rising costs make localised production chains more economically feasible and competitive. Whilst this is not the case for service segments of manufacturing firms that transmit information digitally, the bottlenecks in other segments of the chain may also affect these firms' profitability. Given these concerns, the debate regarding re-coupling production lines, reshoring and nearshoring have been given more airtime as a means to build greater regional resilience.

Against this backdrop, manufacturing activities in rural areas have also been evolving to add more value-added to their activities in multiple ways:

- **Manufacturers who streamline their internal administration and operations by outsourcing service functions**. This might include basic functions such as cleaning and catering services for the factory's canteen or more sophisticated functions such as the firm's payroll management, bookkeeping and customer relationship management. Recent decades have seen the emergence of several specialised software products and cloud services for such functions.

- **Manufacturers who improve GVC linkages of their local industry**. Several variations on this have developed whereby companies send some or all of their production to facilities in other countries that they may or may not own, meaning that the parts of the firm that remain in the home country are increasingly service-oriented. Some firms, for example, German appliance maker Miele, have off-shored the production of some of their lower-end products and components to China while continuing to build high-end appliances and high-value components, such as the motors for their vacuum cleaners, at home in Germany. Another example might be Apple, which, until the late 1990s, built its products at its own factories in California, Ireland and Singapore but has since outsourced virtually all of its production to third-party firms. Today, Apple's employees work almost exclusively on the design and development processes that occur before production and the sales and after-market service functions that follow production, with the production itself entrusted almost entirely to other firms. The company also derives an increasing portion of its revenue from subscription services (such as music and video content) designed to run on its hardware platforms.
- **Manufacturers who transform their business model to become service providers through manufactured products**. For example, a company that previously built and sold air compressors might instead sell customers a promise of readily available compressed air, for which the customer pays a subscription fee rather than purchasing the compressor itself. The company might still build air compressors but now sells a service instead of manufacturing products.

Policy takeaways to make the most of GVCs

- Manufacturing in rural areas has been transforming; as such, the best means of adding value should be carefully considered by policy makers.
- Whilst historically, vertical production lines meant vast amounts of cheap land was the reason for locating in rural areas, today, value chains are more fragmented and the production segment is considered the lowest value-added part of the chain.
- Therefore, rural regions are no longer solely competitive in low-cost production functions. At the same time, manufacturing is more integrated with services.
- Policies that wish to benefit from this tertiarisation must look beyond the product itself and consider the higher value-added functions in the chain (including R&D activity, marketing or post-sales services).
- The fragmentation of supply chains can be an advantage in finding niche opportunities and markets for rural regions.
- Given the disruptions in GVCs, their assets and locations can be considered a strategic advantage.

Summary

The previous chapters focus on identifying some key drivers of rural manufacturing and examined the trends across rural regions and inside countries in rural manufacturing over the past two decades. The trends indeed confirm that although there is a long-term process of deindustrialisation, in OECD rural economies they remain an important driver of productivity growth. The analysis also showed a gradual transformation of more capital intensity in rural manufacturing activities. This chapter examines several megatrends and their implications for rural manufacturing moving forward.

Technological advances are becoming increasingly important to sustain competitiveness in manufacturing. Indeed, advancements in digital manufacturing, advanced robotics, bio- and nanotechnology, photonics, micro-and nano-electronics, new materials, amongst others are changing the industry and leading to a range of new business models for manufacturers. The chapter examines trends in technology intensity across types of regions and reveals a higher share of manufacturing employees in high technology (twice) in metropolitan against non-metropolitan regions. In turn the share of manufacturing employees in medium-high technology appears to be equally distributed in all types of regions except for remote regions, which appears lower. Medium-low technology is higher in all three non-metropolitan regions and low-technology is higher in remote regions. These average figures of course mask important variations within countries. The case of Slovenia is an interesting case study illustrating non-metropolitan regions have gradually integrated into global value chains upgrading their technology intensity gradually over the past two decades.

The chapter then focuses on the importance of upgrading skills to mitigate the risks of automation in rural regions and to take advantage of new possible manufacturing jobs in the green economy. In particular, it calls for an urgent need to close the gap in digital skills between rural and urban areas with the share of individuals living in rural areas with basic or above digital skills standing at 23% against 62% in cities.

Finally, the chapter also highlights the need for the manufacturing sector to transition towards a net zero emissions economy, especially in rural remote regions where per-capita emissions in industry are higher. In this respect it highlights policy responses that can accelerate the greening of manufacturing through direct grants in R&D and other policies, increased energy efficiency, improving material circularity amongst others.

Annex 4.A. Data summary

Annex Table 4.A.1provides a summary of the data collected from national statistics agencies and utilised as part of this report.

