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June 2020

Advanced Technologies for Industry – General findings

Report on technology trends, technology uptake, investment and skills in advanced technologies

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Executive summary

Key findings

Through an in-depth analysis of traditional data sources such as patents and trade, business survey and novel metrics such as investment data, LinkedIn and text-mining of company websites, the study carried out an assessment of the trends in the generation and uptake of advanced technologies, the related entrepreneurial activities and venture capital investment, the supply of and demand for skills and also assessed the digital opportunities for Europe. The full methodology behind the data calculations is available here: https://ati.ec.europa.eu.

Undoubtedly, today's economies and societies are ruled by the extremely fast development of advanced technologies. European industry is at a crossroads, both in terms of bolstering its existing strengths and getting back to the driver's seat in the digital transformation race.

Overall, the EU27 shows clear global strengths in Advanced manufacturing technologies, catching up in AI but has clear gaps in Security and Big data across the various parts of the value chain starting from research and technology development, firm activity, technology deployment and related skills:

- **Advanced manufacturing technologies are one of the technologies where the EU27 is particularly strong** and has the highest share of world patent applications, the highest number of venture capital backed firms and investment and supply of skills. It is also the EU27's one remaining area of international advantage in terms of trade. Nevertheless, the number of patent filing, startups and the available professionals with such skills are slowing down in terms of growth relative to other technologies while global competitors are catching up. Related technologies such as Internet of Things or Advanced materials exhibit strengths but the EU27 is losing ground in Robotics especially to China.
- **Cybersecurity is a technology where the EU27 falls behind** the US according to the results of all metrics including patents, startups, investments and available professionals with cybersecurity skills. Even if some security solutions have been taken up by the majority of firms surveyed, this is of a particular concern. EU Member States, industries and businesses will face complex security threats and the development of technology-based industries will require strong information protection.
- In the field of **Artificial Intelligence, despite the gap between the EU27 and the US but also China, the EU is catching up fast.** The EU27 falls behind the US and China in world share of patents, but AI is among the most dynamic technologies in terms of patent filing and startup activity. Furthermore, the availability of professionals with skills in AI is also growing fast. **Big data,** which is highly relevant to enable the deployment of AI technologies, **is a relative European weakness** compared to the US and China, although it plays a crucial role in the future development of a digital-based economy.
- **Blockchain is still a niche technology, but the EU27 shows some advantage** over competitors in terms of startup creation, VC investments and skills.
- It is not a surprising but a worrisome result that **patents, VC and talent is concentrated in some key geographies within the EU27** while many regions across Europe lag behind.

The EU27 has a leading position in terms of the invention of various advanced technologies; however, its competitive advantages have been declining and are greatly challenged:

- The EU27 holds the **highest share (over 25%) of worldwide patent applications in Advanced manufacturing Technologies as well as in applications related to the Internet of Things (IoT) and IT for Mobility**[1].
- While the EU27 has positioned itself very well in technologies that ensure the necessary framework conditions for the factories of the future through Advanced manufacturing, **the EU27 is falling behind** its main competitors in terms of **Artificial Intelligence and Big data.** Nevertheless, there is also increasing dynamics in AI-related patenting and its **compound annual growth rate has been the highest** among all technologies in focus.
- The EU27 share in worldwide patenting has **significantly dropped in Robotics**, where the gap with China stands out the most.
- The EU27 has been gradually losing leadership in most of the technologies in terms of its share in worldwide patent applications, especially due to the **parallel rise in Chinese patent applications but also patent activity in Taiwan and South Korea**.
- The area in which the EU27 managed to secure a better position throughout the period from 2005 to 2017 is **IT for Mobility**, where the EU27 is one of the largest exporters of vehicle technologies with its dynamic automotive sector. The other technology where the EU continues to be specialised is **Nanotechnology**.
- Industries that are most active in technological patent applications include **Electronics, Machinery, Chemicals and Automotive**. Firms in the Electronics and Machinery industries file simultaneously in a number of the advanced technology fields analysed for this study, although their emphasis remains notably different.
- **Artificial Intelligence and IoT** are the two technologies showing the highest share of companies willing to invest in them in the next 12 months, suggesting that their implementation is moving fast.

In terms of international trade, the EU27 is not favourably positioned in producing the fundamental components of advanced technologies, however, it leverages significant advantages by integrating advanced technology components into complex final products:

- **The EU27 is a net importer of goods related to advanced technologies**, although less prominently so than the US or China. **Europe's one remaining area of international advantage is Advanced manufacturing** and, to a lesser extent, Robotics. In all other areas, the the EU27 remains a net importer of technologies.
- Overall, this situation has remained more or less stable over the last decade. Even before the 2008 economic crisis, the EU27 had relinquished most AT production capacities and seen many of them, in particular in microelectronics, relocate to East Asia (Japan, South Korea, Chinese Taipei, China, etc.) during the 1990s and early 2000s.
- **The EU27 leverages significant advantages through the integration of components into complex final products later classified under different trade categories**. It remains remarkable that, different from the United States or China, the EU27 cannot position itself as a net exporter in any other advanced technology field.
- At the level of individual Member States, positive outside-EU27 trade balances still exist for particular goods. Austria, the Netherlands, Italy, France and Sweden display positive balances in goods related to IT for Mobility; Austria and Sweden in goods related to the Internet of Things; Italy, Germany and Sweden in goods related to robotics. Some EU Member States even display positive balances in Nanotechnology, Microelectronics, Photonics and Industrial Biotechnology.

The uptake of advanced technologies has been accelerating, thus contributing to the ongoing process of industrial modernisation in Europe. In particular:

- In terms of the adoption of advanced technologies, **Cloud computing, Security and Connectivity** solutions are at the forefront of Europe's[2] digital transformation. Other

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[1] The patent, trade, prodcom, investment and skills analysis captures IT for Mobility as a sub-section of mobility, which is related to vehicles e.g. satellite navigation and radiolocation, which are the core technologies that are necessary to make autonomous driving work.

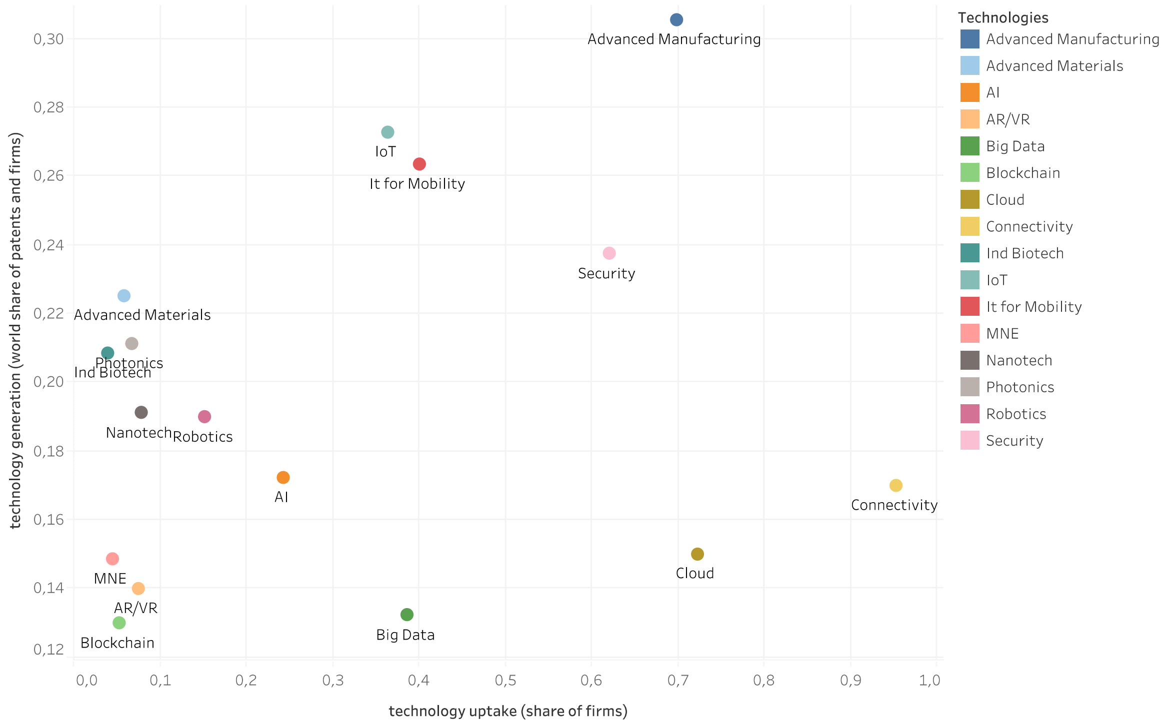
[2] The Advanced Technologies for Industry Survey (July 2019) sample consisted of 900 interviews of European organisations with more than 10 employees in the Czech Republic, Denmark, France, Germany, Hungary, Italy, the Netherlands, Poland, Spain, Sweden and United Kingdom. Eligible respondents were individuals best qualified to answer questions about overall ICT, digital and technology strategy and activities. A screening question was used to determine respondents' eligibility.

technologies such as Big Data and IoT, but also Artificial Intelligence (AI), Augmented/Virtual Reality (AR/VR), Blockchain, Industrial Biotechnology and Photonics are rapidly gaining in uptake and thus expected to play a prominent role in the industrial digitisation process in Europe[3].

- The analysis of share of professionals with advanced technology skills, however, shows that **European industry employs less professionals in particular in Security, Big data and Cloud technologies than the US,** which might also reflect the differences in the level of uptake. Interestingly, AI is a field where the EU27 is close to the US in the share of employed professionals across several industries. In Blockchain the EU27 and US perform close, although the EU27 has a slight advantage.
- In terms of technology co-presence, about 78% of European companies and organisations **adopt between two and five advanced technologies**. The technologies that are more likely to be implemented together are Cloud and Security solutions, often in synergy with IoT, AI and Big Data.
- Reaping the benefits from advanced technologies requires having not only technological capabilities, but also data management culture, organisational culture as well as trust and ethics.
- General **awareness and adoption of digital platforms in Europe[4] is high,** with most companies in Europe having at least heard of B2B industry digital platforms and nearly 60% on average evaluating some related business cases.

Figure 1 links up the level of technology adoption in terms of world share patent applications and the level of uptake as the share of firms having adopted these technologies on a scatter plot.

Figure 1: Technology generation vs adoption, EU27



Source: authors[5]

Note: some advanced technologies such as connectivity and cloud are relevant across all sectors of the economy while industrial biotechnology or nanotechnology are taken up by a more limited number of industries. The lower adoption rate should be interpreted considering the possible industrial application of the technology.

Additional information on survey methodology can be found in the Advanced Technologies for Industry Survey - Methodological Report

[2] ibidem

[3] ibidem

[4] ibidem

[5] Diagrams in this report have been prepared with the help of tableau.

Private equity and venture capital investment is still behind expectations and urgently needed to scale up technology ventures in the EU27:

- With regard to the number of startups and scale-ups and the average investment amount per firm of any size, the **EU27 is in a strong position, especially in Advanced manufacturing**. The number of startups and scale-ups indicate that the EU27 has a relative advantage in the Internet of Things and boasts more startups and scale-ups than the US also in the fields of Blockchain, Nanotechnology, IT for Mobility and Photonics (although the level of average investment has been significantly lower in these areas).
- Interestingly, the number of startups and scale-ups in **Artificial Intelligence** is not far behind the US and **has been growing steadily** in recent years. Improving the innovation ecosystem around this technology will be key.
- The areas where startup and scale-up activity has been much weaker than in the US include Security, Big Data, Cloud Technologies, Industrial Biotechnology, Micro- and Nanoelectronics and Connectivity.
- In terms of the types of the investments, **we find relatively less series B and series C types of investments** in the EU27 than in the US. Several startups have benefitted also from grants from the European Union.
- **Digital platforms have already reached a significant market value** - estimated at almost $2.8 bn in 2019, approximately €2.5 bn in 2019 in Europe.[6] A growing number of leading organisations across all industry sectors is shifting to B2B Digital Platforms with direct impacts on their business models and their technology architecture.

With regard to Skills, the EU27 shows strengths in several advanced technologies driven by science and engineering but has weaknesses in key digital technology fields when compared with the US:

- In the EU27, within the pool of currently active professionals in advanced technologies registered in the LinkedIn database, Advanced manufacturing and Cloud technologies are the two top available skills, which reflects the fact that the market for Advanced manufacturing is mature and the fact that cloud services are on the rise. In the US, similar patterns can be observed, and Cloud and Advanced manufacturing are also among the top skills reported.
- The **EU27 has higher relative share of professionals with skills in Advanced manufacturing technology, Advanced materials, Industrial biotechnology and Nanotechnology** than the US. The EU27 lags behind the US in particular in Cloud technologies but also Big Data, AI and Security. The EU27 and US have similar shares in Blockchain, AR/VR, the Internet of Things, Micro- and Nanoelectronics, IT for Mobility, Robotics and Photonics.
- Technologies where the **EU shows higher growth in comparison with the US are the Internet of Things, Micro- and nanoelectronics, Advanced materials, Industrial biotechnology and Cloud** (14% average growth rate in the EU27 versus 7% in the US in the aforementioned technologies). The results also indicate that the **supply of skills has grown the most in Blockchain, AI and AR/VR in the EU27**.
- The results indicate that the automotive sector in the EU27 is more advanced in terms of employing skilled professionals in advanced technologies than in the US, especially in the fields of Advanced manufacturing and IoT, but also Advanced materials, AI, Nanotechnology, Industrial biotechnology, Photonics and Blockchain. The situation is not so positive in other industries. In the chemicals industry, the EU27 is ahead in the fields of Industrial biotechnology and Nanotechnology but it is behind in Advanced manufacturing. The electronics industry in the EU27 is also lagging behind the US in several technologies. While the EU27 employs more professionals skilled in IoT and Advanced manufacturing across various industries such as automotive, chemicals, food production or medical devices, it has less industry employees skilled in Big data, Cloud technologies and Security than the US.

[6] Data retrieved by using a combination of the IDC Industry Cloud Tracker and the IDC IoT Spending Guide. IDC Cloud Trackers describes how cloud technologies and services continue to form the foundation for digital transformation and innovation. Retrieved from https://www.idc.com/promo/trackers/cloud. The Worldwide Internet of Things Spending Guide examines the Internet of Things (IoT) opportunity from a use case, technology, industry, and geography perspective. Retrieved at: https://www.idc.com/getdoc.jsp?containerId=IDC_P29475

- Skills can increase in value when used in combination, however, **the fusion of advanced technology and other professional and business skills within individuals is still low** with the EU27 performing slightly behind the US.
- **Hiring demand is high for most advanced technology** related skill sets and reflects a gap in finding sufficiently skilled professionals.

Section 1

1. Introduction

This report has been prepared in the framework of the Advanced Technologies for Industry (ATI) project, initiated by the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises. European industry is facing technological, socio-political (including globalisation and geopolitics) and climate change challenges. To remain at the forefront of technological and social leadership, it is important to strengthen and revitalise the European industrial base.

Using both traditional and novel types of data, this report carries out an in-depth analysis by exploring trends in the generation and uptake of advanced technologies, related entrepreneurial activities and skills. It interprets data from a list of data sources compiled to monitor advanced technologies and their applications in industry across the EU27 and key competitor economies such as patent data, business survey, Crunchbase, Dealroom, LinkedIn and textmining of company websites.

The starting point of this analysis has been sixteen advanced technologies that are a priority for European industrial policy and that enable process, product and service innovation throughout the economy and hence foster industrial modernisation. Advanced technologies are defined as recent or future technologies that are expected to substantially alter the business and social environment and include Advanced materials, Advanced manufacturing, Artificial Intelligence, Augmented and Virtual Reality, Big data, Blockchain, Cloud technologies, Connectivity, Industrial biotechnology, the Internet of Things, Micro- and nanoelectronics, IT for Mobility, Nanotechnology, Photonics, Robotics and Security. The full methodology behind the data calculations is available here: https://ati.ec.europa.eu.

This report is structured as the following:

- The second section analyses technological trends in terms of patent applications in the EU and globally.
- The third section summarises the findings of the Advanced Technologies for Industry Survey and textmining analysis about the uptake of advanced technologies in Europe.
- The fourth section presents findings about private equity investment and startup/spinoff activity.
- The fifth section explores the supply and demand of skills related to advanced technologies.
- The sixth section presents the analysis of digital maturity in key economic sectors.
- The seventh section deals with the trade-related aspects of advanced technologies in Europe and at the international level.

Section 2

2. Technology generation trends

2.1 Patenting trends

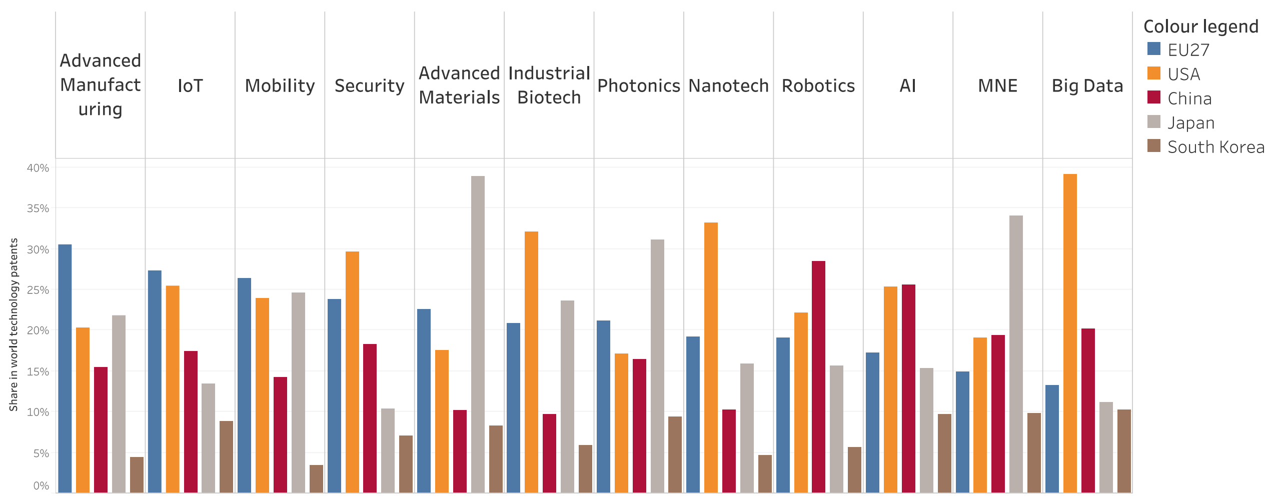
Technology trends have been captured through patent analysis. Patents are a well-accepted and widely used data source to track technological trends, even if there are certain forms of innovation that are not patented and hence capture only a part of reality. The analysis is based on so-called transnational patents, i.e. those filed through the WIPO PCT procedure or at the European Patent Office directly. They have been localised/attributed to countries based on the location/address of the applicant. The different advanced technologies have been identified based on International Patent Classification (IPC) codes and keyword searches.

Starting with a benchmarking of global economies, Figure 2 sketches out the share of technological patents in the world total by comparing the performance of the EU27 relative to its major competitors. With above 25%, the EU27 holds the **highest share of worldwide patent applications** in **Advanced manufacturing technologies** as well as in applications related to the **Internet of Things** and IT for **Mobility**[7].

Europe holds a high share of applications in **Security**, **Nanotechnology** and **Industrial biotechnology** regarding which, however, it lags behind the US. Likewise, it holds a good share in **Advanced materials** and **Photonics** but lags behind Japan. In these fields, its share ranges between 18% and 24%. In the areas of **Robotics, Artificial Intelligence and Big data, the EU27 performs worse** than the US and China and it is especially behind in **Micro- and nanoelectronics**, in which field it takes a smaller share than the US, China and Japan.

The results indicate that while the EU has positioned itself very well in technologies that ensure the necessary framework conditions for the factories of the future through Advanced manufacturing, the EU27 is falling behind its main competitors in terms of scientific leadership especially in the Artificial Intelligence race**,** Big data and Robotics.

Figure 2: Share in world transnational advanced technology patent applications, EU27 and global comparison, 2017

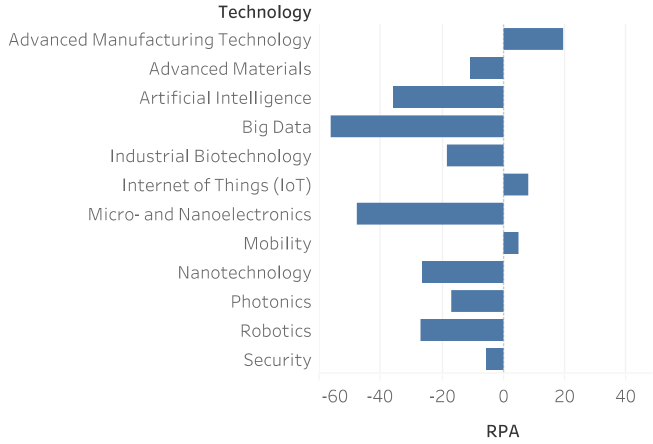


Source: Fraunhofer ISI calculations based on EPO Worldwide Patent Statistical Database (PATSTAT)

[7] In the patent analysis, mobility has been defined related to vehicles, e.g. satellite navigation and radiolocation, which are also the core technologies that are necessary to make autonomous driving work.

The revealed patent advantage index (RPA[8]) shows the same pattern as above from a different perspective (see Figure 3), it measures a country's share of patent applications in a specific technology relative to its overall share in patent applications. In line with the above observations, key technology fields in which the European Union retains a relative specialisation include **Advanced manufacturing technologies,** the **Internet of Things** and IT for **Mobility** while its focus on digital technologies remains notably below the world average. An overall decline in Europe's specialisation can be observed in most technologies over time, which is a result of a further global dispersion of strengths and the intensification of global competition in science and technology.

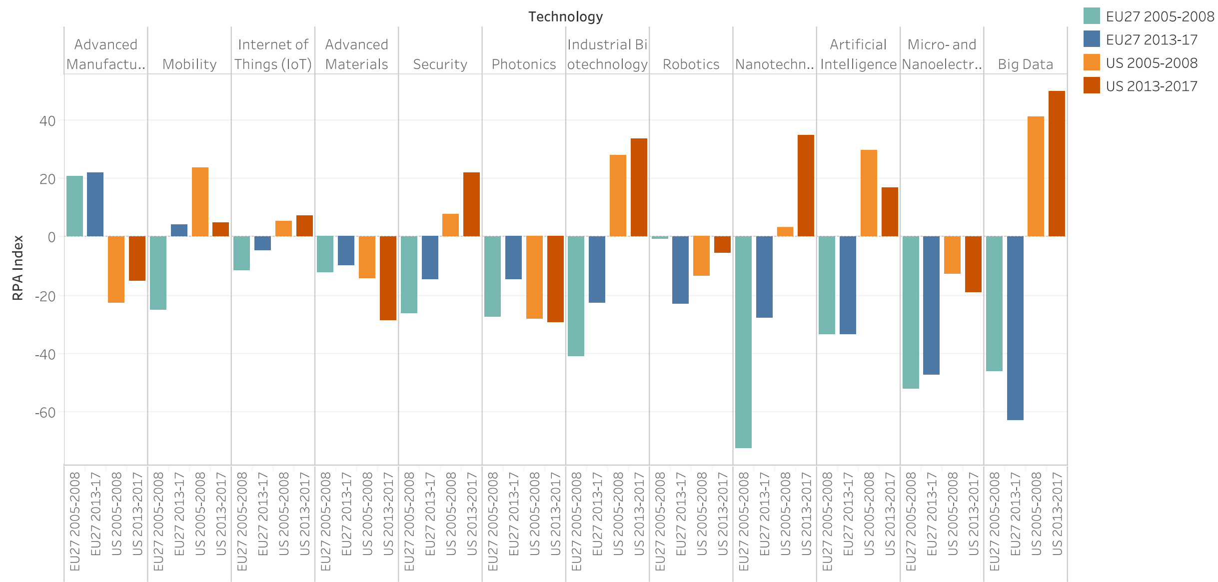
Figure 3: Specialisation in transnational technology patents EU27, revealed patent advantage, 2015-2017



Source: Fraunhofer ISI calculations based on EPO Worldwide Patent Statistical Database (PATSTAT)

The EU27 appears specialised in a smaller number of advanced technologies than some of its competitors, especially the United States (with a positive specialisation in seven technology fields) or Japan (with a positive specialisation in six technology fields).

Figure 4: Specialisation in technology patents, revealed patent advantage, comparing the periods 2005-2008 and 2013-2017



	Industrial Biotech	Nanotech	Micro- and Nanoelectronics	Photonics	Advanced Materials	Advanced Manufacturing	Artificial Intelligence	Security	Big Data	Internet of Things	Mobility	Robotics
EU27	-22,33108	-27,73334	-47,19832	-14,56057	-9,840129	**21,95**	-33,29602	-14,54334	-62,63586	-4,606342	**3,95**	-22,71421
US	**33,29**	**34,80**	-19,08842	-29,30943	-28,32548	-15,13787	**16,66**	**21,76**	**49,61**	**7,20**	**4,93**	-5,499581
China	-62,31935	-62,03315	-4,05123	-13,69645	-55,99866	-27,7683	**27,92**	**18,50**	**22,33**	**5,04**	-31,6048	**22,44**
Japan	**19,74**	-25,42352	**53,86**	**42,07**	**61,71**	**13,20**	-22,77797	-55,03748	-48,11323	-31,2152	**20,73**	-7,894235

Source: Fraunhofer ISI calculations based on EPO Worldwide Patent Statistical Database (PATSTAT)

When we look at the trends over time (see Figure 5 below), we see that the **EU27 has been gradually losing leadership in most of the technologies in terms of its share of worldwide patent applications**, especially due to the parallel rise in Chinese patent applications but also patent activity

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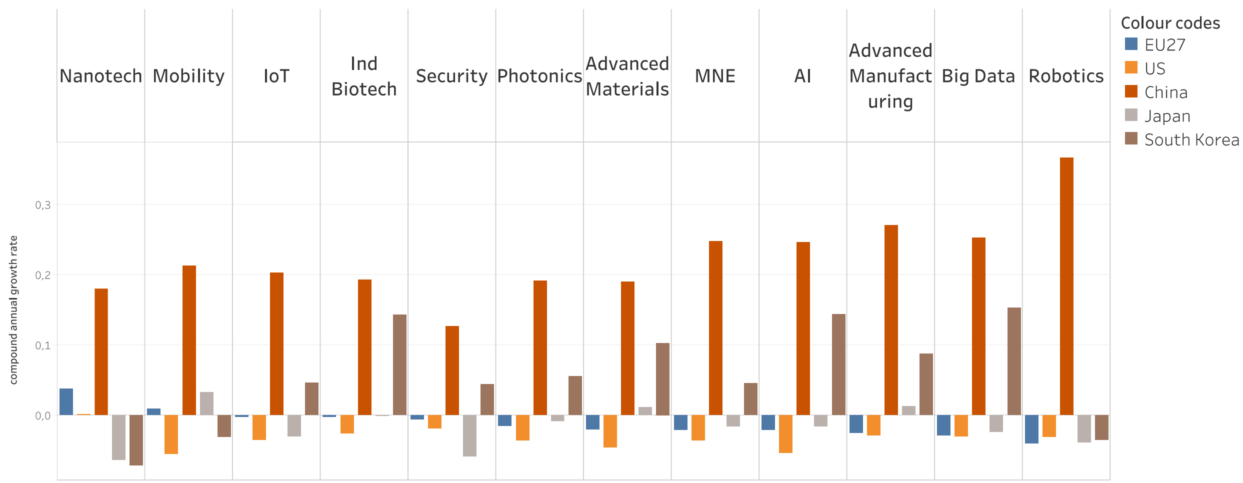
[8] The specialisation index RPA (Revealed Patent Advantage) is defined as: RPAkj = 100 * tanhln [(Pkj/ΣjPkj)/(Σj/ΣkjPkj)], with Pkj indicating the number of patents of country k in technology field j

in Taiwan and South Korea. The area in which it managed to secure a better position throughout the period from 2005 to 2017 is IT for **Mobility**, where Europe is one of the largest exporters of vehicle technologies (EC, 2018) and has a dynamic automotive sector. The other technology where the EU continues to increase its relative global advantage is **Nanotechnology**.

