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Advanced Technologies for Industry – Final Report

Report on technology trends and technology adoption

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Abstract

This report presents the main findings of the data analysis carried out in the framework of the Advanced Technologies for Industry (ATI) project. The study has carried out a systematic monitoring of the technological trends of advanced technologies with the aim to effectively support the implementation of policies and initiatives within the EU's industrial policy approach. Defined as recent or future technologies that are expected to substantially alter business and social processes, advanced technologies include: 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 Cybersecurity (IT for Security).

This report includes:

- An analysis of **advanced technological trends** captured by patent data, private equity/venture capital investment and startup creation.
- The findings of the **Advanced Technologies for Industry survey** and a detailed analysis of the uptake of advanced technologies in the EU.
- The trends and **analysis related to the supply and demand of skills** associated with advanced technologies.
- An assessment of **digital maturity** in key economic sectors.
- An analysis of the **production of advanced technologies-based manufactured goods** with associated employment figures.
- A set of **policy recommendations** stemming from the analysis of advanced technologies' key trends and figures.

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RÉSUMÉ

Ce rapport présente les principales conclusions de l'étude relative aux technologies de pointe au service de l'industrie (Advanced Technologies for Industry - ATI). Aux fins de cette étude, un suivi systématique des tendances technologiques en matière de technologies de pointe a été réalisé afin de soutenir efficacement la mise en œuvre des politiques et des initiatives dans le cadre de l'approche de l'UE en matière de politique industrielle. Définies comme des technologies récentes ou futures permettant de modifier de manière substantielle les processus commerciaux et sociaux, les technologies de pointe comprennent les éléments suivants : fabrication de pointe, intelligence artificielle, réalité augmentée et virtuelle, big data, blockchain, technologies du cloud, connectivité, biotechnologie industrielle, internet des objets, micro et nanoélectronique, informatique liée à la mobilité, nanotechnologie, photonique, robotique et sécurité.

Ce rapport comprend :

- Une **analyse des tendances des technologies de pointe** en termes de demandes de brevets reposant sur l'investissement en capital-investissement/capital-risque et la création de start-ups.
- Les **résultats de l'enquête sur les technologies de pointe** au service de l'industrie et une analyse détaillée de l'adoption des technologies de pointe dans l'UE.
- Les tendances et **l'analyse liées à l'offre et à la demande de compétences** associées aux technologies de pointe.
- Une évaluation de la **maturité numérique** dans les principaux secteurs économiques.
- Une analyse des statistiques Prodcom sur la **production de biens manufacturés reposant sur les technologies de pointe** accompagnée des chiffres en matière d'emploi.
- Une série de **recommandations politiques** découlant de l'analyse des tendances et des chiffres clés des technologies de pointe.

Executive summary

This final 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 European Innovation Council and Small and Medium-sized Enterprises Executive Agency (EISMEA). Through an in-depth analysis of traditional data sources and novel metrics, the study dives deep into the trends in the generation, uptake and diffusion of advanced technologies, the related entrepreneurial activities, and the demand and supply of skills associated with advanced technologies. The study sheds a light on the role that advanced technologies can play in the process of Europe's industrial modernisation and on the influence that they can exert to shape the current and future digital opportunities for the EU. The study further interprets a wide range of existing and new data to monitor advanced technologies in key competitor economies such as the United States, China, Russia, Japan, Canada and South Korea.

The Advanced Technology for Industry (ATI) study revolves around a series of quantitative and qualitative analytical tools to support the implementation of policies and initiatives within the EU's industrial policy approach. In particular:

- The **ATI Data Dashboard** provides countries' and industries' statistical evidence on the level of technology production and uptake with the aim to support policy and technological transformation.
- The **Technology Watch** explores the futuristic, upcoming technologies that are on the horizon of technology development today and that are characterised by high speed of evolution and a significant disruptive potential. Advanced Technology Watch is addressed to policymakers, enterprises (large and SMEs) and business intermediaries. It allows them to better assess the maturity of technologies, the potential market applications and the technical adaptation required to bring advanced technologies to the market.
- The **Product Watch** analyses novel products that are based on advanced technologies for the development of goods and services - enhancing their overall commercial and social value. It analyses the value chain of the selected Advanced Technology-based products, as well as the strengths and weaknesses of the respective EU competitive position. This report specifically supports cluster organisations and S3 (Smart Specialization Platforms) partnerships, providing intelligence on innovation areas where European regions could team up and invest together.
- The **Sectoral Watch** analyses trends in the generation and uptake of advanced technologies, related entrepreneurial activities and skills needs in a number of selected sectors. It interprets data from a list of data sources compiled to monitor advanced technologies and their applications in industry across Europe and key competitor economies. It allows policy makers, industries and intermediaries to contextualise the collected data on advanced technologies specific for the industries in focus.
- The **Policy Briefs** analyse national and regional policy measures focused on a specific policy challenge, technological area or mode of implementation and explore policy tools that have been designed and implemented with the aim of fostering the generation and uptake of advanced technologies. The reports provide a comparative analysis of some of the most relevant national and regional examples on the policy landscape in the EU. They highlight the lessons learnt based on existing policy evaluations, monitoring or any other learning process and present good practices. In the case of novel policy initiatives, they focus on the key challenges in the design process.
- The **International Reports** explore the technology and policy landscape of non-European countries including the US, China, Canada, Japan, South Korea and Russia. These reports provide European

policymakers insights into the most recent developments from overseas. Country performance regarding advanced technologies is presented based on patents, trade and investment data. A concise and informative review of policies relevant for advanced technology development and deployment is also part of the reports.

- The **ATI Technology Centres' mapping** provides businesses and policy-makers with the most up-to-date information on organisations that carry out applied research and close-to-market innovation (Technology Readiness Levels TRL 3 to 8, not necessarily the whole range) in Advanced Technologies for Industry in the EU27 today.

The main findings of the analysis are the following:

The EU27 has a leading position in various advanced technologies such as Advanced Manufacturing and the Internet of Things and has recently managed to considerably increase investment in Artificial Intelligence. On the other hand, its competitive advantages are greatly challenged:

- The EU27 holds the **highest share (30.6%) of worldwide patent applications in Advanced Manufacturing technologies.** This focus on industrial applications is mirrored by the high share of Internet of Things technologies (28.8%) complemented by a high share of digital technologies for Mobility (26.7%) in line with its strengths in the vehicle and aeronautics industry.
- In line with its **weakness in Micro- and nanoelectronics inventions**, EU27 shares remain **low in Big Data** (14.7%), and **Artificial Intelligence** (16.2%).
- Shares in Robotics, Nanotechnology, Industrial Biotechnology, Photonics and Advanced Materials range between 17% and 21%.
- With a view to developments over time, the aggregate figures for all advanced technology patent applications display **a nearly tenfold rise in China's contribution to worldwide patenting** since 2005. Figures have more than doubled since 2012.
- Among the former global leaders, **it is often the European Union that feels the impact of China's rise** most or seems less able to match it with own dynamics. While there are exceptions like the Internet of Things, recent dynamics in Robotics and Advanced Manufacturing provide evidence that the challenge is comprehensive.
- The year **2020 witnessed an increasing level of investment deals in advanced technologies in the EU** and also worldwide despite the pandemic. The increased attention of investors to technology was driven by the accelerated digitalisation trends and new demand for various tech-based applications and services. In 2020 private equity and venture capital funding have been invested most in firms developing Mobility technologies followed up by Biotechnology and Artificial Intelligence in the EU27.
- With regard to the number of startups founded after 2015, countries that have the highest number of startups include **Germany, France and the Netherlands**. When controlling for the size of the country Estonia, Ireland and Belgium also stand out.
- Although some companies register their headquarters in one country, they have relevant labour force and development ongoing in another country. European tech firms had to increasingly look for US investors to back their capital growth. There has been also a tech migration to the US. Some companies moved their headquarters abroad in order to have access to capital and larger markets. The analysis of the geographical location of professionals employed by Artificial Intelligence companies' estimates that **9.9% of AI employment generated by EU27 companies can be attributed to the US**. On the other hand, **14.5% of AI employment generated by US AI companies is linked to India and Israel**.

The **adoption of advanced technologies has increased compared with the previous year,** although the economic crisis and contingency measures have severely tested the digital road maps of EU Industries and slowed down progress against them.

Overall, specific advanced technologies are playing a crucial role in reigniting EU Industries' return to growth, thanks to the importance such technologies have in determining forward-looking strategies in a changing business environment. **AI and IoT are particularly under the spotlight** thanks to their impact in terms of achieving enhanced efficiency and cost reduction while supporting business processes transformation.

Looking at advanced technologies' trends in terms of **patents**, the EU27's share in global patenting in advanced technologies for industry varies between 30.6% in Advanced Manufacturing technologies and 13.7% in Micro- and nanoelectronics.

Technology uptake varies according to the size of the organisation and the industry concerned. Small enterprises, for example, are gaining ground in the adoption of the technologies needed to create the backbone of their future digital environment (such as public cloud and connectivity), while still exploring other advanced technologies. **Across industries, the hardest-hit sectors are also those with the highest rates of technology adoption**: From manufacturing to retail, from transport to healthcare, these sectors are aiming for a more automated and efficient working environment, with considerable benefits for daily business activities. The impact of the economic downturn related to the COVID pandemic can be seen in several areas, such as the adoption of new technologies and new business strategies, but also in changes to resource allocations and budget priorities. The critical economic situation resulting from the pandemic is confirmed by the survey results, which show an even distribution of the number of organisations that are still struggling to emerge from the crisis and are experiencing an economic slowdown or recession, and those that are in the ascending phase, moving towards the next normal.

The pandemic forced European companies to slow down and rethink their advanced technology innovation road maps to cope with the economic shock resulting from lockdown measures and restrictions. **The need to reduce operational and/or product costs, improve efficiency and to innovate in business models are the main drivers** of adoption of advanced technologies. To achieve these objectives, organisations are moving their investments from traditional technology to new, advanced technologies and industrial equipment. Despite economic turmoil, organisations were able to slightly increase the share of ICT spending in their overall budgets. This is coherent with the perception of advanced technologies as key to managing the crisis and moving towards the next normal.

In terms of **use cases**, i.e., the concrete business scenarios where advanced technologies are applied, advanced technologies such as IoT, AI, Robotics, AR/VR, Blockchain, nanotechnology, advanced materials, micro- nanoelectronics, Photonics and industrial biotechnology, enable a good mix of horizontal and industry-specific use cases. Although the range of use cases differs depending on industry-specific needs, some common traits can be found across each sector. This is particularly true for 'horizontal advanced technologies' like IoT, Artificial Intelligence, Robotics and AR/VR.

The main **business units driving** technological change are the **IT function** and **operations**, the former playing a critical role in the overall redefinition of companies' IT, and the latter pushing investments coherent with the changes that companies had to undertake to adjust their operating models. When looking at advanced technologies' budget owners, a balanced picture between internal IT units and lines of business emerges — a further sign those advanced technologies need to be IT user-inspired (particularly with regard to technical aspects such as interoperability and scalability), but at the same time need to speak the language of business, being business outcomes-focused by design.

In terms of production of advanced technology related components, Europe boasts strength in Advanced Manufacturing and Advanced Materials, while also the production of Internet of Things components proves to be significant. In total, advanced technologies comprise around 24% of industrial production implying that ~1/4 of industrial production is strongly dependent on manufacturing advanced technology-based products and applying them in the production of manufacturing goods. Advanced Manufacturing (6.3%), Advanced Materials (5.5%) and Industrial Biotechnology (2.6%) comprise the largest shares, while the shares of Big Data (0.2%), Artificial Intelligence (0.5%) and Security (0.5%) remain low.

Regarding the necessary **skills** associated with advanced technologies, 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:

- **The EU27 has higher relative share of professionals with skills in Advanced Manufacturing technologies, Advanced Materials, Internet of Things and Industrial Biotechnology**. The EU27 lags behind the US in particular in Cloud technologies, Artificial

Intelligence and Cybersecurity but also in Big Data and Robotics. The EU27 and US have similar shares in Blockchain, AR/VR, Micro- and nanoelectronics, digital technologies for Mobility and Photonics.

- Professionals with skills in advanced technologies concentrated in specific countries. After correcting the absolute numbers of professionals registered on LinkedIn reflecting the degree of representativeness and the size of the country, the results suggest that **Finland, Sweden, Germany, Luxembourg, Ireland, Denmark, the Netherlands, Estonia, Belgium and Austria are the top ten countries with the highest available advanced technology skills**.
- The advanced technologies that have witnessed the highest growth rate in the EU27 from December 2019 to December 2020 (covering the COVID period) in terms of skills include **Artificial Intelligence (32%), Blockchain (27%), Cybersecurity (23%) and Connectivity (23%).** The increased importance of Cybersecurity and Connectivity also reflects the changed needs of demand for these skills in the times of COVID and the shift to digital operating models.
- Overall, the types of skills that saw the highest increase from 2019 to 2020 include **Creativity skills, Python, Analytical skills, Laboratory skills and Data analysis**. Several of the skills are related to programming and more specifically programming languages relevant for AI. Laboratory skills might reflect the increased needs in the healthcare sector.
- In terms of the absorption of advanced technology skilled professionals by various industries, the analysis shows that beyond Information and Communication Technologies and Research, the industries that employ most professionals with advanced technology skills in general include **Telecommunications, Electronics and semiconductors, Automotive and Management consulting**. Advanced Manufacturing skilled professionals have been concentrated in manufacturing industries such as Automotive, Electronics and Machinery but also Construction. Artificial Intelligence skilled professionals have been employed most in industries such as Management consulting, financial services and Automotive. Cybersecurity skilled professionals have been employed most in Telecommunications, Management Consulting, Financial services and banking and Government Administration.
- When analysing the evolution of job posts requiring advanced technology skills published over the period from December 2019 to April 2021 on LinkedIn, this report found that the **number of job posts have decreased** in the first half of 2020 except for Industrial Biotechnology (linked to demand of pharma and biotech firms), Photonics, Nanotechnology (which might be linked to vacancies of the research and education sector less affected) and Connectivity (which can be explained by the increased need for connected solutions). Demand for skills for Mobility technologies (electric vehicles) has also stayed strong, although witnessed some drops in autumn 2020. **The number of jobs posts for various advanced digital technologies such as AI, Big Data, Cybersecurity, IoT and Blockchain started to increase again** since the end of 2020 and surpassed 2019 levels by early 2021. For example, EU job posts requiring Artificial Intelligence technology skills have been posted on LinkedIn most by IT firms, online platforms (such as Amazon, Zalando), research institutions, business consultancy companies, the transportation sector and financial services. Interestingly, vacancies posted with a requirement for advanced manufacturing skills have been decreasing since December 2019 and this downward trend can be further observed in 2021.

By leveraging the full body of quantitative and qualitative analysis conducted by the Advanced Technologies for industry (ATI) project, the following policy recommendations are put forward:

- It is imperative to **further bolster the financing of advanced technology development and deployment** both at European, national and regional levels in order to sustain and gain EU technological leadership.

- **Investments must focus both on EU's strengths and on areas that are** critical to protect technological independence.
- Investment into the development of technological excellence and into the deployment of advanced technologies for industry should be **better balanced out**. EU policy should better focus on concrete application areas and commercialisation pathways of advanced technologies while keeping in mind technological sovereignty at the global level.
- **The diffusion of advanced technologies into a broader set of industries and sectors should be better supported** in order to facilitate technological transformation across the economy.
- Besides supporting technology development, EU policy **should bring back the discussion on service innovation and business models for technology** on the policy discussion fora. Policy measures should consider the service innovation element when supporting the generation and deployment of advanced technologies.
- **Skills and talent sourcing should remain a priority area of public policies.** Skills development both related to the technology itself and about the use of technology, including the understanding of how to deploy advanced technologies in a responsible way, should be further bolstered at all policy levels. The attraction and employment of tech talent in industry is a pertinent policy gap that should be addressed by removing existing barriers and facilitating new opportunities.
- **The EU should develop an international strategy for advanced technologies linked to its external economic instruments** including international partnerships on the access to critical raw materials, cooperation of technology deployment, access to skills and the promotion of green technologies at a global level.
- **The regional and local dimension should be a more accentuated part of future EU industrial technology related strategies**. More needs to be done to link the smart specialisation discussion to the fora on developing new industrial pathways.
- **Public policy at all levels should further strengthen the actions related to SME support to advanced technologies**. Initiatives such as the ATI technology centres can become instrumental in this respect but will need to be better connected to other SME related initiatives such as the Enterprise Europe Network, the European Cluster Collaboration Platform and the Digital Innovation Hubs.

SYNTHÈSE

Ce rapport final a été préparé dans le cadre de l'étude « Advanced Technologies for Industry » (ATI), initiée par la Commission européenne, Direction générale du marché intérieur, de l'industrie, de l'entrepreneuriat et des PME et le Conseil européen de l'innovation et l'Agence exécutive pour les petites et moyennes entreprises (EISMEA). Grâce à une analyse approfondie des sources de données traditionnelles et de nouvelles mesures, l'étude examine en profondeur les tendances en matière de conception, d'adoption et de diffusion des technologies de pointe, les activités entrepreneuriales connexes, ainsi que la demande et l'offre de compétences associées aux technologies de pointe. L'étude met en lumière le rôle que les technologies de pointe peuvent jouer dans le processus de modernisation de l'industrie européenne et l'influence qu'elles peuvent exercer sur les possibilités numériques actuelles et futures offertes à l'UE. L'étude examine en outre un large éventail de données existantes et nouvelles afin de suivre les technologies de pointe dans les principales économies concurrentes telles que les États-Unis, la Chine, la Russie, le Japon, le Canada et la Corée du Sud.

L'étude sur les technologies de pointe au service de l'industrie (ATI) s'articule autour d'une série d'outils analytiques quantitatifs et qualitatifs destinés à soutenir la mise en œuvre de politiques et d'initiatives dans le cadre de l'approche de l'UE en matière de politique industrielle. En particulier :

- Le **tableau de bord de l'ATI** fournit aux pays et aux industries des données statistiques quant au niveau de production et d'adoption des technologies, dans le but de soutenir les politiques et la transformation technologique.
- La **veille technologique** explore les technologies d'avenir attendues au terme du développement technologique actuel, marquées par une évolution très rapide et un potentiel de transformation radicale. La veille technologique de pointe s'adresse aux décideurs politiques, aux entreprises (grandes entreprises et petites et moyennes entreprises) et aux intermédiaires commerciaux. Elle leur permet de mieux évaluer la maturité des technologies, les applications potentielles sur le marché et l'adaptation technique nécessaire pour mettre les technologies de pointe sur le marché.
- La **veille produit** analyse les nouveaux produits reposant sur des technologies de pointe et permettant le développement de biens et de services, tout en étant susceptible d'améliorer leur valeur commerciale et sociale globale. Elle analyse la chaîne de valeur des produits sélectionnés basés sur des ATI, leur lien avec les Projets Importants d'Intérêt Européen Commun (Important Projects of Common European Interest - IPCEI) et l'analyse des forces et faiblesses du positionnement concurrentiel de l'UE. Ce rapport soutient spécifiquement les organisations de clusters et les partenariats S3, en fournissant des informations sur les domaines d'innovation dans lesquels les régions européennes pourraient s'associer et investir ensemble.
- La **veille sectorielle** analyse les tendances en matière de production et d'adoption de technologies de pointe, d'activités entrepreneuriales connexes et de besoins en compétences dans un certain nombre de secteurs sélectionnés. Il interprète les données provenant d'une liste de sources de données compilées pour surveiller les technologies de pointe et leurs applications dans l'industrie en Europe et dans les principales économies concurrentes. Il permet aux décideurs politiques, aux industries et aux intermédiaires de contextualiser les données collectées en matière de technologies de pointe spécifiques aux industries concernées.
- Les **notes d'orientation** analysent les mesures politiques nationales et

régionales tournées vers un défi politique, un domaine technologique ou un mode de mise en œuvre spécifique et explorent les outils politiques conçus et mis en œuvre dans le but de favoriser la génération et l'adoption de technologies de pointe. Les rapports fournissent une analyse comparative de certains des exemples nationaux et régionaux les plus pertinents dans le paysage politique de l'UE. Ils mettent en évidence les enseignements tirés des évaluations de politiques existantes, du suivi ou de tout autre processus d'apprentissage et présentent les bonnes pratiques comme les mauvaises. Dans le cas de nouvelles initiatives politiques, ils se concentrent sur les principaux défis du processus de conception.

- Les **rapports internationaux** explorent le paysage technologique et politique des pays non européens, notamment les États-Unis, la Chine, le Canada, le Japon, la Corée du Sud et la Russie. Ces rapports donnent aux décideurs européens un aperçu des développements les plus récents intervenus à l'étranger. Les performances par pays en matière de technologies de pointe sont présentées sur la base des données relatives aux brevets, au commerce et aux investissements. Ces rapports présentent également un examen concis et informatif des politiques pertinentes pour le développement et le déploiement des technologies de pointe.
- La **cartographie des centres technologiques ATI** fournit aux entreprises et aux décideurs les informations les plus récentes sur les organisations menant des activités de recherche appliquée et d'innovation proche du marché (niveaux de préparation technologique TRL 3 à 8, et non pas nécessairement toute la gamme) dans le domaine des technologies de pointe au service de l'industrie dans l'UE des 27 aujourd'hui.