Annex Table 4.A.1. Data summary country breakdown

Breakdown of data availability by country regarding employment and GVA

Country	Employment		Gross value added		Number of regions
	Indicator	Year	Indicator	Year	
Finland	Disaggregated	2000-20	Disaggregated	2000-20	19
Portugal	Disaggregated	2013-20	Disaggregated	2013-20	25
Sweden	Aggregated	2007-20	Aggregated	2007-20	21
Japan	Aggregated	2012, 2016	Aggregated	2012, 2016	47
Denmark	Disaggregated	2009-21	X	X	11
Norway	Disaggregated	2008-22	X	X	13
Slovenia	Disaggregated	2000-20	X	X	12
Switzerland	Disaggregated	2011-20	X	X	26
Australia	Aggregated	2011, 2016, 2021	X	X	50
Canada	Aggregated	2001, 2016	X	X	282
Germany	Aggregated	2007-22	X	X	400
Ireland	Aggregated	2012-21	X	X	8

Note: Disaggregated refers to the data being available for the majority of two-digit ISIC Rev. 2 manufacturing sub-industries in a country, while aggregated means the data are only available by technological group (high technology, medium-high technology, medium-low technology, low technology) without further differentiation. X refers to unavailability of data.
Source: Statistics office of the respective country.

Annex Table 4.A.2. Industrial classification used

Two-digit ISIC Rev. 2 industry	Technology group	Manufacturing industry
10	Low	Manufacture of food products
11	Low	Manufacture of beverages
12	Low	Manufacture of tobacco products
13	Low	Manufacture of textiles
14	Low	Manufacture of wearing apparel
15	Low	Manufacture of leather and related products
16	Low	Manufacture of wood and of products of wood and cork
17	Low	Manufacture of paper and paper products
18	Low	Printing and reproduction of recorded media
19	Medium-low	Manufacture of coke and refined petroleum products
20	Medium-high	Manufacture of chemicals and chemical products
21	High	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Medium-low	Manufacture of rubber and plastic products

Two-digit ISIC Rev. 2 industry	Technology group	Manufacturing industry
23	Medium-low	Manufacture of other non-metallic mineral products
24	Medium-low	Manufacture of basic metals
25	Medium-low	Manufacture of fabricated metal products, except machinery and equipment
26	High	Manufacture of computer, electronic and optical products
27	Medium-high	Manufacture of electrical equipment
28	Medium-high	Manufacture of machinery and equipment n.e.c.
29	Medium-high	Manufacture of motor vehicles, trailers and semi-trailers
30	Medium-high	Manufacture of other transport equipment
31	Low	Manufacture of furniture
32	Low	Other manufacturing
33	Medium-low	Repair and installation of machinery and equipment

Annex 4.B. Alternative technological classification

This annex compares the groupings of technological intensity used on the analysis to an alternative grouping based on the work of Lall (2000[6]). Lall (2000[6]) proposes to classify the technological structure based on exports at the three-digit level of the European Commission Standard international trade classification (SITC) Rev. 2, meaning products are categorised into natural resource-base, low-technology, medium-technology, high-technology and primary products.

After classifying all products according to this classification, we mapped SITC Rev. 2 to ISIC Rev. 2, as illustrated in Annex Figure 4.B.1.