The EU share has significantly dropped in Robotics, where the gap with China stands out the most. This drop is also a result of China taking the lead as the world's largest industrial robot market (IFR, 2019). The EU27 has also been falling behind in the areas of Big Data, Advanced manufacturing technologies and Artificial Intelligence.

It also has to be noted that, when we compare the change over time in Europe with the trends in the US, we see that the **share of the EU27 has dropped less than that of the US** in most of the technologies. However, Japan has been able to defend its position better than Europe in more technological fields, for instance in Advanced manufacturing and Advanced materials.

Figure 5: Compound annual growth rate in world technology patent shares, EU27 and global comparison, 2005-2017

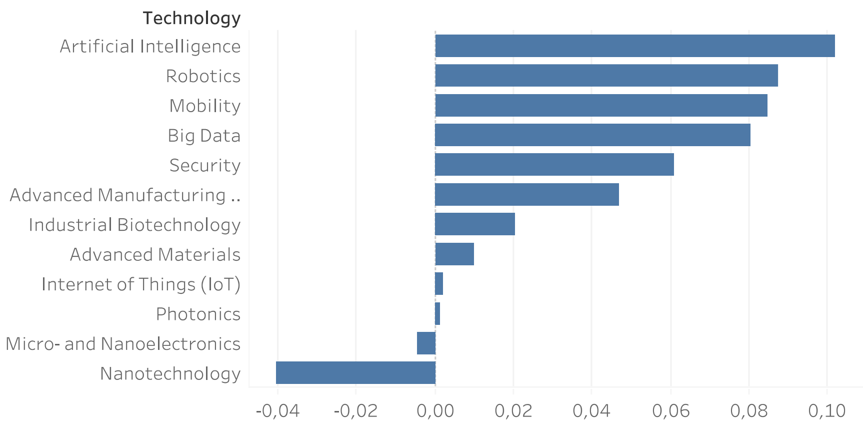


Source: Fraunhofer ISI calculations based on EPO Worldwide Patent Statistical Database (PATSTAT)

Gauging the EU27 performance in terms of absolute number of patent applications (Figure 6), the trends observed in specific technologies provide us with further insights. For instance, **AI-related patenting in the EU27 has been growing considerably** in the period 2010-2017 and the compound annual growth rate has been the highest among the advanced technologies considered in this study.

Despite the overall lower relevance of these fields, the number of patent applications in Robotics, IT for Mobility and Big Data has still grown significantly in absolute terms. By contrast, it has declined in the areas of Micro- and Nanoelectronics and, since 2010, in Nanotechnology (see Figure 6).

Figure 6: Compound annual growth rate in absolute number of patents in EU27, 2010-2017



Source: Fraunhofer ISI calculations based on EPO Worldwide Patent Statistical Database (PATSTAT)

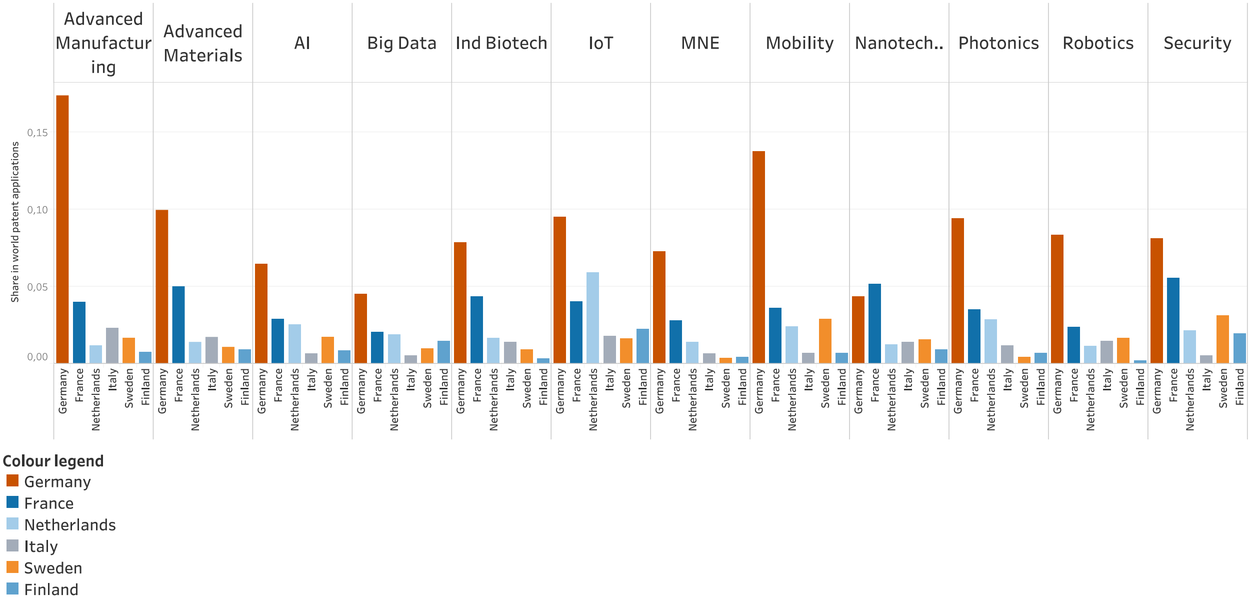
2.2 Country and sectoral trends

Within the EU27, five countries reach a share of worldwide patent applications of more than 1% when taking into account all advanced technologies in the focus of this study: **Germany** (with a considerably higher share than all others – 10.67% in worldwide patents), **France, Netherlands, Italy and Sweden** (see Figure 7). Finland and Austria also follow with a 0.8% share. Within Eastern European countries, Poland, Czech Republic and Slovenia hold the highest share.

Germany and France hold the highest share of worldwide patent applications within the EU27 in all technologies, except for the field of Internet of Things, where the Netherlands takes the second position.

At the national level (within the individual country), Germany and Italy hold their highest shares in Advanced manufacturing technologies, with the share of France being highest in Security-related patenting and Nanotechnology, that of the Netherlands in technologies related to the Internet of Things while Sweden reaches its highest shares in the Security and IT for Mobility areas. The relatively low share of world patent applications in the areas of Artificial Intelligence and Big Data is also visible in this country analysis (as already pointed out above).

Figure 7: Share in world transnational advanced technology patents, EU leading countries, 2017



Source: Fraunhofer ISI calculations based on EPO Worldwide Patent Statistical Database (PATSTAT)

The share of patent applications within the country total gives further insights into the relative importance of advanced technologies within the national borders. We can observe that the **technologies with the highest significance within the EU Member States include Advanced manufacturing, Advanced materials and Photonics**. Micro- and nanoelectronics and IT for Mobility technologies also follow suit. Ireland holds the highest intra-country significance in Artificial Intelligence. Figure 8 provides an overview of patterns across all EU countries.

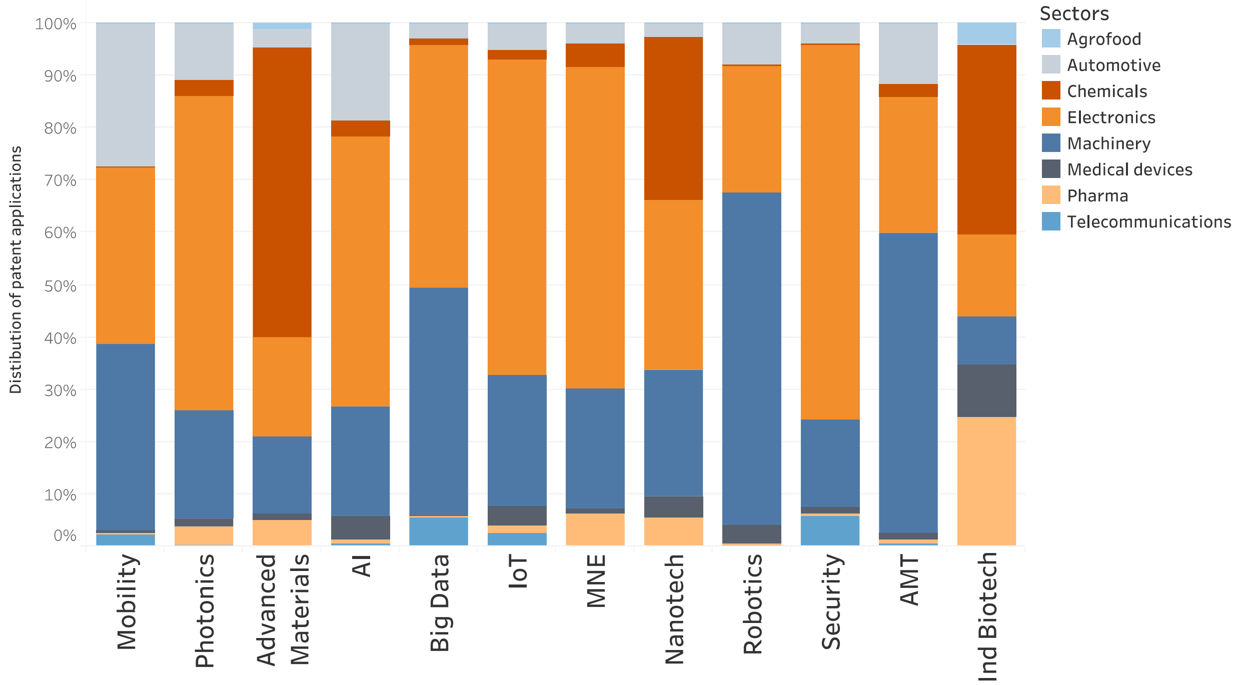
Figure 8: Country significance of transnational patent applications across advanced technologies (from grey lower values towards blue higher values), 2015-2017

Country	Nanotech	Internet of Things	Big Data	Robotics	Mobility	Artificial Intelligence	Industrial Biotechnology	Security	Micro- and Nanoelectronics	Photonics	Advanced Materials	Advanced Manufacturing
Austria	0,15%	0,46%	0,22%	0,79%	1,68%	1,04%	1,51%	0,98%	5,10%	5,31%	8,19%	8,15%
Belgium	0,54%	0,16%	0,45%	0,34%	1,46%	1,34%	3,49%	0,85%	5,96%	3,43%	10,84%	3,28%
Bulgaria	0,00%	0,00%	0,48%	1,55%	0,47%	0,00%	0,48%	2,38%	1,24%	2,67%	0,00%	4,69%
Croatia	1,11%	0,00%	0,00%	0,00%	3,24%	1,82%	0,00%	0,00%	3,05%	3,05%	1,82%	4,17%
Cyprus	0,56%	0,00%	2,39%	0,56%	2,34%	2,93%	0,58%	9,15%	0,00%	0,56%	0,56%	0,56%
Czechia	0,35%	0,22%	0,23%	1,21%	1,01%	0,67%	1,75%	2,38%	1,36%	4,04%	4,73%	8,21%
Denmark	0,12%	0,18%	0,13%	0,98%	0,70%	0,47%	3,63%	0,78%	1,02%	1,50%	2,15%	4,12%
Estonia	0,58%	0,00%	1,85%	15,24%	2,13%	4,18%	2,92%	3,20%	1,27%	0,48%	2,03%	6,40%
Finland	0,25%	0,56%	0,73%	0,15%	2,43%	2,50%	0,96%	3,91%	2,26%	2,50%	5,25%	4,24%
France	0,27%	0,35%	0,45%	0,48%	1,86%	1,67%	1,64%	2,90%	3,37%	2,77%	5,50%	4,68%
Germany	0,09%	0,23%	0,25%	0,59%	2,66%	1,21%	1,08%	1,35%	3,54%	3,08%	4,65%	7,73%
Greece	0,00%	0,00%	0,55%	0,21%	0,21%	1,03%	1,74%	1,56%	0,85%	1,25%	5,50%	2,78%
Hungary	0,36%	0,00%	0,36%	0,19%	2,20%	1,68%	3,31%	1,31%	2,35%	6,65%	2,75%	9,61%
Ireland	0,10%	0,25%	2,40%	0,59%	2,16%	5,57%	1,13%	2,79%	2,76%	1,13%	1,31%	3,66%
Israel	0,58%	0,28%	1,70%	1,15%	3,91%	4,62%	3,03%	3,73%	3,00%	2,76%	2,04%	4,65%
Italy	0,18%	0,23%	0,21%	0,65%	0,94%	0,69%	1,15%	0,62%	1,74%	2,39%	4,61%	6,25%
Latvia	0,68%	0,00%	0,00%	2,08%	0,00%	0,98%	3,32%	0,00%	0,98%	3,00%	5,70%	5,09%
Lithuania	0,00%	0,00%	0,78%	0,83%	0,78%	1,55%	4,05%	0,00%	4,21%	9,75%	8,46%	8,30%
Luxembourg	0,19%	0,00%	0,34%	0,29%	1,84%	0,74%	0,41%	1,14%	0,62%	0,51%	4,04%	1,81%
Malta	0,00%	0,00%	0,56%	0,27%	0,27%	1,67%	0,00%	0,27%	0,00%	1,12%	0,00%	1,93%
Netherlands	0,17%	0,62%	0,56%	0,40%	2,47%	2,37%	1,58%	1,57%	2,99%	4,29%	4,18%	2,69%
Poland	0,36%	0,11%	0,53%	0,32%	1,00%	1,35%	1,49%	1,83%	2,21%	2,75%	6,20%	6,60%
Portugal	0,40%	0,55%	0,36%	0,63%	1,05%	2,01%	2,27%	1,45%	2,88%	5,29%	6,63%	4,96%
Romania	0,72%	1,50%	0,00%	1,21%	1,33%	0,78%	1,21%	7,19%	7,89%	7,26%	5,81%	26,72%
Slovakia	0,00%	2,64%	0,88%	0,45%	1,33%	0,89%	3,52%	2,64%	2,23%	3,57%	6,64%	8,38%
Slovenia	0,00%	0,56%	0,00%	0,84%	0,54%	0,27%	2,17%	0,94%	1,90%	2,41%	2,74%	8,75%
Spain	0,76%	0,26%	0,23%	0,70%	1,24%	1,20%	2,62%	0,98%	1,80%	3,18%	5,05%	5,54%
Sweden	0,23%	0,19%	0,34%	0,60%	3,36%	2,12%	1,00%	3,06%	1,07%	1,00%	3,05%	4,84%

Source: Fraunhofer ISI calculations based on EPO Worldwide Patent Statistical Database (PATSTAT)

Looking at the patterns across sectors and industries, the results of this analysis show that firms in the **Electronics and Machinery industries** file **simultaneously in a number of the advanced technology fields** analysed for this study, although their emphasis remains notably different. Firms in the Chemical industry, by contrast, focus their patent activities in Industrial Biotechnology, Nanotechnology and Advanced materials. Likewise, the Automotive industry, has been most active in the area of Photonics, Advanced manufacturing and Artificial Intelligence. Telecommunication firms, finally, patent most in the area of Security. Further sectors such as healthcare, finance and transport contribute to a generally quite small share of technology patenting.

Figure 9: Distribution of patents attributable to selected sectors in the different advanced technologies



Note: Average Sample Sizes between 40% and 55%; Nanotechnology 30% - some less relevant sectors not covered

Source: Fraunhofer ISI calculations based on BvD ORBIS and EPO Worldwide Patent Statistical Database (PATSTAT)

Section 3

3. Technology adoption

When examining the role of advanced technologies in shaping industrial transformation in Europe, it is of paramount importance to measure the current level of uptake of the technologies. The Advanced Technologies for Industry (ATI) survey[9], which was conducted between June and September 2019, investigated a panoply of themes around the uptake of advanced technologies, including their level of adoption, the associated industry-specific use cases, the digital transformation drivers that are sustained by these technologies, their expected business impacts as well as the enabling conditions (e.g. investment in IT, funding sources, skills).

3.1 The status of advanced technology adoption in Europe

Figure 10 shows the current adoption rates and planned usage of advanced technologies. The results reveal a diverse picture with established technologies like Connectivity, Cloud computing, Security solutions and Advanced manufacturing appearing to play a pivotal role in bringing about Europe's technological transformation today. However, these technologies are not alone as other technologies that are being defined at present are also coming into play. Based on our survey results, these technologies seem to display lower, albeit very promising levels of adoption across the European landscape at present. This is likely to be due to their intrinsic nature of specialised technologies or industry-specific technologies and their relevance is probably not well apprehended by the current survey results. This is the case of Big Data and IoT but also Artificial Intelligence (AI), Augmented/Virtual Reality (AR/VR), Blockchain, Industrial Biotechnology and Photonics. Artificial Intelligence and IoT are the two technologies showing the highest share of companies willing to invest in them in the near future (in the next 12 months), suggesting that their implementation is moving quickly from the proof-of-concept stage to more pervasive adoption in organisations' business processes. The current COVID-19 emergency, with its negative impact on investments and on the economy as a whole, is adding a new set of challenges to the actual implementation of these technologies. Although the present outbreak is forcing many organisations to pause their digital proof-of-concepts and innovation experiments, with emerging technologies initiatives sacrificed in favour of business continuity and other business priorities, we expect most of the advanced technologies to continue playing a key role in the recovery and post-recovery phase. In particular, AI and IoT are expected to remain at the forefront of a digitised industry characterised by very high levels of automation, hyper-connectivity and widespread intelligence applications.

The analysis also shows that commercialising research efforts in Industrial biotechnology, Micro- and nanoelectronics, Photonics or Nanotechnology is still difficult and used in very specific sectors. For instance, Photonics is deployed especially in medical technologies, pharmaceuticals, food and agriculture in Europe. These technologies also face long timescales to market adoption and complex regulatory frameworks

Statistics on the adoption rate of some specific technologies are also available through the European ICT usage survey such as cloud, big data and robotics. According to the results, public cloud computing is reportedly used by 40 % of large enterprises and 17 % of SMEs in the EU. 25% of large and 12% of medium enterprises use robots. 33% of large and 12% of all enterprises applied big data for analysis.

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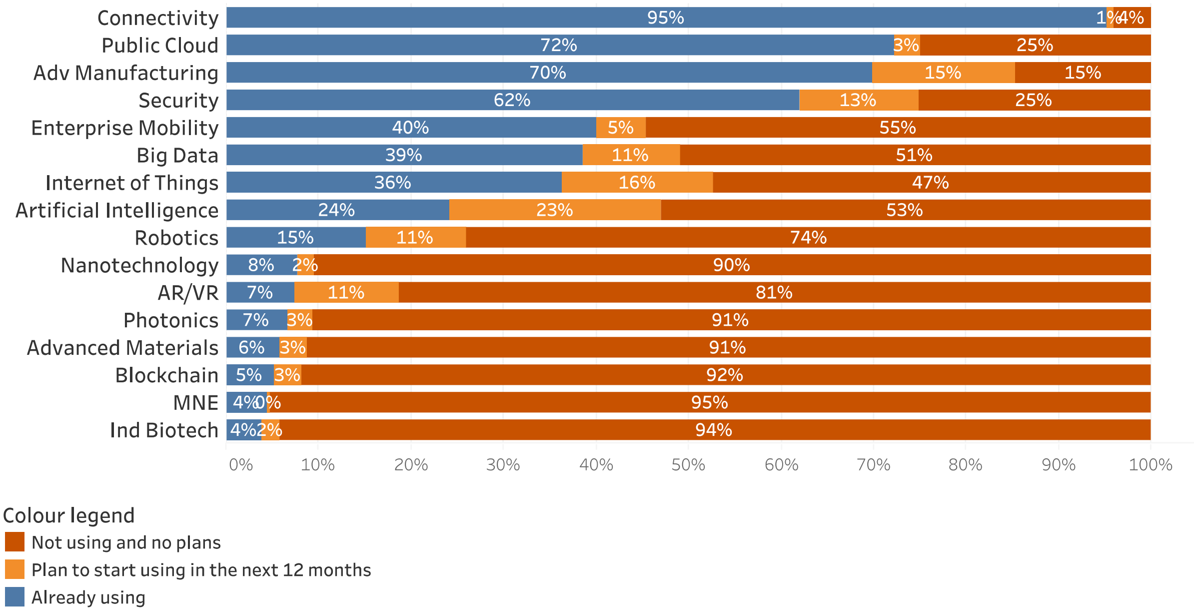
[9] The Advanced Technologies for Industry Survey (July 2019) sample consisted of 900 interviews of European organisations with more than 10 employees in the Czech Republic, Denmark, France, Germany, Hungary, Italy, the Netherlands, Poland, Spain, Sweden and United Kingdom. Eligible respondents were individuals best qualified to answer questions about overall ICT, digital and technology strategy and activities. A screening question was used to determine respondents' eligibility. As a result, eligible respondents were most likely to be senior decision-makers responsible for these strategies and activities. The survey was carried out between July and September 2019 and interviews were conducted via telephone, ensuring high quality and accuracy of responses. A computer-aided telephone interviewing (CATI) system, which permitted simultaneous interviewing and data entry, was used. Considering a 95% confidence level, the margin of sampling error for the entire Advanced Technologies for Industry Survey sample is ±3.3%. In other words, if 50% of respondents say they are investing in a new technology, then there is a 95% chance that adoption for this new technology for the true population is between 46.7% and 53.3%. That means that, if the same question was asked again and again to different samples, the confidence interval from 46.7% to 53.3% will match the results from the actual population 95% of the time. Additional information on survey methodology can be found in the Advanced Technologies for Industry Survey - Methodological Report

These results are close to the Advanced Technologies for Industry Survey results, noting the difference that ATI provides a fresher view of the market since data have been collected in Q3 2019 and has been more oriented towards large organisations, as important representatives of European digital investments and industrial innovation.

The adoption level of some specific technologies is better understood since there is more data available.

Figure 10: Advanced Technologies Current Uptake in the EU



Source: Advanced Technologies for Industry Survey, July 2019

The International Federation of Robotics monitors continuously the uptake of robotics technologies across countries. According to their research, demand for industrial robots has risen considerably due to the ongoing trend towards automation and continued technical innovations in industrial robots since 2010[10]. The World Robotics Report also reveals that Asia is the world's largest industrial robot market, although growth slowed down substantially in 2018. Europe is the second largest market with the highest robot density globally, with an average value of 114 units per 10,000 employees in the manufacturing industry.

In terms of co-presence of technologies, about **78% of the surveyed firms adopted between two and five advanced technologies**. There are converging trends across technologies that are expected to accelerate the pace of technological change generating significant results including significant improvement in human quality of life and life span and higher industrial turnover among the others. Leveraging synergies across technologies can lead to a multiplied innovation effect opening unexpected new opportunities for companies. Nearly 80% of European organisations adopt at least two advanced technologies, the technologies that are more likely to be implemented together are Cloud and Security solutions representing the technology backbone often in synergy with IoT, AI and Big Data, highlighting how data and information are often the drivers of the combined use of multiple technologies. Lower synergetic approach is seen for new technologies such as Blockchain, Augmented and Virtual Reality or Nanotechnologies, for which applications are more niche and focused on few industries and investments are more ad-hoc and on an opportunistic basis rather than part of broader advanced technologies programs.

A closer look at the results of the Advanced Technology for Industry survey reveals the existence of at least three distinct technology groups in terms of uptake:

- The first group of technologies is characterised by an adoption level (measured as current adoption and plan to adopt it in the next 12 months) of 60% or above among European companies and organisations and represents the backbone underpinning the first wave of digital transformation. Ranging from cloud computing to security solutions and connectivity (fixed and

[10] World Robotics Report, 2019

mobile voice and data), these technologies have reached mature adoption levels across European organisations, although at different speeds. Current technologies are well-established and at the core of industrial modernisation.

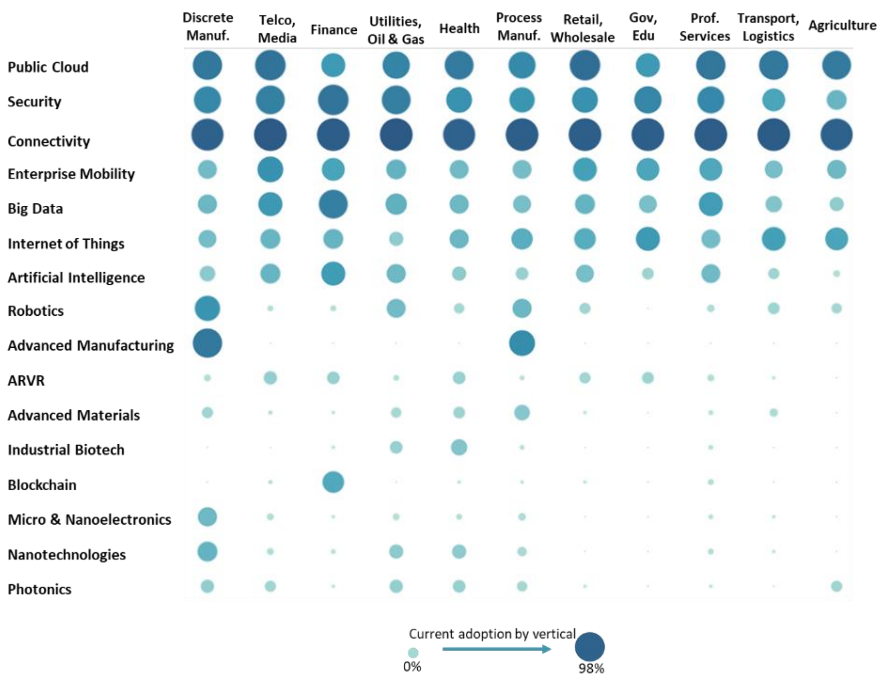
- Big Data & analytics, the Internet of Things (IoT), with the associated advanced connectivity standards (e.g. Low Power Wide Area (LPWA), satellite, short-range wireless), and mobile technologies present adoption levels of between 25% and 60%. This second group consists of technologies that are rapidly growing in terms of uptake and are key innovation accelerators for the European industry.
- Ranging from Artificial Intelligence (AI) and Augmented/Virtual Reality to Blockchain, Industrial Biotechnology and Photonics, the third group of technologies still exhibits moderate adoption levels (below 25%) and attracts the interest of selected users' groups in a relatively limited number of selected industries.