Les principales conclusions de l'analyse sont les suivantes :

L'UE-27 occupe une position de premier plan dans diverses technologies de pointe, telles que la fabrication avancée et l'internet des objets, et a récemment réussi à augmenter considérablement ses investissements dans l'intelligence artificielle. D'un autre côté, ses avantages concurrentiels sont fortement remis en cause :

- L'UE-27 détient la **part la plus importante (30,6 %) des demandes de brevets mondiales dans les domaines** suivants en **Technologies de fabrication avancée.** L'accent mis sur les applications industrielles se reflète dans la part élevée des technologies de l'internet des objets (28,8 %), complétée par une part élevée de technologies numériques en matière de mobilité (26,7), conforme à ses performances dans l'industrie automobile et aéronautique.
- Tout comme la **faiblesse des inventions en micro et nanoélectronique**, les parts de l'UE-27 restent **faibles dans le domaine du Big Data** (14,7 %) et de l'intelligence **artificielle** (16,2 %).
- Les parts de la robotique, de la nanotechnologie, de la biotechnologie industrielle, de la photonique et des matériaux avancés se situent entre 17 % et 21 %.
- En ce qui concerne l'évolution dans le temps, les chiffres cumulés pour toutes les demandes de brevets de technologies de pointe montrent que la **contribution de la Chine aux brevets mondiaux a presque décuplé** depuis 2005. Les chiffres ont plus que doublé depuis 2012.
- Parmi les anciens leaders mondiaux, **c'est souvent l'Union européenne qui ressent** le plus l'**impact de la montée en puissance de la Chine** ou qui semble moins capable de l'accompagner dans sa propre dynamique. S'il existe des exceptions, comme l'internet des objets, la dynamique récente de la robotique et de la fabrication avancée montre que le défi est global.
- L'année **2020 a été marquée par une augmentation des investissements dans les technologies de pointe dans l'UE** et dans le monde entier, malgré la pandémie. L'attention accrue des investisseurs à l'égard de la technologie est due à l'accélération des tendances à la numérisation et à la nouvelle demande en faveur de diverses applications et services

technologiques. En 2020, les fonds de capital-investissement et de capital-risque ont été investis surtout dans des entreprises développant des technologies de mobilité, suivies par les biotechnologies et l'intelligence artificielle dans l'UE-27.
- En ce qui concerne le nombre de startups fondées après 2015, les pays qui comptent le plus grand nombre de startups sont l'Allemagne**, la France et les Pays-Bas**. Si l'on tient compte de la taille des pays, l'Estonie, l'Irlande et la Belgique se distinguent également.
- Bien que certaines entreprises établissent leur siège social dans un pays, elles disposent d'une main-d'œuvre pertinente et d'un développement continu dans un autre pays. Les entreprises technologiques européennes ont dû se tourner de plus en plus vers les investisseurs américains pour soutenir la croissance de leur capital. Une migration des technologies a également eu vers les États-Unis. Certaines entreprises ont transféré leur siège à l'étranger afin d'avoir accès aux capitaux et à des marchés plus importants. L'analyse de la localisation géographique des professionnels employés par les entreprises d'intelligence artificielle montre que **9,9 % des emplois liés à l'IA générés par les entreprises de l'UE-27 peuvent être attribués aux États-Unis**. D'autre part, **14,5 % des emplois générés par les entreprises américaines d'IA sont liés à l'Inde et à Israël**.

L'**adoption des technologies de pointe a augmenté par** rapport à l'**année précédente,** même si la crise économique et les mesures d'urgence ont mis à rude épreuve les feuilles de route numériques des industries européennes et ralenti les progrès réalisés au regard de celles-ci.

Dans l'ensemble, les technologies de pointe spécifiques jouent un rôle crucial dans la relance du retour à la croissance des industries européennes, grâce à l'importance de ces technologies en vue de déterminer des stratégies prospectives dans un environnement commercial en mutation. L'**IA et l'Internet des objets sont particulièrement sous le feu des projecteurs** grâce à leur effet en termes d'obtention d'une efficacité accrue et de réduction des coûts ainsi que de transformation des processus métier.

- Si l'on examine les tendances des technologies de pointe en termes de **brevets,** la part de l'UE-27 dans les brevets mondiaux sur les technologies de pointe au service de l'industrie varie entre 30,6 % pour les technologies de fabrication de pointe et 13,7 % pour la micro et nanoélectronique. L'accent mis sur les applications industrielles se reflète dans la part élevée des technologies de l'internet des objets (28,8 %), complétée par une part élevée de technologies numériques en matière de mobilité (26,7 %), conforme à ses performances dans l'industrie automobile et aéronautique. Tout comme la faiblesse des inventions en micro et nanoélectronique les parts de l'UE-27 restent faibles dans le domaine du Big Data (14,7 %) et de l'intelligence artificielle (16,2 %). Les parts de la robotique, de la nanotechnologie, de la biotechnologie industrielle, de la photonique et des matériaux avancés se situent entre 17 % et 21 %.
- L'**adoption de la technologie varie en fonction de la taille de l'organisation et du secteur** concerné. Les petites entreprises, par exemple, gagnent du terrain dans l'adoption des technologies nécessaires pour créer le support de leur futur environnement numérique (comme le cloud public et la connectivité), tout en continuant à explorer d'autres technologies de pointe. **Parmi les industries, les secteurs les plus concernés sont également ceux qui présentent les taux les plus élevés d'adoption des technologies** : de la fabrication au commerce de détail, du transport aux soins de santé, ces secteurs visent à mettre en place un environnement de travail plus automatisé et plus efficace, comportant des avantages considérables pour les activités quotidiennes. L'effet du ralentissement économique lié à la pandémie de COVID

se manifeste dans plusieurs domaines, tels que l'adoption de nouvelles technologies et de nouvelles stratégies commerciales, mais aussi par des changements dans l'allocation des ressources et les priorités budgétaires. La situation économique critique résultant de la pandémie est confirmée par les résultats de l'enquête, qui montrent une répartition égale entre les organisations luttant encore pour sortir de la crise et connaissant un ralentissement économique ou une récession, et celles qui sont en phase ascendante, proches de la normalité.

- La pandémie a contraint les entreprises européennes à ralentir et à repenser leurs feuilles de route en matière d'innovation technologique avancée afin de faire face au choc économique résultant des mesures de confinement et des restrictions. **La nécessité de réduire les coûts d'exploitation et/ou des produits, d'améliorer l'efficacité et d'innover dans les modèles d'entreprise constitue le principal moteur portant à** l'adoption de technologies de pointe. Pour atteindre ces objectifs, les organisations transfèrent leurs investissements des technologies traditionnelles vers les nouvelles technologies de pointe et les équipements industriels. Malgré les turbulences économiques, les organisations ont pu augmenter légèrement la part des dépenses en TIC dans leur budget global. Cela est en cohérence avec la perception des technologies de pointe comme des éléments clés permettant de gérer la crise et de revenir à la normalité.
- En termes de **cas d'utilisation**, c'est-à-dire de scénarios commerciaux concrets dans lesquels les technologies de pointe sont appliquées, les technologies de pointe telles que l'Internet des objets, l'IA, la robotique, l'AR/VR, la blockchain, les nanotechnologies, les matériaux avancés, la micro-nanoélectronique, la photonique et la biotechnologie industrielle, permettent un bon mélange de cas d'utilisation horizontaux et spécifiques à l'industrie. Bien que l'éventail des cas d'utilisation diffère en fonction des besoins spécifiques de chaque industrie, certaines caractéristiques communes se retrouvent dans chaque secteur. Cela est particulièrement vrai pour les « technologies de pointe horizontales » telles que l'Internet des objets, l'intelligence artificielle, la robotique et l'AR/VR.
- Les principales **unités commerciales à l'origine du** changement technologique sont la **fonction informatique** et l'**exploitation**, la première jouant un rôle essentiel dans la redéfinition globale de l'informatique des entreprises, et la seconde conduisant à des investissements conformes aux changements que les entreprises ont dû entreprendre pour adapter leurs modèles d'exploitation. Concernant les responsables du budget des technologies de pointe, on constate une répartition équilibrée entre les unités informatiques internes et les secteurs d'activité ; cela signifie également que les technologies de pointe doivent être proposées par les utilisateurs de l'informatique (notamment en ce qui concerne les aspects techniques tels que l'interopérabilité et l'évolutivité), mais qu'elles doivent aussi parler le langage de l'entreprise, s'agissant d'activités orientées vers les résultats.
- **En termes de production de composants liés aux technologies de pointe, l'Europe peut se targuer de ses performances dans le domaine de la fabrication avancée et des matériaux avancés, tandis que la production de composants de l'internet des objets s'avère également importante**. Au total, les technologies de pointe représentent environ 24 % de la production industrielle, ce qui signifie qu'environ un quart de la production industrielle dépend fortement de la fabrication de produits basés sur des technologies de pointe et de leur application dans la production de biens manufacturés. La fabrication avancée (6,3 %), les matériaux avancés (5,5 %) et la

biotechnologie industrielle (2,6 %) constituent les parts les plus importantes, tandis que la part du Big Data (0,2 %), de l'intelligence artificielle (0,5 %) et de la sécurité (0,5 %) reste faible.

En ce qui concerne les **compétences** nécessaires associées aux technologies de pointe, l'UE-27 présente des atouts dans plusieurs technologies de pointe axées sur les sciences et l'ingénierie, mais des faiblesses dans des domaines clés de la technologie numérique par rapport aux États-Unis :

- L'**UE-27 présente une part relative plus élevée de professionnels possédant des compétences dans les technologies de fabrication avancée, les matériaux avancés, l'internet des objets et la biotechnologie industrielle**. L'UE-27 se trouve à la traîne par rapport aux États-Unis, notamment en ce qui concerne les technologies du cloud, l'intelligence artificielle et la cybersécurité, mais aussi le big data et la robotique. L'UE-27 et les États-Unis détiennent des parts similaires dans les domaines suivants : blockchain, AR/VR, micro et nanoélectronique, technologies numériques en matière de mobilité et photonique.
- Les professionnels possédant des compétences dans les technologies de pointe se concentrent dans certains pays. Après correction du nombre absolu de professionnels inscrits sur LinkedIn reflétant le degré de représentativité et la taille du pays, les résultats suggèrent que la **Finlande, la Suède, l'Allemagne, le Luxembourg, l'Irlande, le Danemark, les Pays-Bas, l'Estonie, la Belgique et l'Autriche sont les dix pays où les compétences en technologies de pointe sont les plus disponibles**.
- Les technologies de pointe qui ont connu le plus fort taux de croissance dans l'UE-27 de décembre 2019 à décembre 2020 (couvrant la période Covid) en termes de compétences comprennent l'intelligence **artificielle (32 %), la blockchain (27 %), la cybersécurité (23 %) et la connectivité (23 %).** L'importance accrue de la cybersécurité et de la connectivité reflète également l'évolution des besoins de la demande de ces compétences pendant la période du Covid et du passage à des modèles d'exploitation numériques.
- Dans l'ensemble, les types de compétences qui ont connu la plus forte augmentation de 2019 à 2020 comprennent les **compétences en créativité, le python, les compétences analytiques, les compétences en laboratoire et l'analyse des données**. Plusieurs de ces compétences sont liées à la programmation et plus particulièrement aux langages de programmation pertinents pour l'IA. Les compétences relatives aux laboratoires pourraient refléter les besoins accrus du secteur des soins de santé.
- En ce qui concerne l'absorption des professionnels possédant des compétences en technologies de pointe par différentes industries, l'analyse montre qu'au-delà des technologies de l'information et de la communication et de la recherche, les industries qui emploient le plus de professionnels possédant des compétences en technologies de pointe en général sont les **télécommunications, l'électronique et les semi-conducteurs, l'automobile et le conseil en gestion**. Les professionnels qualifiés de la fabrication avancée se sont concentrés dans les industries manufacturières telles que l'automobile, l'électronique et les machines, mais aussi la construction. Les professionnels qualifiés en intelligence artificielle sont surtout employés dans des secteurs tels que le conseil en gestion, les services financiers et l'automobile. Les professionnels qualifiés en matière de cybersécurité ont été employés principalement dans les secteurs des télécommunications, du conseil en gestion, des services financiers et bancaires et de l'administration publique.
- En analysant l'évolution des offres d'emploi nécessitant des compétences en technologies de pointe publiées sur la

période allant de décembre 2019 à avril 2021 sur LinkedIn, ce rapport a constaté que le **nombre d'offres d'emploi a diminué** au cours du premier semestre 2020, à l'exception de la biotechnologie industrielle (liée à la demande des entreprises pharmaceutiques et biotechnologiques), de la photonique, de la nanotechnologie (qui pourrait être liée aux offres d'emploi du secteur de la recherche et de l'éducation moins touché) et de la connectivité (qui peut s'expliquer par le besoin accru de solutions connectées). La demande de compétences pour les technologies de la mobilité (véhicules électriques) est également restée forte, même si elle a connu quelques baisses à l'automne 2020. **Le nombre de postes correspondant à diverses technologies numériques de pointe telles que l'IA, le Big Data, la cybersécurité, l'Internet des objets et la Blockchain a recommencé à augmenter** depuis la fin de 2020 et a dépassé les niveaux de 2019 au début de 2021. Par exemple, les offres d'emploi de l'UE nécessitant des compétences technologiques en intelligence artificielle ont été publiées sur LinkedIn le plus souvent par des entreprises informatiques, des plateformes en ligne (telles qu'Amazon, Zalando), des instituts de recherche, des sociétés de conseil aux entreprises, le secteur des transports et les services financiers. Il est intéressant de noter que les offres d'emploi publiées portant sur un besoin de compétences en fabrication avancée sont en baisse depuis décembre 2019 et que cette tendance à la baisse peut encore être observée en 2021.

En s'appuyant sur l'ensemble des analyses quantitatives et qualitatives réalisées par le projet « Advanced Technologies for Industry » (ATI), les recommandations politiques suivantes sont proposées :

- Il est impératif de **renforcer encore le financement du développement et du déploiement des technologies de pointe** aux niveaux européen, national et régional afin de maintenir et d'acquérir le leadership technologique de l'UE.
- Les **investissements doivent se concentrer à la fois sur les points forts de l'UE et sur les domaines** essentiels afin de protéger l'indépendance technologique.
- Les investissements dans le développement de l'excellence technologique et dans le déploiement de technologies de pointe au service de l'industrie devraient être **mieux équilibrés**. La politique de l'UE devrait mieux se concentrer sur les domaines d'application concrets et les voies de commercialisation des technologies de pointe tout en gardant à l'esprit la souveraineté technologique au niveau mondial.
- La **diffusion des technologies de pointe dans un ensemble plus large d'industries et de secteurs devrait être mieux soutenue** afin de faciliter la transformation technologique dans l'ensemble de l'économie.
- Outre le soutien au développement technologique, la politique de l'UE **devrait recentrer le débat sur l'innovation en matière de services et les modèles commerciaux en matière de technologie** dans les forums de discussion politique. Les mesures politiques devraient tenir compte de l'élément d'innovation dans les services lorsqu'elles soutiennent la conception et le déploiement de technologies de pointe.
- **La recherche de compétences et de talents doit demeurer un domaine prioritaire des politiques publiques.** Le développement des compétences liées à la technologie elle-même et à l'utilisation de la technologie, y compris la compréhension de la manière de déployer les technologies de pointe de manière responsable, devrait être davantage soutenu à tous les niveaux politiques. L'attraction et l'emploi de talents technologiques dans l'industrie est une lacune politique pertinente qui doit être comblée en éliminant les obstacles

existants et en facilitant les nouvelles opportunités.

- **L'UE devrait développer une stratégie internationale en matière de technologies de pointe liée à ses instruments économiques externes**, y compris des partenariats internationaux sur l'accès aux matières premières critiques, la coopération pour le déploiement des technologies, l'accès aux compétences et la promotion des technologies vertes au niveau mondial.
- **La dimension régionale et locale devrait occuper une place plus importante dans les futures stratégies de l'UE en matière de technologie industrielle.** Il faut agir davantage afin de relier le débat sur la spécialisation intelligente aux forums sur le développement de nouvelles perspectives industrielles.

Les politiques publiques à tous les niveaux devraient renforcer les actions liées au soutien des PME aux technologies de pointe. Des initiatives telles que les centres technologiques de l'ATI peuvent jouer un rôle déterminant à cet égard, mais elles devront être mieux reliées à d'autres initiatives liées aux PME, comme le réseau Enterprise Europe Network, la plateforme européenne de collaboration entre clusters et les pôles d

Section 1

1. Introduction

This report discusses the main findings from the data that have been collected as part of the Advanced Technologies for Industry (ATI) project. ATI has been initiated by the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the European Innovation Council and SMEs Executive Agency (EISMEA). 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 and LinkedIn.

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/reports/eu-reports/advanced-technologies-industry-methodological-report.

This report is structured as the following:

- The second section analyses technological trends in terms of patent applications in the EU and globally and based on private equity/venture capital investment and startup creation.
- The third section summarises the findings of the Advanced Technologies for Industry survey and analysis about the uptake of advanced technologies in the EU.
- The fourth section presents findings about the supply and demand of skills related to advanced technologies.
- The fifth section presents the analysis of digital maturity in key economic sectors.
- The sixth section includes the analysis of Prodcom statistics on the production of manufactured goods and related employment.
- The report is accompanied by a set of policy recommendations and conclusions which could serve as a basis for future activities in the field of advanced technologies.

Section 2

2. Technology trends

2.1 State of play of EU27 technological strengths

EU27 global leadership in Advanced Manufacturing, Internet of Things and digital technologies for Mobility

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 patents filed at the European Patent Office and relies on International Patent Classification codes. Patents have been localised based on the location of the legal owner of the patent application and hence the analysis reflects the owner/applicant of the technology.

The EU27's share in global patenting in advanced technologies for industry varies between 30.6% in **Advanced Manufacturing** technologies and 13.7% in Micro- and nanoelectronics. This focus on industrial applications is mirrored by the **high share of Internet of Things technologies** (28.8%) complemented by a **high share of digital technologies for Mobility (26.7%)** in line with its strengths in the vehicle and aeronautics industry. In line with its weakness in Micro- and nanoelectronics inventions, Europe's shares remain low in Big Data (14.7%) and Artificial Intelligence (16.2%). Shares in Robotics, Nanotechnology, Industrial Biotechnology, Photonics and Advanced Materials range between 17% and 21%.

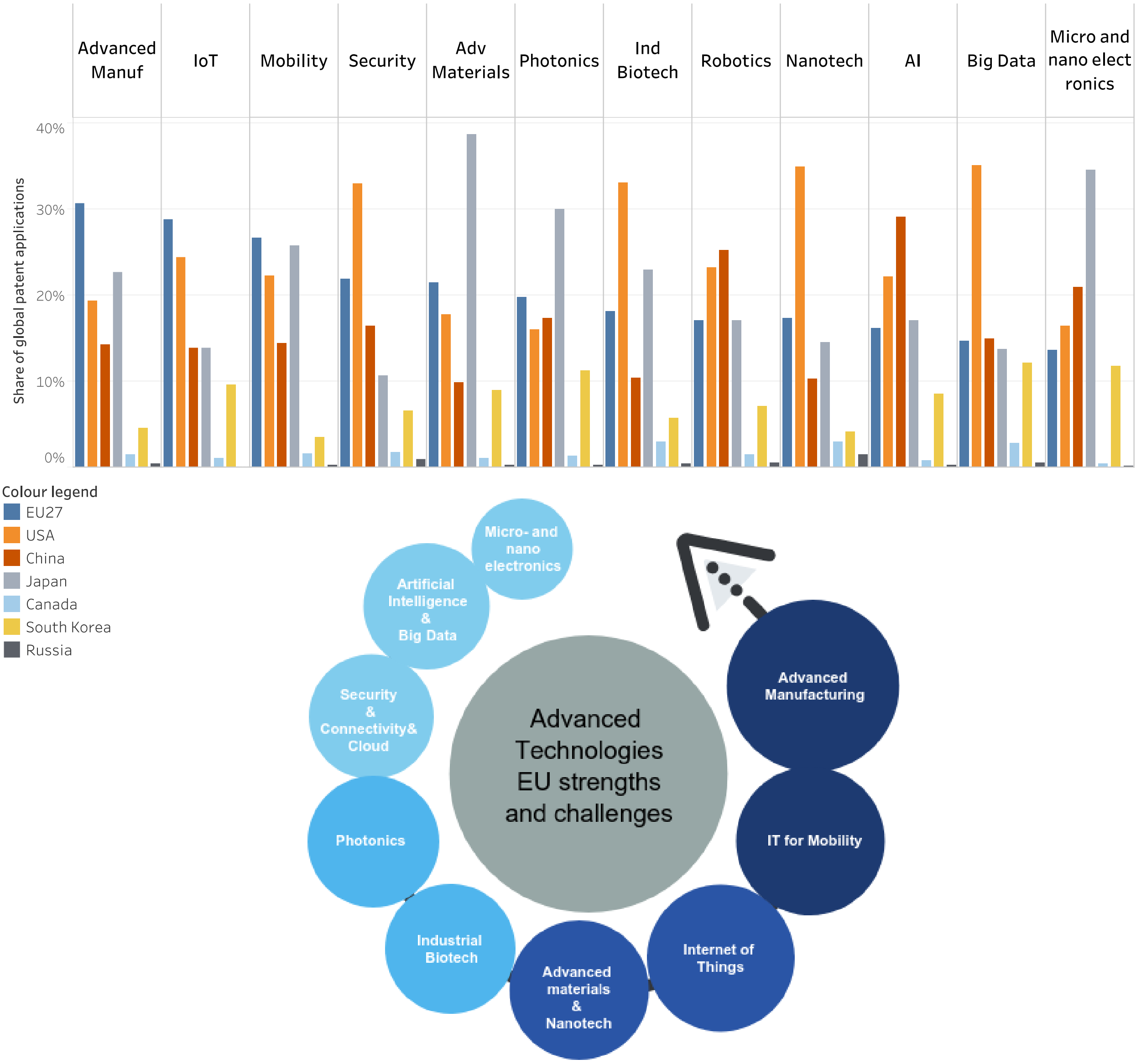
With a view to patent applications internationally, Japan is the strongest competitor in Micro- and nanoelectronics, Photonics and Advanced Materials, while the US holds their dominant position in Industrial Biotechnology, Nanotechnology, IT for Security and Big Data. In parallel, China has taken the lead in Artificial Intelligence and Robotics.