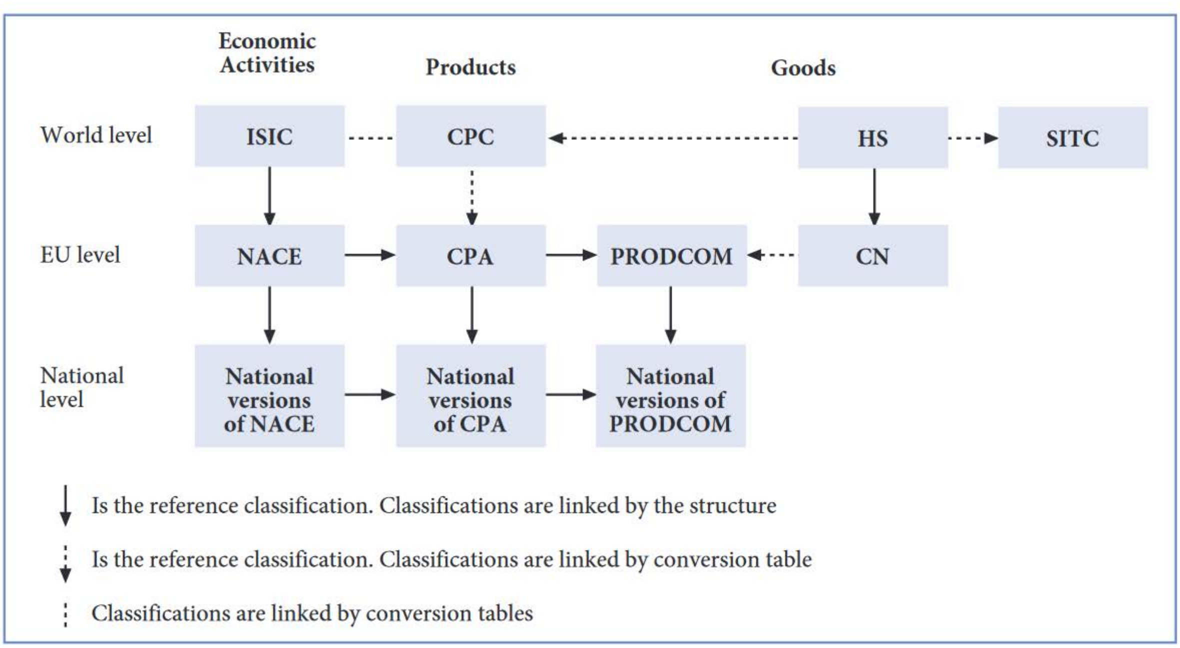
- SITC Rev. 2 to HS 2007
- HS 2007 to CPC Ver. 2
- CPC Ver. 2 to ISIC Rev. 4
- ISIC Rev. 4 to NACE Rev. 2.

Annex Figure 4.B.1. Mapping tree

ISIC and the integrated system of classifications of economic activities and products

The international system of economic classifications

3. The comparability at world level of statistics produced on the basis of NACE is due to the fact that NACE is part of an integrated system of statistical classifications, developed mainly under the auspices of the United Nations Statistical Division. From the European point of view, this system can be represented as follows:

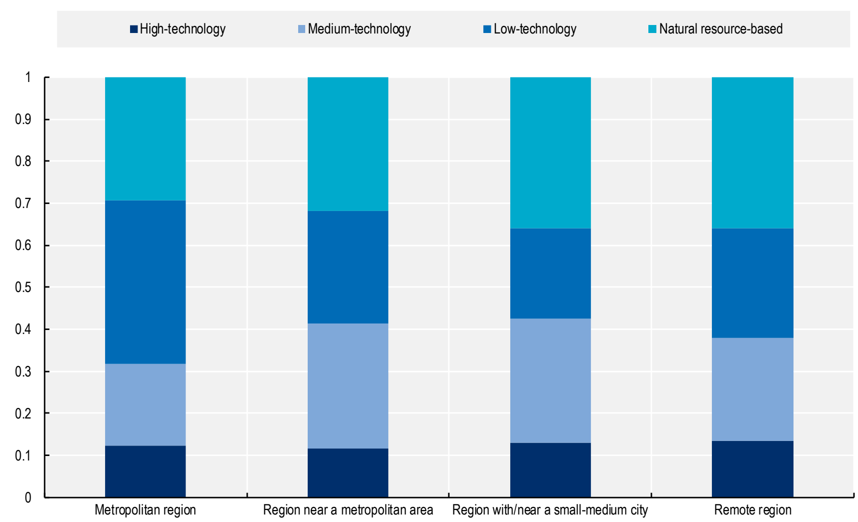


Source: Eurostat (2008[88]), *NACE Rev. 2 - Statistical Classification of Economic Activities*, https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/ks-ra-07-015. United Nations Department of Economic and Social Affairs (United Nations Department of Economic and Social Affairs, 2008[8]) https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

Building on this new classification of technological intensity, we compared this technological intensity breakdown with the one as used throughout the report for the case of Norway.

As can be seen in Annex Figure 4.B.2 and Annex Figure 4.B.3, there are some differences regarding the specific breakdown. The alternative methodology shows a slight more even distribution of technology types across regions allocating a higher share of high-technology employment across all region types. Medium-low technology is also higher, while low technology is consistently higher. Medium-low-technology employment, however, is relatively similar. All in all, this suggests that caution should be taken in the categorisation of industries.