While some technologies are generic in nature and show a marked horizontal diffusion, other technologies clearly display a more niche or industry-specific orientation. However, this does not mean that they do not provide opportunities for investments outside their main industry field. Indeed, in the next few years, different factors such as **new technology features, price levelling, stronger external infrastructure and evolutions** in terms of digital maturity will lead to a higher uptake of all the technologies identified above across the board.

Looking at the results by industry, it is possible to observe that, while more mature general-purpose technologies such as Connectivity, but also Cloud and Security, show a homogenous uptake across all economic sectors and industries, new emerging technologies are more niche and industry-specific oriented. An example is Blockchain that has gained a foothold in the Financial sector, but also Micro- and nanoelectronics and Nanotechnologies, which, together, show **high levels of verticalisation**, particularly in the manufacturing space. As technology matures new areas of applications and use cases emerge and proliferate to drive business value in other industries. In manufacturing for example Blockchain is increasingly used to keep track and certify product source along the value chain.

Figure 11 shows the uptake level (measured as current adoption) of advanced technologies across industries in the surveyed countries. The bubble size and colour represent the share of companies and organisations in each industry that are already using a given technology, ranging from 0% to 98%.

Figure 11: Advanced Technologies European current uptake by economic sectors



Source: Advanced Technologies for Industry Survey, July 2019

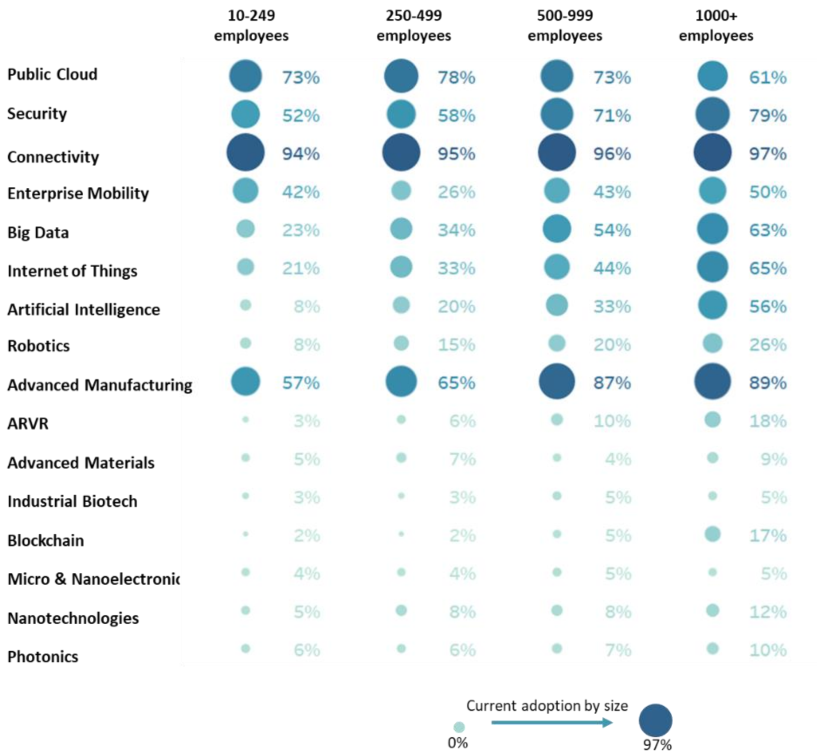
June 2020

Looking at current adoption across industries, it is possible to see that **Discrete Manufacturing, Finance and Telco/Media are leading innovative sectors in the European landscape.**

Figure 12 shows the current uptake of advanced technologies according to the size of the organisations adopting the technology. Four companies' and organisations' sizes have been considered: companies with 10-249 employees, companies with 250-499 employees, companies with 500-999 employees and companies with more than 1,000 employees. Bubble size, colour and related labels refer to the level of current adoption (as shares of companies in that specific size band already using a given technology). **Results across technologies confirm a positive correlation between company size and uptake of technologies,** with just a few exceptions.

Public Cloud is an exception where small-medium businesses show higher adoption than larger companies. There is indeed a cost-opportunity argument behind the choice of adopting public versus private cloud so that, over a certain business size, the recurring public cloud cost overcomes the cost of a proprietary infrastructure investment. **The distance between large and small companies is smaller for more mature technologies such as Connectivity, Security but also Enterprise Mobility**. **It is, on the contrary, bigger when it comes to emerging technologies, for example AR/VR, Blockchain and AI**. High initial investment, piloting stages and opportunities for scale are the main drivers of this size effect.

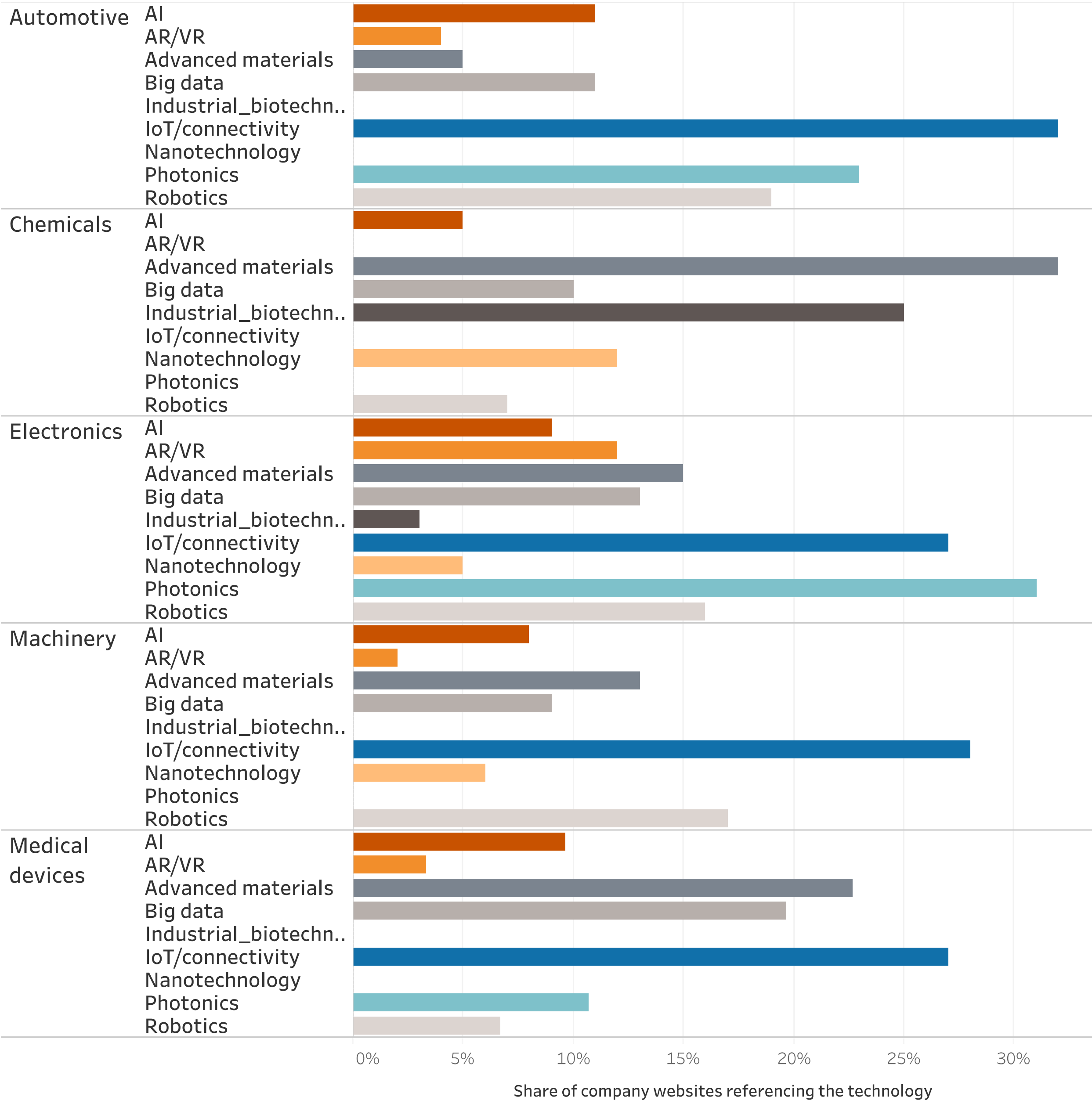
Figure 12: Advanced Technology current uptake by size



Source: Advanced Technologies for Industry Survey, July 2019

Complementing the survey and providing another angle to the discussion about technology adoption, the uptake of advanced technologies in specific sectors have been further explored based on a large-scale of text-mining of company websites. This analysis has been conducted based on a search algorithm and keywords. This analysis reflects about the use of technologies embedded in new products and services and about technological advantages that companies communicate about. It cannot be used, however, to conclude about the adoption of advanced technologies in terms of the more hidden production processes that are being less revealed in these types of online content. The detailed methodology is presented in the methodological report. From the analysis, the advanced technologies appearing most frequently in online content of electronics firms are Photonics and IoT. A considerable share is also referencing Advanced materials, Big data, AR/VR and AI technologies. In the case of medical devices firms, the advanced technologies that have been referenced the most as part of products and services are the Internet of Medical Things (27% of firms in the sample), Advanced materials (22%) and Big data (19%) in the sense of patient data collection or supporting e-health databases. IoT technology appears in the references to connected healthcare devices and the use of the Internet of Medical Things. IoT is the technology appearing most frequently on the websites of automotive companies, followed by Photonics, Robotics, AI and Big data (see Figure 13).

Figure 13: Share of company websites referencing advanced technology related products or services per selected industry



Source: Technopolis Group, based on text-mining of company websites

A cluster analysis was performed based on respondents' adoption of Advanced Technologies. Cluster analysis is a statistical technique aiming at grouping respondents in such a way that respondents within the same group or cluster are more similar to each other than to other groups in relation to particular characteristics (advanced technology adoption, for the purpose of this analysis). Based on respondents' level of maturity with respect to advanced technology uptake, four groups of respondents were identified:

- **Investigators**: this cluster includes respondents that are at the bottom of advanced technology maturity pyramid, showing low level of innovation propensity, about **30%** of respondents fall into this cluster.
- **Experimenters:** respondents with a medium-low level of technology adoption. They have some initial advanced technology investment in place even though these initiatives are still siloed and not supported by a corporate vision. They represent about the **48%** of the sample.
- **Adventurers**: respondents with a medium-high level of advanced technology adoption. They show some initial efforts in orchestrating multiple technologies. The **17%** of the sample is in this cluster.
- **Innovators:** respondents showing the highest levels of technology uptake and co-presence being able to leverage the synergies between different technologies. This cluster of innovators not surprisingly represent the smallest share of the sample, only **5%** of the sample falls in this cluster.

Looking at clusters' characteristics, there are 5 major areas where clusters traits emerge:

- **Industry distribution.** Figure 14 displays the clusters distribution by industry. The industries where it is more likely to spot the two most mature clusters are Telecom & Media and Finance. As we have seen these are the industries where cross advanced technologies uptake is at highest. In is interesting to notice how considering only innovators the highest share of them can be found in Healthcare and Utilities/Oil & Gas. These results highlight how in both industries companies have now undertaken a process of deep digital transformation with some champions leading the change. The industries where there are more companies resistant to change are on the contrary Agriculture and Transport.
- **Size distribution.** Looking at clusters' distribution by size, we observe that, the bigger the size the higher the maturity. Figure 15 shows the distribution of clusters by size.
- **Technology co-presence.** The higher the maturity of the cluster the higher the ability to exploit technology synergies. The average number of technologies adopted indeed increases from being around 2 for investigators to more than 9 for innovators.
- **Business goals.** Another interesting clusters' characteristic is represented by the business goals driving their technological investments and represented in Figure 16. It is interesting to notice how investigators and innovators have a polarised approach on some business goals. Customers for example are in the top three priorities for investigators but low priority for innovators, which on the contrary place a lot of emphasis on Security and Marketing.
- **IT and Technology Investment.** As the level of advanced technology maturity increases, the share of total revenues that companies allocate to technology investments also tend to augment. While 60% of investigators allocate less than 5% of revenues to technology, more than 80% of innovators and adventurers devote more than 5% of their revenues to it.

Figure 14: Clusters distribution by vertical

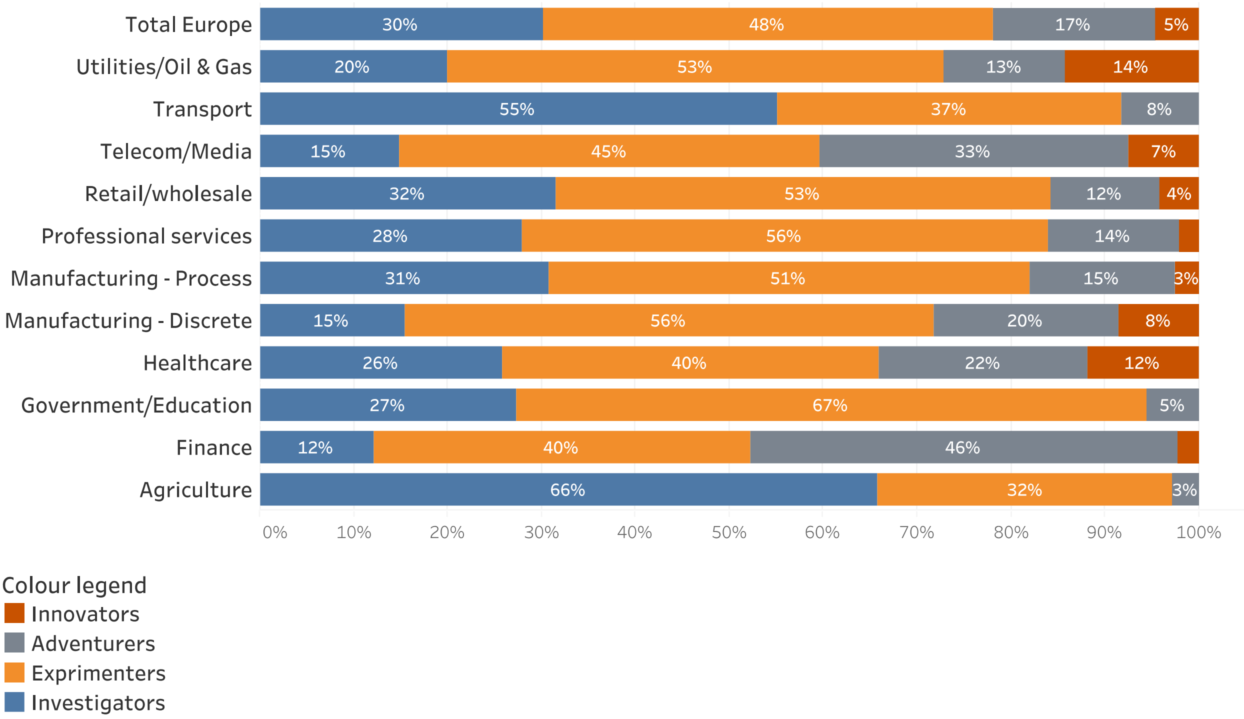
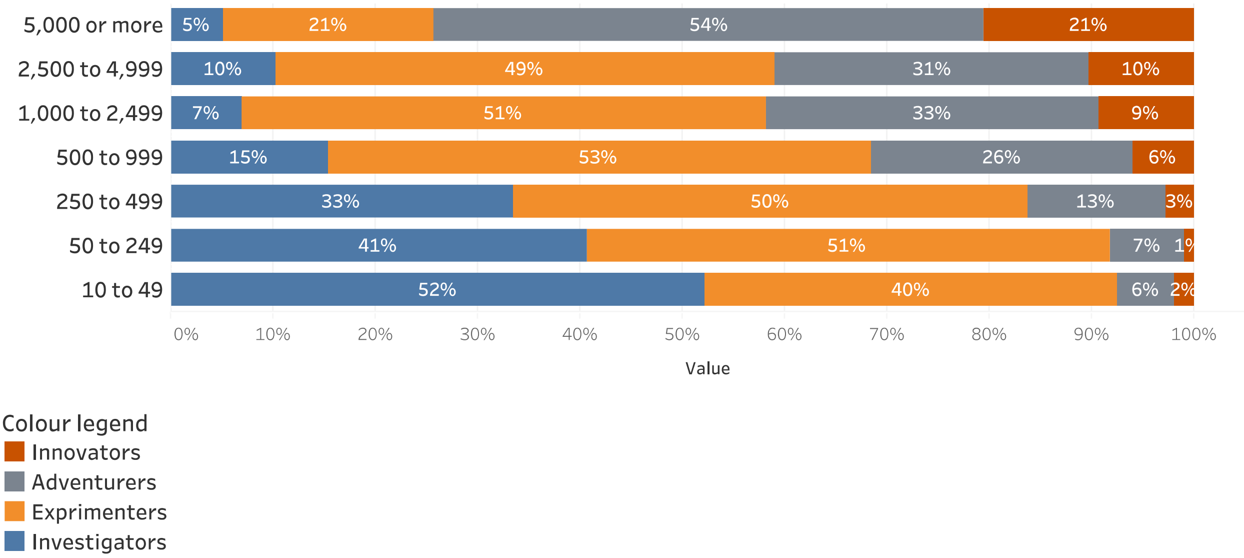


Figure 15: Clusters distribution by size



Source: Advanced Technologies for Industry Survey, July 2019

3.2 Drivers behind the uptake of advanced technologies

As lines of business are increasingly strengthening their influence over technology investment and IT budget decisions, the drivers behind technological investment are becoming more and more business-related rather than purely technology oriented. Providing clear business outcomes aligned with strategic priorities, as well as measurable returns on investment (ROIs), are must-haves for undertaking a technology investment.

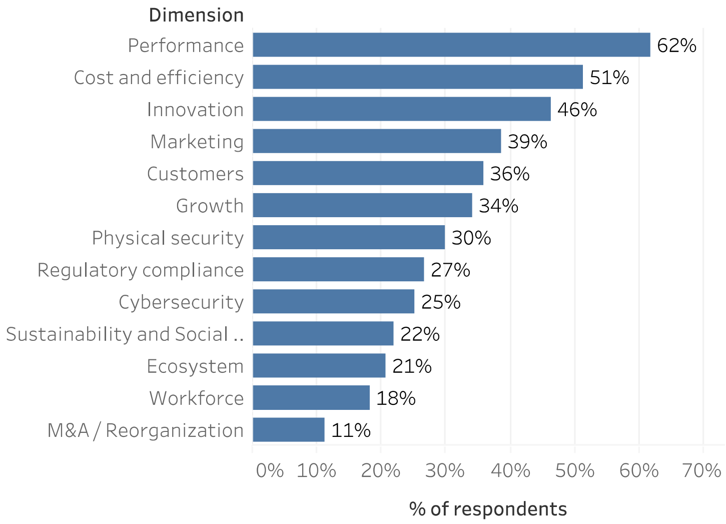
Figure 16 shows the main business goals that are driving technological investments and thus technology uptake, across European firms. According to the survey, the top three priorities driving investments in advanced technologies in the surveyed countries[11] are:

Performance: Being able to improve top lines, driving operational performance (EBITDA, revenues) was considered a top priority by 62% of respondents

Cost & Efficiency: The other side of the coin, where the focus is to reduce bottom lines by cutting operational and or product costs or improving efficiency of processes and operations. It was considered a top priority by 51% of respondents

Innovation: Third is the ability to improve or innovate products, services and programmes. It was considered a top priority by 46% of respondents.

Figure 16. European business goals driving technology uptake



Source: Advanced Technologies for Industry Survey, July 2019
*priorities have been framed differently according to the specific vertical. For examples for Government, Education and Healthcare the customers priority related to Citizens, Students and Patients respectively.

The heatmap below shows what the respondents of different industries selected as their top business goals behind digital investments. It is interesting to notice how vertical characteristics clearly emerge. **Marketing** and/or **Customers** stand out among the top three priorities in industries that are highly customer-facing and where competition is at its highest, including Telecom & Media, Retail, Professional services and Finance. It is worth noticing also that commitment **to sustainability and social welfare** is still a very niche priority, ranking very high in Government and Healthcare and really low across all the other sectors, which highlights how there is an urgent need to educate around the relevance of this theme and that government and educational organisations are best placed to do so. Cybersecurity and compliance with regulations are also more niche priorities, relevant in Finance and Government/Education in the first case and in Healthcare and Government/Education in the latter, particularly due to the need for compliance with the General Data Protection Regulation (GDPR).

[11] The Advanced Technologies for Industry Survey (July 2019) sample consisted of 900 interviews of European organisations with more than 10 employees in the Czech Republic, Denmark, France, Germany, Hungary, Italy, the Netherlands, Poland, Spain, Sweden and United Kingdom. Eligible respondents were individuals best qualified to answer questions about overall ICT, digital and technology strategy and activities. A screening question was used to determine respondents' eligibility. Additional information on survey methodology can be found in the Advanced Technologies for Industry Survey - Methodological Report

Figure 17: European business goals driving technology uptake by industry

	Finance	Gov/Edu	Health	Manuf. - discrete	Manuf. - process	Prof. Services	Retail, Wholesale	Telecom, Media	Transport,Logistics	Utilities, Oil & Gas	Agriculture
Performance	54%	36%	41%	75%	65%	63%	59%	61%	80%	60%	84%
Customers	52%	11%	12%	20%	37%	54%	55%	57%	42%	16%	26%
Cost & Efficiency	41%	49%	49%	56%	68%	43%	48%	45%	54%	60%	53%
Innovation	38%	40%	58%	62%	50%	42%	46%	52%	43%	43%	38%
Growth	44%	4%	22%	44%	31%	43%	43%	36%	38%	34%	27%
Regulatory compliance	26%	48%	40%	17%	26%	23%	17%	15%	23%	39%	23%
M&A/Reorganization	12%	4%	9%	15%	12%	18%	12%	15%	9%	11%	4%
Physical Security	28%	44%	44%	31%	36%	20%	20%	16%	26%	39%	30%
Cybersecurity	43%	38%	20%	23%	15%	31%	25%	33%	8%	30%	12%
Workforce	20%	18%	20%	23%	15%	25%	19%	16%	17%	19%	5%
Marketing	46%	27%	45%	28%	24%	50%	53%	54%	31%	34%	27%
Ecosystem	26%	12%	20%	25%	27%	16%	19%	30%	23%	13%	15%
Sustainability & Social Welfare	19%	60%	46%	14%	8%	10%	12%	12%	14%	29%	25%

Priorities Relevance

Low High

Source: Advanced Technologies for Industry Survey, July 2019

The analysis of business goals by size (in Figure 18) also provides some interesting insights. The relevance of **performance** and **cost & efficiency** priorities seems to decline as the size increases, as opposed to the **innovation** priority, which, on the contrary, increases with size. This finding suggests that, while the smaller the size the greater is the focus on more short-term business goals, as the sizes increases priorities become more long-term, including investing in innovating products and services to achieve a competitive edge.

Figure 18: European business goals driving technology uptake by size

	10-249 employees	250-499 employees	500-999 employees	1,000+ employees
Performance	66%	66%	61%	47%
Customers	39%	35%	31%	35%
Cost & Efficiency	51%	48%	56%	51%
Innovation	40%	47%	48%	57%
Growth	33%	32%	32%	41%
Regulatory compliance	23%	27%	32%	29%
M&A, Reorganisation	12%	7%	13%	14%
Physical security	26%	32%	35%	31%
Cybersecurity	22%	21%	30%	34%
Workforce	15%	19%	23%	21%
Marketing	37%	40%	37%	43%
Ecosystem	16%	21%	28%	22%
Sustainability & social welfare	19%	23%	24%	25%

Priorities Relevance

Low High

Source: Advanced Technologies for Industry Survey, July 2019

Figure 19: Business goals by cluster

	Investigators	Experimenters	Adventurers	Innovators
Performance	63%	62%	56%	66%
Customers	35%	38%	37%	15%
Cost & Efficiency	55%	50%	48%	54%
Innovation	35%	51%	53%	44%
Growth	21%	37%	47%	39%
Regulatory compliance	29%	26%	24%	29%
M&A/Reorganization	11%	11%	12%	15%
Physical Security	25%	31%	30%	41%
Cybersecurity	25%	22%	29%	41%
Workforce	12%	20%	22%	27%
Marketing	27%	44%	44%	37%
Ecosystem	11%	22%	33%	22%
Sustainability & Social Welfare	17%	25%	22%	22%

Priorities Relevance

Low High

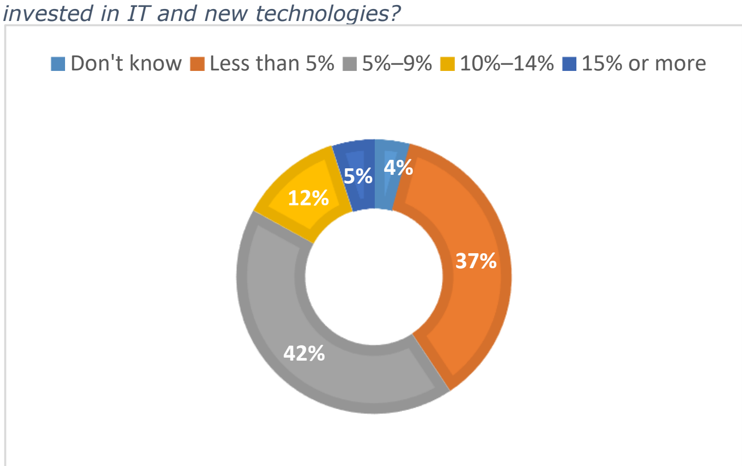
Source: Advanced Technologies for Industry Survey, July 2019

3.3 IT and advanced technology spending up to 10% of firm revenues

Growing technology uptake indicates that advanced technology investments represent an **increasing percentage of companies' budget and have become of strategic relevance for all organisational decision-makers**, not just IT executives. According to the survey results, spending on IT and advanced technologies represents up to 10% of company's revenues for about 80% of respondents and for another 17% of them, this spending amounts to more than 10%.

Looking at the relationship between technology investments and revenues by industry, we find that Finance and Telco/Media are leading the way together with Professional Services and Healthcare.