In the different technological categories, all other countries together make up between five and ten percent of overall patent volume - in line with their overall share of about 8%. Their share is lowest in Micro- and nanoelectronics with around 4% and highest in Nanotechnology with about 18%. Central players include Switzerland, Canada, Israel, India, Turkey, Singapore, Taiwan, Russia, Norway and Brazil. The fact that Liechtenstein comes next in the ranking graphically illustrates how small the contribution of any remaining countries, including South Africa and Mexico actually is.

This overall picture as presented above is confirmed also in terms of specialisations. The EU27 displays positive specialisations in Advanced Manufacturing and digital technologies for Mobility (in line with Japan) as well as Internet of Things (in line with South Korea). In terms of specialisation, Micro- and nanoelectronics, Photonics and Advanced Materials are key focus areas for Japan and South Korea. The US focuses on Industrial Biotechnology, Security as well as Big Data which is also a specialisation of South Korea. Despite the fairly balanced absolute distribution of all areas, Robotics has - in relative terms - become a focus of China.

In this international comparison, the conclusions are similar to a year ago, notably that the EU27 is still safeguarding its position in technologies that ensure the necessary framework conditions for the manufacturing industry, but the EU27 is very much disadvantaged in terms of technological leadership in the area of Artificial Intelligence, Big Data or Robotics.

Figure 1: Share of global patent applications in the EU27 and competing economies in 2018 (last available year with complete patent data)



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

Concentration of advanced technology patent applications in a number of EU Member States

With a view to relevant Member States' shares in ATI patenting, **Germany dominates the picture** in all areas but Nanotechnology where it reaches a mere 13%. In line with its overall share of about two fifths of all European patenting, its share in the different ATI domains ranges between 35% and 55%.

In most areas, France follows second with shares between 10% (Robotics) and 28% (Nanotechnology). On the following ranks, most of the other Member States display specialised profiles such as the Netherlands whose contribution fluctuates between 4% and 15%, with an emphasis on Photonics, Artificial Intelligence, Big data and Internet of Things.

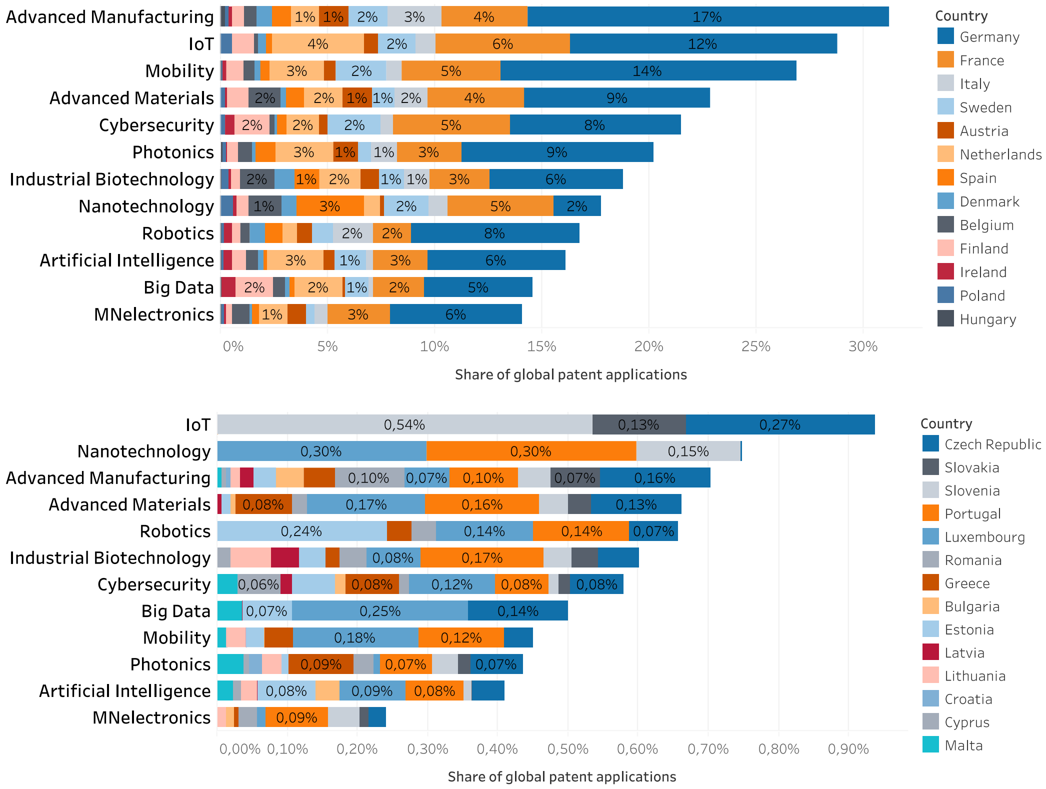
In a similar manner **Italy's contribution to the global patent applications fluctuates between 2% and 11%** with a focus on Robotics.

Sweden, as well, contributes between 3% and 11-12% with outstanding activities in the areas of IT for Security and Nanotechnologies. **Finland** excels in Big Data (12%) and to a lesser extent in digital Security (7%) while its contribution to other areas can be as low as 2%. **Spain** is a central player in Nanotechnology (18%) while its contribution in other areas, can be as low as 1%.

Austria displays yet another specialisation profile with 6-7% in Micro- and nanoelectronics, Photonics and Advanced Materials - yet only 1% in nanotechnology. **Belgium** makes relevant contributions in Industrial Biotechnology, Nanotechnology, Advanced Materials and Micro- and nanoelectronics (between 6% and 9%) while in some areas it does not contribute at all.

Denmark focuses on Industrial Biotechnology (5%) and Robotics (4%) and **Ireland** contributes 4% in the field of Big Data. In none of the ATI fields does the contribution of all other Member States combined exceed 8%, typically it ranges around 4%.

Figure 2: Share of global patent applications of EU MS



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

2.2 Trends over time: nearly tenfold rise in China’s contribution to global patent applications

With a view to developments over time, the aggregate figures for all advanced technology patent applications display **a nearly tenfold rise in China's contribution to worldwide patenting since 2005**, with figures having more than doubled since 2012. In general, this has led to a corresponding, yet equal decrease in the contributions of the US, the EU27 and Japan, with only South Korea having further increased its relative share since the 2000s. While the development dynamics in several of the specific domains by and large mirror these general trends, some display additional, interesting particularities which are illustrated in this section.

While **Advanced Manufacturing technologies** remain Europe's one central stronghold, the EU’s contribution to global patenting has dropped gradually from about 45% in 2008 to about 30% in 2018. In parallel Japan and South Korea have increased their contribution by about 5 percentage points each. The US experienced a first sharp decline in the late 2000s (from about 30% to about 20%) but has been able to maintain its contribution since. While China's share developed in line with South Korea's in the late 2000s it has taken a notable lead since, reaching about 15% of all global patenting in 2018.

In the field of **Artificial Intelligence**, the US contribution experienced a significant decrease from nearly 50% in the mid-2000s to about 25% in 2018. Initially, this shift was fuelled by parallel increases in European and Japanese efforts, while, since the mid-2010s, dynamics in China eclipse those in all other countries. Initially, China and South Korea followed a similar development path but from 2014 onwards China has started to accelerate reaching its globally leading position today. Interestingly, its rise seems to have occurred mostly at the expense of the US, while the contributions of Japan and South Korea remained stable, and the EU’s declined only moderately.

With a view to technologies relevant for the **Internet of Things**, the EU and the US have been able to maintain their leading positions with about 25-30% each since the early 2010s. Likewise, Japan and South Korea have stabilised their contribution around 15% and 10% respectively. While during the late 2000s, China's and South Korea's dynamic rise came at the expense of the US, Japan and, partially, Europe, the overall global division of contributions seems to have stabilised since. In fact, China now even displays a slight decrease in globally oriented, transnational patenting since 2016.

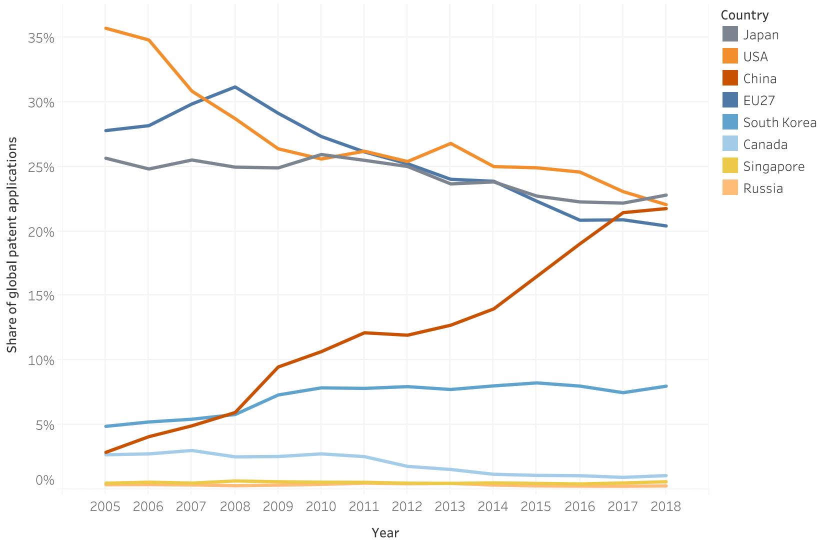
The area of **Robotics**, finally, provides the most graphic evidence of the rise of China, visibly since about 2008 and much more obviously since 2015. While Japan and South Korea had begun to increase their contributions until the late 2000s and early 2010s respectively, their global role has been gradually decreasing since. Most, prominently, however, it is Europe that has felt the impact of China's expansion, and seen its share decrease from 40% to hardly more than 20%. The global contribution of the US, on the contrary, has not changed much since the early 2010s.

With a view to **Micro- and nanoelectronics**, the trends analysis reveals interesting differences in patterns. The decrease of the US share started early in the mid-2000s, too early to be attributed to China's rise but, more likely, to a more general shift towards different Asian countries. Japan, on the contrary, was able to sustain its patenting share until the mid-2010s when it started to drop although it has stabilised in the latest years. The share of Europe's contribution appears to drop starting in the late 2000s.

It can be concluded that:

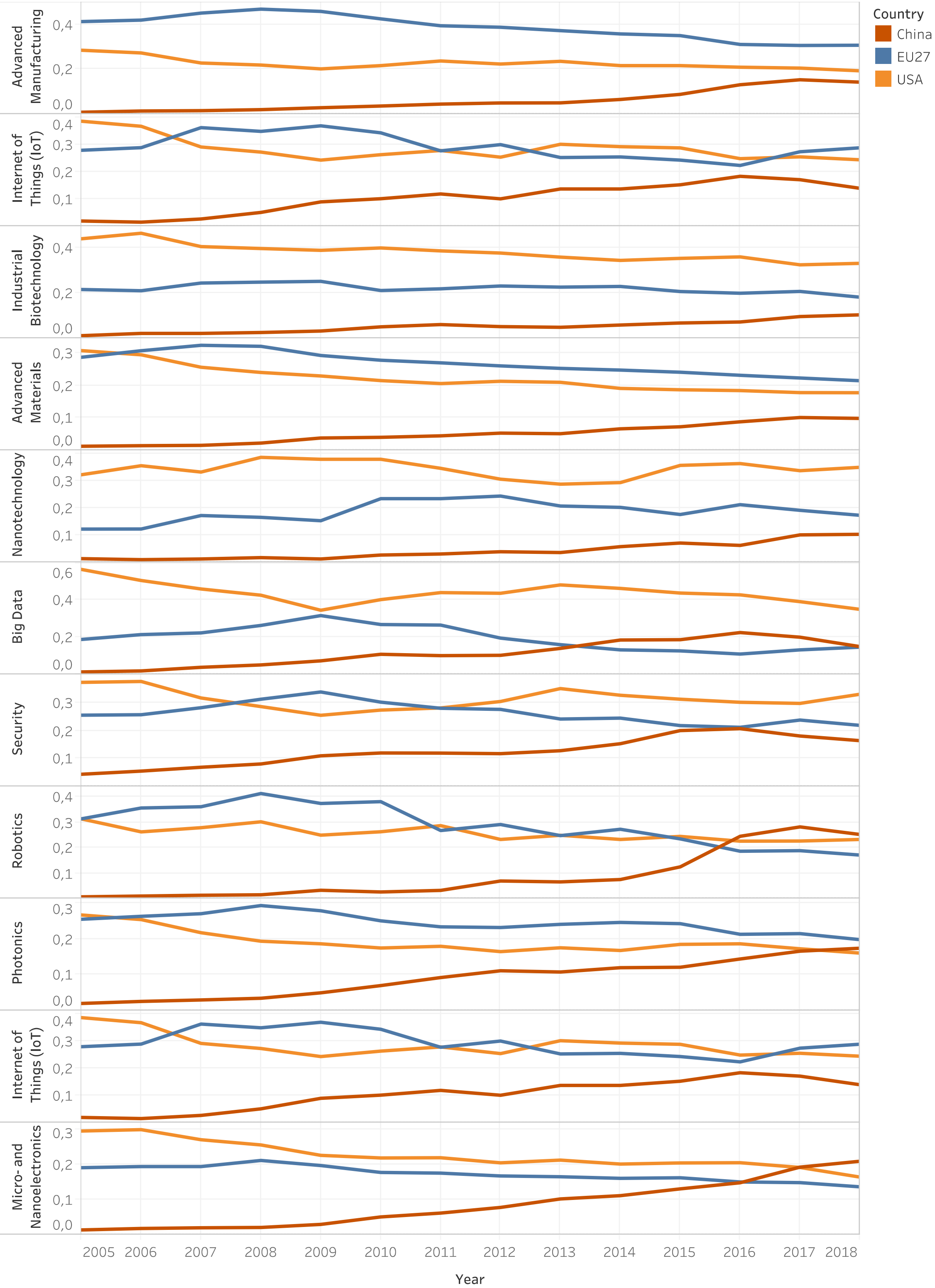
- Among the former global leaders, it is often Europe that feels the impact of China's rise most or seems less able to match it with own dynamics.
- While there are exceptions like the Internet of Things, recent dynamics in Robotics and Advanced Manufacturing provide evidence that the challenge is comprehensive.

Figure 3: Share of global patent applications in all advanced technologies over time



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

Figure 4: Share of global patent applications per advanced technology over time



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

2.3 Private equity and venture capital investment focused on Mobility, Biotechnology and Artificial Intelligence

The analysis of technological trends with patent data can be complemented by investigating firm-level data about startups and scaleups and related investment patterns. The landscape of private equity/venture capital investment and startup creation in advanced technologies has been analysed with the help of a merged dataset from Crunchbase and Dealroom[1]. These two databases provide detailed insights into innovative tech companies and startups that have recently received investment through various funding sources. The merged data offer a good basis with which to compare firm priorities and trends 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 investment market, the representativeness check and the caveats in interpretation are further explained in the ATI methodological report[2].

Continued investment in 2020 in particular in Mobility, Biotechnology and Artificial Intelligence

The collected data suggest that the year **2020 witnessed an increasing level of investment deals in advanced technologies in the EU** and also worldwide despite the pandemic. The increased attention of investors to technology was driven by the accelerated digitalisation trends and new demand for various tech-based applications and services. Moving towards new business models, however, has become more urgent not only for manufacturing and service industries but even for tech firms as a result of lockdowns and restrictions to travel.

In 2020 private equity and venture capital funding have been invested most in firms developing **Mobility technologies** followed up by **Biotechnology** and **Artificial Intelligence** in the EU27.

Mobility technologies include electric vehicles and e-bikes and to some extent autonomous vehicles. One of the highest VC investments went into the German TIER Mobility that is a shared micro-mobility provider offering light electric vehicles such as e-scooters, e-bikes or e-mopeds, powered by a proprietary energy network. TIER operates across 90 cities in 11 countries in Europe and the Middle East[3]. Einride, headquartered in Sweden, is a freight mobility company that designs and builds intelligent freight mobility solutions that are both autonomous and electric for shippers and carriers.

The COVID-19 pandemic accelerated **Biotechnology** investments that were once considered to be riskier. Besides CureVac and BioNTech, famous biopharmaceutical firms, investment went into agricultural technology such as to InnovaFeed, a biotech company producing insect-based protein for the feed industry or Ynsect that provides products and services for agri-food and environmental biotech.

In **Artificial Intelligence** several unicorns appeared on the European horizon. The German Infarm[4] builds and distributes efficient vertical farms throughout cities. Infarm combines efficient vertical farms with IoT technologies and machine learning, to offer an alternative food system that is resilient, transparent and affordable. The firm raised approx. €150 m from a Series C funding in 2020. Collibra is a data intelligence company headquartered in Belgium. The company's platform opens up organisational data and provides business intelligence to specific customers. Kodit.io is a Finnish AI-powered real estate platform making the buying and selling of homes simple. Kodit.io has raised a total of €113.7 m in funding over 6 rounds.

The US has seen similar patterns, but venture capital funds also invested to a large extent in the Internet of Things, Cybersecurity and Cloud technologies in 2020. US venture capital funding has been traditionally strong. Total figures for the US are much higher compared to the EU across all technologies which is due to US investment being more active in later stage funding and also reflecting the overall larger average deal size in the US compared to the EU27.

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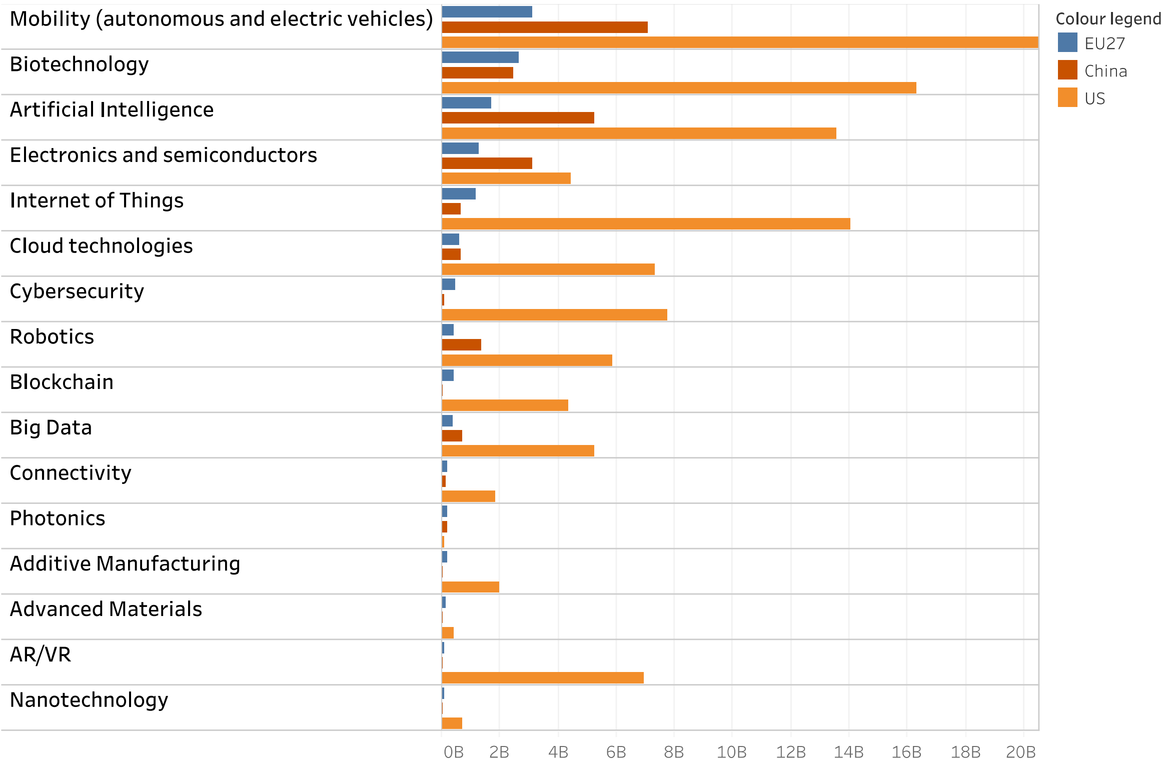
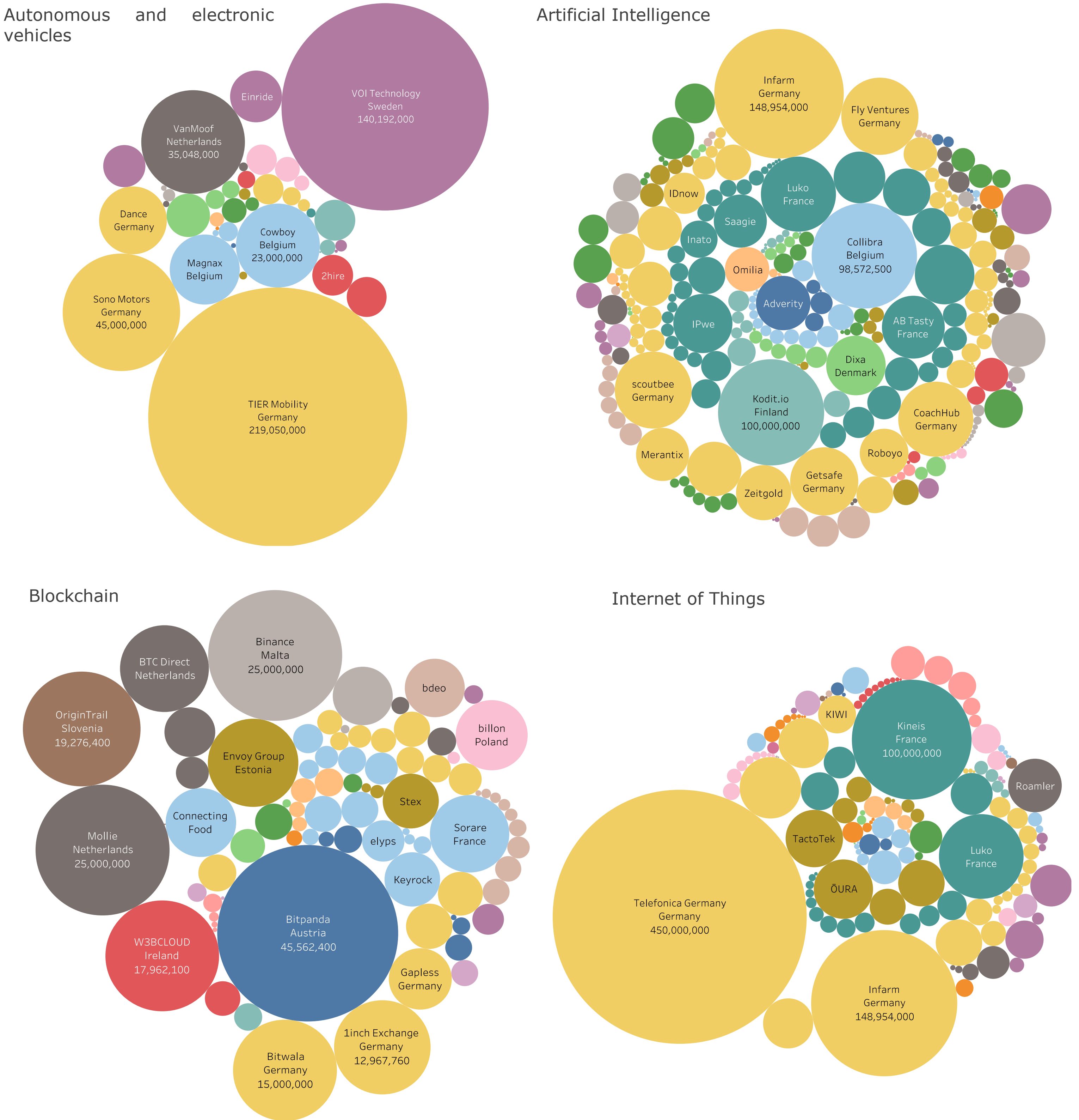
[1] Crunchbase.com and Dealroom.com
[2] https://ati.ec.europa.eu/reports/eu-reports/advanced-technologies-industry-methodological-report
[3] https://www.crunchbase.com/organization/tier-mobility/company_financials
[4] https://www.crunchbase.com/organization/infarm