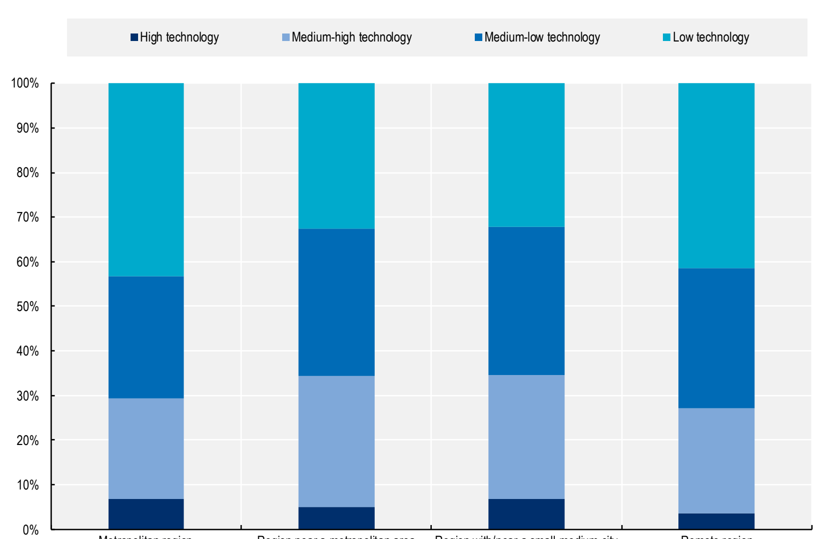
Annex Figure 4.B.2. Alternative technological intensity breakdown for Norway, 2019



Source: Based on data from Statistics Norway.

StatLink https://stat.link/ebrlph

Annex Figure 4.B.3. Original specification of technological intensity breakdown for Norway, 2019



Source: Based on data from Statistics Norway.

StatLink https://stat.link/2tdb0z

References

Adalet McGowan, M. and D. Andrews (2017), "Skills mismatch, productivity and policies: Evidence from the second wave of PIAAC", *OECD Economics Department Working Papers*, No. 1403, OECD Publishing, Paris, https://doi.org/10.1787/65dab7c6-en. [39]

Anas, A., R. Arnott and K. Small (1998), "Urban spatial structure", *Journal of Economic Literature*, Vol. 36/3, pp. 1426-1464, https://www.jstor.org/stable/2564805 (accessed on 8 November 2022). [84]

Andres, P. et al. (2021), *Seizing Sustainable Growth Opportunities from Carbon Capture, Usage and Storage in the UK*, Centre for Economic Performance, https://cep.lse.ac.uk/pubs/download/special/cepsp38.pdf. [74]

Andrews, D., C. Criscuolo and P. Gal (2015), "Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries", *OECD Productivity Working Papers*, No. 2, OECD Publishing, Paris, https://doi.org/10.1787/5jrql2q2jj7b-en. [10]

Arntz, M., T. Gregory and U. Zierahn (2016), "The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis", *OECD Social, Employment and Migration Working Papers*, No. 189, OECD Publishing, Paris, https://doi.org/10.1787/5jlz9h56dvq7-en. [37]

Awano, G. and J. Vyas (2018), *Information and Communication Technology Intensity and Productivity*, Office for National Statistics, United Kingdom. [24]

Bailey, D. and L. De Propris (2016), "Manufacturing Challenges and Opportunities in Europe: Emerging Models and Policy Interventions for Local and National Growth", *OECD Local Economic and Employment Development (LEED) Papers*, No. 2016/3, OECD Publishing, Paris, https://doi.org/10.1787/5jlv81rk1z5k-en. [87]

Balland, P. and D. Rigby (2016), "The geography of complex knowledge", *Economic Geography*, Vol. 93/1, pp. 1-23, https://doi.org/10.1080/00130095.2016.1205947. [85]

Baù, M. et al. (2018), "Roots to grow: Family firms and local embeddedness in rural and urban contexts", *Entrepreneurship Theory and Practice*, Vol. 43/2, pp. 360-385, https://doi.org/10.1177/1042258718796089. [45]

Berlingieri, G. et al. (2020), "Laggard firms, technology diffusion and its structural and policy determinants", *OECD Science, Technology and Industry Policy Papers*, No. 86, OECD Publishing, Paris, https://doi.org/10.1787/281bd7a9-en. [13]

Bessant, J. and J. Buckingham (1993), "Innovation and organizational learning: The case of computer-aided production management", *British Journal of Management*, Vol. 4/4, pp. 219-234, https://doi.org/10.1111/j.1467-8551.1993.tb00060.x. [23]

Bloom, N., J. Van Reenen and H. Williams (2019), "A toolkit of policies to promote innovation", *Journal of Economic Perspectives*, Vol. 33/3, pp. 163-184, https://doi.org/10.1257/jep.33.3.163. [77]

Cammeraat, E. and M. Squicciarini (2021), "Burning Glass Technologies' data use in policy-relevant analysis: An occupation-level assessment", *OECD Science, Technology and Industry Working Papers*, No. 2021/05, OECD Publishing, Paris, https://doi.org/10.1787/cd75c3e7-en. [42]