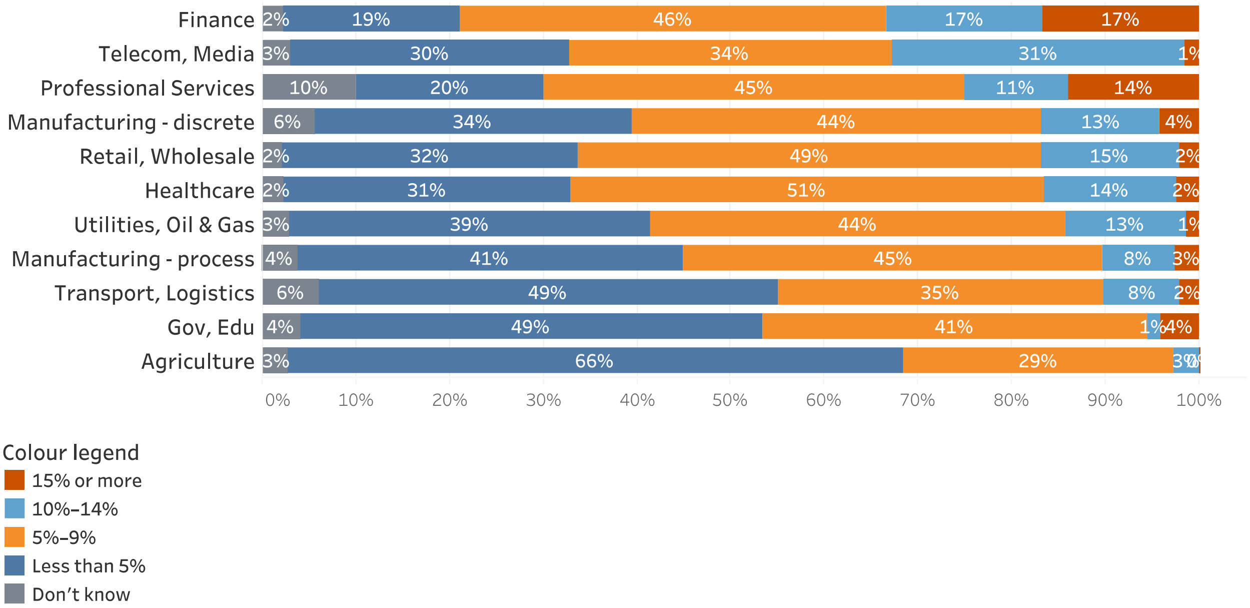
Figure 20: What percentage of your organisation's revenue is invested in IT and new technologies?



Source: Advanced Technologies for Industry Survey, July 2019

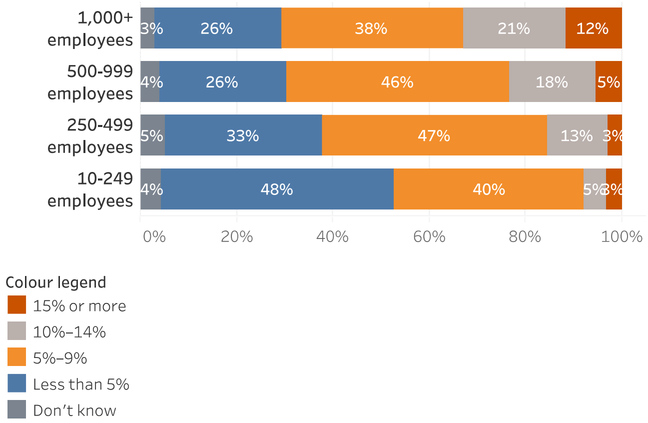
Results by size confirm the positive trend between share of investment and size with about 70% of large companies devoting more than 5% and about half of small companies devoting less than 5%.

Figure 21: What percentage of your organisation's revenue is invested in IT and new technologies? (by vertical)



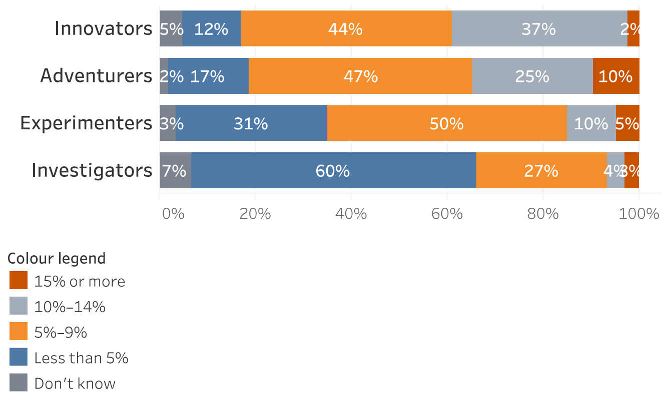
Source: Advanced Technologies for Industry Survey, July 2019

Figure 22: What percentage of your organisation's revenue is invested in IT and new technologies? (by size)



Source: Advanced Technologies for Industry Survey, July 2019

Figure 23: What percentage of your organisation's revenue is invested in IT and new technologies? (by cluster)



Source: Advanced Technologies for Industry Survey, July 2019

3.4 Adoption of B2B Platforms

Organisations across all sectors see multiple benefits in the adoption of B2B platforms, such as the potential to access significantly larger markets and thus increase revenue. The perceived growth potential associated with these technologies reveals companies' faith in such solutions. However, as yet, few companies are focusing on strategic targets, such as delivering new as-a-service offerings, optimising the use of assets (e.g. by sharing them in the ecosystem via a networked operational model), and finding new partners. The vision concerning potential opportunities is still nascent; it is limited to the most immediate benefits that can be attained rather than encompassing broader strategic transformation.

B2B Digital Platforms can be defined as virtual environments facilitating the exchange and connection of data between different organisations through a shared reference architecture and common governance rules (IDC). A growing number of leading organisations across all industry sectors is shifting to B2B Digital Platforms with direct impacts on their business models and their technology architecture. IDC estimates that B2B industrial data platforms have already reached a significant market value (estimated at almost $2.8 bn in 2019, approximately €2.5 bn) – one that is poised to grow at a compound annual growth rate (CAGR) of around 18% by 2023.[12] Benefits' analysis by company size shows a relatively even distribution of benefits, with the exception of those around market expansion, which heavily correlate with company size.

General awareness and adoption of digital platforms in Europe[13] is high. The Advanced Technology for Industry survey[14], conducted between June and September 2019, shows that most companies in Europe have at least heard of B2B industry digital platforms, with nearly 60% on average at least evaluating some related business cases. However, results vary from country to country with Western European Member States (WE) exhibiting a slightly higher awareness than their counterparts in Central & Eastern Europe (CEE). The adoption level in the EU also differs across company-size segments. It generally rises proportionally with company size as most companies currently running or deploying pilots are large entities.

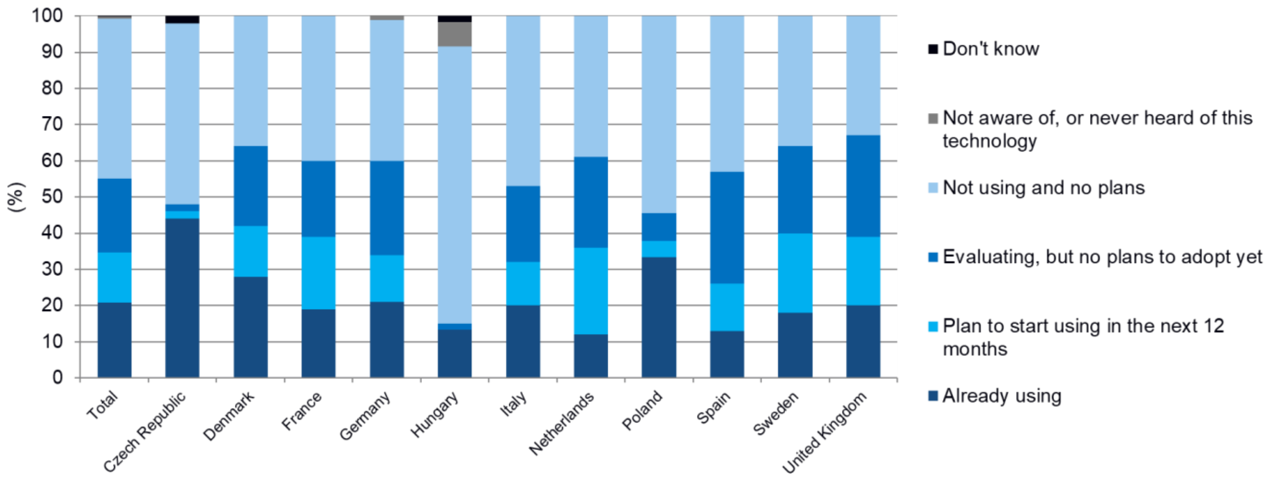
[12] Data retrieved by using a combination of the IDC Industry Cloud Tracker and the IDC IoT Spending Guide. IDC Cloud Trackers describes how cloud technologies and services continue to form the foundation for digital transformation and innovation. Retrieved from https://www.idc.com/promo/trackers/cloud. The Worldwide Internet of Things Spending Guide examines the Internet of Things (IoT) opportunity from a use case, technology, industry, and geography perspective. Retrieved at: https://www.idc.com/getdoc.jsp?containerId=IDC_P29475

[13] The Advanced Technologies for Industry Survey (July 2019) sample consisted of 900 interviews of European organisations with more than 10 employees in the Czech Republic, Denmark, France, Germany, Hungary, Italy, the Netherlands, Poland, Spain, Sweden and United Kingdom. Eligible respondents were individuals best qualified to answer questions about overall ICT, digital and technology strategy and activities. A screening question was used to determine respondents' eligibility. Additional information on survey methodology can be found in the Advanced Technologies for Industry Survey - Methodological Report

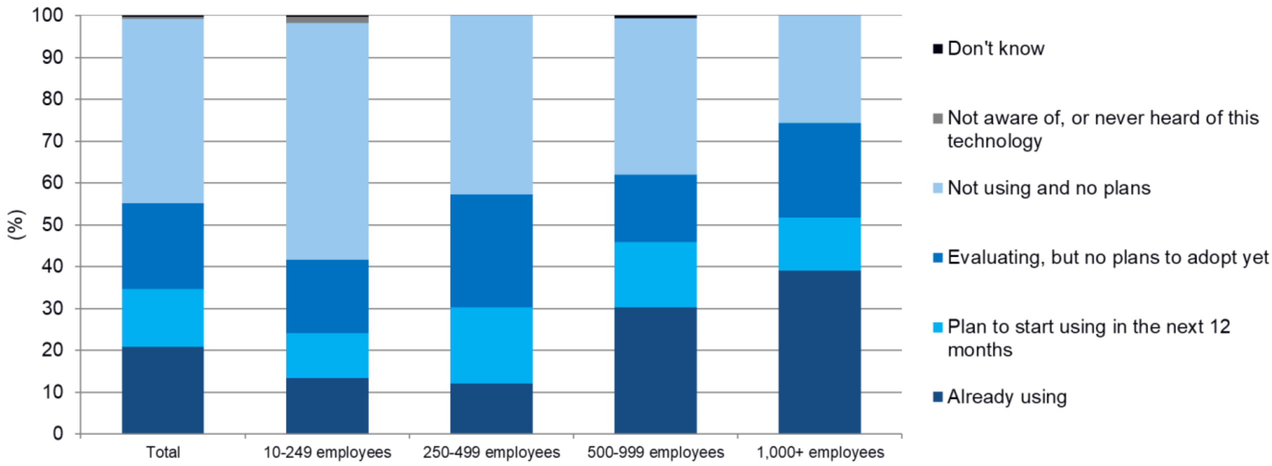
[14] Advanced Technologies for Industry (ATI) Survey, July 2019

Figure 24: "Is your organisation using or planning to use B2B industrial digital platforms?"

a) By Geography



b) By Company Size



Source: Advanced Technologies for Industry Survey, July 2019

4. Venture capital investment into advanced technologies

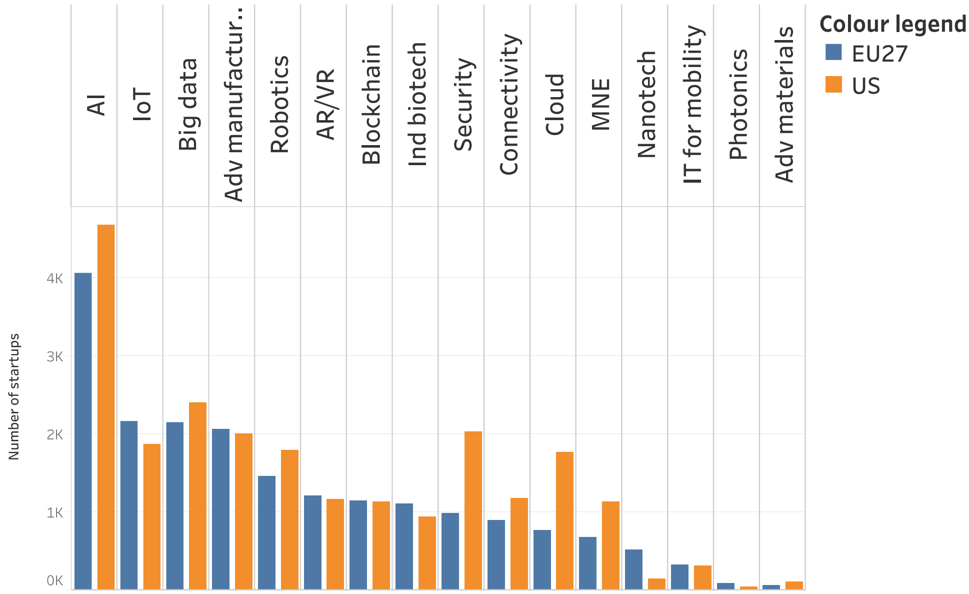
Tech firms have been the fastest growing investment target of venture capital investors who have played a vital part in kick-starting tech startups. In 2019 venture capital deal volume continued to increase, driven especially by seed-stage deals as well as ongoing development and maturation of international startup markets (Crunchbase, 2019). Investments in European tech companies broke records in 2019 increasing to €7.6 bn, up from €2.7 bn in 2015 (Dealroom, 2019).

This investment and startup landscape in advanced technologies has been analysed with the help of data from Crunchbase and Dealroom[15], two databases which provide detailed insights into innovative tech companies with investors behind them. The merged data provide a good basis with which to compare firm activity in Europe and the US. The methodology to capture technologies and merge the data from these two databases in order to cover a representative sample of the European and US venture capital market, the representativeness check and the *caveats* in interpretation are further explained in the methodological report.

4.1 Venture-backed startups, scaleups and innovative tech firms

With regard to the number of startups and scale-ups and the average investment amount per firm of any size, the EU27 has a relative advantage, in **Advanced manufacturing**[16] when taking the broader term of this technology and including the investments of innovative manufacturing firms, as the results of the analysis show. The number of startups and scale-ups indicate that the EU27 has a relative advantage in the **Internet of Things** and boasts more startups and scale-ups than the US in the fields of **Nanotechnology, Industrial biotechnology and Photonics** (although the level of average investment has been significantly lower in these areas). It is very close to the US in Blockchain, AR/VR and IT for Mobility.

Figure 25: Number of active VC backed startups and scaleups established since 2009



Source: Technopolis Group analysis based on Crunchbase and Dealroom

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[15] https://dealroom.co/

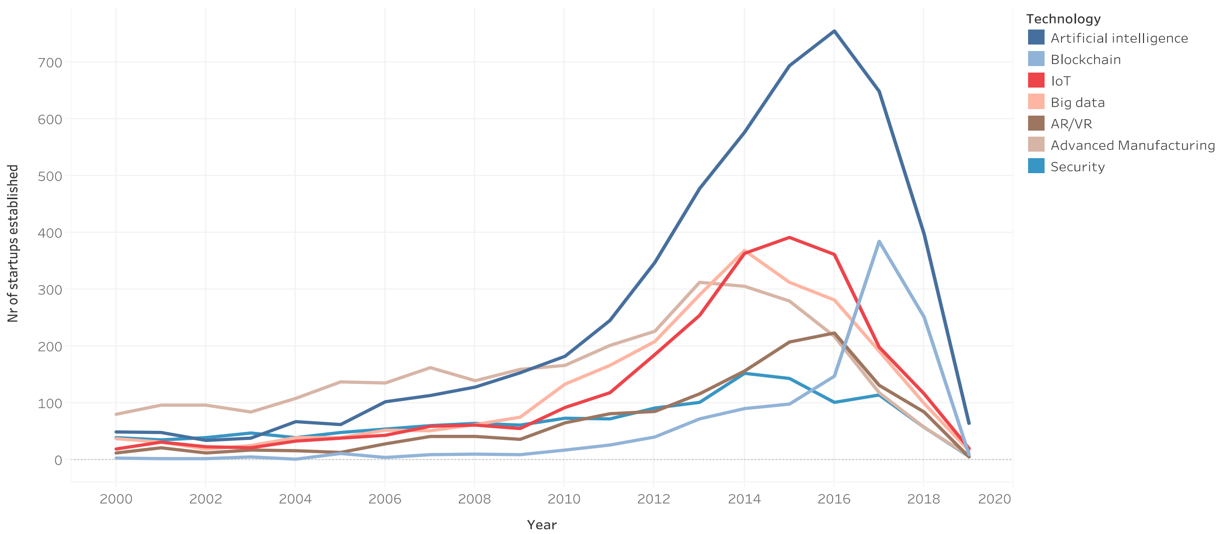
[16] Advanced manufacturing has been defined as the use of innovative technologies to improve products or processes that drive innovation. Our sample includes startups that aim to offer such innovative technologies (e.g. 3D printing, Advanced materials, new automation etc.) but also manufacturing startups that use such technologies extensively.

Interestingly, the number of startups and scaleups in **Artificial Intelligence** has been the highest relative to the other technologies in focus and is not far behind the US. AI startup creation has been growing steadily in recent years and has risen markedly, especially since 2012. The areas where startup and scaleup activity has been much weaker than in the US includes Security, Big Data, Cloud technologies, Micro- and nanoelectronics and Connectivity. The gap is prominent especially in Security, where the US cybersecurity startups scene shows higher dynamics.

It has to be noted that the advanced technology categories are not exclusive but might overlap. There are lot of firms that focus on robotics but develop AI algorithms at the same time such as the Danish Blue Ocean Robotics that develops robotics solutions with the help of AI. Another example is the German KONUX that combines machine learning and IoT to make railway a mobility choice by increasing capacity, reliability, and cost-efficiency. KONUX is categorised both under AI and IoT in our research. Advanced manufacturing has been defined as a broad category as already mentioned above and for instance robotics startups can be also behind these values. These overlaps reflect a natural co-evolution and interlinkages between technologies.

The number of active startups and scaleups[17], the change over time and the average amount of private equity investment are displayed in Figure 26. **Growing intensity in terms of European startup activity is visible, especially in the case of Artificial Intelligence, Blockchain, IoT and Big Data** in the period from 2012 to 2017. The total number of Advanced manufacturing startups that were newly established peaked in 2013 and, since then, the rate of their establishment has been decreasing (the drop in the number of startups after 2017 does not reflect less entrepreneurial activity but rather a lag in the reporting of the firms in the database).

Figure 26: Trends in the establishment of investment-backed firms, 2000-2019

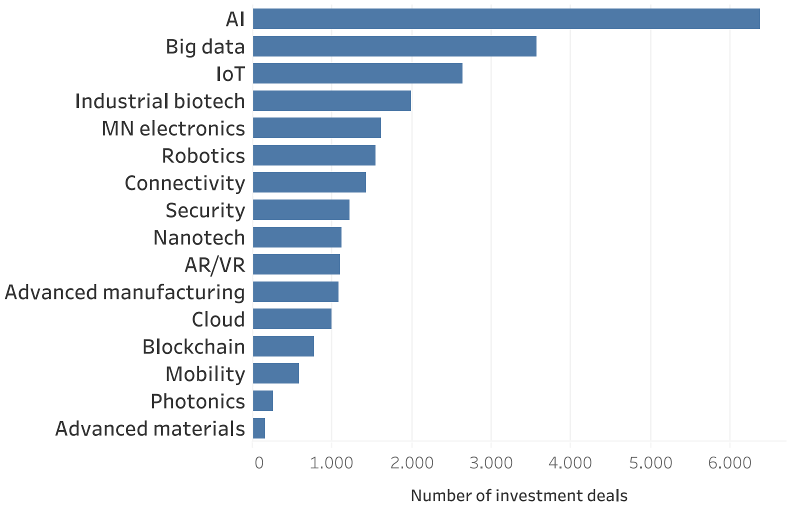


Source: Technopolis Group analysis based on Crunchbase and Dealroom

The number of investment deals was the highest in Artificial Intelligence, followed up by Big Data and the Internet of Things. In Advanced manufacturing the number of deals has been lower but with larger capital amounts each. The recent growth reflects that European tech has been receiving an increased attention from venture capitalists and private investors.

[17] Startups and scaleups have been defined according to two criteria: founding date after 2009, active and having received venture capital/private equity investment – analysed based on Crunchbase and Dealroom company investment databases.

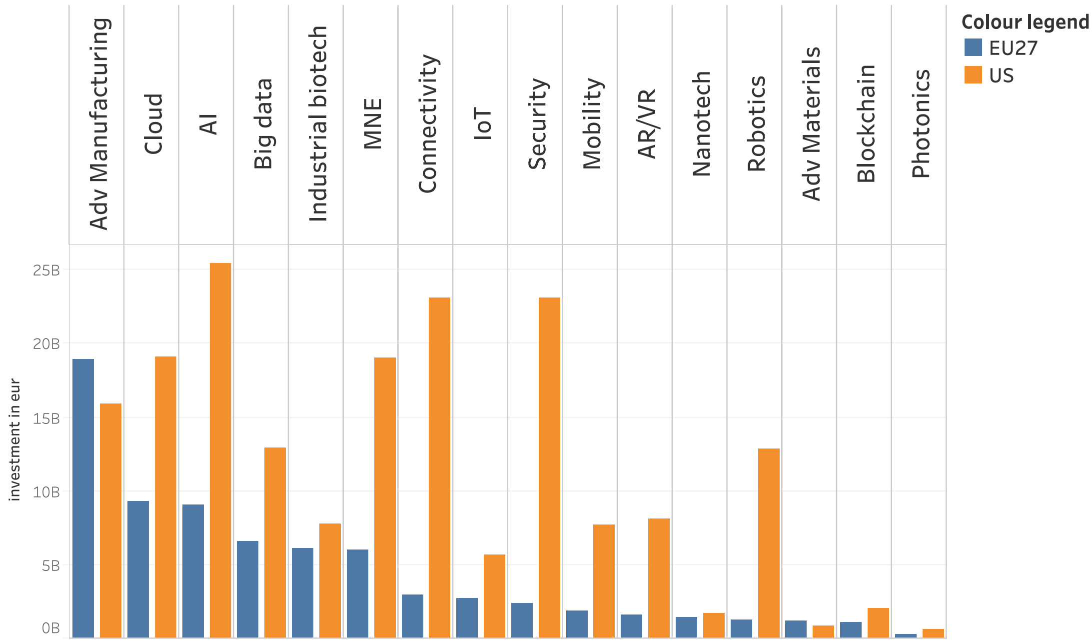
Figure 27: Number of investment deals in EU27, 2000-2019



Source: Technopolis Group analysis based on Crunchbase and Dealroom

In terms of total capital investment (cumulative) from 2010 to 2019 the advanced technologies with the highest amounts in the EU27 have been **Advanced manufacturing, Cloud technologies, Artificial Intelligence and Big data**. Due to variations in industrial investments, when we look at the average investment per company, we find that Micro- and nanoelectronics, Advanced manufacturing and Cloud technologies received the highest deal value. The total and the average private investment amounts are higher in the US than in the EU27 in the case of all advanced technologies, which on the one hand is due to the prevalence of the much stronger venture capital market in the US, on the other hand, the comparison of total investment figures has to be interpreted with caution given the somewhat different coverage of data for the EU27 and the US[18].

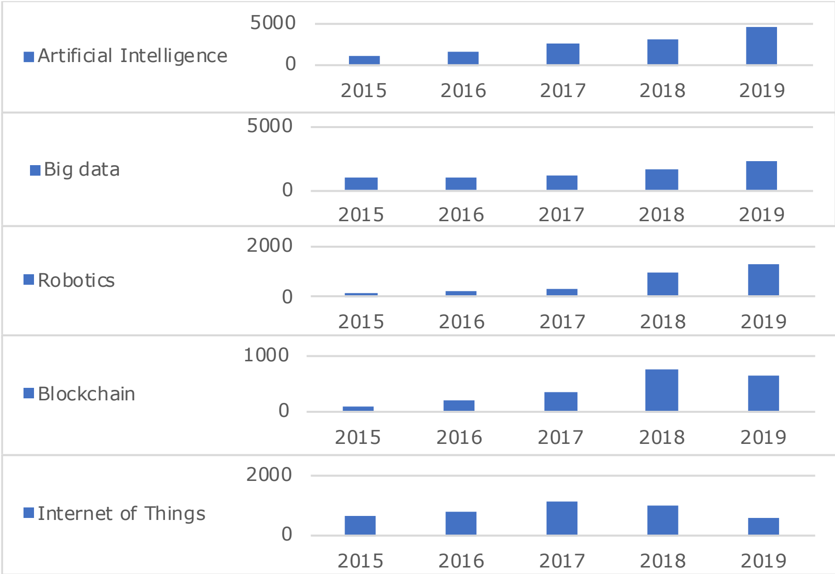
Figure 28: Total last investment in advanced technologies 2010-2019



Source: Technopolis Group based on Crunchbase and Dealroom

[18] Please note that the coverage of EU investment deals have been improved to a large extent after completing Crunchbase with Dealroom data.

Figure 29: Investment trends in selected advanced technologies in EU27, from year 2015 to 2019



Source: Technopolis Group analysis based on Crunchbase and Dealroom

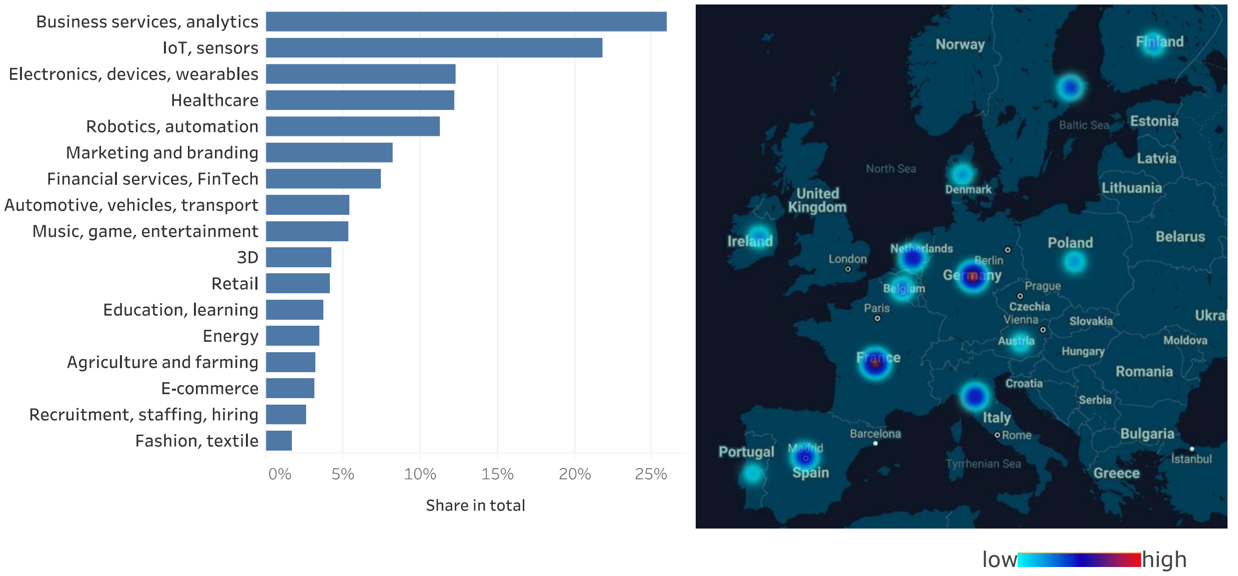
In terms of the types of the investments, **we find relatively less series B and series C types of investments** in the EU27 than in the US, but seed and Series A funding is common across technology types. Several startups have benefitted from grants from the European Union. Public investments via grants have a higher rate in the EU27, especially in AI, Robotics and Advanced manufacturing, which reflects the importance of the public sector in Europe in nurturing advanced technologies.