Figure 5: Private equity and VC investment in advanced technology in the EU27, US and China in 2020



Source: Technopolis Group based on Crunchbase and Dealroom

Figure 6: Investment deal patterns in 2020 in Mobility, Artificial Intelligence, Blockchain and the Internet of Things (the titles of the largest indicated)



Source: Technopolis Group based on Crunchbase and Dealroom

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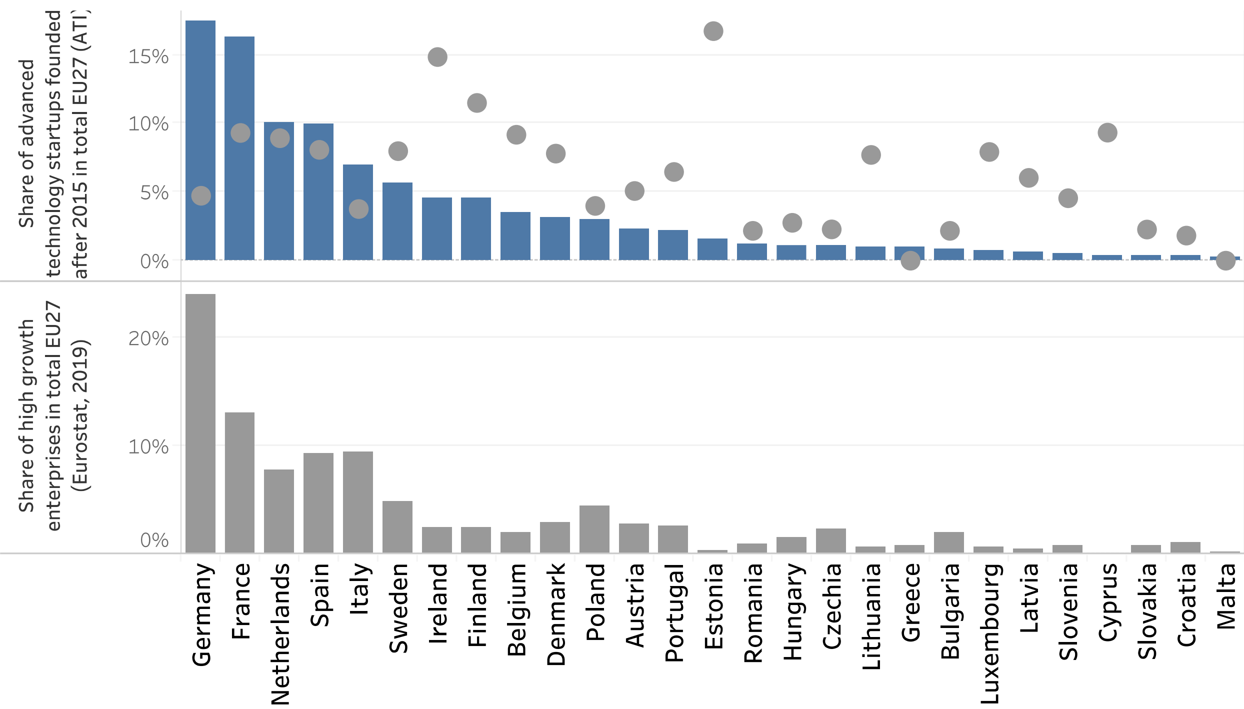
With regard to the number of startups founded after 2015, countries that have the highest number of startups include Germany, France and the Netherlands. When controlling for the size of the country (as indicated by the grey circles in the diagram below) in terms of the total population of enterprises active in NACE: Computer programming, consultancy and related activities, Information service activities, Scientific research and development and Telecommunications, we find however that Estonia, Ireland and Belgium also stand out.

Figure 7 also provides a comparison in terms of the share of advanced technology startups and high growth enterprises as measured by Eurostat, two indicators that are conceptually different but still can be contrasted.

Figure 7: Share of advanced technology startups founded after 2015 across EU27 countries



= refers to the share of startups in total population of enterprises active in NACE: Computer programming, consultancy and related activities, Information service activities, Scientific research and development and Telecommunications

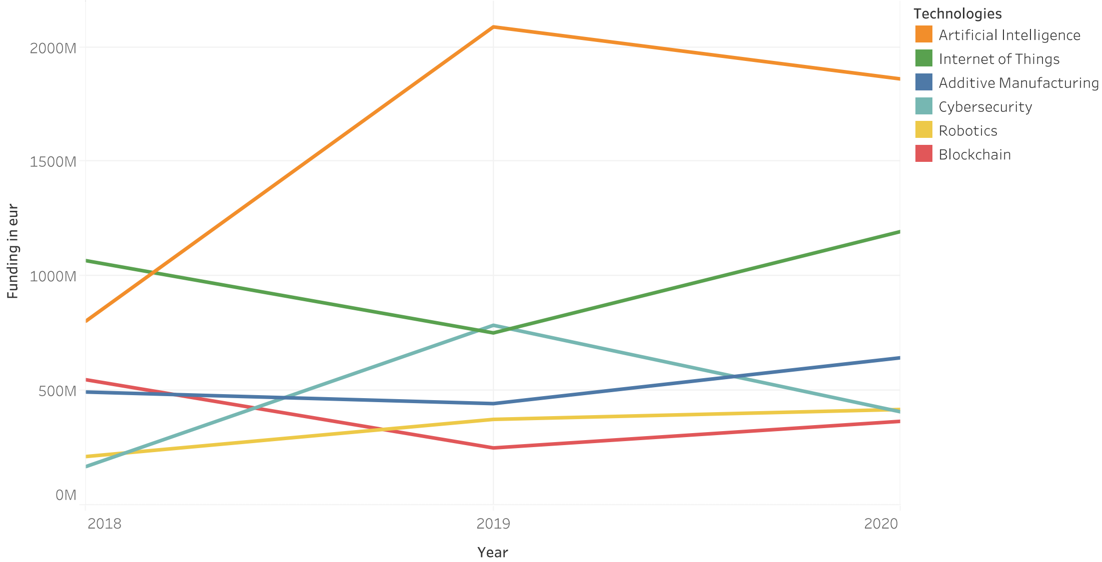
Source: Technopolis Group based on Crunchbase and Dealroom

Increasing investment trends over time

Overall, venture capital deal volume continued to increase, driven especially by seed-stage deals as well as ongoing development and maturation of international startup markets in 2020. The picture is more nuanced across technologies. While some areas saw an increase in 2020 compared to the previous year such as Blockchain, Internet of Things or Additive Manufacturing, others like Cybersecurity had a lower investment volume compared to 2019. Firms developing Artificial Intelligence technologies managed to sustain their funding level although they received somewhat less funding than in 2019. In Blockchain technologies the year 2018 had a specific peak and a drop in 2019 (not just in the EU27 but also globally) but it started to increase again in 2020. Back in 2018 the centre of interest was on companies developing bitcoin as currency, then it has been shifted to private Blockchain providers. 2020 saw a lot of investment into the token economy[5].

[5] These findings are also in line with the analysis of CBInsights, please see https://www.cbinsights.com/research/report/blockchain-trends-opportunities/

Figure 8: Private equity and venture capital investment in the EU27 over the period from 2018 to 2020 for selected advanced technologies



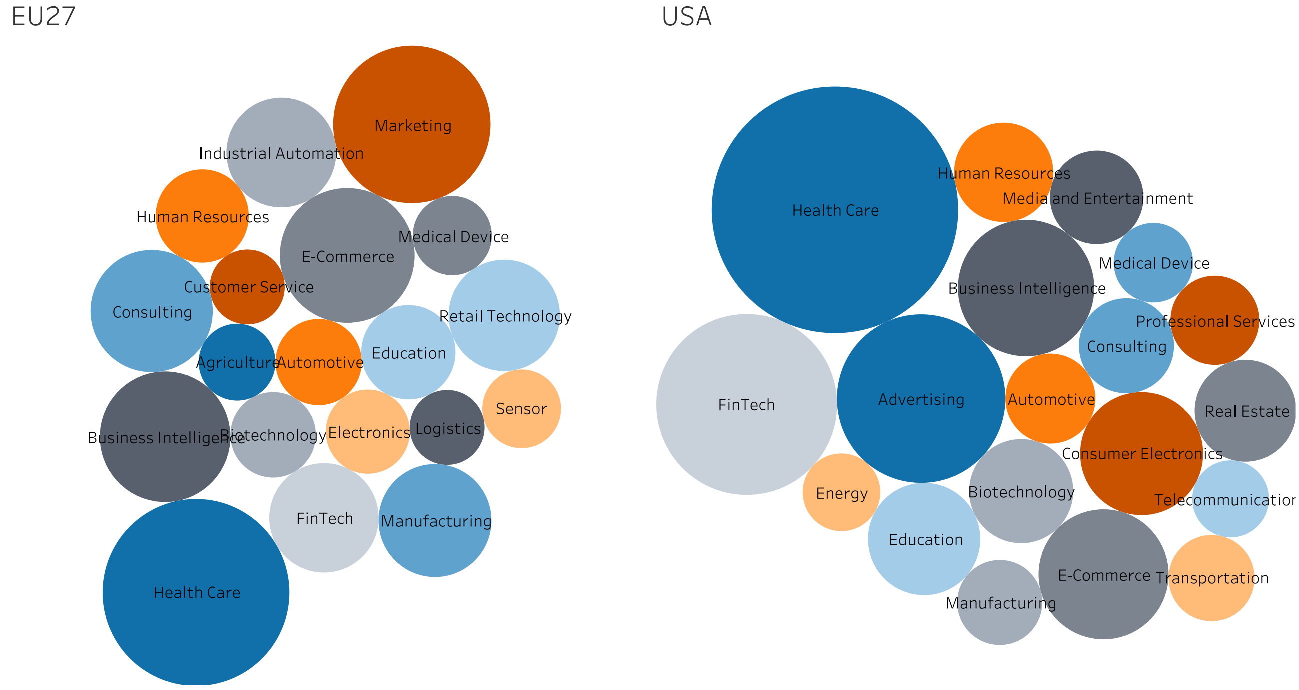
Source: Technopolis Group based on Crunchbase and Dealroom

Advanced technologies used for a specific purpose

Investment-backed firms can also provide an insight into the application areas that these firms are targeting, since each firm is tagged not just in terms of its main technological orientation but also related to its activity in a specific industry. When merging all the tags for each advanced technology, first of all we find that **advanced tech companies in the EU27 are connected to a lower number of industrial fields than companies in the US**, which might suggest a lower diffusion of technologies across the economy.

Figure 9 depicts the top 20 related fields to all advanced technologies for both global economies. The analysis of the tagging shows that while both in the EU27 and US it is **business analytics** that is the key focus area especially for AI and Big Data, followed by applications developed for the **healthcare sector**, the EU27 has a stronger orientation towards applications related to e-commerce, manufacturing, automotive, electronics, retail/supply chain management, while the US is focused on FinTech, healthcare/biotechnology, consumer electronics and education.

Figure 9: Top 20 industry tags related to investment-backed firms developing advanced technologies (2021)



Source: Technopolis Group based on Crunchbase and Dealroom

2.4 AI employment generated by EU27 and US companies across headquarters and other company locations

In order to better interpret the findings behind the data, one has to keep in mind that although some companies register their headquarters in one country, they have relevant labour force and development ongoing in another country. As it is well-known, European tech firms had to increasingly look for US investors to back their capital growth. There has been also a tech migration to the US. Some companies moved their headquarters abroad in order to have access to capital and larger markets. Examples include Dataiku that is an AI and machine learning company which was founded in 2013 in Paris. In 2019, Dataiku announced that CapitalG - the late-stage growth venture capital fund financed by Alphabet Inc. - joined Dataiku as an investor and that it had achieved unicorn status, valued at $1.4 billion[6]. Dataiku currently employs people worldwide in New York, Paris, London, Munich, Sydney, Singapore and Dubai.

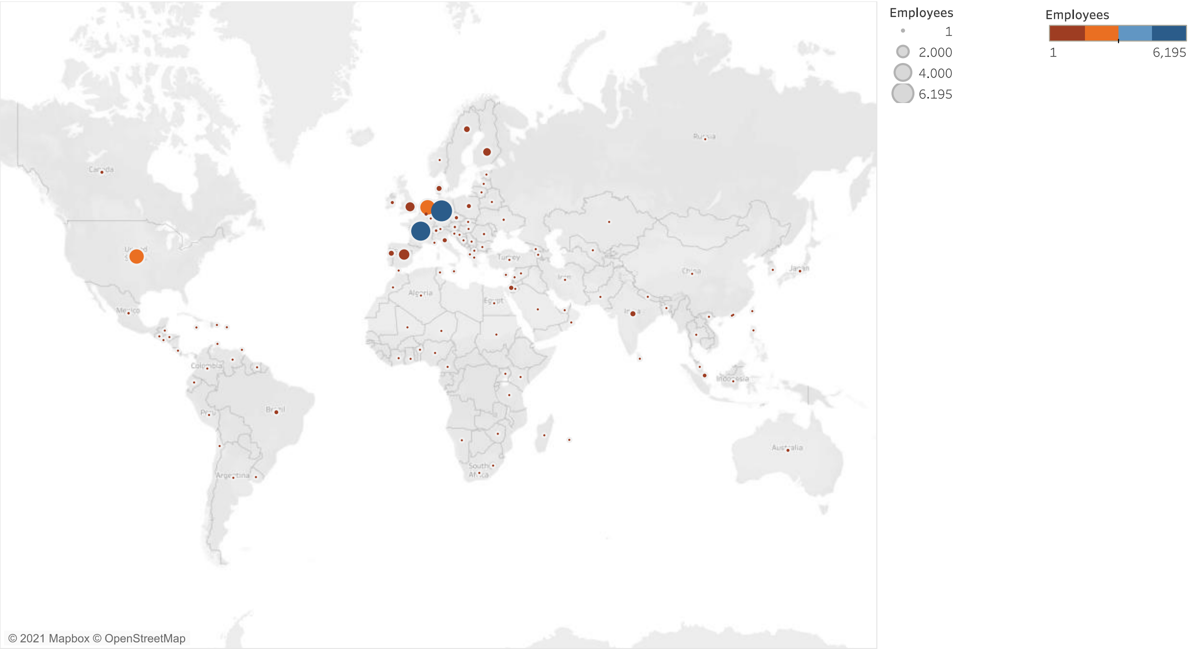
In order to get some insights into the geographical locations of the top AI investment-backed firms, we linked the Crunchbase and Dealroom data to their profile as published on LinkedIn. We have analysed the geographical location of the current employees (employed at these companies and with a profile on LinkedIn) and 1-year growth trends of AI firms (established after 2010 and backed up by private equity or venture capital) both in the EU27 and the US.

The results show that 9.9% of the workforce of EU27 AI venture capital backed companies are employed in the US according to the registered profiles of LinkedIn. On the other hand, 14.5% of the workforce in US AI companies is located in India and Israel.

[6] https://www.dataiku.com/

Figure 10: Employment related to EU27 Artificial Intelligence companies, 2021

EU27

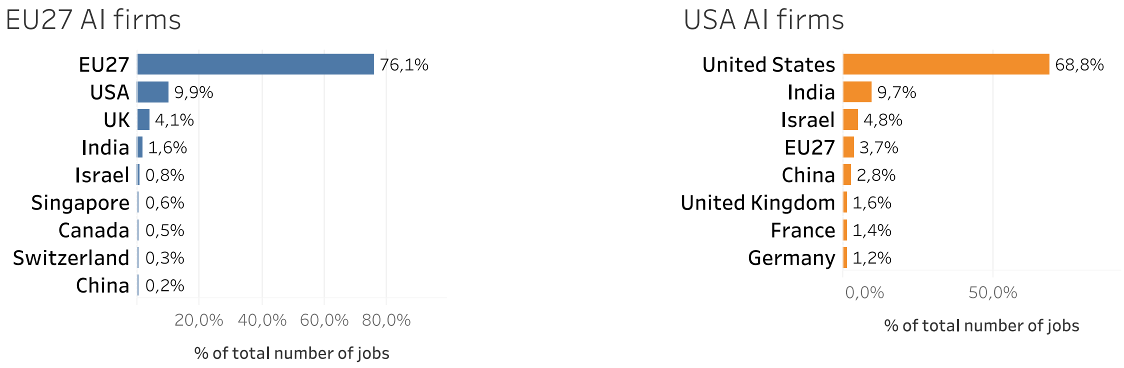


US

Source: Technopolis Group based on Crunchbase/Dealroom and LinkedIn

July 2021

Figure 11: Geographical distribution of the workforce employed by EU27 venture capital backed companies developing Artificial Intelligence technologies as registered on LinkedIn (2021)



Source: Technopolis Group based on Crunchbase/Dealroom and LinkedIn

2.5 Trade in goods relevant for advanced technologies

In general terms, Japan and South Korea display a positive trade balance in goods relevant for advanced technologies. South Korea has been able to improve it even further in recent years. The US, China and the EU27 on the contrary, have negative trade balances which, however, display different trends. While the US trade balance has been continuously decreasing from an initially close to balanced situation, the EU27 has been able to improve its position somewhat during the early 2010s although it now once more appears to be losing ground. China, finally, has seen its already negative relative trade balance decrease further, from -20% in 2008 to -30% in 2018. While the development dynamics in several of the specific domains mirror these general trends, some display additional, interesting particularities which will be illustrated in the following.

In the area of Micro- and nanoelectronics, South Korea has further improved its already robustly positive trade balance since 2016, while Japan's has decreased from +30% to +20% during the early 2010s. The US experienced this decay of a formerly substantial trade surplus even earlier and more fundamentally when imports started to match exports by about 2012. While the EU27 was able to improve its positioning notably during the early 2010s, its efforts seem to have stalled since. At the same time, China's trade balance remained persistently negative between -60% and -80% over time.

In the more specific field of goods relevant for Artificial Intelligence, in contrast, China features as a net exporter of relevant goods throughout the period of observation, as does, to a more limited extent, South Korea. This is interesting, as it documents that relevant capacities were present in these countries in the mid- to late-2000s, long before Artificial Intelligence per se rose to prominence. Europe, the US and Japan display notable, yet moderately negative relative trade balances. All three are losing ground less obviously than could be expected. Instead, Europe stabilised its position.

Concerning goods relevant for advanced manufacturing technologies, Japan, the EU27 and remarkably, also the US remained a net exporter throughout the period of observation, although the US experienced a visible decrease during the early 2010s. During the late 2000s, South Korea improved its position notably from that of a dependent net importer in 2005 (60%) to a more balanced situation in 2013 (-20%), where it has remained since. As in other domains, China's trade balance remained persistently negative between -60% and -80% over time.