Castells-Quintana, D., M. Krause and T. McDermott (2020), "The urbanising force of global warming: The role of climate change in the spatial distribution of population", *Journal of Economic Geography*, Vol. 21/4, pp. 531-556, https://doi.org/10.1093/jeg/lbaa030. [69]

Castro-Vincenzi, J. (2022), "Climate hazards and resilience in the global car industry". [70]

Cirera, X. et al. (2020), "Technology within and across firms", *Policy Research Working Paper Series*, No. 9476, World Bank, Washington, DC. [11]

Colombelli, A. and F. Quatraro (2017), "Green start-ups and local knowledge spillovers from clean and dirty technologies", *Small Business Economics*, Vol. 52/4, pp. 773-792, https://doi.org/10.1007/s11187-017-9934-y. [79]

Damioli, G. and G. Marin (2020), *The Effects of Foreign Entry on Local Innovation*, Joint Research Centre, European Commission, https://op.europa.eu/en/publication-detail/-/publication/03023c0f-4019-11eb-b27b-01aa75ed71a1/language-en (accessed on 13 November 2022). [20]

D'Aveni, R. (2015), "The 3-D printing revolution", *Harvard Business Review*, Vol. 93, https://hbr.org/2015/05/the-3-d-printing-revolution (accessed on 22 August 2023). [2]

De Backer, K., I. Desnoyers-James and L. Moussiegt (2015), "'Manufacturing or Services - That is (not) the Question': The Role of Manufacturing and Services in OECD Economies", *OECD Science, Technology and Industry Policy Papers*, No. 19, OECD Publishing, Paris, https://doi.org/10.1787/5js64ks09dmn-en. [1]

Dechezleprêtre, A., R. Martin and M. Mohnen (2014), "Knowledge spillovers from clean and dirty technologies", *CEP Discussion Papers*, No. CEPDP1300, Centre for Economic Performance, London School of Economics and Political Science, London, UK. [78]

Dechezleprêtre, A., D. Nachtigall and F. Venmans (2023), "The joint impact of the European Union emissions trading system on carbon emissions and economic performance", *Journal of Environmental Economics and Management*, Vol. 118, p. 102758, https://doi.org/10.1016/j.jeem.2022.102758. [68]

Desmet, K. and E. Rossi-Hansberg (2015), "On the spatial economic impact of global warming", *Journal of Urban Economics*, Vol. 88, pp. 16-37, https://doi.org/10.1016/j.jue.2015.04.004. [73]

Dhakal, S. et al. (2022), "Emissions trends and drivers", in *Climate Change 2022: Mitigation of Climate Change*, Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, NY, USA, https://doi.org/10.1017/9781009157926.004. [60]

Ding, X. et al. (2022), "Structural change within versus across firms: Evidence from the United States", *Working Paper*, No. 30127, National Bureau of Economic Research, Cambridge, MA, https://doi.org/10.3386/w30127. [83]

DLG (2023), *Additive Manufacturing in Agricultural Technology - AGRITECHNICA*, Deutsche Landwirtschafts-Gesellschaft, https://www.agritechnica.com/en/systems-components/assisted-farming-engineering-agriculture-through-smart-solutions/additive-manufacturing-in-agricultural-technology (accessed on 16 September 2023). [25]

EC (2023), *EDGAR - Emissions Database for Global Atmospheric Research*, Joint Research Centre, European Commission, https://edgar.jrc.ec.europa.eu/ (accessed on 30 August 2022). [62]

Ettlie, J. and E. Reza (1992), "Organizational integration and process innovation", *Academy of Management Journal*, Vol. 35/4, pp. 795-827, https://doi.org/10.2307/256316. [22]

Eurostat (2023), *International Trade and Production of High-tech Products*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_trade_and_production_of_high-tech_products#Manufacturing_of_high-tech_products. [7]

Eurostat (2020), *The European Social Survey*, European Commission, https://ec.europa.eu/eurostat/cros/content/european-social-survey_en. [53]

Eurostat (2008), *NACE Rev. 2 - Statistical Classification of Economic Activities*, European Union, https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/ks-ra-07-015. [88]

Fatica, S., G. Kátay and M. Rancan (2022), *Floods and Firms: Vulnerabilities and Resilience to Natural Disasters in Europe*, Joint Research Centre, European Commission, https://joint-research-centre.ec.europa.eu/publications/floods-and-firms-vulnerabilities-and-resilience-natural-disasters-europe_en. [80]