Investment trends have been driven within the EU27 mainly by France and Germany, but the Netherlands and Sweden have been powerhouses of AI and Big Data and of IoT and Spain and Italy have been powerhouses of Advanced manufacturing. Other countries with high overall investments in advanced technologies include Ireland, Austria, Poland, Romania and the Czech Republic.

4.2 Drivers of technological investments

Artificial Intelligence has been the most common topic of startups in Europe when only comparing the sixteen advanced technologies in focus. As pointed out earlier, startup dynamics have been recently catching up fast with the level of activity in the US. European firms that are active in the field and have received the largest total venture capital investment include, for example, UiPath from Romania, developing AI skills; Kreditech from Germany that uses machine-learning technologies to provide access to better credit for the underbanked; AnotherBrain from France that created a new kind of Artificial Intelligence, called Organic AI, which is very close to the functioning of the human brain; or MessageBird, which is a Dutch startup that connects enterprises to global customers through SMS, Voice and Chat APIs. The profile of European AI startups has been broad and includes several industrial and business activities. The most common activity area has been business services and analytics, followed by IoT and sensors, electronics and healthcare.

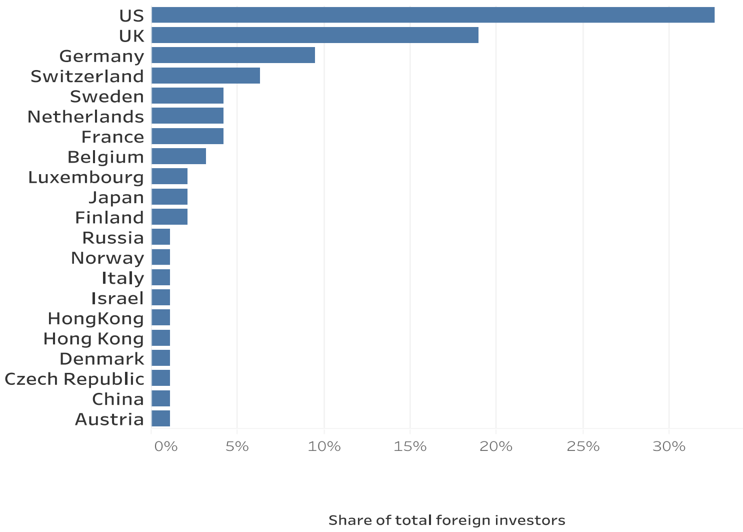
Figure 30: Main activity areas of European AI startups and scale-ups (share in total firms) and geographical concentration of AI active startups and scale-ups



Source: Technopolis Group based on Crunchbase and Dealroom data, with geolytics

In the case of Artificial Intelligence, the country of origin of the lead investors in startups has been explored in more detail. This analysis found that in 28% of the cases the lead investors come from the same country where the startup is headquartered. In the rest of the 72% the lead investors come from 2-6 different countries. **31% of the foreign lead investors originate from the US**, **19% from the UK and 9% from Germany** (see Figure 31). Further investment originated from Switzerland, Sweden, Netherlands or France. German investors have been active in Eastern Europe.

Figure 31: Country or origin of foreign investors in AI startups



Source : Technopolis Group, based on Crunchbase

Europe has been leading in terms of the number of Blockchain deals in recent years. Key European Blockchain companies with the highest total deal values include the full-service Bitcoin company called Bitfury Group from the Netherlands, the Cypriot PumaPay offering a unique smart-contract-based protocol, Blockchain Industries Inc from Germany with Blockchain infrastructure and the French Ledger offering security solutions for cryptocurrency and Blockchain applications. Crypterium and Nortal AS are two Estonian firms. The Crypterium mobile app allows instant payments in cryptocurrency and Nortal offers e-government strategy and solutions.

The difference in private investment stands out the most in **Mobility technologies** (autonomous and electric vehicles), where the **US and also China boast significantly larger investment** tickets. Besides Tesla, with its well-known activity, Cruise, which builds self-driving vehicles, and Argo AI, a self-driving technology platform company, have received the largest amounts of venture capital. In China, key competitors include Xiaopeng Motors, which is an electric vehicle and technology company that designs and manufactures smart cars, WM Motor, which is an emerging energy vehicle product and travel solution provider, and BYTON, which operates as an electric vehicle company that designs cars as a fully connected smart device on wheels.

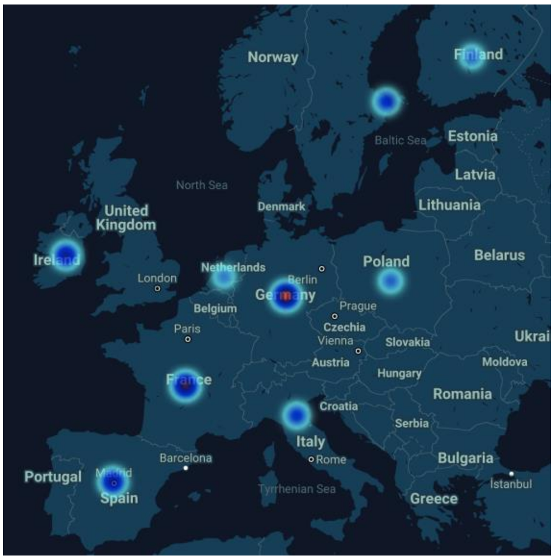
Advanced manufacturing investment has especially increased in 3D printing, industrial sensors and machine vision. The key hotspots of 3D printing/additive manufacturing have been Germany, France and the Netherlands, followed by Italy and Spain. Sweden, Belgium and Finland have also been active in advanced manufacturing technology centres. 10% of startups in the Advanced manufacturing sample also focused on developing green manufacturing solutions and aimed at reducing waste. Examples of startups with the highest recent investment tickets include the French company Aledia, which develops and manufactures innovative light-emitting diodes (LEDs) based on a unique 3D architecture, the Irish company Mcor Technologies, an innovative manufacturer of full colour and eco-friendly 3D printers or 3D Hubs from the Netherlands and a distributed manufacturing platform founded in 2013 that makes manufacturing easy from prototyping to production. Startups with computer vision technology include, for instance, Lateral Reality Ltd from Hungary, which is a computer vision startup that creates 3D face models for trying on virtual glasses using a unique patented technology. In Advanced materials, it is Covestro[19], a German supplier of high-tech polymer materials that received a large amount of investment recently and is behind the strong average ticket size in this technology.

Figure 32: Main activity areas of European advanced manufacturing startups and scaleups

Source: Technopolis Group based on Crunchbase and Dealroom, geolytics

Low high

Figure 33: Main activity areas of European cloud startups and scaleups



Source: Technopolis Group based on Crunchbase and Dealroom, geolytics

low high

Cloud technologies have witnessed large deal sizes in the EU. This also reflects some of the recent activity of service provider firms. For instance, Spotify has moved its music provision service to the cloud, from its own servers to Google's cloud platform. The storage, computer and network services available from cloud providers are as high quality, high performance and low cost as what is provided by the traditional approach. Examples of startups with the highest series C and D investments include Blade Shadow, a French tech firm specialised in cloud-based high-end computer technology. Blade was founded in 2015 and had four successive rounds of fundraising, also making its debut both in the United States and Europe. Gigas in Spain is a cloud service provider in Spain and Latin America, which offers mission-critical quality services to business customers.

[19] Covestro became an independent company listed on the stock exchange in 2015. https://www.covestro.com/

Section 5

5. Demand for and supply of skills for technological transformation

5.1 Skills supply

In order to respond to the disruptive force of today's technological advances, European industry has to have access to the relevant technical and digital skills. However, the number of tech-savvy professionals does not meet the exponentially increasing current demand. The rapidly developing fields of Artificial Intelligence, Robotics or Biotechnology are changing the game across all sectors and hence the nature of published job profiles has been focusing more and more on ICT skills, problem-solving and creativity. The World Economic Forum estimated that more than half of all employees will require significant reskilling by 2022 while around 37% of workers in Europe do not even have basic digital skills (EC, 2018).

In the midst of heated policy discussions about the availability of digital skills, this report aspires to provide new insights into the supply of and demand for skills at the level of individual advanced technologies relying on data from the self-reported skills of professionals in LinkedIn, a widely used and accepted online job platform. The database provides a unique opportunity to enrich our understanding of the supply of skills with a level of granularity that is not available in any of the traditional data sources. The number of skilled professionals employed across different economic sectors can also give some indication about the level of technology uptake in industry.

LinkedIn represents a different sample of the workforce in Europe, across European countries and the US and as a result it needs a correction in order to confidently generalise to the total population and allow for comparison. To harvest the data from LinkedIn, keywords capturing skills by advanced technology have been defined and queries have subsequently been constructed to filter the database by location and industry. When members fill in their LinkedIn profile, the skills they indicate are grouped by LinkedIn's algorithms and organised into standardised skill titles. This allows a structured search among professionals with specific skills in advanced technologies. The representativeness of the LinkedIn sample has been assessed against several criteria including the level of education, gender and the share of registered users in information and communications technology and science and engineering compared to the actual active population in these fields in each individual country resulting in a corrective weighting. Data have been captured in three time points (December 2019, January and March 2020). The detailed methodology, the analysis of the representativeness and the caveats in interpreting the data are further explained in the methodological report available on the ATI website (https://ati.ec.europa.eu).

5.1.1 Professionals with advanced technology skills currently on the labour market and on LinkedIn

In the EU27, within the pool of currently active professionals with skills in advanced technologies and registered in the LinkedIn database, **Advanced manufacturing and Cloud technology** are the two top available skills (31% and 28% of all professionals with advanced technology skills). This might reflect, on the one hand, the growing market for Advanced manufacturing that is expected to double in size by 2020 and has also a high demand for skills in additive manufacturing, 3D printing, embedded systems and materials. On the other hand, cloud computing skills are also on the rise as more and more companies are adopting cloud services and it is a technology highly relevant across economic sectors and industries.

In the US similar patterns can be observed and Cloud and Advanced manufacturing are also among the top skills reported (40% and 25% respectively). This is illustrated in the figure below, which shows the supply of professionals by technology in absolute values measured as a share of total professionals in the 16 advanced technologies in Europe and the US.

Figure 34: Skills supply: Share of professionals with advanced technology skills measured within the total AT professionals in absolute figures in the EU27, 2020

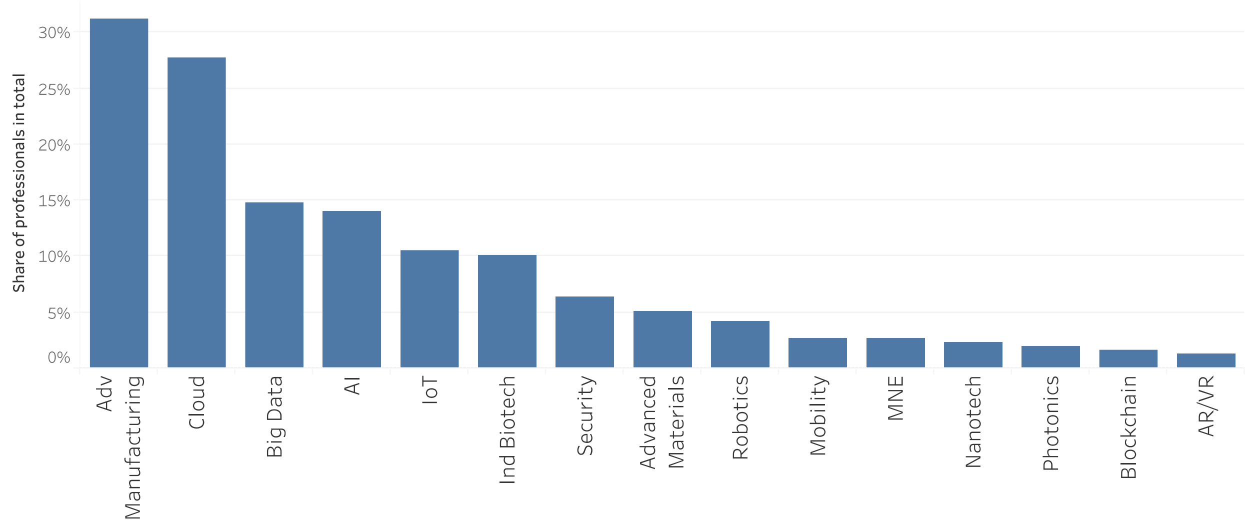
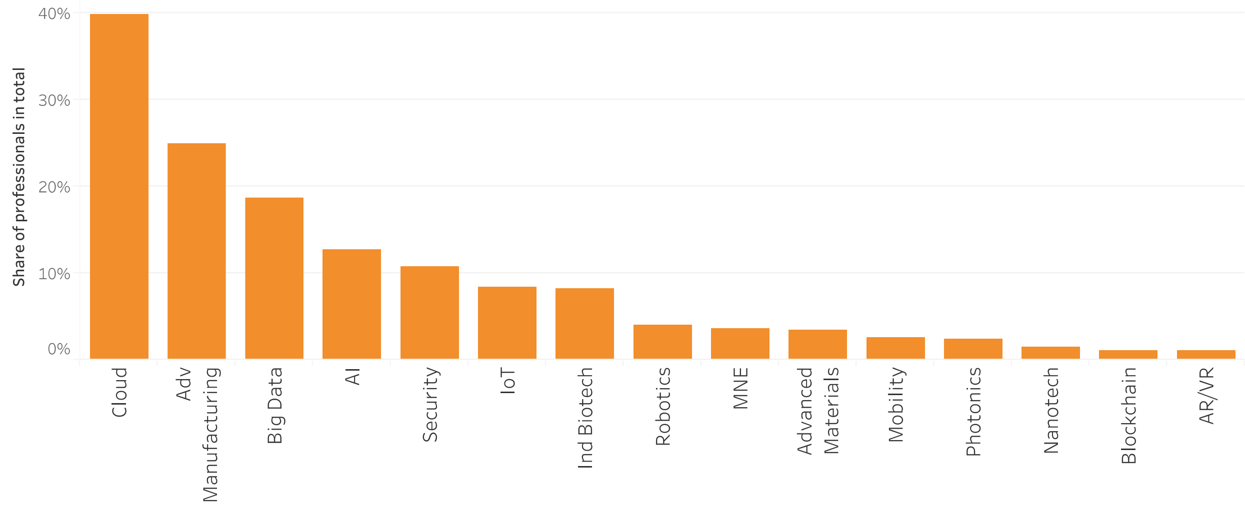


Figure 35: Skills supply: Share of professionals with advanced technology skills measured within the total AT professionals in absolute figures in the US, 2020



Source: Technopolis Group calculations using LinkedIn, 2020

The number of professionals with advanced technology skills and registered on LinkedIn in the EU27 and the US has been weighted by the representativeness of the sample in terms of the active population in ICT and research/science. This weighting method allows a comparison between the two economic regions and is described in detail in the methodological report.

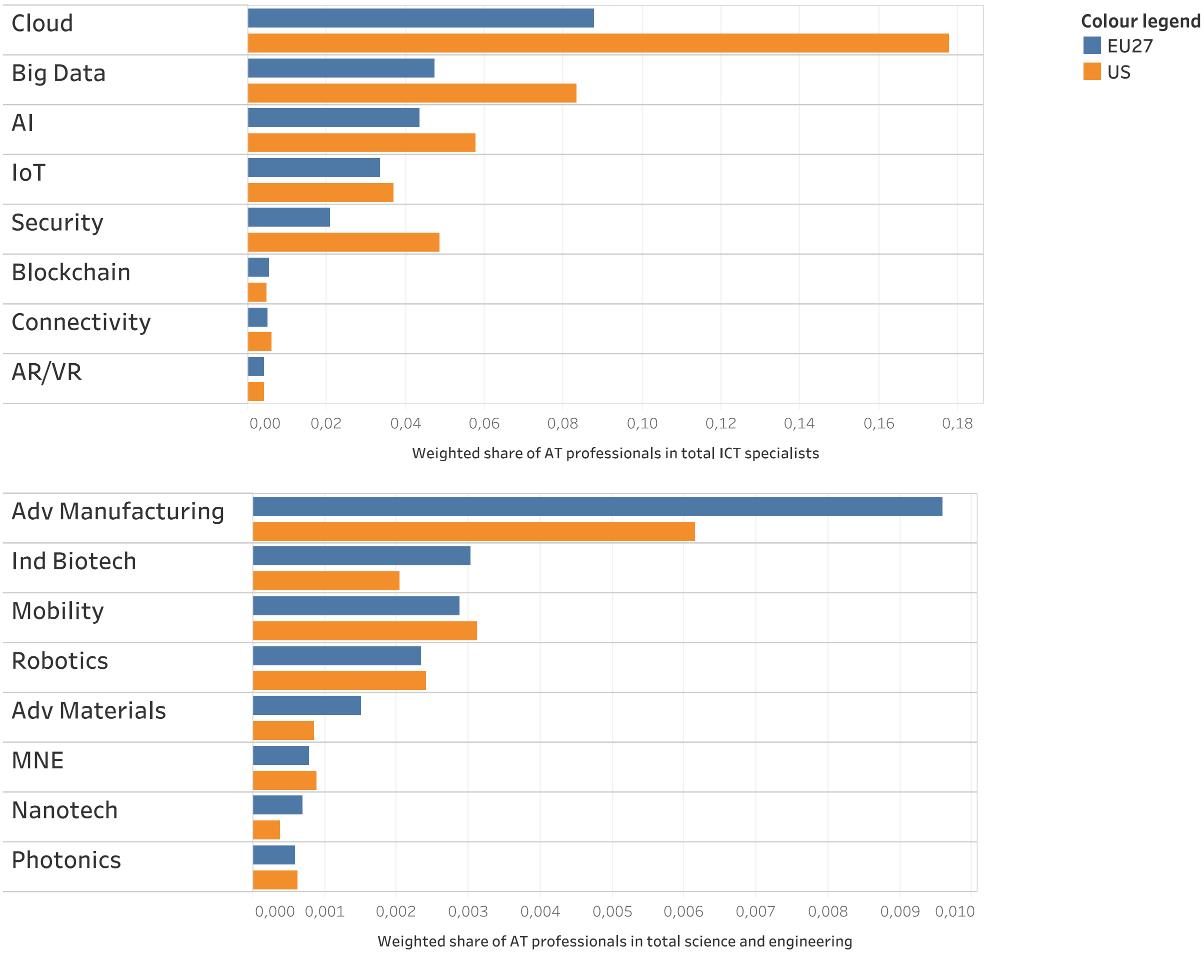
When compared with the US, the EU27 shows strengths in several advanced technologies driven by science and engineering but has weaknesses in key digital technology fields.

The EU27 has higher relative share of professionals with skills in Advanced manufacturing technologies, Advanced materials, Industrial biotechnology and Nanotechnology.

The EU27 lags behind the US in particular in Cloud technologies but also in Big data, AI and Security.

The EU27 and US have similar shares in Blockchain, AR/VR, the Internet of Things, Micro- and Nanoelectronics, IT for Mobility, Robotics and Photonics.

Figure 36: Weighted share of professionals with advanced technology skills in the EU27 & US, 2020



Source: Technopolis Group calculations using LinkedIn, 2019

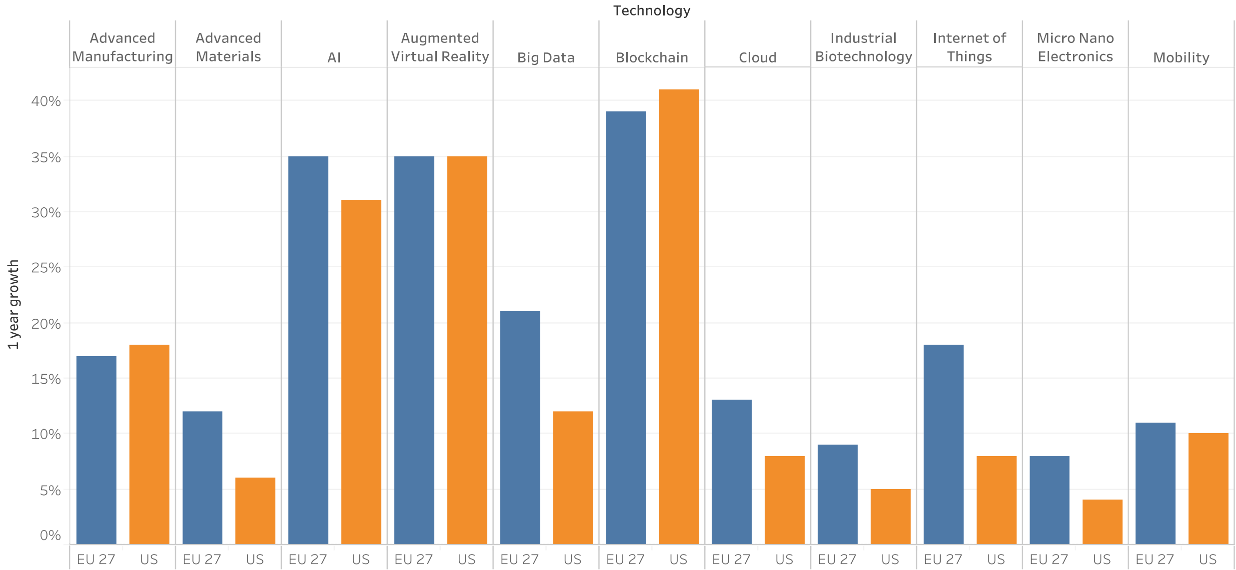
5.1.2 Patterns of change over the period 2018-2019

The **one-year growth** (2018-2019) patterns in the number of advanced technology skilled professionals indicate that the EU27 has been catching up **fast** by comparison with the US in the fields of the **Internet of Things, Micro- and Nanoelectronics, and Cloud** (14% average growth rate in the EU27 versus 7% in the US in the aforementioned technologies).

The results also indicate that **the supply of skills has grown the most in AI, Blockchain and AR/VR in Europe.** The dynamics in Blockchain skilled professionals is driven by a strong recent demand for such professionals especially in the Financial services and Management consulting sectors, but the higher growth is also a result of the relative smaller number of available professionals (as better indicated on the scatter plot of Figure 38). These findings are in line with the recent World Economic Forum report (2020)[20], which found that the roles with the highest rate of growth within high-volume jobs include Artificial Intelligence Specialists and Data Scientists. The trends over time reflect also the growing opportunities related to these specific technologies.

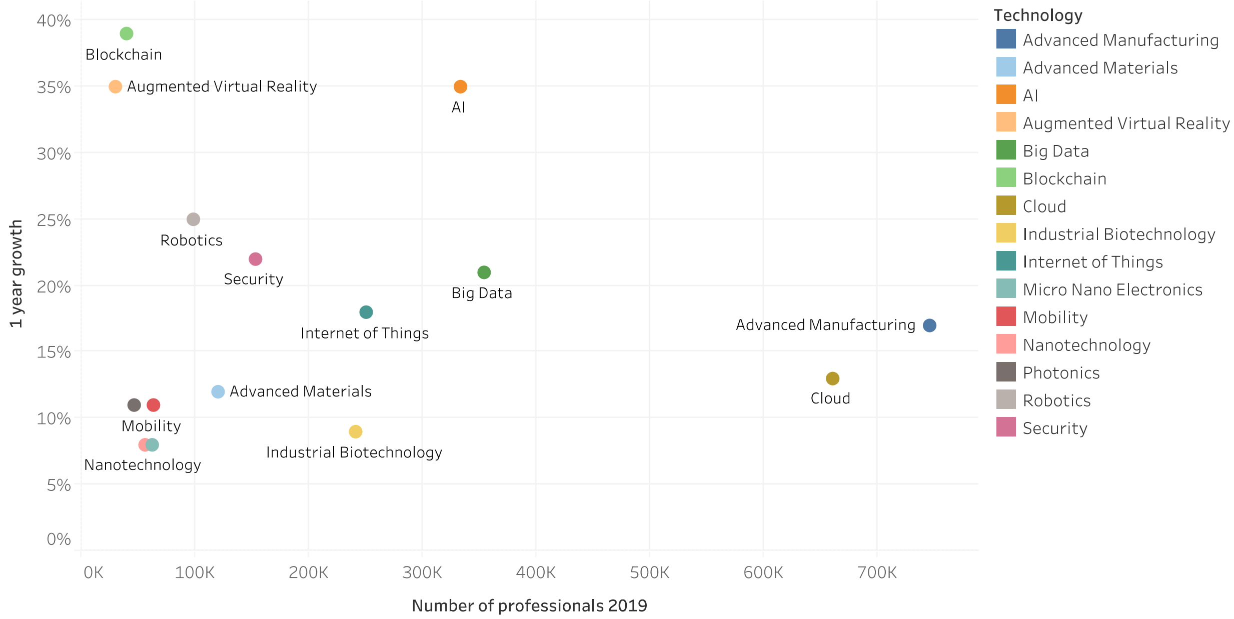
[20] WEF (2020). Jobs of Tomorrow Mapping Opportunity in the New Economy

Figure 37: 1-year growth in the supply of professionals by advanced technology (2018-2019)



Source: Technopolis Group calculations using LinkedIn, 2019

Figure 38: Growth and current number of professionals in advanced technologies



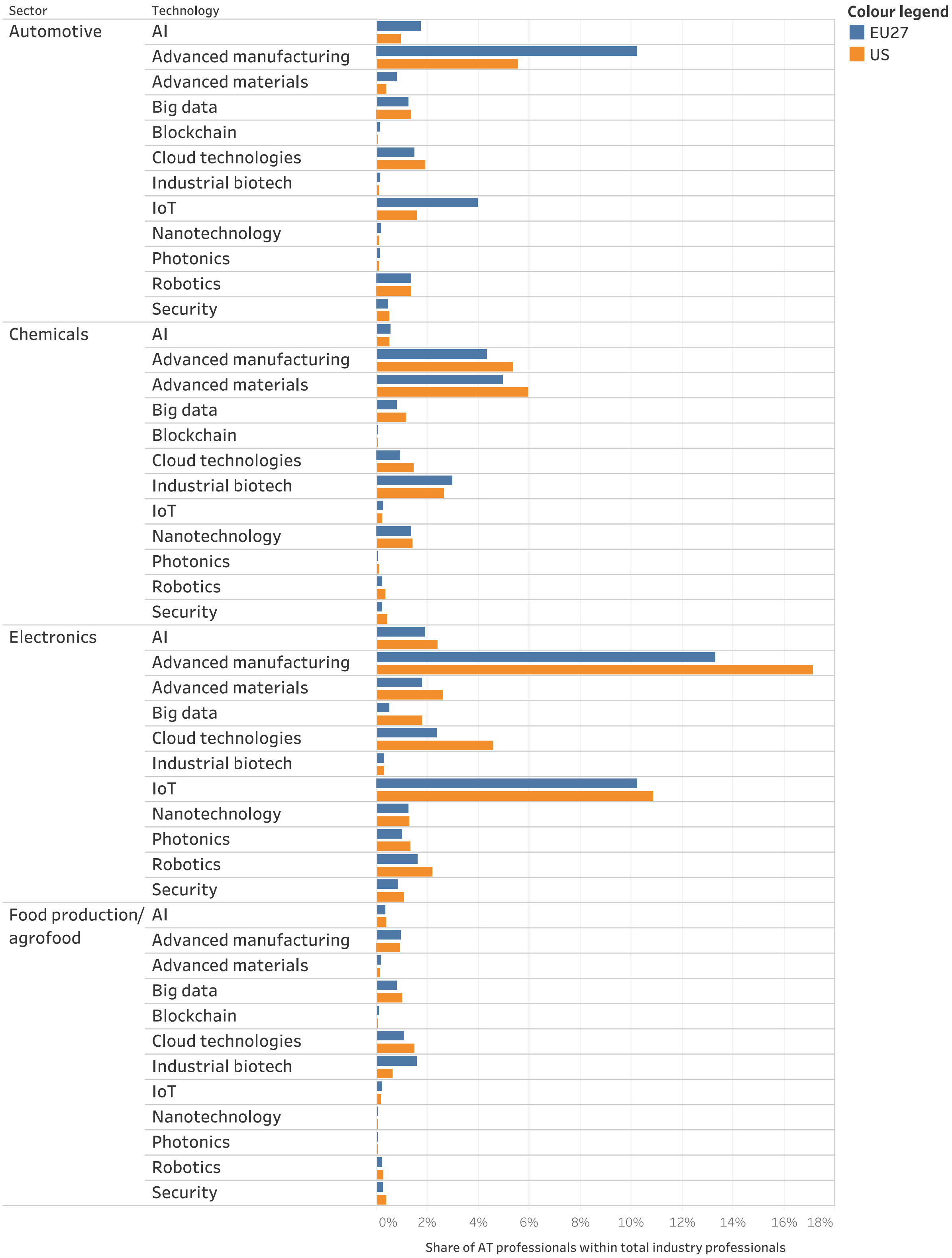
Source: Technopolis Group calculations using LinkedIn, 2019

5.1.3 Sectoral patterns

A further insight that this analysis can provide is the absorption of skilled professionals by economic sectors and industries in the EU27 and the US. Based on the profile of registered users on LinkedIn, the share of advanced technology skilled professionals employed in selected industries has been calculated within the total number of professionals[21] in the respective industry. Since the share of total is taken, the results of the EU27 and US become more easily comparable although these results should be interpreted with caution (see Figure below).