Figure 12: Trade balance, 2018 (latest data available)

Source: Fraunhofer ISI calculations based on UNCOMTRADE data

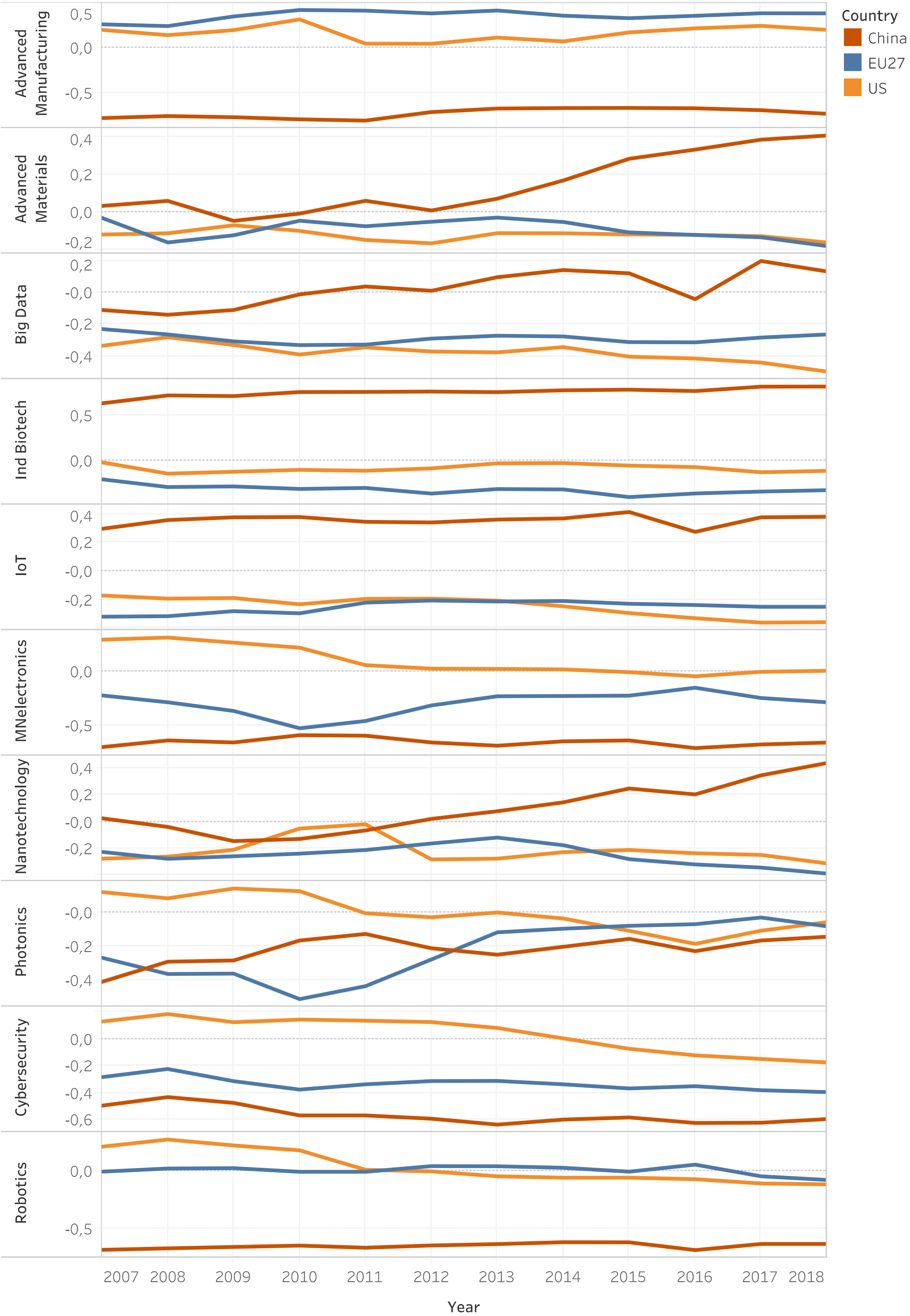
With a view to goods relevant for the Internet of Things, China and South Korea display notably positive trade balances from the outset, while Japan lost its position during the late 2000s and now runs a limited trade deficit. The US and the EU27 in contrast, featured as net importers throughout. While, during the mid-2000s, the US held a better position than Europe, the EU27 caught up until about 2012 after which it maintained its - still notably negative - relative trade balance of about -25%. The US, on the contrary, lost further ground during the mid-2010s, putting it in a more dependent position than ever by the end of the decade, with a relative trade balance of about -35%.

In the field of goods relevant for Big Data, a similar picture emerges with China and South Korea consolidating their position as net exporters (around 20%), Europe maintaining its own as a notable yet moderate net importer (around -25%) while the US gradually lost further ground, in this case, down to a relative trade balance of -50%. In this case, however, Japan's position has been much weaker to start with (-30%) and gradually worsened towards a state of substantive external dependency, similar to that of China in the domain of Micro- and nanoelectronics.

In the area of Robotics, finally, the analysis documents how dependent China still remains on the import of core components, and how little this situation has changed, despite the country's much improved capacity of exporting final products. South Korea and Japan, to the contrary, remain net exporters. While Japan has lost some ground, South Korea has increased its relation of exports to imports during the late 2000s and once more since 2016. The EU27 has displayed a neutral trade balance throughout as have the US, who used to be a net exporter during the late 2000s.

A final note of relevance is China's dynamic move towards becoming a substantial net exporter in Nanotechnology and Advanced Materials, two areas in which its trade balance had long been neutral. Since 2012, exports increasingly exceeded imports so that China's relative trade balance now matches that of the respective most prominent net exporters, Japan in Advanced Materials and Japan and South Korea in Nanotechnology, at around 40% respectively. Figure 13 on the next page presents the trade balance per advanced technology.

Figure 13: Evolution of trade balance in advanced technologies over the period from 2007 to 2018 (latest data available)



Source: Fraunhofer ISI calculations based on UNCOMTRADE data

Section 3

3. Technology uptake

3.1 COVID-19 reshaping EU Industries

The EU is recognised as a benchmark for technology implementation and innovation. When it comes to specific advanced technologies, some countries of the region play a pivotal role internationally[7]. The **second release of the Advanced Technologies for Industry (ATI) survey[8] (November 2020)** investigated a panoply of themes around the uptake of advanced technologies in the EU, 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, and the enabling conditions (e.g. investment in IT, funding sources, skills). As the survey took place at the end of 2020, it already reflects the pandemic's effects and the actions taken and priorities followed in industries to cope with the crisis. This survey is an updated version of the ATI survey held between June and September 2019.

The pandemic has **significantly reshaped industries across EU Member States.** The impact of the economic downturn on the data driven technologies and advanced technologies market can be seen in several areas, such as adoption of new technologies and new business strategies, but also in changes to resource allocations and budget priorities. The critical economic situation resulting from the pandemic is confirmed by the survey results, which show an **even distribution of the number of organisations that are still struggling to emerge from the crisis and are experiencing an economic slowdown or recession, and those that are in the ascending phase, moving towards the next normal**. However, the picture is different when we break down the data by sector. The pandemic hit industries unevenly depending on the varying impact of lockdown and social distancing restrictions on companies' business. The severe restrictions of movement imposed in almost all countries in the EU, for example, seriously affected the transportation industry, where more than 40% of firms are still stuck in the economic slowdown phase. Those restrictions, together with the general economic crisis and the loss of jobs, also significantly impacted the retail industry. Nevertheless, a significant proportion of organisations in this sector were able to keep their businesses running and growing thanks to the implementation of new retail platforms, the enablement of e-commerce interfaces and collaboration with suppliers and partners. Professional services is another sector in which organisations are struggling to emerge from the crisis. In this sector, the high proportion of small and midsize businesses (e.g. legal and accounting services providers, architectural and engineering firms), which are striving to adapt their models to meet new needs while facing lower demand for their services, also plays a role. Most organisations in the government and education sector are, due to the high levels of uncertainty and the crucial role they play in supporting citizens and other sectors, still in the economic recession or slowdown phases, and are not expected to recover quickly (although the overall effect of the pandemic has been less serious than in other sectors).

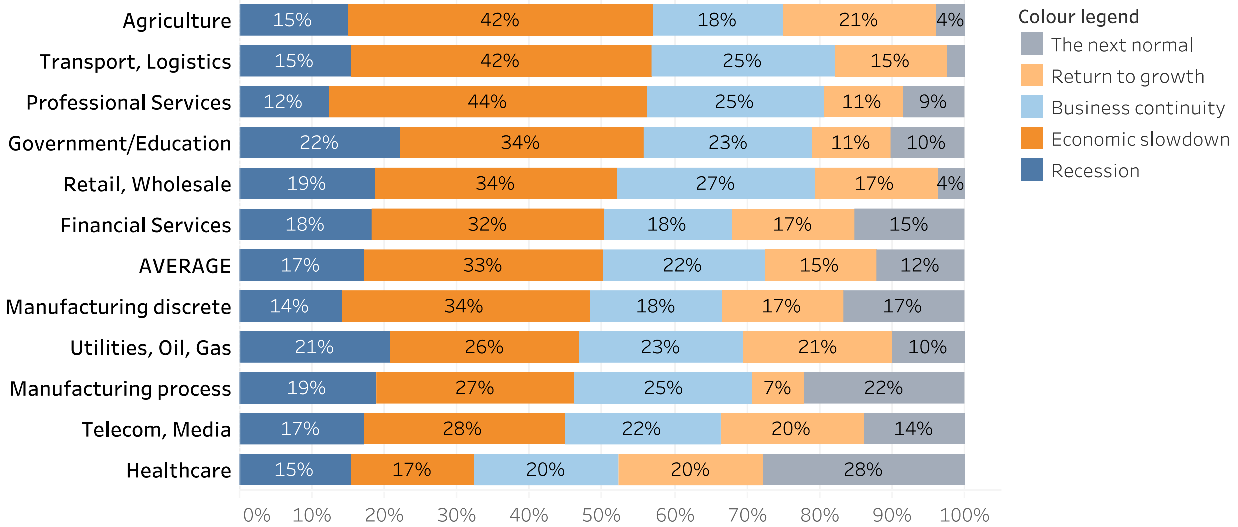
Although manufacturing was one of the hardest-hit sectors in terms of revenue declines in the first half of 2020, manufacturers were able to preserve the resiliency of the supply chain and production, slowly moving through the business continuity phase. In contrast, organisations in the healthcare sector are already getting back on the path of growth and getting ready for the new normal. Better management of the crisis and the fundamental role played by the healthcare sector during the pandemic are bringing the sector out of the recession phase. Telecom and media is another sector in which an above-average percentage of firms were able to keep their business running or are already back to growth and stabilising around the new normal. This is related to the pivotal role the sector has in the current situation: supporting remote working and improving internet connectivity have been the focal points of lockdown economies. The sector is also expected to benefit from the altered behaviour of consumers.

[7] See also the international analysis of the World Bank beyond what has been presented in the chapter before: Europe 4.0: Addressing Europe's Digital Dilemma, World Bank, November 2020., https://www.worldbank.org/en/region/eca/publication/addressing-europes-digital-dilemma

[8] The Advanced Technologies for Industry Survey (November 2020) sample consisted of 1 547 interviews of European organisations with more than 10 employees in Denmark, France, Germany, Italy, Poland, Spain and Sweden. Eligible respondents were individuals best qualified to answer questions about overall ICT, digital and technology strategy and activities. Additional information on survey methodology can be found in the ATI Methodological Report https://ati.ec.europa.eu/reports/eu-reports/advanced-technologies-industry-methodological-report

At the same time, the surge in end-user demand and potential customers represents an important source of growth for the coming months.

Figure 14: Where are EU industries on the COVID-19 'Return-to-Growth Curve'? (% of respondents)



Source: Advanced Technologies for Industry Survey, November 2020

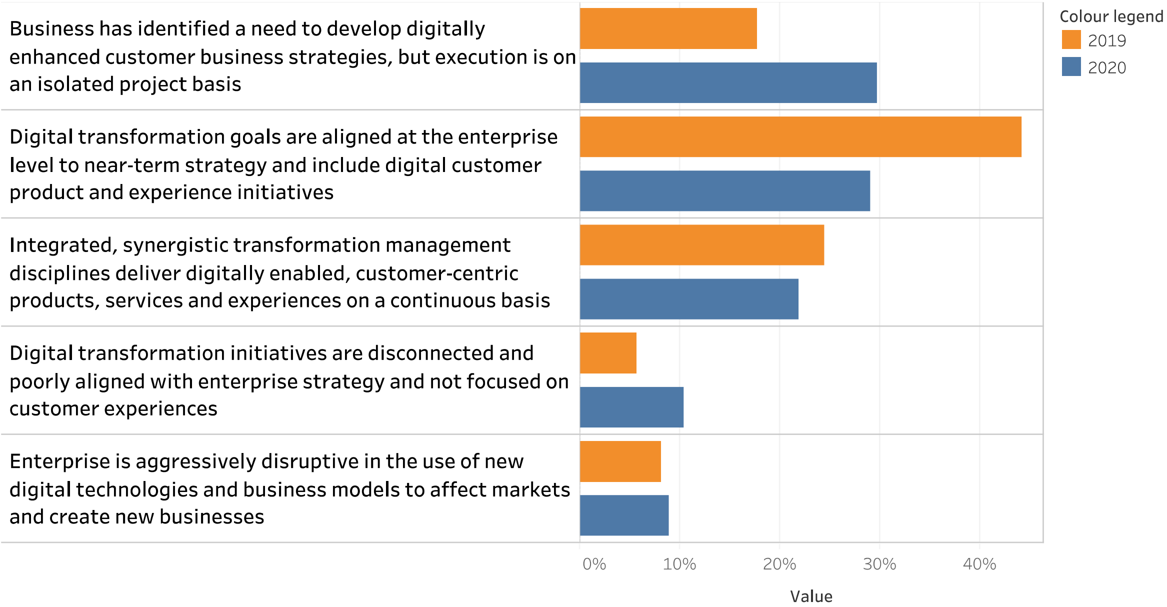
Notes: Business continuity — organisations are responding to the crisis and are focused on business continuity; Economic slowdown — organisations experienced a slowdown in revenue growth, shifting to cost-optimisation mode.; Recession — organisation expect revenues to be in prolonged decline, therefore focusing on building business resiliency; Return to growth — organisations are looking for more aggressive investments, as revenues are growing.; The next normal — organisations are stabilising into what is now the new normal, working to operate more as a digital enterprise as organisations see it vital to the success of business.

3.2 European digital transformation plans and advanced technologies uptake

Though, on one hand, the pandemic led to severe economic damage to organisations, on the other hand it gave them a new awareness of their digital transformation maturity levels. Compared with the previous ATI survey, there has been a strong shift back to early digital maturity stages. **The crisis not only changed and accelerated industries' digital trajectories, but also dramatically tested their digital strategies and maturity, touching some 'sensitive nerves' and highlighting some latent challenges** in organisations' digital backbones. This led to a more realistic self-assessment of in-house digital maturity and capabilities and is behind the year-to-year change.

Businesses realised the need for a solid and structured digital business strategy, as advanced technologies represent one of the main tools to overcome the crisis. The proportion of organisations that identified this need is 50% higher than in the previous ATI survey, showing the role of the pandemic as a forceful digital transformation driver. Moreover, the actual downturn significantly changed enterprises' digital transformation goals and short-term strategies. Enterprises are now looking for enhanced efficiency and significant cost savings, which is in turn affecting technology adoption by pushing firms towards those innovations that can support enterprises' strategies. This has led to a significant mismatch between digital transformation goals and the enterprises' short-term strategies, as can be seen by comparing the blue bar (2020) to the orange bar (2019) in Figure 15, below.

Figure 15: European organisations' approach to digital transformation (% of respondents)

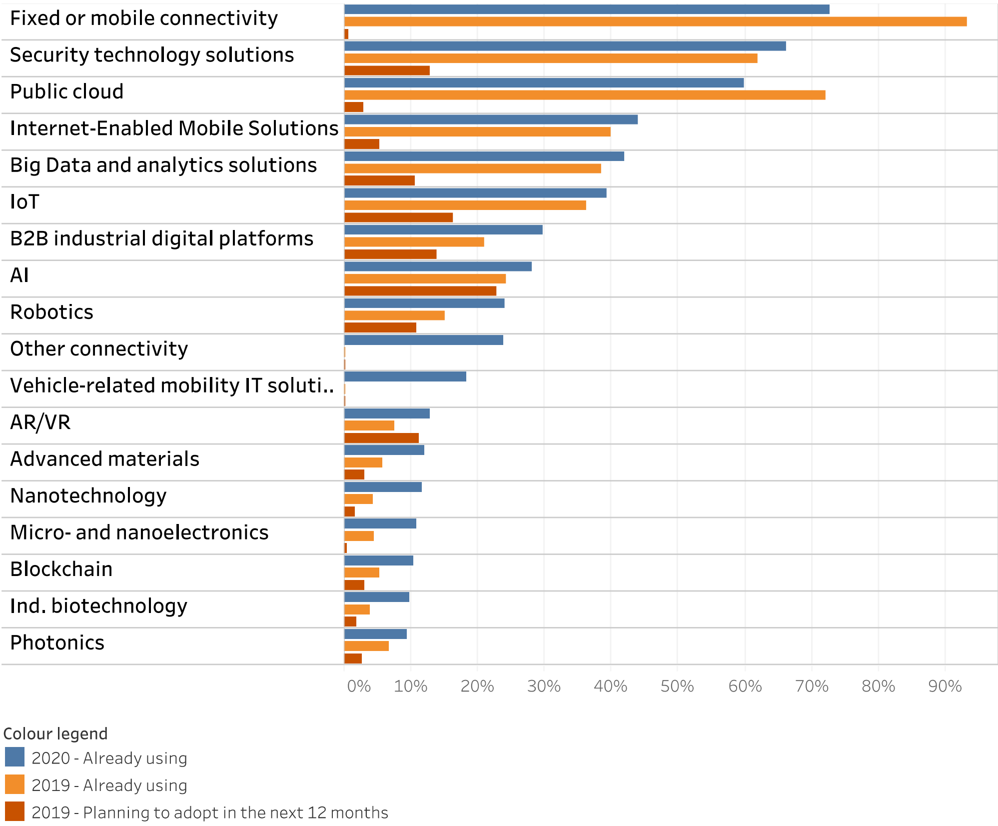


Source: Advanced Technologies for Industry Survey, November 2020

Compared with the previous ATI survey, all advanced technologies show a higher level of adoption. The pandemic forced enterprises to embrace a new way of working and running the business, with technologies that played a pivotal role in enabling business initiatives around response and resiliency. **Fixed and mobile Connectivity, Cloud and Big Data solutions** — in conjunction with other traditional technologies — are at the core of new-normal imperatives such as process automation, agile customer interaction and remote working. Moreover, technologies such as **industrial digital platforms show a significant upsurge** compared with last year, due to the increased need for collaboration between colleagues, peers and employees. However, while **the pandemic** has fostered the adoption of technologies that can help businesses to continue their daily activities, the impact on the economy, and therefore on enterprises' revenues, has **pushed companies to reassess their long-term strategies and digital investment plans**.

The focus on more business-contingent priorities forced many organisations to postpone and delay their innovation road maps, meaning that some adoption plans that were in place at the beginning of 2020 have been drastically revised. This phenomenon is well shown in Figure 16, where the actual adoption of advanced technology in 2020 is compared with the adoption and plans for adoption in 2019. For instance, adoption of **AI and IoT** was expected to increase significantly in 2020, according to the 2019 survey results, with the proportion of firms adopting AI predicted to almost double. These technologies **ended up with much smaller, although significant, growth**. On the other hand, technologies such as Blockchain, industrial biotechnology, micro- and nanoelectronics and nanotechnology are faring well in the uncertain landscape, recording a greater-than-expected number of firms implementing them in their activities. This can be explained by both the new role that these technologies are playing in some sectors (such as advanced materials in Utilities, where this innovation is leveraged to achieve a more efficient use of energy) and by the maturity starting point for these technologies, which are still at a very early stage in terms of market understanding and penetration.

Figure 16: Adoption of advanced technologies across European organisations – comparing 2019 and 2020 ATI survey results (% of respondents)

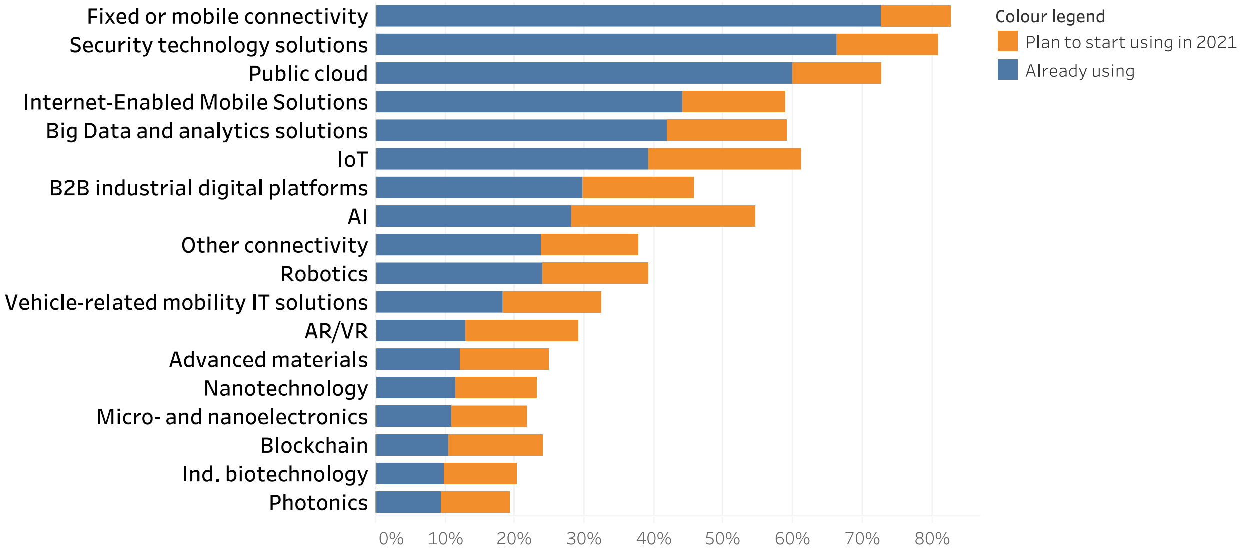


Source: Advanced Technologies for Industry Survey, July 2019; November 2020

Note: Orange bar shows the percentage of firms who were adopting or planning to adopt a certain advanced technology in 2019, while the blue bar represents the adoption level in 2020.