Fuentes Hutfilter, A., S. Lehmann and E. Kim (2018), "Improving skills and their use in Germany", *OECD Economics Department Working Papers*, No. 1516, OECD Publishing, Paris, https://doi.org/10.1787/8a251b1f-en. [38]

Fuentes, A., J. Noels and D. Derecichei (forthcoming), "Regional industrial transitions to net climate neutrality: Identifying most affected", OECD Publications, Paris. [66]

Gale, H. (1997), "Is there a rural-urban technology gap? Results of the ERS Rural Manufacturing Survey", *Agricultural Information Bulletins*, No. 33709, Economic Research Service, United States Department of Agriculture, https://doi.org/10.22004/ag.econ.33709 (accessed on 12 September 2023). [9]

Georgieff, A. and A. Milanez (2021), "What happened to jobs at high risk of automation?", *OECD Social, Employment and Migration Working Papers*, No. 255, OECD Publishing, Paris, https://doi.org/10.1787/10bc97f4-en. [34]

Goldman Sachs (2023), *Investing $100 Million in the Heart of Rural Communities*, https://www.goldmansachs.com/citizenship/10000-small-businesses/US/investing-in-small-businesses-across-rural-communities/index.html (accessed on 16 September 2023). [27]

Government, Queensland (2023), *Women in Manufacturing*, https://www.rdmw.qld.gov.au/manufacturing/manufacturing-assistance-programs/women-in-manufacturing. [55]

Graham, K. and R. Moore (2017), "Abstract: Firm-level technology adoption processes - A qualitative investigation", in *Creating Marketing Magic and Innovative Future Marketing Trends, Developments in Marketing Science: Proceedings of the Academy of Marketing Science*, Springer International Publishing, Cham, https://doi.org/10.1007/978-3-319-45596-9_207. [30]

Haipeter, T. (2020), "Digitalisation, unions, and participation: The German case of 'industry 4.0'", *Industrial Relations Journal*, Vol. 51/3, https://doi.org/10.1111/irj.12291. [52]

Hauschildt, K. et al. (2021), *Social and Economic Conditions of Student Life in Europe*, Eurostudent VII 2018-2021, Synopsis of Indicators, https://doi.org/10.3278/6001920dw. [54]

IEA (2017), *Digitalisation and Energy*, International Energy Agency, Paris, https://www.iea.org/reports/digitalisation-and-energy. [61]

IEA (2017), *Energy Technology Perspectives 2017: Catalysing Energy Technology Transformations*, International Energy Agency, Paris, https://doi.org/10.1787/energy_tech-2017-en. [59]

ILO (2017), *A Just Transition to a Sustainable Future - Next Steps for Europe*, International Labour Organisation, https://www.ilo.org/wcmsp5/groups/public/---europe/---ro-geneva/---ilo-brussels/documents/publication/wcms_614024.pdf. [48]

Indaco, A., F. Ortega and S. Taşpınar (2020), "Hurricanes, flood risk and the economic adaptation of businesses", *Journal of Economic Geography*, Vol. 21/4, pp. 557-591, https://doi.org/10.1093/jeg/lbaa020. [71]

Kristianto, Y. et al. (2012), "A study of technology adoption in manufacturing firms", *Journal of Manufacturing Technology Management*, Vol. 23/2, pp. 198-211, https://doi.org/10.1108/17410381211202197. [12]

Lall, S. (2000), "The technological structure and performance of developing country manufactured exports, 1985-98", *Oxford Development Studies*, Vol. 28/3, pp. 337-369, https://doi.org/10.1080/713688318. [6]

LaMorte, W. (2022), *Behavioral Change Models: Diffusion of Innovation Theory*, Boston University School of Public Health. [18]

Lightcast (2023), *Homepage*, https://lightcast.io/ (accessed on 15 September 2023). [43]

Maes, M. et al. (2022), "Monitoring exposure to climate-related hazards: Indicator methodology and key results", *OECD Environment Working Papers*, No. 201, OECD Publishing, Paris, https://doi.org/10.1787/da074cb6-en. [89]

McCain, G. et al. (2011), "Enhancing rural manufacturers competitiveness through design automation for new product development", *Journal of Business and Economics Research*, Vol. 2/9, https://doi.org/10.19030/jber.v2i9.2921. [19]

McKinsey (2021), "Human + machine: A new era of automation in manufacturing", https://www.mckinsey.com/capabilities/operations/our-insights/human-plus-machine-a-new-era-of-automation-in-manufacturing (accessed on 28 March 2023). [33]

McKinsey (2017), *Jobs Lost, Jobs Gained: What the Future of Work Will Mean for Jobs, Skills, and Wages*, https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages. [44]