[21] The total number of professionals includes employees in manufacturing, engineering, research and technology, information technology and management related positions, but it does not include professionals in finance, accounting, secretary and administrative jobs within the industry.

Figure 39: Share of advanced technology skilled professionals within total industry professionals, 2020



Source: Technopolis Group calculations using LinkedIn, 2019

The results indicate that the **Automotive sector in Europe is more advanced in terms of employing skilled professionals in advanced technologies than the US**, especially in the fields of Advanced manufacturing and IoT, but also Advanced materials, AI, Nanotechnology, Industrial biotechnology, Photonics and Blockchain. Where the industry employs less professionals than in the US is Big data, Cloud technology and Security.

The situation is not so positive in other industries. In the chemicals industry, the EU27 is ahead in the fields of Industrial biotechnology and Nanotechnology but it is behind in Advanced manufacturing. The electronics industry in the EU27 is also lagging behind the US in most of the technologies.

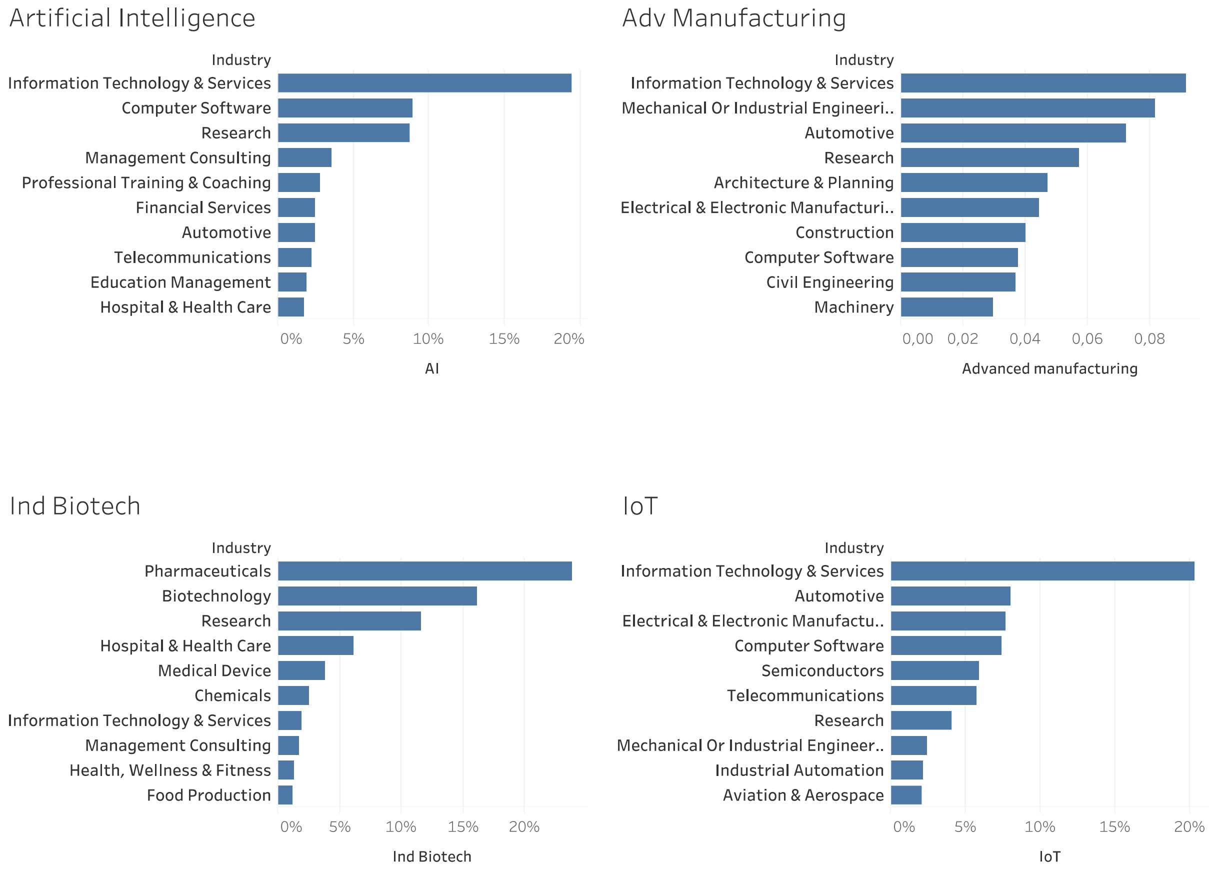
Overall, it can be included that while the EU27 employs more professionals skilled in IoT and Advanced manufacturing across various industries such as automotive, chemicals, food production or medical devices, it has **less industry employees skilled in Big data, Cloud technologies and Security than the US**. Interestingly, AI is a field where the EU27 is close to the US in the share of employed professionals across several industries. In Blockchain the EU27 and US perform close, although the EU27 has a slight advantage.

Besides the analysis per industry, the LinkedIn data allow investigating in which sectors professionals in advanced technologies are employed. Some examples for selected technologies are presented in the Figure 40. An expected finding was the large amount of absorption of professionals by the research and the ICT sector (as captured in LinkedIn's sectoral classification: Information technology & services and Computer services) across all technologies. Other sectors that absorb professionals with a variety of advanced technologies skills are **the Automotive sector, Mechanical or industrial engineering and Electrical and electronic manufacturing.** Other expected results include the absorption of industrial biotechnology skills by the pharma, biotech, hospital and medical devices' sectors or the absorption of Advanced manufacturing skills by the construction, architecture and planning sectors.

While Big Data or Cloud technologies are relevant for a broader range of sectors, Advanced materials, Photonics, Nanotechnology have been absorbed by specific sectors. For example, skills in Advanced Materials have been the most relevant in Chemicals, although grew most in the Automotive and Medical Devices sector. Professionals with Nanotechnology skills are employed most in the Chemicals manufacturing sector, but the growth was the highest in Semiconductors and Electronics.

Figure 40: Top ten sectors for selected advanced technologies

(Measured a share of professionals by sector in total professionals by advanced technology)



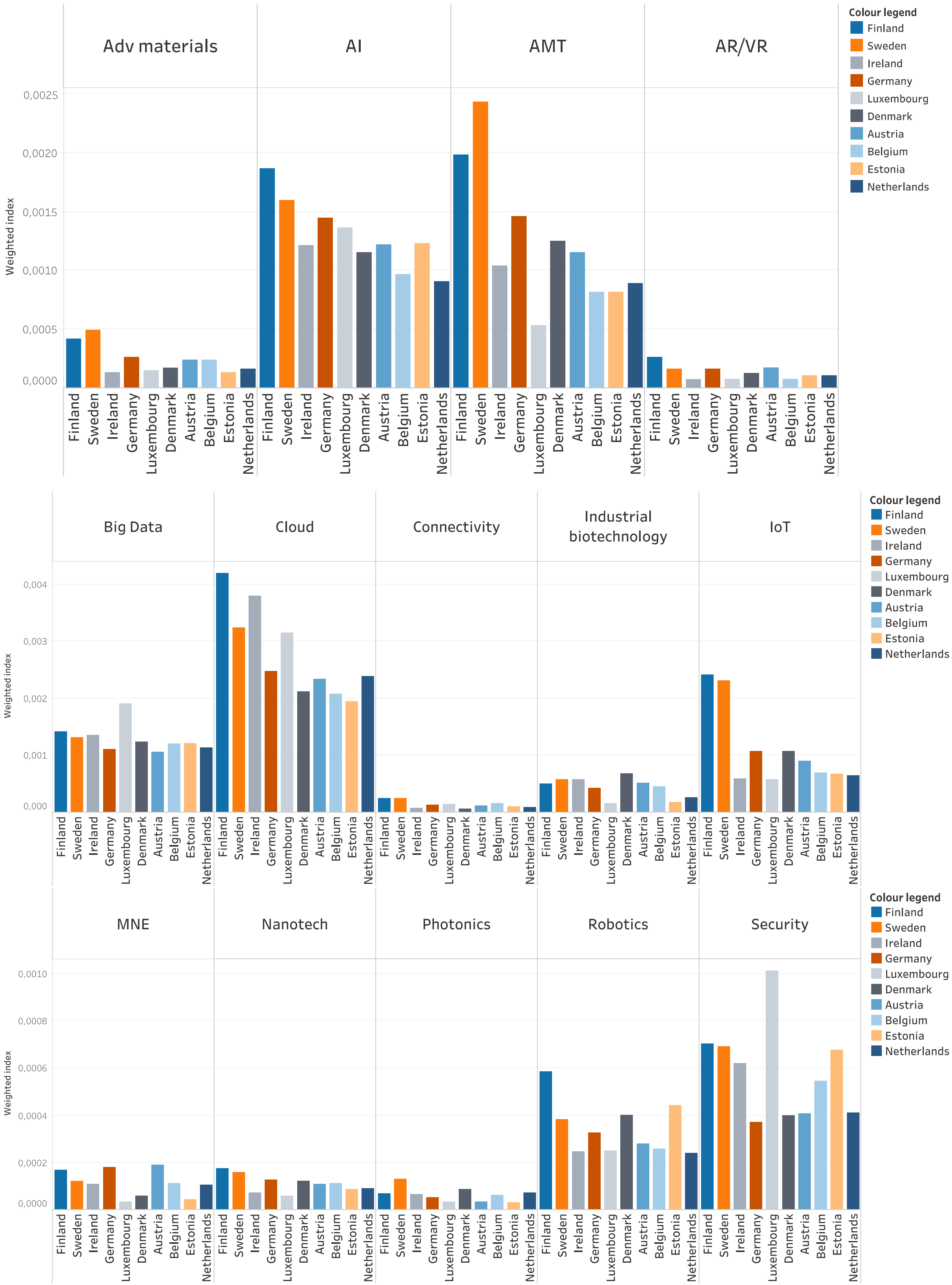
Source: Technopolis Group calculations using LinkedIn, 2019

5.1.4 Country patterns

Within Europe we find professionals in Advanced manufacturing skills concentrated in specific countries. When weighting the absolute numbers of professionals registered on LinkedIn with the degree of representativeness as measured by the share of ICT specialists, respectively human resources in science and engineering, moreover also correcting for the size of the country, the results suggest that Finland, Sweden, Germany, Luxembourg, Ireland, Denmark, the Netherlands, Estonia, Belgium and Austria are among the top ten countries with the highest available advanced technology skills (see Figure 41). To some extent, this finding is also in line with the overall conclusions of the Digital Economy and Society Index[22] that found Finland, Sweden and Luxembourg with the highest scores in the dimension of human capital with a dynamically growing number of ICT specialists.

[22] https://ec.europa.eu/digital-single-market/en/desi

Figure 41:Top ten EU countries in terms of available professionals with advanced technology skills, 2019



Source: Technopolis Group calculations using LinkedIn, 2019

5.1.5 Combination of advanced technology skills

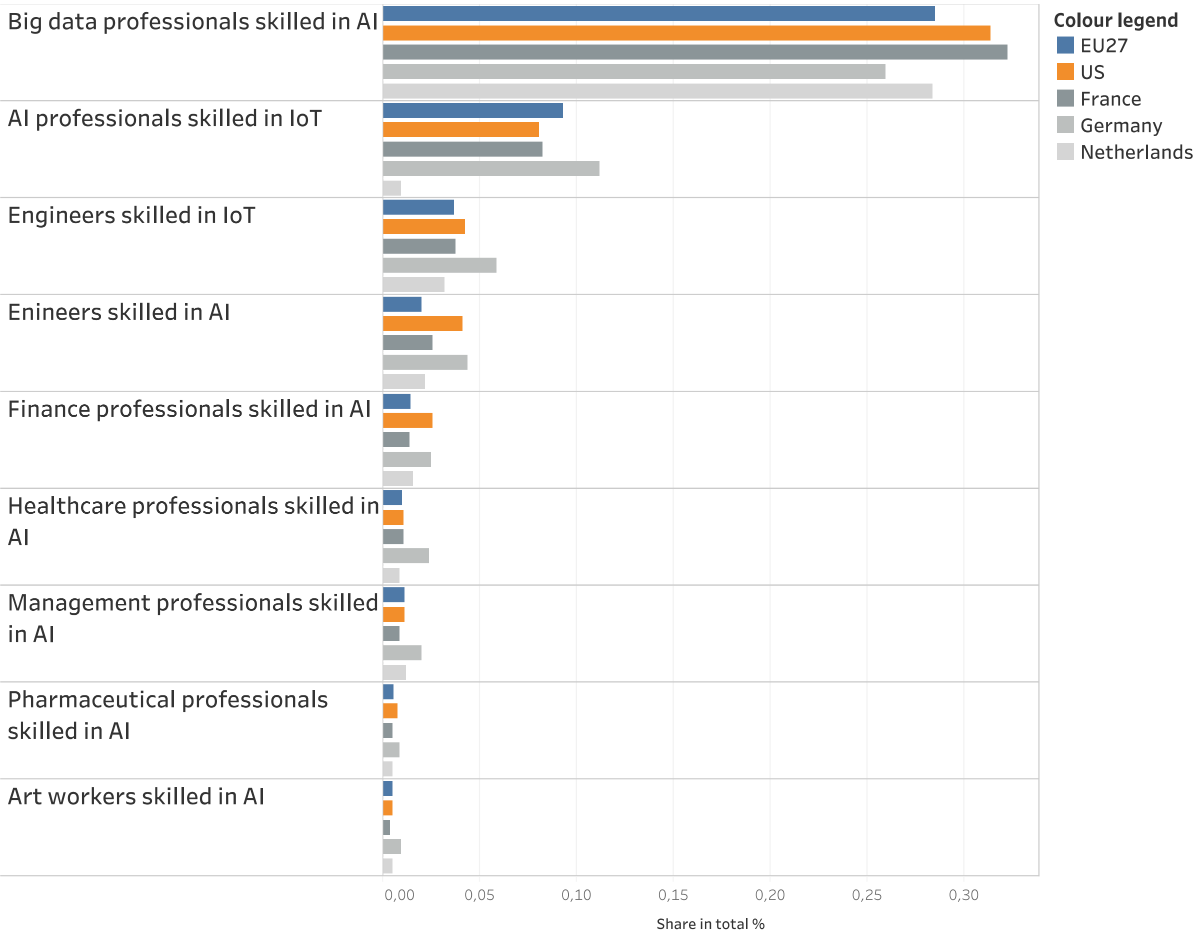
Developing the professionals of the future will require a combination of advanced professional, digital and soft skills. In some positions such as research, finance, marketing, education or healthcare possessing advanced technology skills will help accelerating the deployment of these technologies in a specific sector or industry. For instance, if a person working in finance or accounting gains knowledge in AI, this can be turned into a new opportunity and increase performance instead of fearing for the job being simply replaced. The fusion of different skills won't be only relevant within organisations but also within individuals who will need to equip themselves with a better understanding of emerging technologies in order to face the challenges of the future labour market.

The share of skilled professionals that are both active in a professional field and in an advanced technology is still low both in the EU27 and the US, although the US shows some strengths in several occupations related to finance, management, pharmaceutical and engineering.

There are relatively more professionals knowledgeable both in AI and Big data in the US than in the EU27. The share of engineers who are also skilled in IoT is higher in the US (4% while 3% in the EU27) and also in AI (4% in the US and 2% in the EU27).

It is only 1% of employees in management and healthcare occupations and 0.5% of art workers who are skilled in AI both in the EU27 and US (as registered on LinkedIn). Figure 42 displays the values for the US and EU27 (highlighting country differences with the examples of Germany, France and the Netherlands).

Figure 42: Professionals skilled in AI and related advanced technologies and other skills (examples of combinations)



Source: Technopolis Group calculations using LinkedIn, 2019

5.2 Demand for skills

Producing metrics on the demand for advanced technologies' skills is equally challenging as both the supply of and demand for professionals' secondary data is scarce. Most of the recent initiatives experiment with online job ads using Big Data (see for instance the work of Cedefop entitled ''Skills in online job vacancies'[23] among others). The Cedefop data published does not, however, provide a job ads taxonomy matching the advanced technologies of this project. Therefore, for the analysis of demand, the project has relied on the jobs data from LinkedIn. LinkedIn data is in fact increasingly used by institutions despite its limitations in terms of providing insights on demand for skills (see for instance the publication of the World Economic Forum 'Jobs of Tomorrow' using LinkedIn data to identify rising demand for certain skill sets). LinkedIn's online jobs repository includes both jobs posted directly on LinkedIn via LinkedIn Jobs as well as jobs ingested from over 40,000 sources, including company websites, applicant tracking systems, job boards, aggregators and job feeds. The methodology and limitations in using LinkedIn for the production of indicators about the demand for skills are further explained in the methodological report.

Examples of the data collected in the context of this project includes the hiring demand by sector and by technology (see Figure 43). Hiring demand is estimated by LinkedIn as the average number of Recruiter InMails sent to these professionals over the past 12 months compared to the average number of InMails sent to other professionals in all other talent pools on LinkedIn. In the examples provided below, only those technologies where the industries show a substantial volume of professionals have been included. This has been done by filtering the raw data to include only the top 10 industries in terms of volume of professionals by technology.

Among the examples, the rapid transformation of the automotive sector is clearly reflected in the data by the (very) high demand in digital technologies combined with Advanced Materials and Micro-Nanoelectronics. On the other hand, in machinery and engineering there is a moderate demand for robotics. In the banking sector, a pioneer in the applications of Blockchain technology, the data confirms the current and near future importance of this technology. Data skills (cloud and Big Data) are, as expected, highly demanded by sectors with a wealth of data, such as the banking sector and financial services. In medical devices and pharmaceuticals, the demand is (very) high for Microelectronics and Nanoelectronics, Advanced Materials and Industrial Biotechnology, which represent core technologies in these sectors. The transformation of personalised medicine represented by the demand for Big Data and cloud professionals also shows a high level of demand. This is, however, not included in the table as the two sectors are not among the top 10 sectors attracting professionals skilled in Big Data or Cloud Technologies.

Figure 43: Demand in advanced technologies for selected sectors according to the classification of LinkedIn

Industry	Hiring demand	Technology
Automotive	**High**	Advanced manufacturing
		AI
		Robotics
	Very high	Advanced materials
		Connectivity
		IoT
		Microelectronics nanoelectronics
Banking	**High**	Big data
		Blockchain
	Very high	Cloud
		Cybersecurity
Electrical & Electronic Manufacturing	**High**	Advanced manufacturing
		Advanced materials
		Microelectronics nanoelectronics
		Nanotech
		Photonics
		Robotics

[23] Available at: https://www.cedefop.europa.eu/en/events-and-projects/projects/skills-online-job-vacancies

Industry	Hiring demand	Technology
	Low	IoT
	Moderate	Connectivity
Financial Services	**Very high**	AI
		Big data
		Blockchain
		Cloud
		Cybersecurity
Machinery	**Moderate**	Robotics
Mechanical or Industrial Engineering	**High**	Nanotech
	Low	IoT
	Moderate	Advanced manufacturing
		Advanced materials
		Microelectronics nanoelectronics
		Photonics
		Robotics
Medical Devices	**High**	Microelectronics nanoelectronics
	Very high	Advanced materials
		Industrial biotech
		Nanotech
Pharmaceuticals	**Very high**	Industrial biotech
		Nanotech

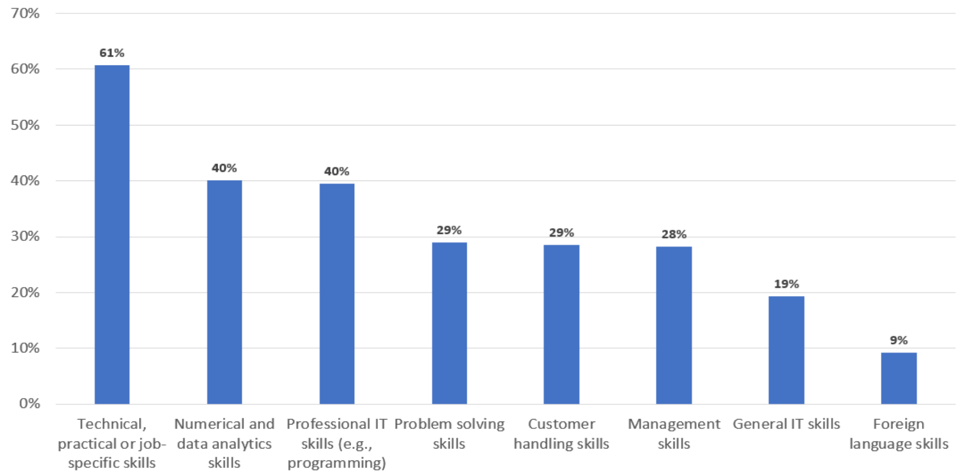
Source: Technopolis Group based on LinkedIn

Note: hiring demand is measured by the LinkedIn tool directly by monitoring the number of online job advertisement requiring the specific skill

An analysis of the online jobs for advanced technologies (measured by advanced technology as a share of total jobs for all advanced technologies) shows that the ‘new gold’, data, is by far the most wanted skill. This is not surprising as big data and the cloud are skills required by every business across all sectors and there are different data jobs and hence people working in teams to extract intelligence from data.

Finally, the Advanced Technologies for Industry (ATI) Survey inquired companies about the skills they need in their organisation and can enable them to develop advanced technology-based products, services and projects. Figure 44 outlines the overall results and a detailed analysis by country, vertical market/industry sector and company-size is present in the accompanying dataset. The top required skills require technical and job-specific skills, data analytics and programming skills. Other relevant skills set include customer handling and management. Foreign languages also reflect the international aspect of going digital.

Figure 44: Which skills are most needed in the organisation to implement advanced technology-based products and projects?



Source: Advanced Technologies for Industry (ATI) Survey, July 2019

Section 6

6. Digital Maturity Index

6.1 Overview

European industries differ in their level of adoption of advanced technologies and their ability to exploit critical innovation enabling factors such as skills, entrepreneurship and research investments. The Industry Digital Maturity Index combines data from the ATI survey (July 2019) with data from Eurostat and other public sources to measure the use of these factors and therefore evaluate the level of digital maturity by industry. By digital maturity we mean the ability of enterprises to fully exploit digital innovation in their business processes through digital transformation and technology adoption. The Index is aligned with the ATI conceptual framework model of technology innovation, particularly concerning the identification of key enabling conditions.

The Index is measured on a scale from 1 to 5, where 1 means very low maturity, 3 medium-high maturity and 5 fully developed maturity. The Index results from the aggregation of 5 sub-indicators (Figure 45), normalised on the same scale, reflecting the mix of factors needed for successful technology innovation. Analysing the level of each of the sub-indicators by industry provides useful insights on the industries' capabilities to achieve digital maturity and their relative strong and weak points[24].

Figure 45: Digital Maturity Index: Main Compontents

Source: IDC – Digital Maturity Index (2020)

More specifically, two of the sub-indicators concern enabling conditions and come from public sources:

- **Skills**: the availability of skills is a critical enabling factor for enterprises to adopt new technologies. In the Index this is measured through data about the supply of skills from higher education (the number of STEM graduates) and training (share of enterprises providing ICT training). The data is sourced from Eurostat.
- **Leadership:** vision and entrepreneurship are necessary for enterprises to become innovators and lead in digital transformation, even though they are difficult to measure. To understand industries capability in this dimension we combine several proxy indicators including the intensity of business R&D investments by sector, start-up birth and death rates and the share of enterprises investing in innovative business models, sourced from Eurostat, the IMF and the World Economic Forum Competitiveness survey.

The other three sub-indicators are sourced from the ATI survey and are the following:

- **Adoption level:** a composite indicator of the level of take-up of digital technologies, providing a good comparative measure of industries' technology innovation capability. The innovation process is boosted by the synergies between technologies, particularly digital technologies, as underlined also in section 3.1 "The status of Advanced technology adoption in Europe" so that a comprehensive measurement of technology adoption is particularly interesting.