Figure 17 below shows the current adoption levels of advanced technologies and how the landscape will change in light of organisations' plans for the next 12 months. **The high level of adoption of security** solutions is related to their crucial role in day-to-day activities, ensuring trust and protecting the enterprise's digital environment from external threats. **Fixed/mobile connectivity and public cloud** represent the foundation of technological innovation in Europe, making viable the implementation of new technologies such as IoT, AI, big data and analytics, and mobile solutions. The role of these technologies in shaping the digital environment has been increasingly affirmed in recent years. However, their adoption levels are still far from the top-ranking technologies shown on Figure 17. **Artificial intelligence and IoT are the two technologies** in which companies are investing heavily and are therefore increasingly gaining ground. These technologies are crucial in allowing enterprises to adapt to the new models based on, for example, remote collaboration and custom interaction automation. Other technologies, such as **Robotics, B2B industrial platforms and AR/VR, are quickly taking ground** thanks to the increasing number of use cases and business scenarios where they can be applied. On the opposite side, the results show how **Photonics, industrial biotechnology, micro- and nanoelectronics, nanotechnology, Blockchain, and advanced materials are still niches** for specific industries and generally have low penetration rates across verticals.

Figure 17: Advanced technologies current uptake in the EU (% of respondents)



Source: Advanced Technologies for Industry Survey, November 2020

AI and IoT are playing pivotal roles in the crisis, as will be evident in the adoption growth rates over the next 12 months. According to the survey results, these two technologies are expected to record the highest adoption-rate increases as firms change their business models and implement new processes to foster efficiency, achieve cost savings and improve performance. Although the levels of AI and IoT adoption have thus far been lower than those of some other technologies, the expected AI and IoT adoption-rate increases will be far higher than those of most, if not all, others. Irrespective of the causes, a common adoption growth pattern can be outlined — one resulting from several factors, including an abrupt change to established business paradigms over the past year. Clearly, then, the pandemic is driving deeper adoption of advanced technologies, both to cope with the current situation and to prepare for the next normal.

As depicted in Figure 18, while some technologies are generic in nature and show a marked horizontal spread, other technologies clearly show 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. In the next few years, factors such as new features, price levelling, enhanced ICT infrastructure and evolutions in terms of digital maturity will lead to higher uptake of all the technologies identified, across the board. In the matrix below, colours refer to the percentage of firms adopting a specific technology, ranging from 5% (light green) to 90% (dark green) of firms in each industry.

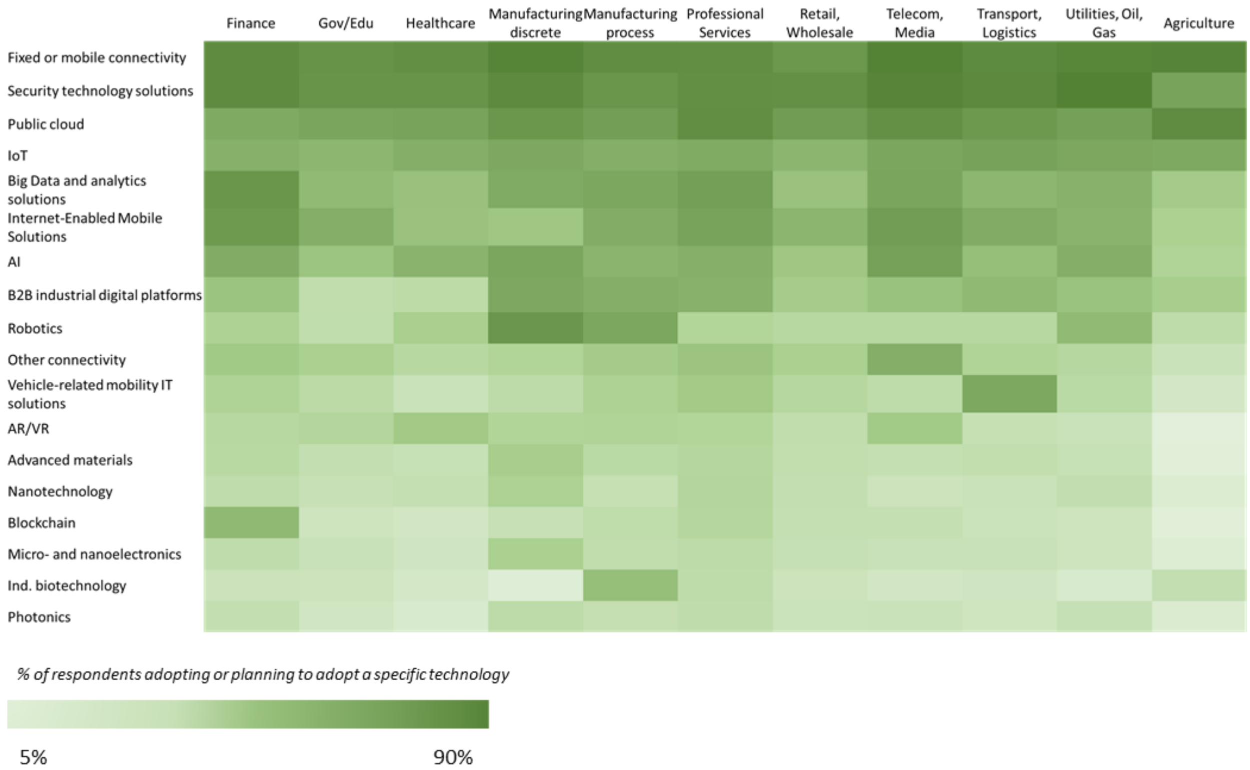
Looking at the results by industry, while **more mature general-purpose technologies such as connectivity, cloud and security show homogenous uptake across all industries**, **new emerging technologies are more niche and industry specific**. Examples include Blockchain, which has gained a foothold in the finance sector, and micro- and nanoelectronics and nanotechnologies, which, together, show high levels of verticalisation, particularly in the manufacturing domain. As the technology matures, new application areas and use cases will emerge and proliferate to drive business value in other industries. In manufacturing, for example, Blockchain is increasingly used to keep track of and certify product sources along the value chain, while Robotics, initially implemented for production automation and warehouse inventory management, has found applications in the healthcare sector, where it is used to support medical personnel in enhancing safety procedures, reducing operative costs, disinfecting rooms, preparing and storing medications, and much more.

Compared with the 2019 ATI survey results as presented in the Advanced Technologies for Industry – General Findings report on technology trends, technology uptake, investment and skills in advanced technologies[9], **industries show some similar technological patterns**. Connectivity, public cloud and security technologies are among the most adopted technologies, with small differences between industries, while advanced materials, nanotechnologies and industrial biotechnology represent a niche in a few sectors, such as manufacturing and healthcare. **Compared with the 2019 results, B2B industrial digital platforms are quickly taking ground in manufacturing and agriculture, while**

[9] https://ati.ec.europa.eu/reports/eu-reports/report-technology-trends-technology-uptake-investment-and-skills-advanced

IoT and AI show an interesting increasing pattern in transport and healthcare. While this might seem in contradiction with the struggling status of the transport sector, the adoption of these two technologies was necessary to cope with the crisis through several methods, such as real-time data exchange and contactless interaction. Moreover, the transport sector is a broad sector. Though on the one hand, public transport has been seriously affected by the pandemic, on the other hand, growth in e-commerce has increased courier activity, which has ultimately affected overall spending and the adoption of advanced technologies. Firms in the finance sector are more and more interested in robotic process automation, with the 7% of organisations that had adopted or were planning to adopt this technology in 2019 jumping to 36% in 2020, representing one of the highest increases in adoption rate across industries and proving the high potential this technology has in the sector. On the other hand, some technologies are slowing down. While industrial biotechnology is increasingly adopted in manufacturing, it is decelerating in utilities. A similar trend is visible for public cloud in healthcare and retail.

Figure 18: Advanced technologies uptake by EU industry, 2020 (% of respondents adopting or planning to adopt a specific advanced technology)

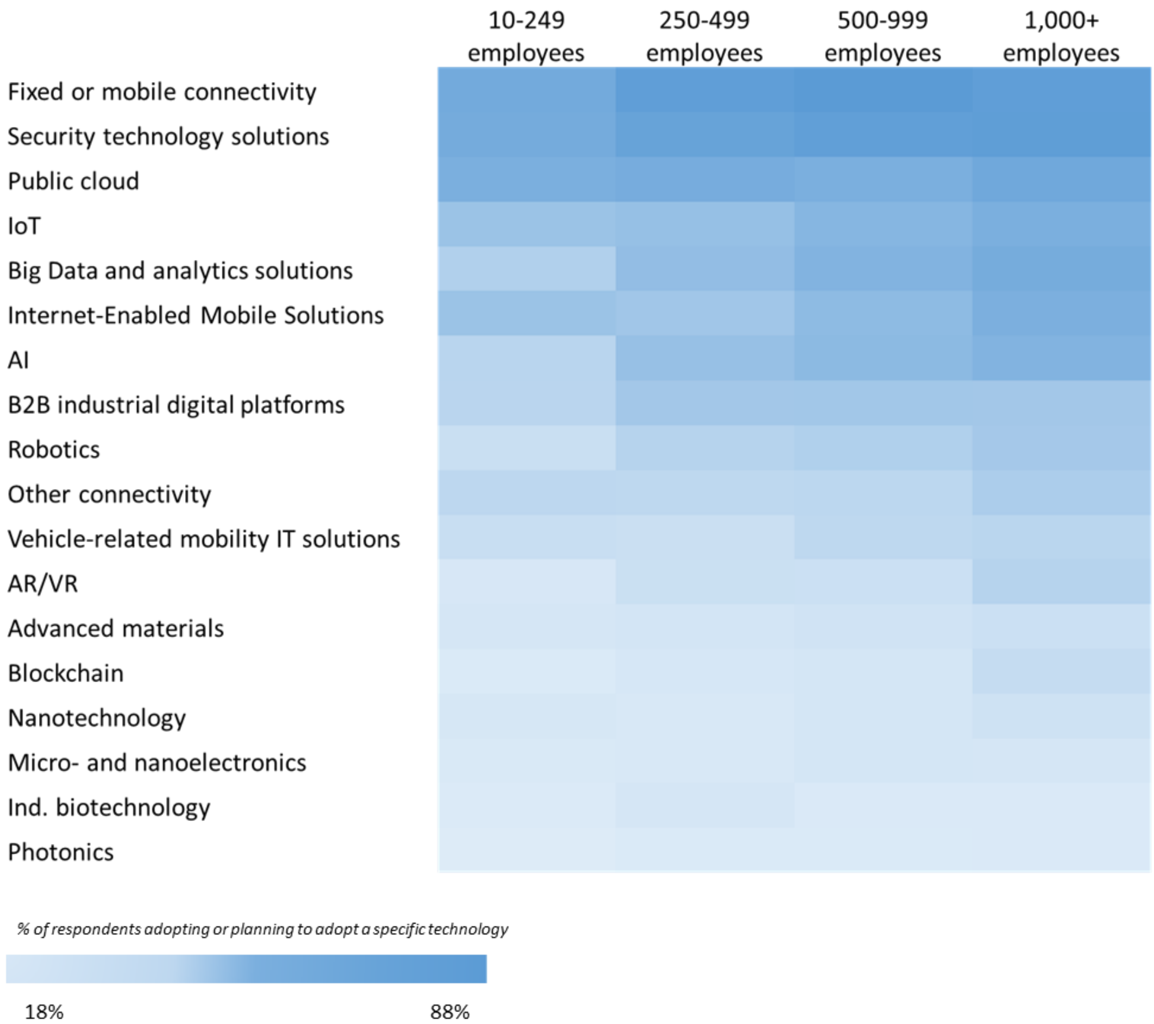


Source: Advanced Technologies for Industry Survey, November 2020

Figure 19 shows organisations' **adoption of advanced technologies based on their size**. Four size bands 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. In the matrix below, colours refer to the percentage of firms adopting a specific technology, ranging from 18% (light blue) to 88% (dark blue). When comparing the latest results with those from 2019, some interesting points emerge. **Regardless of size, all organisations are opening up to new technologies**, exploiting their functionalities in dedicated activities and adapting them to completely new contexts. On average, compared with the previous survey, the proportion of firms that are already adopting a certain technology or planning to use it is almost 20 percentage points higher. This **phenomenon is more pronounced if we only consider small enterprises (25 percentage points higher).**

Although SMEs are rapidly moving towards a new digital environment, pre-COVID barriers to digital adoption remain. Access to infrastructure, low interoperability of systems, a lack of data culture and digital awareness, internal skills gaps, financing gaps to cover high sunk costs for transformation, and uncertainty about liabilities and responsibilities when engaging in new digital activities are among the main hurdles small firms have faced. These problems widen the adoption gap between small and large firms, especially in more sophisticated technologies such as data analytics, Artificial Intelligence and Robotics. Smaller firms were less prepared for the impact of COVID-19 during 2020, with the lack of adequate infrastructure, the need for high initial investment, and few opportunities to scale being among the main drivers of that situation. Therefore, small enterprises had to investigate new opportunities and start planning for new technology adoption over the subsequent year, to adapt their business and operating processes and get ready for the next normal.

Figure 19: Advanced technologies uptake by size, 2020 (% of respondents adopting or planning to adopt a specific advanced technology)



Source: Advanced Technologies for Industry Survey, November 2020

Note: The graph considers the number of firms that are adopting or planning to adopt one of the listed advanced technologies.

3.3 Use cases — where advanced technologies are applied

While adoption levels are interesting on their own, it is important to look at the concrete business scenarios where advanced technologies are applied: the **use cases**. Some emerging technologies, such as IoT, AI, Robotics, AR/VR, Blockchain, nanotechnology, advanced materials, micro- nanoelectronics, Photonics and industrial biotechnology, enable a good mix of horizontal and industry-specific use cases. Although the range of use cases differs depending on industry-specific needs, some common traits can be found across each sector. **IoT**, for example, finds its main role in process automation, prediction and monitoring functions. The first use case is mainly used in manufacturing processes to track materials and products, while agriculture and transportation organisations leverage IoT to manage climate conditions and monitor container conditions, respectively. For many industries, **Artificial Intelligence** means higher efficiency. AI has found common uses in diverse sectors, from finance to manufacturing, from healthcare to utilities: AI is used to enhance the efficiency of digital channels for finance organisations (e.g. voice banking and webchat), for intelligent patient monitoring in healthcare and to create prevention systems for professional services. **Robotics** also shows some common traits across industries. Monitoring, surveillance, customer assistance and inventory management are some of the main uses of robotic process automation across different sectors, which ultimately allows companies to save time and foster efficiency. Robotics is also playing a crucial role in coping with the pandemic, enabling zero-touch production (ZTP) and contributing to process automation and autonomous operations. **AR/VR** can provide in-depth and more concrete training, ranging from simulated agriculture training to on-field technician assistance to customer-experience improvement. AR/VR is also fostering efficiency by providing remote support to on-field operators and industrial maintenance. Moving on to **Blockchain**, this technology is mainly used to comply with regulations, although several other use cases have been exploited such as smart logistics networks, digital rights protection, clinical records and identity management. **Nanotechnologies**, **advanced materials**, **micro- and nanoelectronics**, **Photonics** and **industrial biotechnologies** present very similar use cases across different sectors, but their applications are far from being completely exploited. For example, micro- and nanoelectronics are bringing equipment technology to the next level, alongside progress in Photonics technology that enables enhancement of intelligent/sensor-based equipment. However, it is very likely that these new technologies will be implemented in different industries in the future, leaving behind their niche status. For example, Photonics is slowly gaining ground in the transport sector, where it can be used for traffic analysis and surveillance, smart vehicles and infrastructure quality assessment, while advanced materials are increasingly used in the utility sector to improve the usable lifetime and charging rates of energy storage devices.

Figure 20: Most frequently adopted use case by advanced technology

Advanced technology	Use case	Description	Industry
Internet of Things	Asset tracking and monitoring	Tracking of assets and monitoring of different metrics and variables	Manufacturing, Finance, Retail, Professional services
Artificial intelligence	IT automation	Creation of software and systems to replace repeatable processes	Manufacturing, Healthcare, Professional services, Telecom, Media
Robotics	Security and surveillance; inventory management	Automated monitoring and investigating operations; automation of handling, picking, sorting, and replenishment of products	Agriculture, Finance, Gov/Edu, Manufacturing, Professional services, Telecom, Media
AR/VR	Workforce training	Enabling learners to practice skills in a simulated environment	Transportation, Healthcare, Gov/Edu, Manufacturing, Utilities, Oil&Gas, Telecom, Media
Blockchain	Regulatory compliance; asset/goods management	Keeping track of the steps required by complex regulations; managing the transfer of an asset from one entity to another.	Agriculture, Finance, Transportation, Manufacturing, Professional services, Telecom, Media, Retail
Nanotechnology	Nanoparticles, nanowires and tubes	Nanoscale particles, wires and tube used in many different fields (optics, genetics, electronics)	ALL SECTORS
Advanced materials	Advanced metals	Metals with enhanced features obtained with specific manufacturing processes	ALL SECTORS
Micro/Nanoelectronics	Integration system	Integration of multiple functions on a chip	ALL SECTORS
Photonics	Sensor-based equipment	Use of devices equipped with sensors able to collect and generate large amount of data and information	ALL SECTORS
Industrial biotechnology	Bio-based chemicals	Chemical products that are wholly or partly derived from materials of biological origin (e.g., biomasses, feedstock, but also plants, algae and crops)	ALL SECTORS

Agriculture · Healthcare · Retail · Utilities, Oil&Gas · Finance · Manufacturing · Telecom, Media · Gov/Edu · Professional services · Transportation

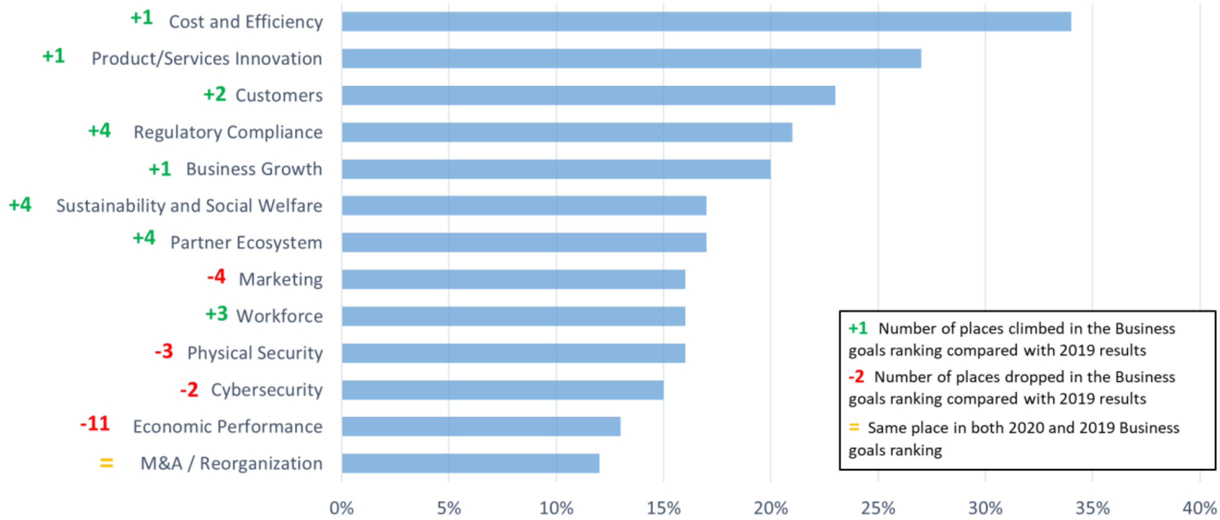
Source: Advanced Technologies for Industry Survey, November 2020

Note: The list picks the most recurrent use case by sector for each technology.

3.4 Business goals — what are the drivers of advanced technology adoption?

As mentioned above, the pandemic forced European companies to slow down and rethink their advanced technology innovation road maps to cope with the economic shock resulting from lockdown measures and restrictions. Firms were forced to focus on the technological investments needed to face the crisis, allocating the available resources to the key priorities for supporting business activities. However, the adjustment of operating models was not the only reason why European organisations invested in advanced technologies. The pandemic was also an occasion to accelerate the innovation plans already in place, and in some cases, even to transform business models.

Figure 21: Business goals driving advanced technologies adoption across EU Industries (% of respondents)



Source: Advanced Technologies for Industry Survey, November 2020; July 2019

Note: Business goals have been framed differently according to the specific vertical. For examples for government, education and healthcare, the customer priority is related to citizens, students and patients, respectively. For each driver on the left, the difference in the business goals ranking compared with 2019 results is indicated.