Mudambi, R. (2008), "Location, control and innovation in knowledge-intensive industries", *Journal of Economic Geography*, Vol. 8/5, pp. 699-725, https://doi.org/10.1093/jeg/lbn024. [86]

Muro, M. et al. (2017), *Digitalisation and the American Workforce*, Brookings Institution. [51]

Navaretti, G. et al. (2020), *Multinational Firms in the World Economy*, Princeton University Press, https://doi.org/10.2307/j.ctv10crfcz. [82]

Nedelkoska, L. and G. Quintini (2018), “Automation, skills use and training”, *OECD Social, Employment and Migration Working Papers*, No. 202, OECD Publishing, Paris, https://doi.org/10.1787/2e2f4eea-en. [31]

OECD (2023), *Assessing and Anticipating Skills for the Green Transition: Unlocking Talent for a Sustainable Future*, Getting Skills Right, OECD Publishing, Paris, https://doi.org/10.1787/28fa0bb5-en. [49]

OECD (2023), *Job Creation and Local Economic Development 2023: Bridging the Great Green Divide*, OECD Publishing, Paris, https://doi.org/10.1787/21db61c1-en. [50]

OECD (2023), *OECD Regional Outlook 2023*, OECD Publishing, Paris, https://doi.org/10.1787/21db61c1-en. [40]

OECD (2023), *OECD Sustainable Manufacturing Indicators*, OECD, Paris, https://www.oecd.org/innovation/green/toolkit/oecdsustainablemanufacturingindicators.htm. [81]

OECD (2023), *Regional Industrial Transitions to Climate Neutrality*, OECD Regional Development Studies, OECD Publishing, Paris, https://doi.org/10.1787/35247cc7-en. [65]

OECD (2023), “Regulatory sandboxes in artificial intelligence”, *OECD Digital Economy Papers*, No. 356, OECD Publishing, Paris, https://doi.org/10.1787/8f80a0e6-en. [29]

OECD (2022), *OECD Regions and Cities at a Glance 2022*, OECD Publishing, Paris, https://doi.org/10.1787/14108660-en. [64]

OECD (2022), *Unlocking Rural Innovation*, OECD Rural Studies, OECD Publishing, Paris, https://doi.org/10.1787/9044a961-en. [3]

OECD (2021), *Delivering Quality Education and Health Care to All: Preparing Regions for Demographic Change*, OECD Publishing, https://doi.org/10.1787/83025c02-en. [47]

OECD (2021), *OECD Regional Outlook 2021: Addressing COVID-19 and Moving to Net Zero Greenhouse Gas Emissions*, OECD Publishing, Paris, https://doi.org/10.1787/17017efe-en. [63]

OECD (2020), *Rural Well-being: Geography of Opportunities*, OECD Rural Studies, OECD Publishing, Paris, https://doi.org/10.1787/d25cef80-en. [36]

OECD (2019), *OECD Regional Outlook 2019: Leveraging Megatrends for Cities and Rural Areas*, OECD Publishing, Paris, https://doi.org/10.1787/9789264312838-en. [35]

OECD (2018), *Job Creation and Local Economic Development 2018: Preparing for the Future of Work*, OECD Publishing, Paris, https://doi.org/10.1787/9789264305342-en. [32]

OECD (2018), *PISA 2018 Results (Volume V): Effective Policies, Successful Schools*, OECD Publishing, https://doi.org/10.1787/ca768d40-en. [46]

OECD (2017), *Green Growth Indicators 2017*, OECD Green Growth Studies, OECD Publishing, Paris, https://doi.org/10.1787/9789264268586-en. [58]

OECD (2003), *OECD Science, Technology and Industry Scoreboard 2003*, OECD Publishing, Paris, https://doi.org/10.1787/sti_scoreboard-2003-en. [4]

OECD (forthcoming), *Enhancing Rural Innovation in Canada*, OECD Publishing, Paris. [41]

Pavitt, K. (1984), “Sectoral patterns of technical change: Towards a taxonomy and a theory”, *Research Policy*, Vol. 13/6, pp. 343-373, https://doi.org/10.1016/0048-7333(84)90018-0. [5]

Pedersen, P. (2010), “Innovation diffusion within and between national urban systems”, *Geographical Analysis*, Vol. 2/3, pp. 203-254, https://doi.org/10.1111/j.1538-4632.1970.tb00858.x. [16]

Phillipson, J. et al. (2019), “Shining a spotlight on small rural businesses: How does their performance compare with urban?”, *Journal of Rural Studies*, Vol. 68, pp. 230-239, https://doi.org/10.1016/j.jrurstud.2018.09.017. [15]