[24] This Index is completely different from the DESI "Integration of Digital Technology Index", which is composed of two composite indicators of business take-up of digital technologies, business digitisation and e-commerce, sourced from Eurostat ICT survey. This Index is not calculated by country but by industry and includes a more articulated range of sub-indicators from various sources purely at business level.

- **Use case rates:** this composite indicator measures the level of adoption of innovative use cases of digital technologies investigated in the survey, with higher ratings for the use cases focused on improving the customer experience or creating new products and services (rather than those focused on costs savings and process efficiency). This provides an additional measure of innovation capability by industry.
- **Business Impacts**: this composite indicator measures the share of enterprises who achieved relevant business benefits (over 10% improvement) thanks to the adoption of digital technologies. This was measured in the survey for 7 business KPIs of high industrial relevance, including: revenues/profit increase, cost reduction, time efficiency, product/service quality improvement, number of new products or services launched, customer satisfaction and business model innovation. By combining the answers for all business impacts we enhance the reliability of the overall indicator. Even though the assessment of the business impacts is self-declared and not based on objective evidence, it reflects the enterprises' awareness of the relative success of their technology investments for their business. This provides the basis for a valuable comparative assessment of business impact by industry.

The robustness of the Index is enhanced by the combination of public statistical sources such as Eurostat with survey data. The indicators sourced from the ATI survey are calculated by industry for the total EU, without breaking down the sample in sub-categories. This corresponds to high reliability and confidence levels[25].

Figure 46: Digital Maturity Index: sub-indicators and data sources

Index Component	Weight	Measure	Data Source
Skills	50%	Share of Stem Graduates	Average EU28/ Eurostat
	50%	Enterprises providing ICT Training	Eurostat
Leadership	14%	Enterprises providing ICT Training	Eurostat
	14%	Enterprises innovating products and services	Eurostat
	14%	Business expenditure in R&D (BERD)	Eurostat
	14%	Direct Investment	Average EU28/ IMF
	14%	Startups Birth Rate	Eurostat
	14%	Startups Death Rate	Eurostat
	14%	Local Equity Finance Availability	Average EU28-WE Forum - Global competitiveness Index Annual data, % of GDP
Adoption level	100%	Adoption rates of advanced digital technologies	Composite from ATI survey
Use Cases	100%	Adoption rates of Use Cases	Composite from ATI survey (only digital technologies)
Business Impacts	14%	Business model innovation	Composite from survey (only digital technologies)
	14%	Cost reduction	
	14%	Customer satisfaction	
	14%	Number of new products or services launched	

[25] The ATI Methodological Report provides more details about the Index calculation method.

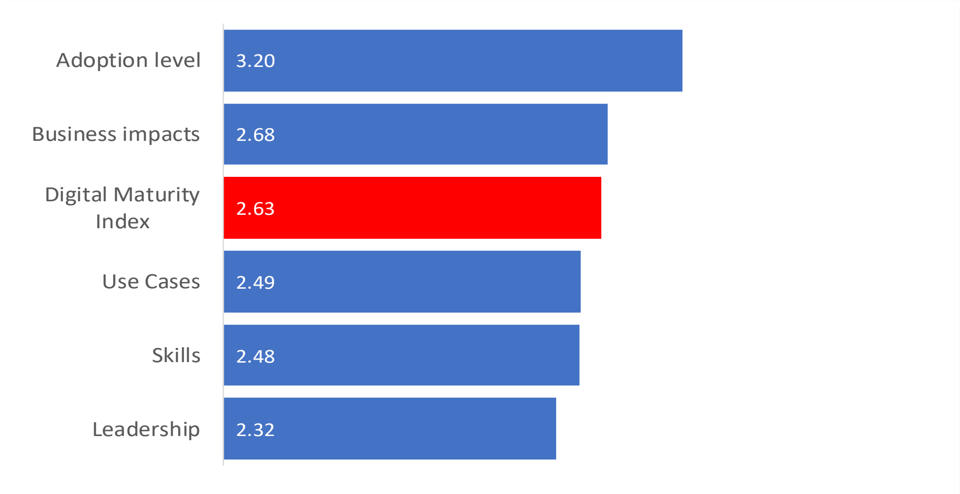
Index Component	Weight	Measure	Data Source
	14%	Product/service quality	
	14%	Revenue and/or profit growth	
	14%	Time efficiency	

Source: IDC

6.2 Main results

Based on the Industry Digital Maturity Index, the European industry in 2019 was positioned at an intermediate level in the path towards full exploitation of advanced digital technologies (overall score 2.63, Figure 47). The progress in digital maturity is driven particularly by a high level of adoption of the multiple technologies included in the ATI portfolio (the first sub-indicator in the Figure below, with a 3.2 score). However, the business impacts resulting from these technologies appear to be lagging slightly behind adoption (with a 2.68 score), perhaps because of an insufficient implementation of innovative use cases (measured by the third sub-indicator, with a 2.49 score). In other words, on average enterprises are adopting technologies but are still learning how best to integrate and apply them to business processes and the launch of new services and products.

Figure 47: Industry Digital Maturity Index – total EU28[26]



Source: IDC calculation – Digital maturity Index (2020)

The sub-indicators on use cases, skills and leadership, however, are less advanced than the previous ones (with a score of 2.49, 2.48 and 2.32, respectively), showing a medium-low level of maturity. The insufficient availability of advanced technology skills is a known liability for the European technology environment, particularly for emerging digital technologies such as Big Data, Artificial Intelligence, Cloud Computing and Security as highlighted by the ATI project Linkedin analysis (see section 5.1 "Skills Supply". This confirms the usefulness of proactive policies building advanced digital skills supply in Europe, which is one of the strategic objectives of the forthcoming Digital Europe[27] programme 2021-2027.

[26] Please note this section presents data and analysis at the level of EU28 and not EU27. As indicated in the methodological report available on the ATI website (https://ati.ec.europa.eu), the Digital Opportunity Index and its underlined model are based on a variety of sources, among which: the Advanced Technology for Industry Survey (July 2019), IDC's annual survey on vertical markets and industries, the World Economic forum Global Competitiveness index (http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf), as well as the European Data Market (European Data Market Study update – SMART2016/0063) indicators for the Data Market and for the Data Economy. In most cases, the data at industry level in these sources are available for the EU28 only, hence the model underpinning this Digital Opportunity indicator has been developed at the level of EU28.
[27] https://ec.europa.eu/digital-single-market/en/europe-investing-digital-digital-europe-programme

More worrying is the low level of the Leadership sub-indicator, which assembles data on several enabling conditions of digital maturity. The good news is that the entrepreneurship component of this indicator (share of enterprises innovating business models) reflects a positive business dynamism (with a 3 score). On the other hand, the birth and death rates of startups are not where Europe would like them to be and they influence the low level of this sub-indicator.

But the real weak point is represented by the scarce availability of funding and low private R&D investments (BERD). In fact, according to the OECD, business enterprise expenditure on R&D (BERD) was 1.35% of GDP in 2018 in the EU28, against 1.7% for the OECD average, 2.05% for the US and a peak of 3.64% in South Korea[28]. Digital maturity represents the ability to apply technologies, but given the speed of evolution of technology trends, enterprises need to invest in R&D to be ready to solve technology challenges and anticipate market trends, as well as develop advanced skills. Therefore, this weakness can hinder European industries performance in exploiting digital technologies. As will be discussed below, this is also one of the factors with the greatest differentiation by industry. Traditional industries (such as retail) did not use to require high R&D investments like high-tech sectors, but the world has changed with the emergence of technologies with widespread disruptive potential such as artificial intelligence. No industry today can afford to ignore research and innovation investments and their impact on their value chains.

6.3 Digital Maturity Index by Industry

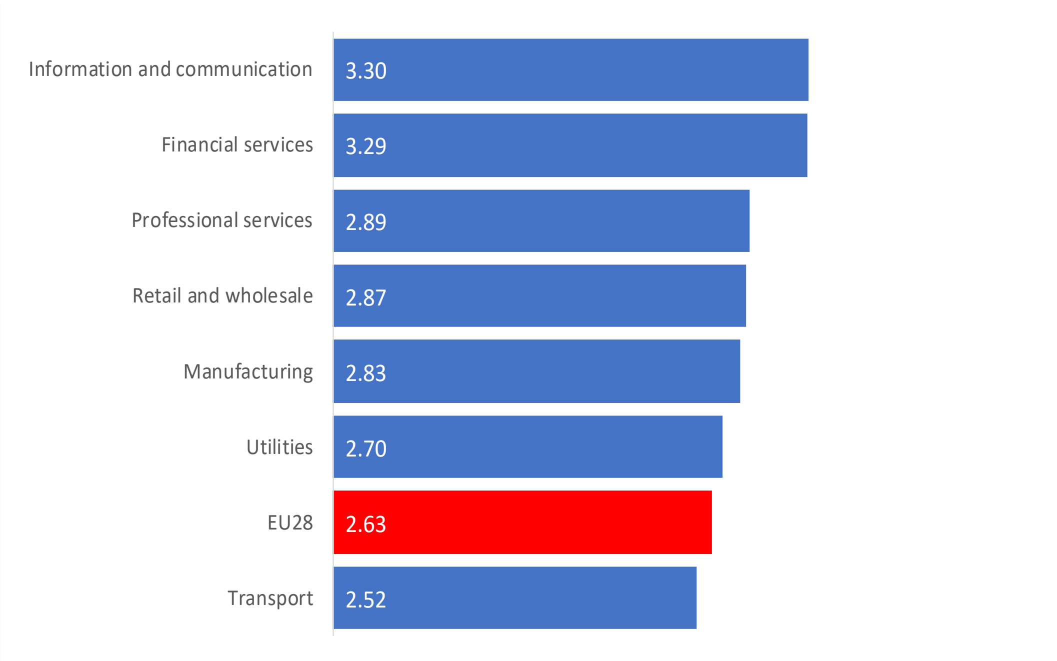
The Industry Digital Maturity Index highlights a wide variation of performance by sector in Europe, driven by different competitive positioning and strong/weak points balance. As shown in the Figure 48 below, the Index confirms the leading position of the information and communication sector as well as finance (the opposite would be surprising). These industries are close to high digital maturity and include a high number of innovative enterprises, as confirmed by the cluster analysis insection 3.1 "The status of Advanced technology adoption in Europe". These industries have high scores in all the components of the Index, including leadership, thanks to a high number of innovative start-ups and the competitive pressure driving them to innovation investments.

Professional services is the third runner-up with an Index score of 2.89 close to medium-high digital maturity. This industry shows a high level of adoption of technologies, with a good level of business impacts (score 3), and a higher than EU average score for the Leadership sub-indicator (2.9) thanks to good entrepreneurship and availability of funding levels. The skills availability indicator is also higher than the EU average, while the Use cases indicator is aligned with the EU average, hinting at a lower focus on disruptive innovation application. In fact, the cluster analysis of section 3.1 shows a relatively low share of pioneer innovative enterprises in this industry, but a solid majority of "experimenters".

The retail and wholesale industry is experiencing massive competitive pressure to adopt technical innovation because of the emergence of e-commerce: on the other hand this is one of the largest and most fragmented industries in Europe, with a high number of traditional micro-enterprises with few resources to invest. Nevertheless, the Index positions Retail at a 2.87 score, similarly to professional services. The main weak point is the insufficient availability of skills (score 2.3 lower than the EU28 average). This industry's Use case sub-indicator (2.45) is also slightly lower than the EU28 average, reflecting a lower propensity to highly innovative use cases.

[28] OECD Main Science and technology indicators database, https://read.oecd-ilibrary.org/science-and-technology/business-enterprise-expenditure-on-r-d-berd-as-a-percentage-of-gdp_83b74c19-en#page1

Figure 48: Industry Digital Maturity Index – selected industries



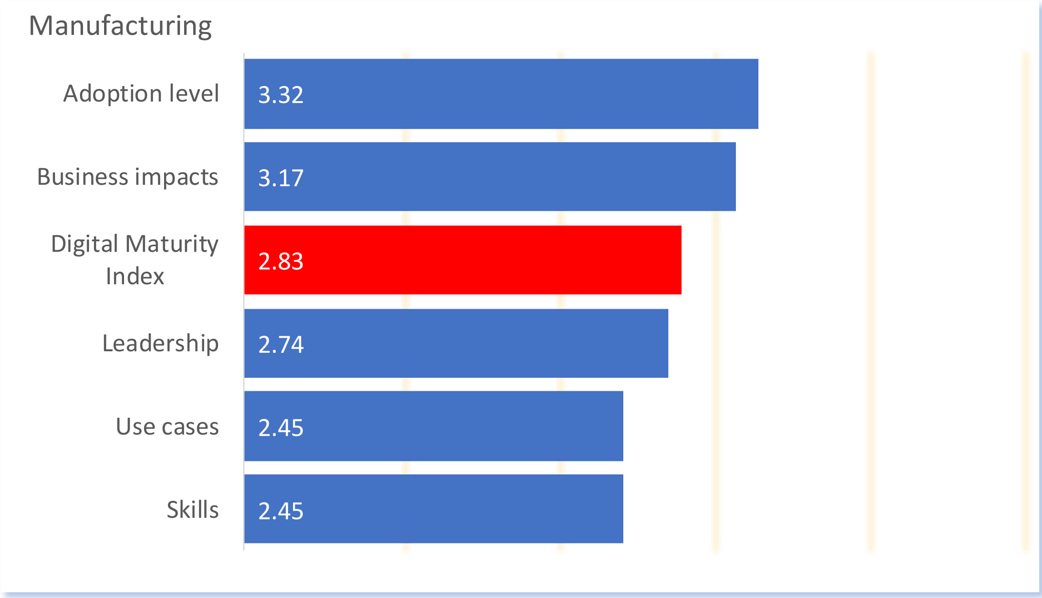
Source: IDC calculation – Digital maturity Index (2020)

The Digital Maturity Index of the Manufacturing industry (see Figure 49 on the next page) is 2.83, better than the EU28 average and very close to the Professional services and Retail industries scores. This is one of the largest European sectors in terms of employment, whose value added represented 15% of EU GDP in 2018[29], with a high share of innovative enterprises (as shown by the cluster analysis in section 3.1) but also traditional enterprises, slowly evolving towards digital maturity. The Index reflects the complexity and size of the sector. Discrete manufacturing shows higher levels of digital innovation than process manufacturing, including sectors such as automotive highly oriented to robotics and advanced technologies.

Looking at the main Index components, manufacturing shows a high level of adoption of technologies and the corresponding business impacts. The Leadership sub-indicator is higher than the EU28 average score, driven by better availability of funding and intensity of innovation adoption, while the intensity of start-ups is lower than in other industries. The availability of skills is slightly lower than the EU average score. Manufacturing is focused on operational technology skills related with their core business processes, more so than on advanced digital skills. While the supply of advanced manufacturing skills appears to be competitive in the EU with the other world regions (see Section 5.1 above), the supply of advanced digital skills cannot keep up with demand. Manufacturing enterprises probably have difficulty to compete with industries such as ICT or finance for digital talent, due to lower salaries and less attractive digital career opportunities. The use case indicator is also lower than the EU average score, but this reflects a strong focus of the industry on cost reduction and improving process efficiency use cases (which this sub-indicator considers less relevant).

[29] https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=EU

Figure 49: Manufacturing Industry Digital Maturity Index



Source: IDC calculation – Digital maturity Index (2020)

Finally, there is a group of industries with Digital Maturity scores close to or lower than the EU28 average, including utilities and transport.

Utilities are a small industry, which has been investing in digital technologies because of the need to implement smartgrids and deal with the emergence of renewable energy sources, disrupting their operational processes. This industry shows a high level of adoption of technologies and higher than average availability of skills. Their business impacts score is lower than for other industries, perhaps due to the still ongoing radical transformation of processes, which does not yeld relevant business benefits - yet. The Leadership sub-indicator is also low in all its components.

Transport services also shows a high level of adoption of technologies, but lower scores for business impacs and use cases. The Leadership and skills indicators are both lower than EU28 average.

The Construction and Agriculture industries are not shown because of the lack of some key input data which impedes a comparative analysis with other industries.

Section 7

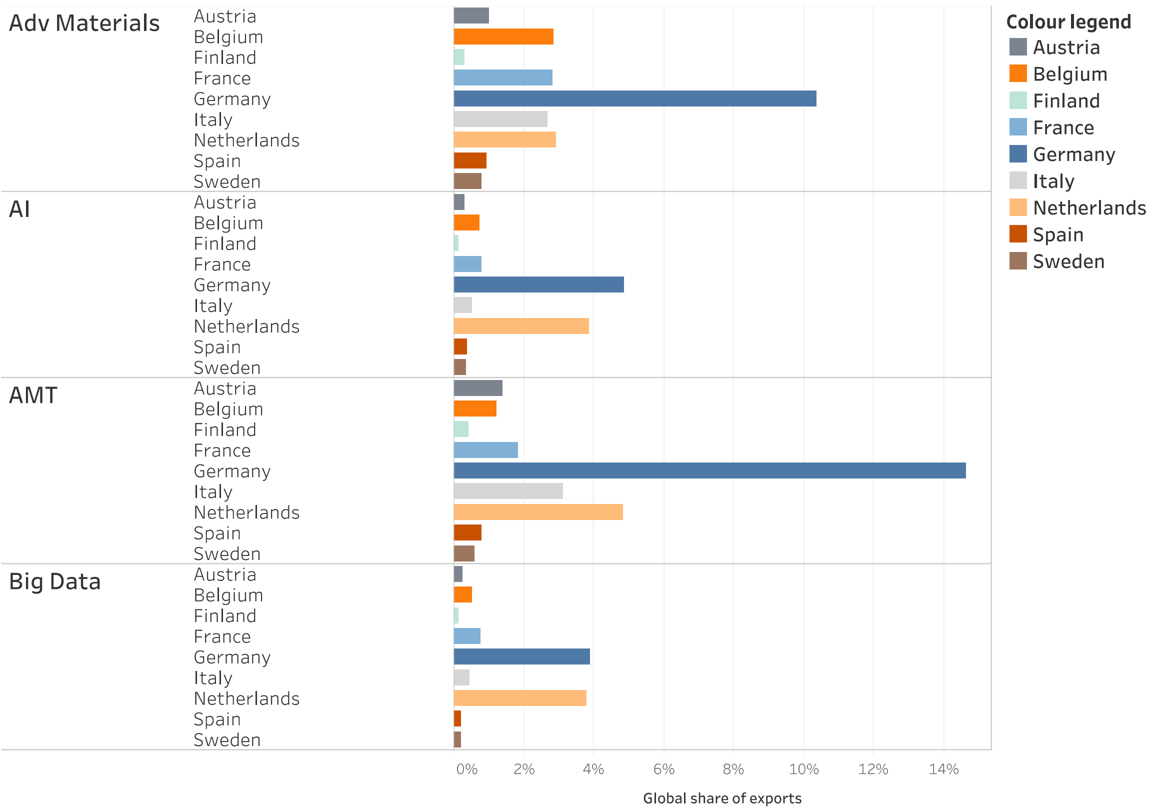
7. Trade in advanced technologies

7.1 Country overview

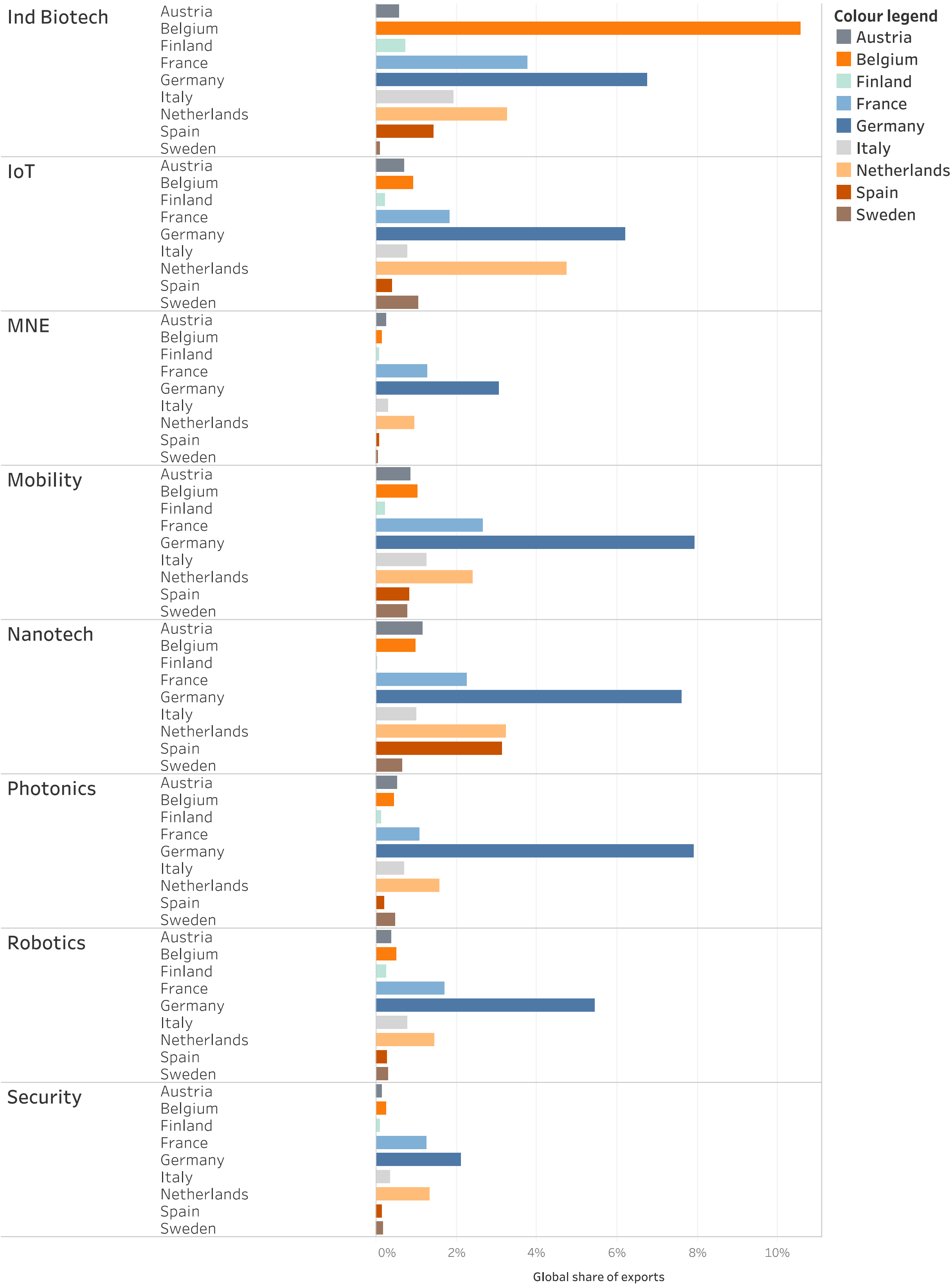
Technology exploitation has been also captured through trade of technology-based components in this study. The analysis of trade data found that EU27 Member States typically accounted for between 15% and 30% of world trade in advanced technologies as illustrated in Figure 50 below. This figure is the highest in the fields of Industrial biotechnology, Advanced materials, and Advanced manufacturing technologies, where it slightly exceeded about 30% share in all global exports. In goods incorporating Nanotechnology, IT for Mobility, Internet of Things and Artificial Intelligence the EU27 reached about 20% global export share. With regard to Photonics this value was 15%, in Security and Micro- and nanoelectronics the EU27 value was below 10% and ranged below average.

The strongest EU player is Germany, with the exception of Industrial biotechnology, where most exports originated from Belgium. Typically, the Netherlands occupied a second rank followed by France, Belgium and Italy. Austria, Sweden, Spain and Finland played relevant but smaller roles. Contributions of other EU Member States were largest in the fields of export goods relevant for Big data and Artificial Intelligence applications.

Figure 50: Global export shares of top EU countries, 2016



Source: Fraunhofer ISI, analysis based on UN COMTRADE, latest available year is 2016



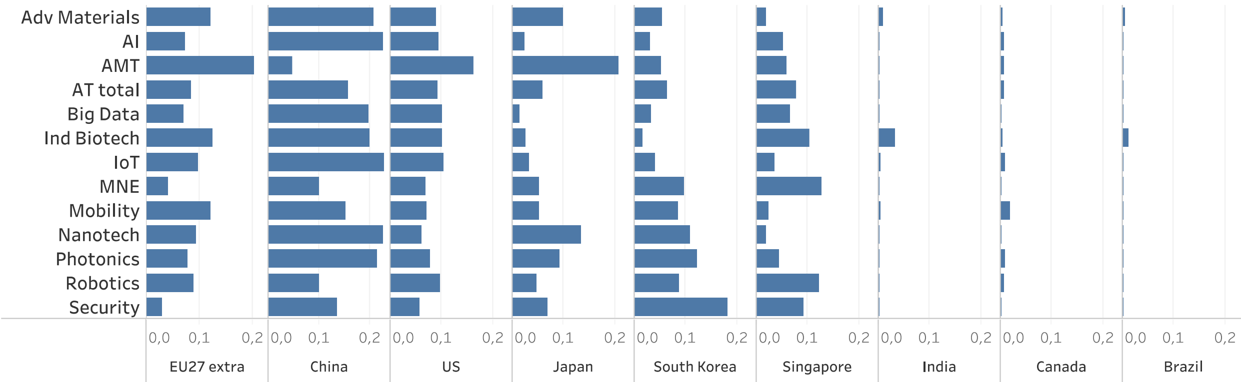
Source: Fraunhofer ISI, analysis based on UN COMTRADE

7.2 International comparison

Among the EU's international competitors, China is the most prominent producer of products incorporating advanced technologies for manufacturing. The only areas where its export volume has not (yet) surpassed that of the European Union are Advanced manufacturing, Robotics as well as components for Micro- and nanoelectronics (which China still often imports to integrate them into diverse final products, including those classified under non-Microelectronics headings). With somewhat clearer profiles, Japan exports a large share of all goods relevant for Advanced manufacturing, Nanotechnology and Advanced materials, while South Korea contributes strongly to exports of goods relevant for Cybersecurity, Photonics, Micro- and nanoelectronics and Nanotechnology. The US contributes, however, an even smaller share to world exports than the EU27 in most advanced technology fields, among which their contribution to Advanced manufacturing exports remains the strongest. Singapore, like Hong Kong, plays a particular role as a regional hub through which various Asian countries' exported products are channelled. Accordingly, Singaporean exports rank high in the areas of Micro- and nanoelectronics, Robotics and Industrial biotechnology. Other countries' contribution remains negligible with particular national contributions in specific fields (e.g. Taiwan/Chinese Taipei - listed as 'other Asia', Malaysia and the Philippines on electronic circuits). Figure 51 illustrates the global export shares of the EU27 compared to its main competitors.

When considering extra-EU exports as a point of international reference, the picture becomes even clearer: Advanced manufacturing technologies is the only field in which the EU27 remains the most important exporter, in Robotics and IT for Mobility it stays close to the leading players. In most other areas, China leads by factor two or more.