Figure 21 clearly shows how securing and maintaining the business was among the main reasons for the adoption of advanced technologies, together with the opportunity to proactively exploit the new social and economic scenarios that have arisen from the pandemic in Europe. By analysing the top five business goals, it is possible to identify the main reasons underpinning decisions to invest in advanced technologies at European companies in 2020:

- **Reducing operational and/or product costs:** The top investment driver (34%) for European companies was the need to optimise their own operating model, eliminating inefficiencies and cutting costs as much as possible.
- **Product/service improvement and innovation:** European firms not only had to rethink their business processes, but also to innovate their products and services (27%) to meet clients' emerging needs and to exploit new market opportunities (e.g. remote customer service to avoid physical interaction).
- **Attracting and retaining customers:** The pandemic also pushed organisations to rethink the interaction with both business and consumers clients (23%).
- **Managing regulatory compliance:** This driver was important (21%) for all the regulated industries in parallel to the other business-oriented motivations.
- **Expanding into new markets, segments or geographies:** In many cases, the pandemic did not slow down companies' strategies, but offered an opportunity to expand (20%) — for example, high-tech electronics manufacturers widening their offer for home-based workers.

When comparing the 2019 and 2020 survey results, it is notable **that the pandemic did not shake up the priorities underlying the adoption of advanced technologies, with the single exception of the economic performance driver**. European companies partially postponed economic performance objectives, focusing in the short and medium term on both the operational and strategic changes needed for the survival of the organisation.

Figure 22: Business goals driving advanced technologies adoption by EU industry (% of respondents driven by specific business goal)

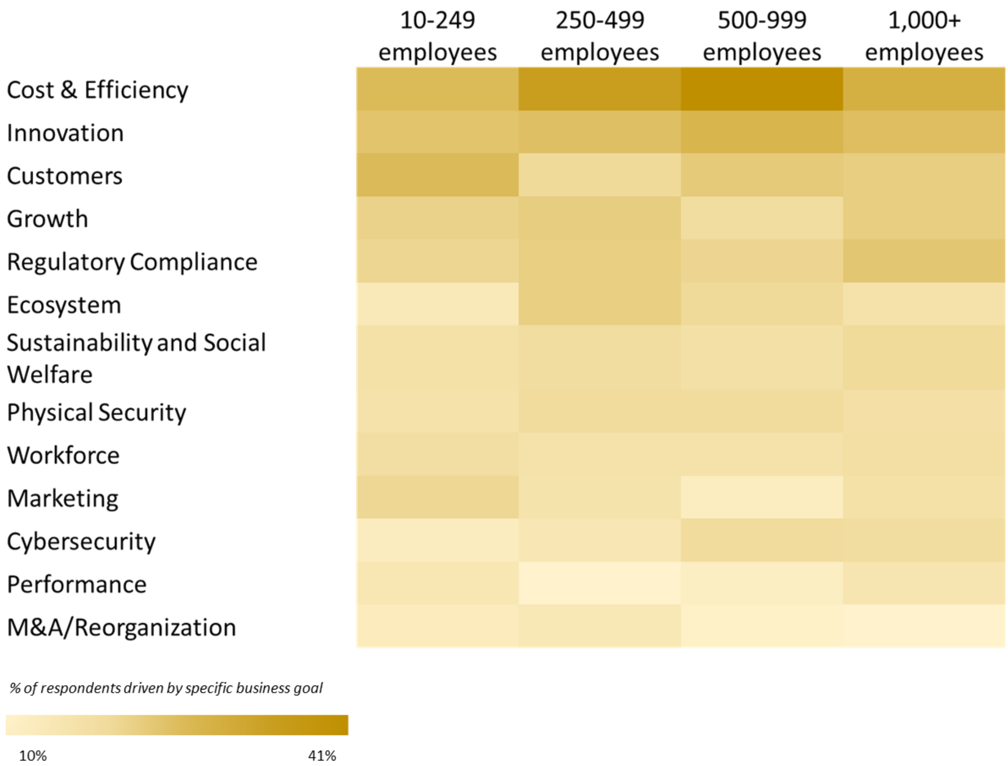
Source: Advanced Technologies for Industry Survey, November 2020

Figure 22 above provides a breakdown of business goals by industry. Colours refer to the percentage of firms driven by specific business goal, ranging from 4% (light red) to 52% (dark red). Some relevant differences across sectors can be highlighted.

Firstly, **reducing operational and/or product costs was especially important for the industries that were impacted the most by the restrictions** and had to significantly alter their business processes, namely discrete manufacturing, transport/logistics and utilities/oil and gas. The industrial sector (manufacturing and utilities/oil and gas), agriculture and healthcare also focused on product/service improvement and innovation to cope with the radical changes in the market and to society. Client-facing industries (retail/wholesale, telecom/media and transport/logistics) were shocked by lockdowns and restrictions and had to adjust or even reinvent their own front-end processes. As already highlighted, highly regulated industries such as finance, government/education, professional services and utilities/oil and gas had to deal with the changing business landscape in parallel with regulatory compliance. Finally, some of the industries most impacted by the crisis, such as retail/wholesale, manufacturing and transport/logistics, also tried to leverage advanced technologies to foster their own growth through expansion into new market segments.

If we look at the breakdown of the business goals driving advanced technologies adoption by company size, we can also identify some relevant trends (Figure 23). As before, colours refer to the percentage of firms driven by specific business goal, ranging from 10% (light yellow) to 41% (dark yellow).

Figure 23: Business goals driving advanced technologies adoption by European company size (% of respondents driven by specific business goal)



Source: Advanced Technologies for Industry Survey, November 2020

While **cost and efficiency was a relevant business goal in small and very large firms, it represented a real priority for medium-sized and large enterprises**. For small companies, this business goal was accompanied by more attention to customers, considered as a critical factor for the organisation's survival in the uncertain economic landscape. For very large companies, other 'non-emergency' factors such as regulatory compliance were also at the top of the business agenda. Another interesting trend is the importance that developing a business ecosystem had in medium-sized companies (250-499 employees) — it is considered as a key factor in improving collaboration with both suppliers and customers and helps absorb the impacts on the supply chain.

3.5 Business impact — how advanced technologies are impacting business variables

Besides business goals, the concrete impact that advanced technologies had in supporting EU companies' abovementioned objectives should also be considered. Firms were asked to specify what percentage of improvement was linked to the adoption of advanced technologies for the following business KPIs (Key Performance Indicators). Considering only the answers indicating at least a 10 percentage points positive increase, we can define the following ranking (Figure 24).

Figure 24: Business KPI improvements linked to advanced technologies adoption (% of respondents)

Source: Advanced Technologies for Industry Survey, November 2020; July 2019

Note: For each business KPI, only the answers indicating at least a 10% positive increase are depicted.

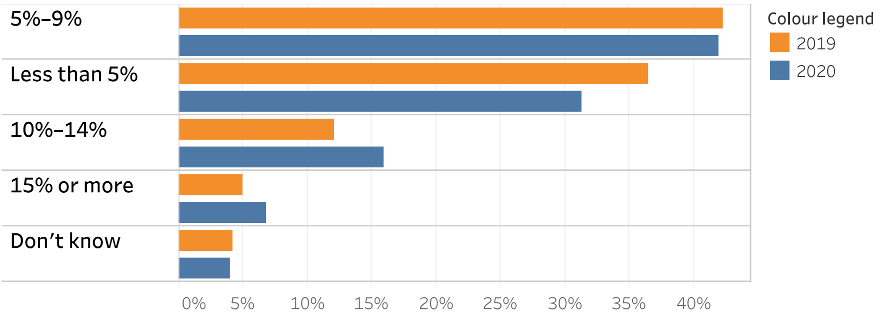
It is notable that, for all the KPIs analysed, **more than one-third of the interviewed companies stated that the benefit from the adoption of advanced technologies was more than 10%.** This is a clear confirmation that the abovementioned objectives were effectively supported by the use of those technologies. It is also worth mentioning that the two KPIs on which advanced technologies had the biggest impact were customer satisfaction (53%) and time efficiency (50%). Therefore, advanced technologies guaranteed the expected results both in terms of effectiveness (satisfying clients' emerging needs) and in terms of efficiency (improving the organisation's operating processes). Moreover, time efficiency and cost reduction were also the two KPIs with the most improved performance from 2019 to 2020 (27 p.p. and 23 p.p., respectively), which is significant considering that both KPIs are closely linked to the top 2020 business goal, namely cost and efficiency.

For all the KPIs analysed, the percentage of companies that indicated a positive impact of at least 10% was significantly higher in the 2020 ATI survey than in the previous year. This performance can be explained by the rationalisation and optimisation of investments in advanced technologies that were necessary to cope with the crisis. Therefore, companies decided to invest in a more efficient and short-term oriented way, focusing mainly on safe bets rather than on big bets.

Investments — advanced technology budget allocation and management

Investments in IT and new technologies slightly changed in comparison with the pre-COVID scenario, with 65% of firms stating they spent at least 5% of their revenue on IT, against the 59% that said the same at the end of 2019 (Figure 25).

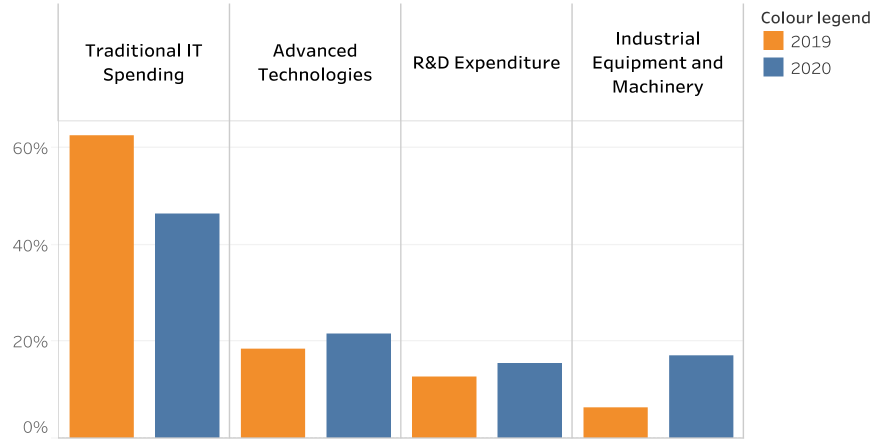
Figure 25: Revenue invested in IT and new technologies by EU Industry (% of respondents)



Source: Advanced Technologies for Industry Survey, November 2020; July 2019

However, some major changes in IT spending splits can be seen. European companies significantly decreased the relative share of investments allocated to traditional IT, **while they proportionally increased the resources dedicated to R&D, advanced technologies** and industrial equipment and machinery (Figure 26).

Figure 26: Allocation of European companies' IT/technology budget (% of respondents)

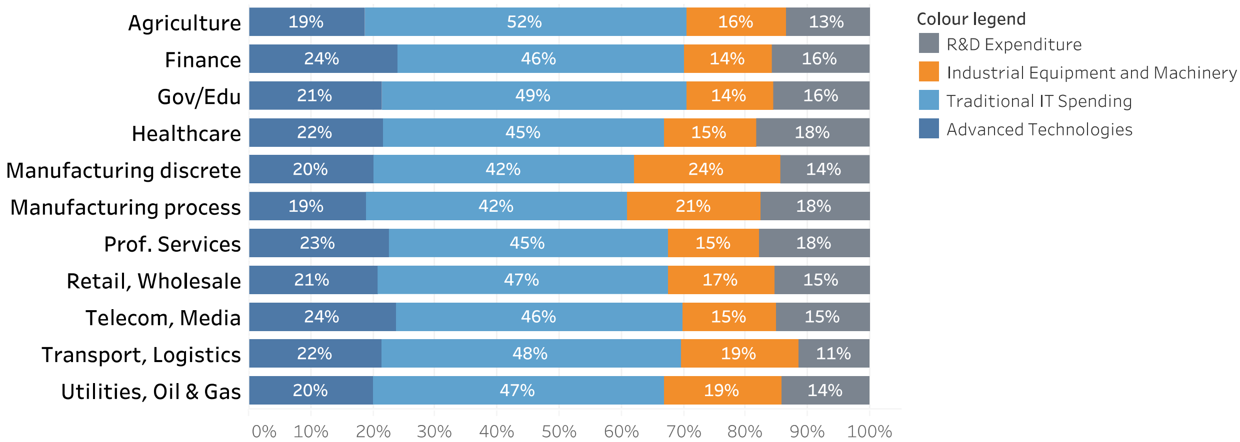


Source: Advanced Technologies for Industry Survey, November 2020; July 2019

Therefore, companies fully understood the relevance of infrastructure and new technologies as one of the key elements to face the economic crisis, as well as the fundamental role of IT in general in the company's yearly budget allocation.

Figure 27 below shows in detail the allocation of European organisations' IT/technology budget by industry. Industries were ranked based on the percentage of their IT/technology budget allocated to advanced technologies.

Figure 27: Allocation of organisations' IT/technology budget by European industry (% of respondents)

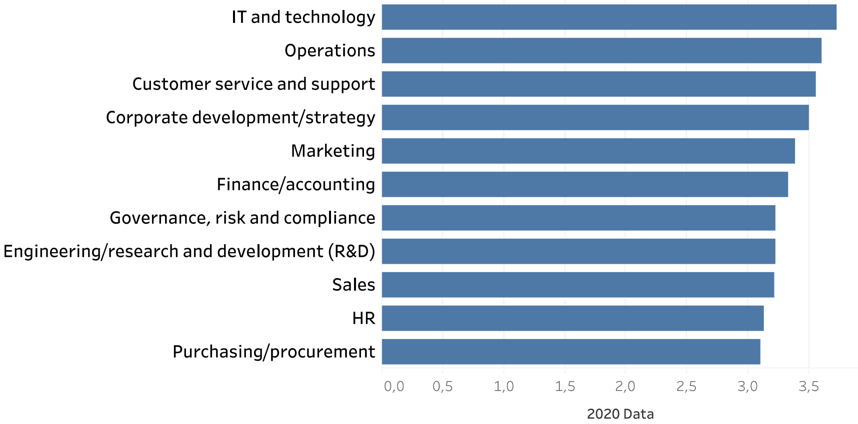


Source: Advanced Technologies for Industry Survey, November 2020

Interestingly, we can see that European organisations' IT/technology budget splits generally followed a common approach across industries, which indicates that the change in IT/technology budget allocation from 2019 to 2020 was a broad trend. However, some differences can be observed in the allocation of advanced technologies budgets, with the most digitally mature industries (finance, telecom and media, professional services) investing relatively more in technology-driven innovation and the industrial (manufacturing, utilities/oil & gas) and agriculture sectors lagging. On the other hand, manufacturing, utilities/oil & gas and transport/logistics were similarly focused on industrial equipment and machinery, which is often a prerequisite for implementing advanced technologies in those industries.

Even though the investments in advanced technologies were key for European companies to withstand the full impact of the crisis on their own business, the adoption of advanced technologies in 2020 was driven by business units (Figure 28).

Figure 28: Relevance of business units in driving adoption of advanced technologies across EU Industries (average score 1–5)



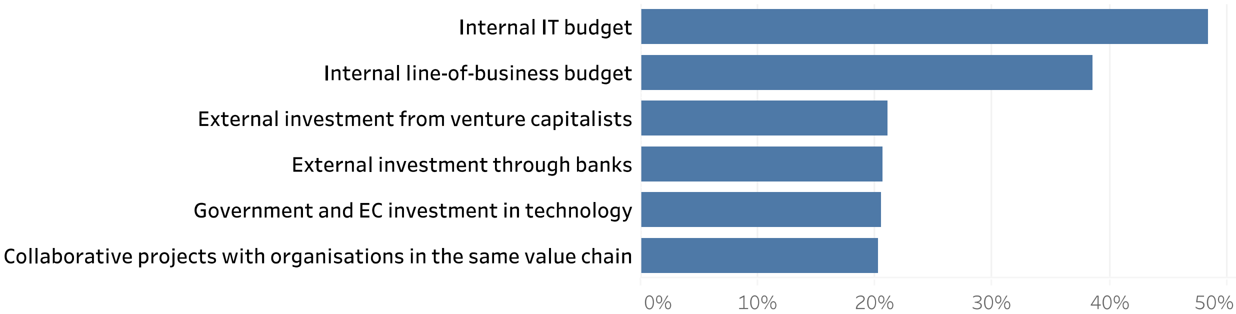
Source: Advanced Technologies for Industry Survey, November 2020

Note: Respondents were asked to rate the relevance of each business unit in driving adoption of advanced technologies from 1 ('Not driving adoption at all') to 5 ('Strongly driving adoption').

The innovation leader in advanced technologies was the IT function, which played a critical role in redefining companies' IT strategies in the past 12 months. In second place, **operations also gave a significant push to investments in advanced technologies**, which is consistent with the changes that many companies had to undertake to adjust their operating models. Next, we can see the **key role of customer service and corporate development functions**. This is consistent with the increasing importance of advanced technologies in 2020 in securing and, sometimes, accelerating companies' business as well as enabling product and service innovation, attraction and retention of customers and expansion into new markets.

Finally, Figure 29 shows the sources of European organisations' funding for investments in advanced technologies in 2020.

Figure 29: Source of European organisations' funding for investments in advanced technologies (% of respondents)



Source: Advanced Technologies for Industry Survey, November 2020

The two main sources were, by a big margin, internal IT and line-of-business budgets. External sources remain behind, all at more-or-less the same level. This is a clear indication of how European organisations relied mainly on their internal resources to boost innovation during the pandemic, but the major role of both private and public institutions in supporting digital transformation plans (especially on more risky and long-term bets) should also be highlighted. Indeed, the right balance of both external and internal sources will be ever more important for companies and the overall European business ecosystem to win the innovation challenge and reach the 'new normal'.

Section 4

4. Skilled professionals as a source of technological transformation

4.1 Distribution of professionals with advanced technology skills across countries

This section aspires to provide 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 **LinkedIn 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. It helps to better understand the distribution of professionals with specific advanced technology skills such as Artificial Intelligence, Big Data or Cloud computing across geographies and industrial sectors.

LinkedIn is a voluntary professional networking platform. This implies that registered users have chosen to sign up leading to self-selection into the sample. When interpreting the data and results, one has to account for the way how LinkedIn is used and the reasons why it is used among its registered members. The self-selection of LinkedIn users implies that they chose to join based on rational arguments and only those who find utility in joining will do so. Clear differences can be observed in popularity of LinkedIn between countries, sectors or type of professionals. It represents a different sample of the workforce across European countries and also globally 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 various time points (December 2019, January, March, June, October, December 2020, February, April 2021).

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**. The representativeness of the LinkedIn database has been assessed through various criteria. In order to derive correct estimates of population parameters (as measured by Eurostat), given that the LinkedIn sample departs from the distribution of population characteristics, a post stratification method has been used by incorporating population distributions of variables into the LinkedIn estimates. This weighting method allows a more robust comparison among the EU27 Member States and also between the EU27 and the US. 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[10].

The number and share of skilled professionals employed by different manufacturing or services industries can also give some indication about the level of technology uptake in industry. It can be safely assumed that the use of advanced technologies also requires a level of technical understanding and professionals that have such skills will also promote this on their profiles. For example, medical professionals working in the healthcare sector need Artificial Intelligence or IoT related skills in order to effectively use new AI-based or connected medical devices. Companies that want to harvest online data about their customers or suppliers will not only work with specialised IT firms on a subcontractor basis but will employ their own colleagues to make sense of the data newly available. All these professionals have an interest to communicate about their new technological skills on their profiles as a way to differentiate themselves on the labour market.

[10] https://ati.ec.europa.eu/reports/eu-reports/advanced-technologies-industry-methodological-report

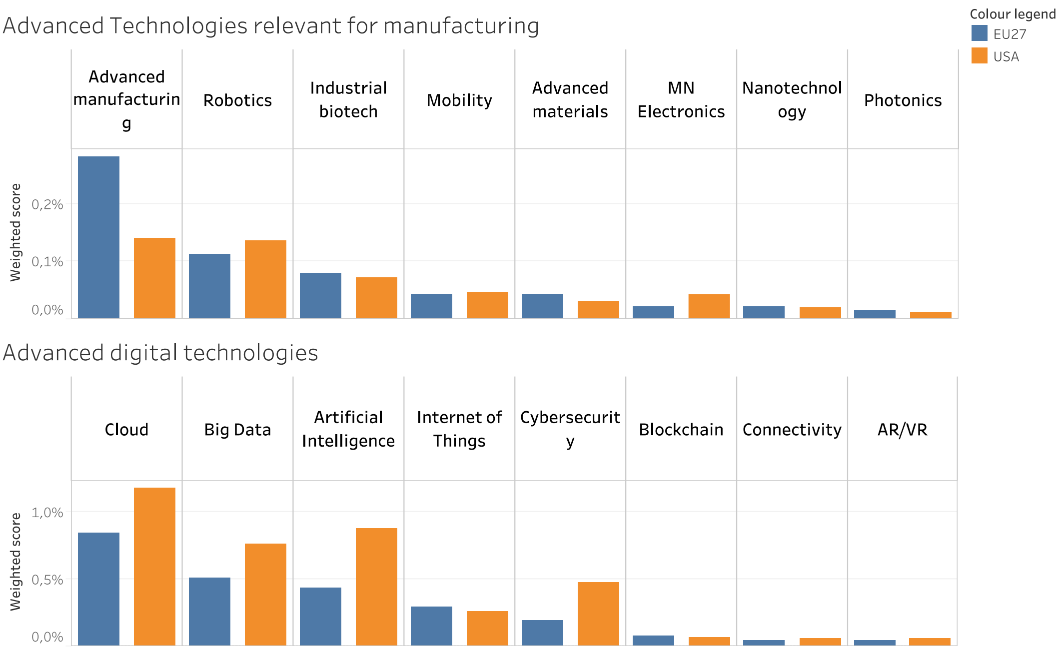
EU27 leading in several advanced technologies relevant for manufacturing but is lagging behind the US in digital technologies in terms of skills

In the EU27, within the pool of currently active professionals with skills in advanced technologies and registered in the LinkedIn database, Cloud technology, Big Data and Artificial Intelligence are among some of the most relevant skills. 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, Internet of Things and Industrial Biotechnology. The EU27 lags behind the US in particular in Cloud technologies, Artificial Intelligence and Cybersecurity but also in Big Data and Robotics.