RED/UNDRR (2020), *The Human Costs of Disasters: An Overview of the Last 20 Years (2000-2019)*, Centre for Research on the Epidemiology of Disasters, United Nations Office for Disaster Risk Reduction, https://www.preventionweb.net/publications/view/74124. [57]

Rogers, E. (1962), *Diffusion of Innovations, Third Edition*, Collier Macmillan Publishers, https://teddykw2.files.wordpress.com/2012/07/everett-m-rogers-diffusion-of-innovations.pdf. [14]

Saussay, A. et al. (2022), *Who’s fit for the low-carbon transition? Emerging skills and wage gaps in job ad data*, Grantham Research Institute on Climate, London School of Economics and Political Science, London, https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2022/10/working-paper-381-Saussay-et-al.pdf. [67]

Stern, N. and A. Valero (2021), “Innovation, growth and the transition to net-zero emissions”, *Centre for Economic Performance Paper*, No. CEPDP1773, London School of Economics and Political Science, https://cep.lse.ac.uk/pubs/download/dp1773.pdf. [76]

Stornelli, A., S. Ozcan and C. Simms (2021), “Advanced manufacturing technology adoption and innovation: A systematic literature review on barriers, enablers, and innovation types”, *Research Policy*, Vol. 50/6, p. 104229, https://doi.org/10.1016/j.respol.2021.104229. [21]

Strietska-Ilina, O. et al. (2012), *Skills for Green Jobs: A Global View*, International Labour Organization, Geneva, https://www.ilo.org/global/publications/ilo-bookstore/order-online/books/WCMS_159585/lang--en/index.htm. [56]

Sun, Z. et al. (2023), “How do contract performance rates affect entrepreneurs’ risk-averse attitudes? Evidence from China”, *Frontiers in Psychology*, Vol. 14, https://doi.org/10.3389/fpsyg.2023.1112344. [17]

Szewczyk, W., I. Mongelli and J. Ciscar (2021), “Heat stress, labour productivity and adaptation in Europe - A regional and occupational analysis”, *Environmental Research Letters*, Vol. 16/10, p. 105002, https://doi.org/10.1088/1748-9326/ac24cf. [72]

Tello, M. et al. (2017), “Innovation and productivity in services and manufacturing firms: The case of Peru”, *CEPAL Review*, Vol. 121. [28]

United Nations Department of Economic and Social Affairs (2008), *International Standard Industrial Classification of All Economic Activities (ISIC)*. [8]

Unsworth, S., R. Martin and D. Verhoeven (2020), *Seizing Sustainable Growth Opportunities from Zero Emission Passenger Vehicles in the UK*, Grantham Research Institute, https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2020/02/GRI_Seizing-sustainable-growth-opportunities-from-zero-emissions-passenger-vehicles-in-the-UK_FULL-REPORT.pdf. [75]

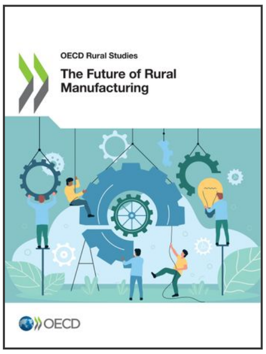
Wojan, T. and T. Parker (2017), "Manufacturing is relatively more important to the rural economy than the urban economy", United States Department of Agriculture, https://www.usda.gov/media/blog/2017/09/12/manufacturing-relatively-more-important-rural-economy-urban-economy (accessed on 9 November 2022). [26]

Notes

[1] See Annex Table 4.A.1 for the list of countries.

[2] In 2019, 73 regions had elderly dependency ratios above 50% and, in 11 regions (including Evrytania from Greece and Akita, Kochi, Shimane and Yamaguchi from Japan), they were above 60%.

[3] Climate-induced natural hazards can range from floods and droughts to extreme heat and wildfires. The OECD has developed a large number of indicators to identify socio-economic exposure to such climate hazards (Maes et al., 2022[89]). Such research has shown that climate-induced hazards have been increasing and are expected to increase further. For example, nearly all (95%) regions in OECD countries have been more exposed to heat stress over the past 5 years (OECD, 2022[64]).



From:
The Future of Rural Manufacturing

Access the complete publication at:
https://doi.org/10.1787/e065530c-en

Please cite this chapter as:

OECD (2023), “How are megatrends transforming rural manufacturing?”, in *The Future of Rural Manufacturing*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/685a0a27-en

This document, as well as any data and map included herein, are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. Extracts from publications may be subject to additional disclaimers, which are set out in the complete version of the publication, available at the link provided.

The use of this work, whether digital or print, is governed by the Terms and Conditions to be found at http://www.oecd.org/termsandconditions.