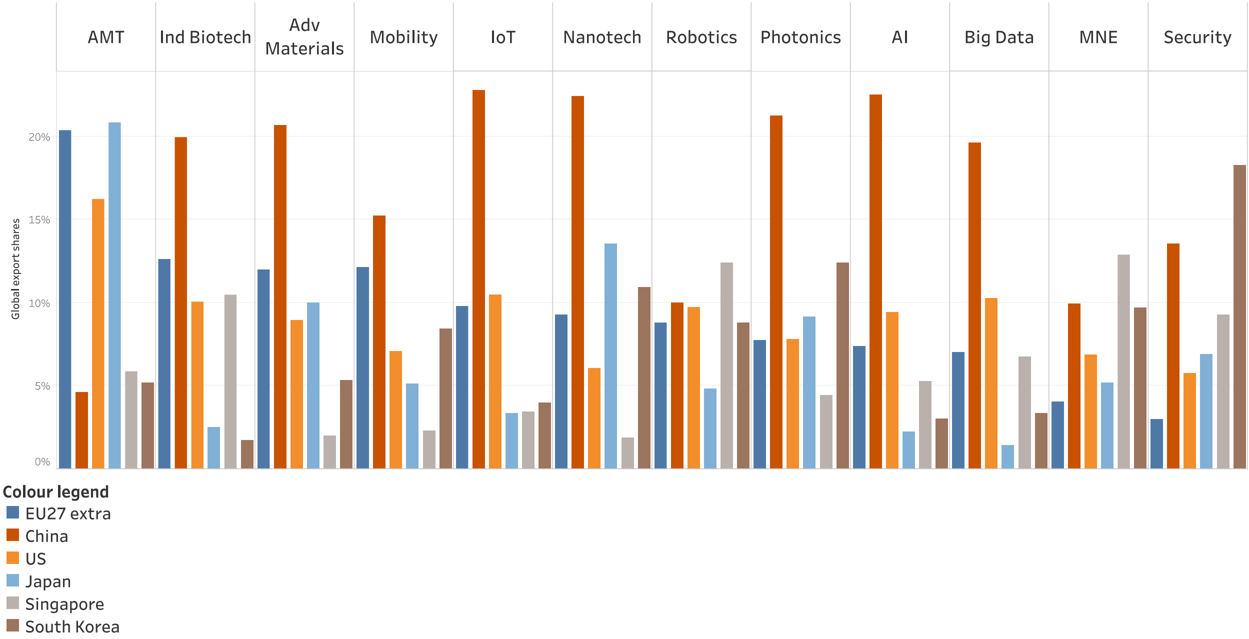
Figure 51: Global export shares of EU27 and competitors, 2016



Source: Fraunhofer ISI, analysis based on UN COMTRADE

Note: latest available year of data is 2016

Figure 52: Global export shares of EU27 and selected main competitors, 2016

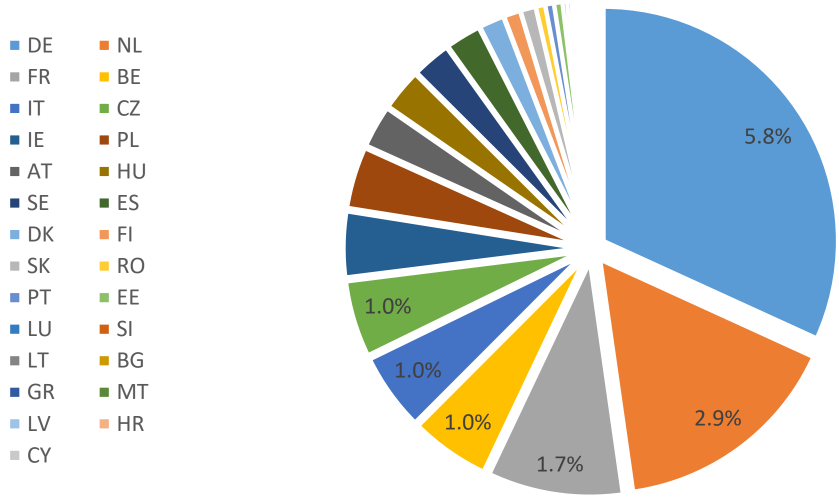


Source: Fraunhofer ISI, analysis based on UN COMTRADE

Note: latest available year of data is 2016

Regarding the national distribution of the EU's exports of goods incorporating advanced technologies, Germany leads with a contribution of 5.8% to all global exports, the Netherlands follow with 2.9%, France with 1.7%, ahead of Belgium, Italy and the Czech Republic with 1.0%.

Figure 53: Global export share of EU MS, ATI total, 2016



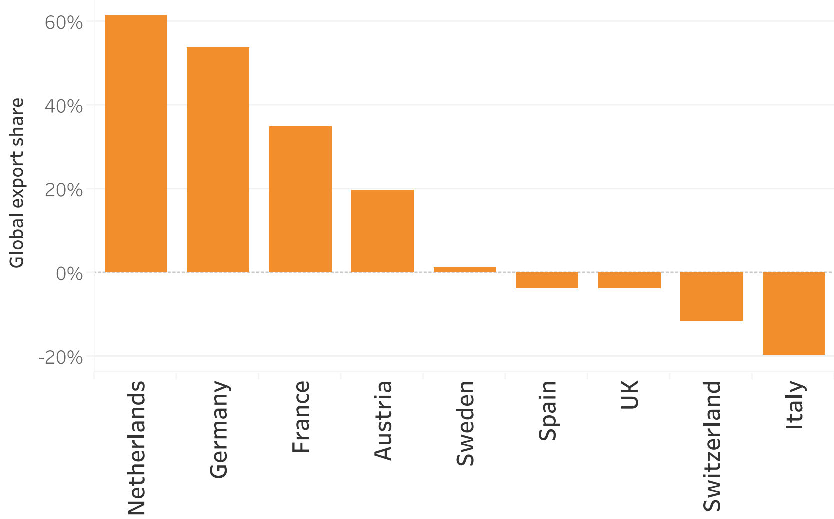
Source: Fraunhofer ISI, analysis based on UN COMTRADE

Among those, the Netherlands, Germany, France and Austria hold higher global shares in all extra-EU exports than they hold in total export volume (see Figure 54). This is relevant as total export includes large volumes of trade resulting from the widespread division of tasks within the EU's single market, rather than international competitiveness. Thus, this indicator provides a more robust indication of the above average global attractiveness of Dutch, German, French and Austrian products. On the contrary, Sweden's respective shares are about equal. In Spain and the UK[30] and - most prominently - Switzerland

[30] this is relevant also for EFTA countries that are not de jure part of the European Union

and Italy, the national share in global exports exceeds that in extra-EU exports - indicating that their trade in goods incorporating advanced technologies has a more intra-European focus.

Figure 54: Global export shares of EU Member States, the UK and Switzerland - extra-EU

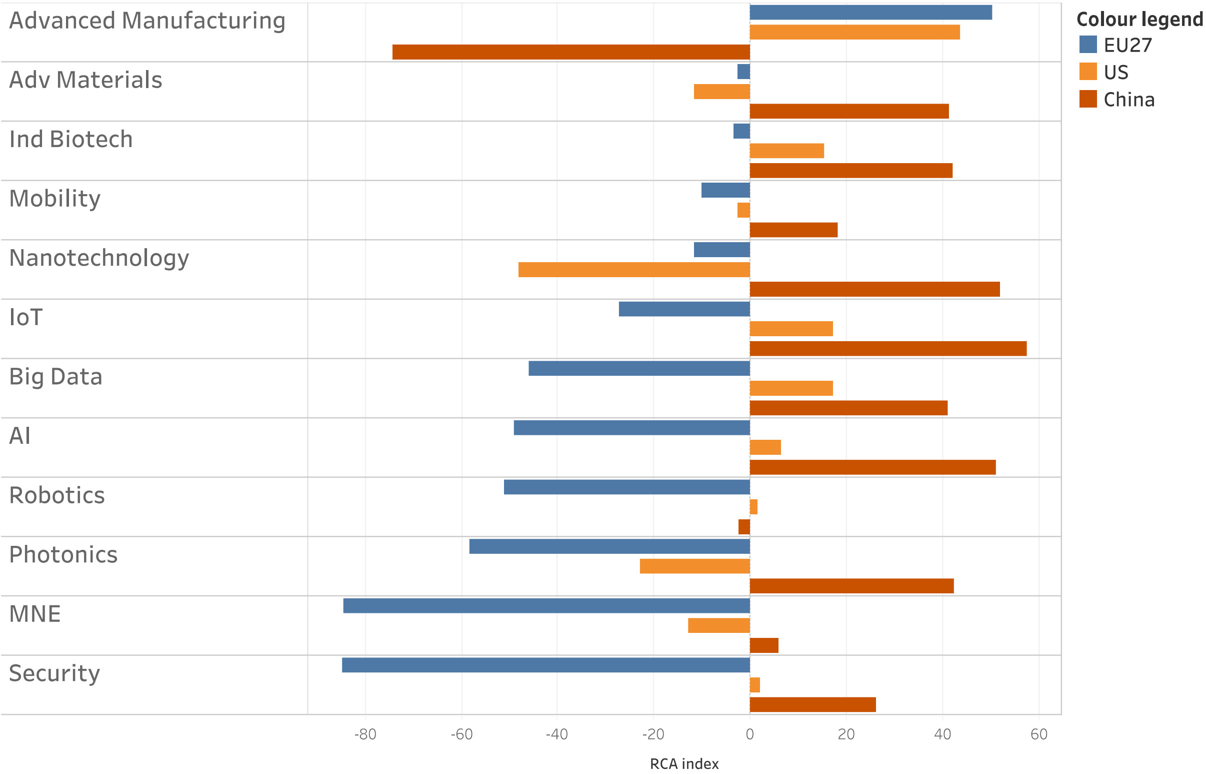


Source: Fraunhofer ISI, analysis based on UN COMTRADE

7.3 Trade specialisation

Regarding trade specialisation, Figure 55 illustrates that the share of goods incorporating advanced technologies in the European Union's exports is below global average for various subgroups. The United States' and, in particular, China's export profiles are much more focused on goods incorporating advanced technologies, most prominently IT related goods. The EU27 contributes an above average share to world exports in advanced technology related goods and it plays the role of a system integrator of technological components which are incorporated into final products in Europe and then are partly re-exported. Among the EU Member States the Netherlands is the only country with significant specialisation in the field of goods incorporating digital technologies, more precisely goods relevant for the Internet of Things, Artificial Intelligence and Big data. Beyond the digital domain, however, some EU Member States display further relevant trade specialisation in goods related to advanced technologies for example France in Industrial biotechnology, Austria in Nanotechnology, and Germany in Advanced materials.

Figure 55: Trade Specialisation (RCA31), EU27 vs. US and China, by AT



Source: Fraunhofer ISI, analysis based on UN COMTRADE

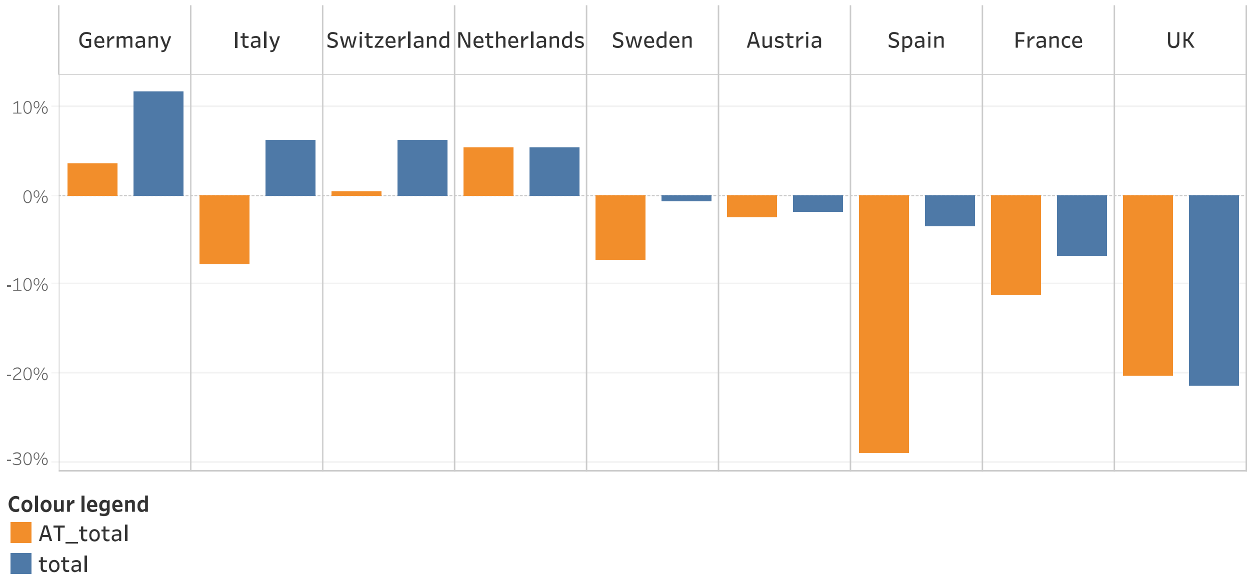
Trade Balance

Figure 56 illustrates that, with the exception of the Netherlands, many EU Member States' trade balance is less favourable with respect to goods incorporating advanced technologies than their trade balance in all goods. This is also the case of Switzerland and of the UK. In some countries such as Italy an overall trade surplus or a nearly balanced situation (such as in Sweden) stand beside a notable trade deficit in goods incorporating advanced technologies. In Spain, a small overall trade deficit is accompanied by a substantial advanced technology goods deficit. However, some smaller EU Member States show a trade surplus in goods incorporating advanced technologies including Ireland, Malta, Estonia, Denmark and the Czech Republic. On the other hand, Belgium, Italy, Hungary, Slovenia, Poland and Slovakia display an overall trade surplus yet a trade deficit in goods incorporating advanced technologies.

In global comparison, the EU27 remains in a relatively balanced position between key exporters of goods incorporating advanced technologies such as Japan, South Korea and Singapore (as hub) on the one hand, and net importers of such goods like the US and China. In any case, the EU27 is currently far from being that dependent on the import of goods incorporating advanced technologies as Canada, India or Brazil.

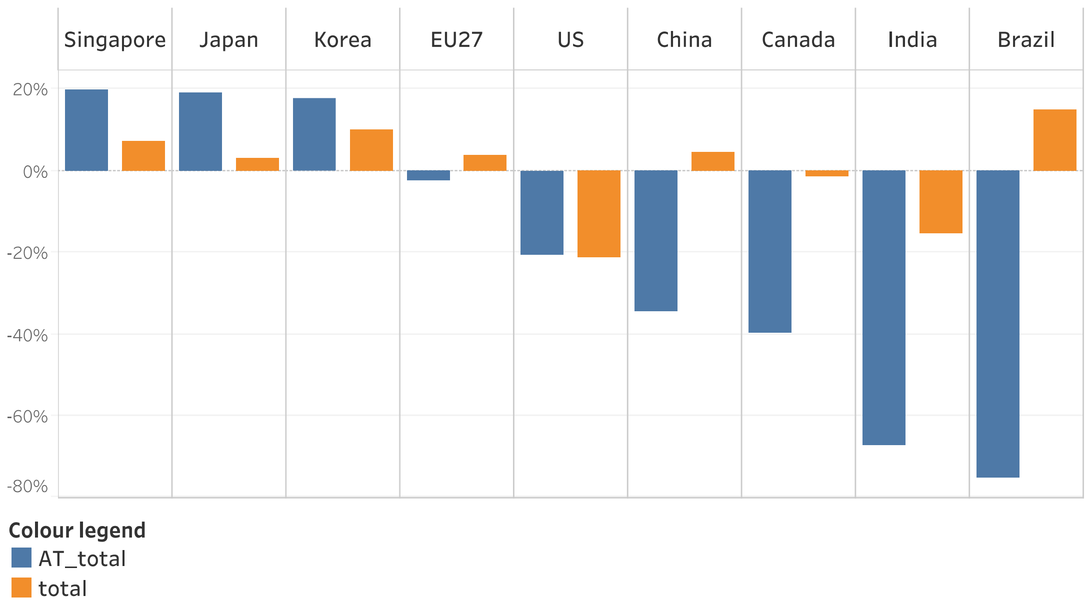
[31] The RCA-Index illustrates relative specialisation on a scale from -100 to +100, putting the share of a specific field in national applications in relation to the global average share; according to the formula: RPAkj = 100 * tanh ln [(Pkj/Σj Pkj)/(Σk Pkj/Σkj Pkj)], with P = no. patent applications, k = country index, j = field index

Figure 56: Relative Trade Balance[32] of main EU Member States, UK and Switzerland total vs. advanced technologies



Source: Fraunhofer ISI, analysis based on UN COMTRADE

Figure 57: Relative Trade Balance[3] EU vs. main competitors, total vs. advanced technologies



Source: Fraunhofer ISI, analysis based on UN COMTRADE

32 Relative Trade Balance/Trade Balance per Trade Volume: Trade Balance/(Exports-Imports)

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Appendix B: Technology definitions

The advanced technologies covered in the 'Advanced Technologies for Industry' project include the following:

Advanced manufacturing technology

Advanced manufacturing technology encompasses the use of innovative technology to improve products or processes that drive innovation in manufacturing. It covers two types of technologies: process technology that is used to produce any of other advanced technologies, and process technology that is based on robotics, automation technology or computer-integrated manufacturing. For the former, such process technology typically relates to production apparatus, equipment and procedures for the manufacture of specific materials and components. For the latter, process technology includes measuring, control and testing devices for machines, machine tools and various areas of automated or IT-based manufacturing technology.

Advanced materials

Advanced materials lead both to new reduced cost substitutes to existing materials and to new higher added-value products and services. Advanced materials offer major improvements in a wide variety of different fields, e.g. in aerospace, transport, building and health care. They facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials that are scarce in Europe.

Artificial Intelligence

Artificial Intelligence is a term used to describe machines performing human-like cognitive functions (e.g. learning, understanding, reasoning or interacting). It comprises different forms of cognition and meaning understanding (e.g. speech recognition, natural language processing) and human interaction (e.g. signal sensing, smart control, simulators). Artificial Intelligence is a heterogenous field in terms of its technology base. While some aspects like sensors, chips, robots as well as certain applications like autonomous driving, logistics or medical instruments refer to hardware components, a relevant part of AI is rooted in algorithms and software.

Augmented/Virtual Reality

Augmented reality devices look to overlay digital information or objects with a person's current view of reality. As such, the user is able to see his/her surroundings while also seeing the AR content - Virtual reality devices place end users into a completely new reality, obscuring the view of their existing reality.

Big data

Big Data is a term describing the continuous increase in data, and the technologies needed to collect, store, manage, and analyse them. It is a complex and multidimensional phenomenon, impacting people, processes and technology. From a technology point of view, Big Data encompasses hardware and software that integrate, organise, manage, analyse, and present data. It is characterised by "four Vs": volume, velocity, variety and value. Big Data technologies are new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high-velocity capture, discovery, and/or analysis.

Blockchain

Blockchain is a digital, distributed ledger of transactions or records, in which the ledger stores the information or data and exists across multiple participants in a peer-to-peer network. Distributed ledgers technology allows new transactions to be added to an existing chain of transactions using a secure, digital or cryptographic signature. Blockchain protocols aggregate, validate, and relay transactions within the blockchain network. Blockchain technology allows the data to exist on a network of instances or "nodes," allowing for copies of the ledger to exist rather than being managed in one centralised instance.

Connectivity

Connectivity refers to all those technologies and services that allow end-users to connect to a communication network. It encompasses an increasing volume of data, wireless and wired protocols and standards, and combinations within a single use case or location.

Standard connectivity includes Fixed Voice and Mobile Voice telecom services to allow fixed or mobile voice communications, but also Fixed Data and Mobile Data services to have access and transfer data via a network.

Advanced connectivity that is in the focus of the ATI project refers to the rise of Internet of Things scenarios, where connectivity technology boundaries expand beyond wired and cellular (e.g. 4G, 5G,…) services to Low Power Wide Area Network (LPWAN), Satellite, and Short Range Wireless technologies.

The survey analysis encompasses all these three elements of the Connectivity definition mentioned above.

Cloud computing

Cloud computing includes the delivery of tools and applications like data storage, servers, databases and software based on a network of remote servers through the Internet. Cloud computing services enable users to store files and applications in a virtual place or the cloud and access all the data via the Internet.

Public Cloud services that have been explored specifically by the ATI survey are available on public networks and open to a largely unrestricted universe of potential users. Public clouds are designed for a market, not a single enterprise.

Industrial biotechnology

Industrial biotechnology is the application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It includes the practice of using microorganisms or components of micro-organisms like enzymes to generate industrially useful products in a more efficient way (e.g. less energy use, or less by-products), or generate substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide. There are many examples of such bio-based products already on the market. The most mature applications are related to enzymes used in the food, feed and detergents sectors. More recent applications include the production of biochemicals and biopolymers from agricultural or forest wastes.

Internet of Things (IoT)

The Internet of Things (IoT) refers to the network of smart, interconnected devices and services that are capable of sensing or even listening to requests. IoT is an aggregation of endpoints that are uniquely identifiable and that communicate bi-directionally over a network using some form of automated connectivity. Objects become interconnected, make themselves recognisable, and acquire intelligence in the sense that they can communicate information about themselves and access information that has been provided by another source. The Internet of Things relies on networked sensors to remotely connect, track and manage products, systems and grids. The Industrial Internet of Things (IIoT) – a subset of the larger Internet of Things – focuses on the specialised requirements of industrial applications, such as manufacturing, oil and gas, and utilities. IIoT systems connect non-consumer devices, used by companies, governments and utility providers in their service delivery.

Micro- and nanoelectronics

Micro- and nanoelectronics deal with semiconductor components and highly miniaturised electronic subsystems and their integration in larger products and systems. They include the fabrication, the design, the packaging and testing from nano-scale transistors to micro-scale systems integrating multiple functions on a chip.

Mobility

IT for Mobility

Mobility covers a large number of different technology areas and markets, which does not only encompass vehicles that take people from point A to point B, but also includes all kinds of technologies that make people more mobile (like for example mobile phones etc.). These, however, consist of a large set of sub-technologies that are hard to capture at the same time. In this project, the patent, trade, prodcom, investment and skills analysis focus on a sub-section of mobility, which is related to vehicles only, e.g. satellite navigation and radio-location, which are also the core technologies that are necessary to make autonomous driving work.

Enterprise mobility

The survey analysis captures mobility in terms of the workforce. The enterprise mobility market is made up of a conglomeration of mobile solutions and technologies, including hardware, software and services, empowering a borderless workforce to securely work anywhere, at any time and from any device. It does not include only the provision of smartphones or tablets to the workforce but also all the tools and applications for transforming key processes, from internal operations to operations with customers and suppliers, all the way from the shop floor to the top floor and from the back office to the end customers.

Nanotechnology

Nanotechnology is an umbrella term that covers the design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometer scale. Nanotechnology holds the promise of leading to the development of smart nano and micro devices and systems and to radical breakthroughs in vital fields such as healthcare, energy, environment and manufacturing.

Photonics

Photonics is a multidisciplinary domain dealing with light, encompassing its generation, detection and management. Among other things it provides the technological basis for the economic conversion of sunlight to electricity which is important for the production of renewable energy, and a variety of electronic components and equipment such as photodiodes, LEDs and lasers.

Robotics

Robotics is technology that encompasses the design, building, implementation, and operation of robots. Robotics is often organised into three categories: 1) Application specific. This includes robotics designed to conduct a specific task or series of tasks for commercial purposes. These robots may be stationary or mobile but are limited in function as defined by the intended application. 2) Multipurpose. Multipurpose robots are capable of performing a variety of functions and movements determined by a user that programs the robot for tasks, movement, range, and other functions and that may change the effector based on the required task. These robots function autonomously within the parameters of their programming to conduct tasks for commercial applications and may be fixed, "moveable," or mobile. 3) Cognitive. Cognitive robots are capable of decision making and reason, which allows them to function within a complex environment. These robots can learn and make decisions to support optimal function and performance and are designed for commercial applications. When measuring production and uptake of robotics, industrial applications will be taken into account.

Security

Security products are tools designed using a wide variety of technologies to enhance the security of an organisation's networking infrastructure — including computers, information systems, internet communications, networks, transactions, personal devices, mainframe, and the cloud — as well as help provide advanced value-added services and capabilities. Cybersecurity products are utilised to provide confidentiality, integrity, privacy, and assurance. Through the use of security applications, organisations are able to provide security management, access control, authentication, malware protection, encryption, data loss prevention (DLP), intrusion detection and prevention (IDP), vulnerability assessment (VA), and perimeter defense, among other capabilities.

Appendix C: ATI survey – sample structure

Table 1: Sample Structure by Country and Vertical (number of respondents)

Segment:	Total	Czech Rep	Denmark	France	Germany	Hungary	Italy	Netherlands	Poland	Spain	Sweden	United Kingdom
Total	**900**	**50**	**50**	**100**	**100**	**60**	**100**	**100**	**90**	**100**	**50**	**100**
Finance	**90**	4	6	10	10	4	10	10	10	10	6	10
Gov/Edu	**73**	4	4	8	8	3	8	8	10	8	4	8
Healthcare	**85**	6	5	9	9	5	9	9	10	9	5	9
Manufacturing – discrete	**71**	5	4	8	8	6	8	8	4	8	4	8
Manufacturing – process	**78**	5	4	8	8	8	8	8	9	8	4	8
Professional Services	**100**	6	5	11	11	7	11	11	11	11	5	11
Retail/Wholesale	**95**	2	5	11	11	8	11	11	9	11	5	11
Telecom/Media	**67**	4	4	8	8	3	8	8	4	8	4	8
Transport	**98**	6	5	11	11	5	11	11	11	11	5	11
Utilities/Oil&Gas	**70**	3	4	8	8	7	8	8	4	8	4	8
Agriculture	**73**	5	4	8	8	4	8	8	8	8	4	8

Table 2: Sample Structure by Country and Company Size (number of respondents)

Segment:	Total	Czech Rep	Denmark	France	Germany	Hungary	Italy	Netherlands	Poland	Spain	Sweden	United Kingdom
Total	**900**	**50**	**50**	**100**	**100**	**60**	**100**	**100**	**90**	**100**	**50**	**100**
10-249 employees	**353**	22	19	37	37	31	37	37	40	37	19	37
250-499 employees	**215**	8	13	25	25	12	25	25	19	25	13	25
500-999 employees	**168**	10	9	19	19	8	19	19	18	19	9	19
1,000+ employees	**164**	10	9	19	19	9	19	19	13	19	9	19

Source: Advanced Technologies for Industry (ATI) Survey, July 2019

About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. The project provides policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship;
- Analytical reports such as on technological trends, sectoral insights and products;
- Analyses of policy measures and policy tools related to the uptake of advanced technologies;
- Analysis of technological trends in competing economies such as in the US, China or Japan;
- Access to technology centres and innovation hubs across EU countries.

You may find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project is undertaken on behalf of the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises (EASME) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

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