The EU27 and US have similar shares in Blockchain, AR/VR, Micro- and nanoelectronics, digital technologies for Mobility and Photonics.

Figure 30: Weighted share of professionals with advanced technology skills in the EU27 and the US

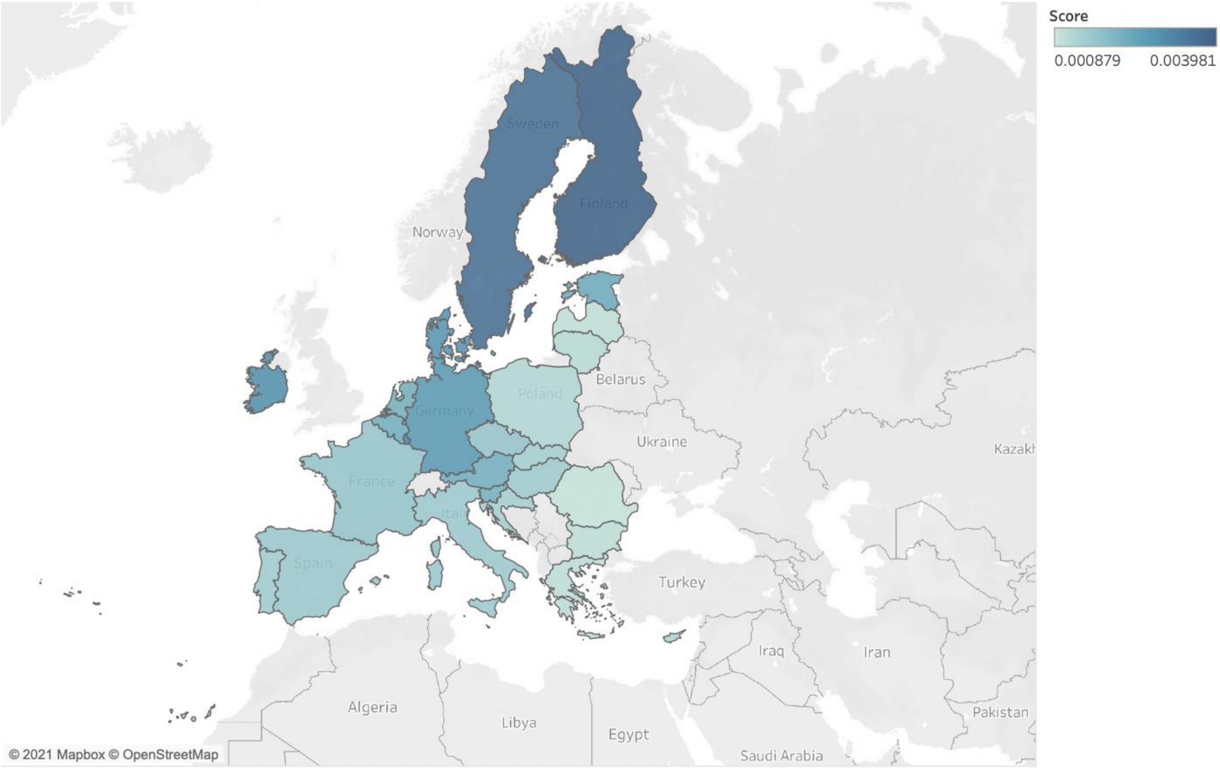


Source: Technopolis Group based on analysis of LinkedIn data

Finland, Sweden and Germany are countries with the highest weighted share of advanced technology skilled professionals

Similar to the results of the country analysis conducted with data from 2019, we find professionals with skills in advanced technologies 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 the top ten countries with the highest available advanced technology skills. Among other countries located in the Eastern part of the EU, Slovenia and the Czech Republic have the largest relative share of advanced technology professionals as the corrected and weighted data suggest.

Figure 31: Mapping of professionals with advanced technology skills across EU countries based on LinkedIn, 2021



Source: Technopolis Group based on analysis of LinkedIn data

Skills related to AI, Blockchain, Cybersecurity and Connectivity with the highest growth rate

The number of professionals with advanced technology skills has continued to increase in the past year (December 2019 - December 2020) with an average growth rate of **13%.** This percentage reflects the change in the total number of professionals within this pool of professionals compared to the situation one year ago. Even if this percentage has to be interpreted with caution taking into account the changes in the overall number of profiles registered in LinkedIn, the growth rate for advanced technology skills is much higher than for instance for general manufacturing related skills (4%) or basic digital skills[11] (9%).

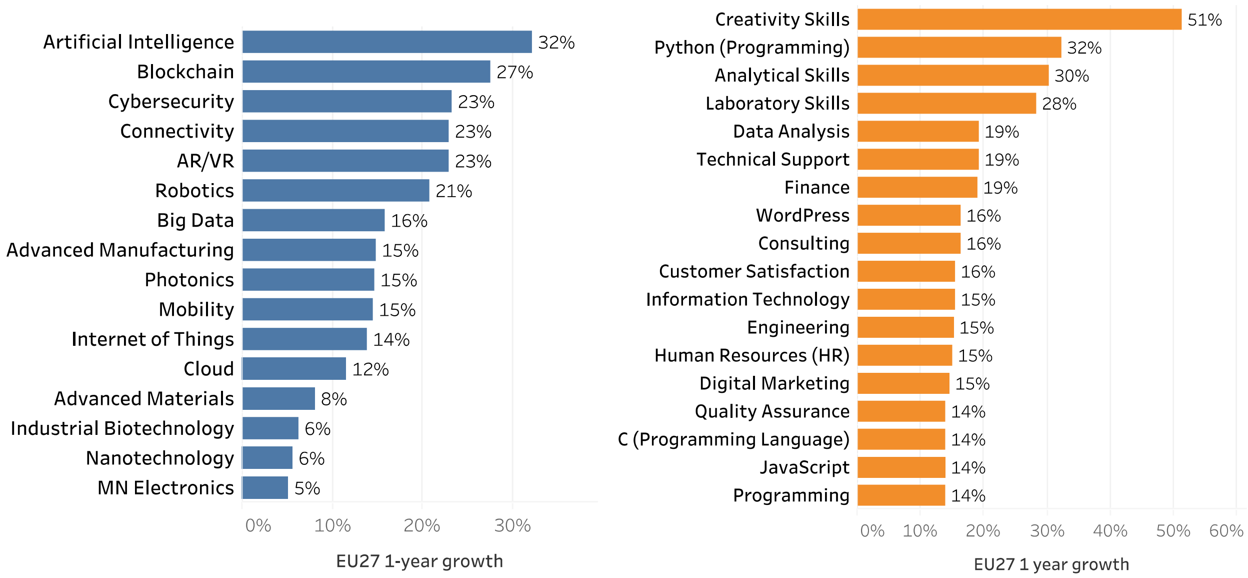
The advanced technologies that have witnessed the highest growth rate in the EU27 from December 2019 to December 2020 (covering the COVID period) in terms of skills include **Artificial Intelligence (32%), Blockchain (27%), Cybersecurity (23%) and Connectivity (23%)**. This growth reflects a different pattern compared to the change from 2018 to 2019, when professionals with skills in Blockchain, AI and AR/VR grew the most. The increased importance of Cybersecurity and Connectivity reflects also the changed needs of demand for these skills in the times of COVID and the shift to digital operating models.

Interestingly, the skills that saw the highest increase in the number of professionals claiming to have them from 2019 to 2020 include **Creativity skills, Python, Analytical skills, Laboratory skills and Data analysis**. This ranking reflects the skills that professionals with a registered LinkedIn profile reported the most compared to one year ago. Several of the skills are related to programming and also programming languages relevant for AI. Laboratory skills might reflect the increased needs in the healthcare sector. Digital marketing and customer relationship related skills have become more relevant for several industries and their business moving their operations online.

When comparing the growth patterns from December 2018 to December 2019 and December 2019 to December 2020, skills that had a steady growth include **Connectivity, Cybersecurity, Cloud and Mobility** (electric vehicles). The increasing importance of these skills can be explained by the new needs generated by the lockdowns and the COVID-19 pandemic.

[11] Captured as skills related to the use of word, excel, power point, microsoft office

Figure 32: 1 year growth rate (December 2019 – December 2020) in the number of advanced technology professionals registered on LinkedIn with skills in advanced technologies (weighted with the country share in EU professionals)



Source: Technopolis Group based on analysis of LinkedIn data, 2021

4.2 Professionals with advanced technology skills across industries

Distribution of skills across sectors reflecting about the level of uptake

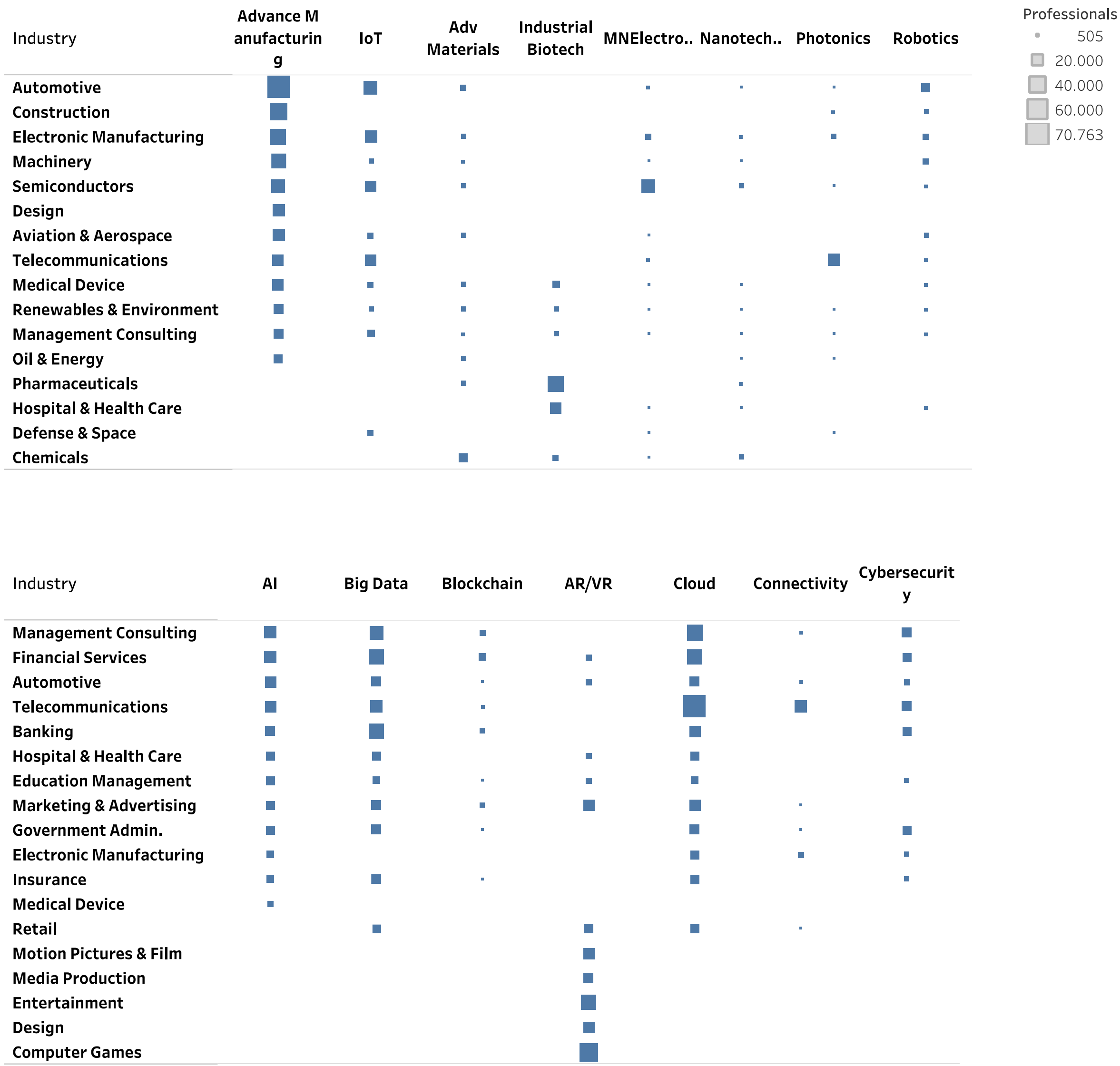
A further insight that this analysis can provide is the absorption of skilled professionals by economic sectors and industries in the EU27 and the US. Based on the profile of registered users on LinkedIn, the number of professionals with advanced technology skills and employed in selected industries can reflect about the level of adoption in these industries.

The results presented in Figure 33 indicate that beyond industries such as Information and Communication Technologies and Research (that have been excluded from the table below on purpose) the industries that employ most professionals with advanced technology skills in general include Telecommunications, Electronics and semiconductors, Automotive and Management consulting. When looking at individual skills sets (status of LinkedIn profiles in April 2021), we find the following patterns:

- **Advanced Manufacturing** skilled professionals have been concentrated in manufacturing industries such as **Automotive, Electronics and Machinery** but also Construction.
- **Artificial Intelligence** skilled professionals have been employed most in industries such as **Management consulting, Financial services and Automotive**.
- **Cybersecurity** skilled professionals have been employed most **in Telecommunications, Management Consulting, Financial services and banking and Government Administration.**

Figure 33: Distribution of advanced technology skilled professionals across industries

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

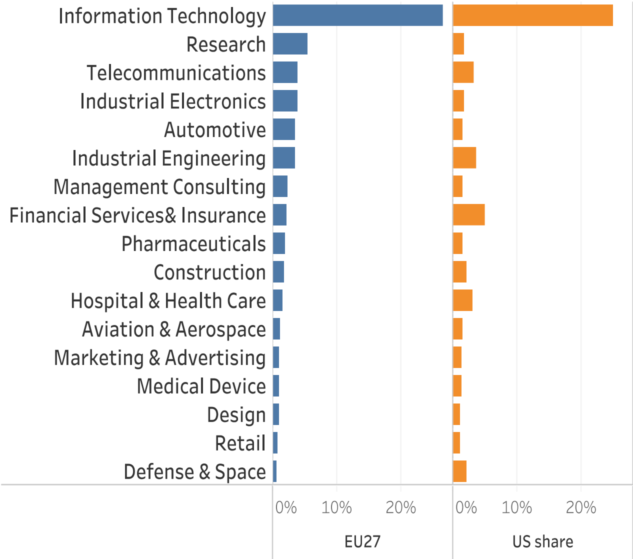


Source: Technopolis Group based on analysis of LinkedIn data, 2021

Advanced technology skilled professionals employed more broadly across industries in the US than in the EU27

When comparing the distribution of advanced technology skilled human resources across industries and sectors in the EU27 and in the US based on LinkedIn data, the results show that besides the ICT sector and research and academia, professionals with advanced technology skills have been employed most in the Telecommunication, Electronics and Automotive industries in the EU27 in 2020. Sectors employing the lowest number of advanced technology skilled talent include public policy, music, printing, furniture and farming.

Figure 34: Distribution of advanced technology skilled professionals across top sectors and industries in the EU27 and US, 2020



Source: Technopolis Group based on analysis of LinkedIn data

In the US, we observe similar patterns but Telecommunications is followed by Financial services and Insurance. Defense & Space is also among the sectors employing the highest share of such skills. In contrast, in the EU27 skills are more concentrated in some of the manufacturing sectors such as Automotive or Industrial Electronics.

Another difference between the two economic powers is that advanced technology skilled professionals are more distributed across sectors in the US than in the EU, which might indicate a better penetration of technological skills throughout the US economy and hence a stronger adoption of advanced technologies.

4.3 Demand for professionals with advanced technology skills

LinkedIn's online jobs repository includes both vacancies 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. Despite its increasing use, the analysis of LinkedIn job posts can reflect only partly about the market demand for a skilled workforce. The results should be further complemented by scraping a range of other online job portals and interpreted in the light of the fact that many of the new jobs created have never been published. The methodology and limitations in using LinkedIn for the production of indicators about the demand for skills are further explained in the ATI methodological report[12].

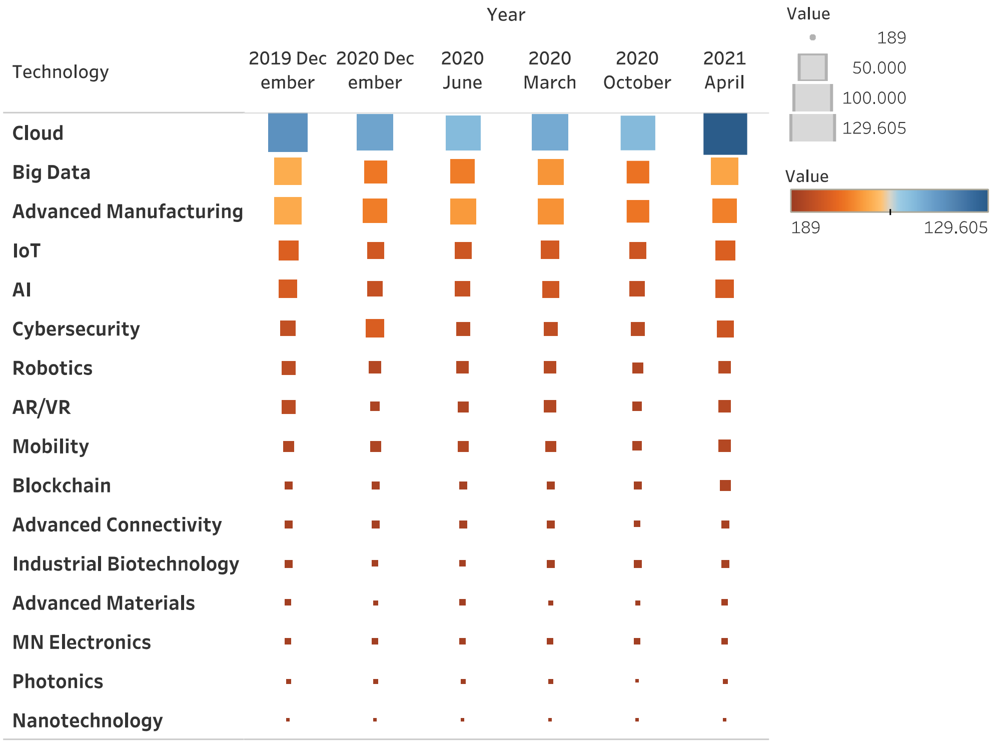
When analysing the evolution of job posts requiring advanced technology skills published over the period from December 2019 to April 2021 (see Figure 35 below), we find first of all that the number of job posts have decreased in the first half of 2020 except for Industrial Biotechnology (linked to demand of pharma and biotech firms), Photonics, Nanotechnology (which might be linked to vacancies of the research and education sector less affected) and Connectivity (which can be explained by the increased need for connected solutions). Demand for skills for Mobility technologies (electric vehicles) have also stayed strong, although witnessed some drops in October 2020.

The number of jobs posts for various advanced digital technologies such as AI, Big Data, Cybersecurity, IoT and Blockchain started to increase again since the end of 2020 and surpassed 2019 levels by early 2021. For example, EU job posts requiring Artificial Intelligence technology skills have been posted on LinkedIn most by IT firms, online platforms (such as Amazon, Zalando), research institutions, business consultancy companies, the transportation sector and financial services.

Interestingly, vacancies posted with a requirement for advanced manufacturing skills have been decreasing since December 2019 and this downward trend can be further observed in 2021.

[12] https://ati.ec.europa.eu/reports/eu-reports/advanced-technologies-industry-methodological-report

Figure 35: Trends in the number of job posts requiring advanced technology skills from December 2019 till April 2021



Source: Technopolis Group based on analysis of LinkedIn data, 2021

Section 5

5. Industry digital maturity index

5.1 Overview

EU Industries' adoption of advanced technologies varies, as does their propensity to enable innovation through factors such as skills, leadership and mindset. The Industry Digital Maturity Index measures these factors to evaluate each industry's level of digital maturity, using data from the latest ATI survey (November 2020) alongside data from Eurostat.

The term 'digital maturity' encompasses enterprises' ability to fully exploit digital innovation in their business processes through digital transformation and technology adoption. Digital transformation is understood as a continuous process by which enterprises adapt to or drive disruptive changes in their customers and markets (external ecosystem) by leveraging digital competencies to innovate new business models, products and services that seamlessly blend digital, physical, business and customer experiences while improving operational efficiencies and organisational performance. Digital transformation is a function of the variety and number of technologies adopted, their implementation in specific application or process areas (defined as use cases) and their ability to generate substantial business impacts to achieve the organisation's business goals (such as revenues or profit rises or increased customer satisfaction). This transformation process requires the availability of appropriate skills, access to investment and funding resources and strong leadership capabilities in the organisation's management. Some of these factors depend not only on the individual organisation, but also on the external framework conditions. The Index is designed to take into account these factors and is aligned with the ATI conceptual framework model of technology innovation, particularly concerning the identification of key enabling conditions.

This Index differs from the DESI 'Integration of Digital Technology Index' by the European Commission, which consists of two composite indicators measuring the business take-up of advanced technologies, business digitisation and e-commerce, sourced from Eurostat's ICT survey[13]. DESI provides a comprehensive set of measures covering both society and the economy.

This Industry Digital Maturity Index, by contrast, focuses purely on business indicators, is calculated by industry rather than country and evaluates the evolution of digital transformation in the business environment.

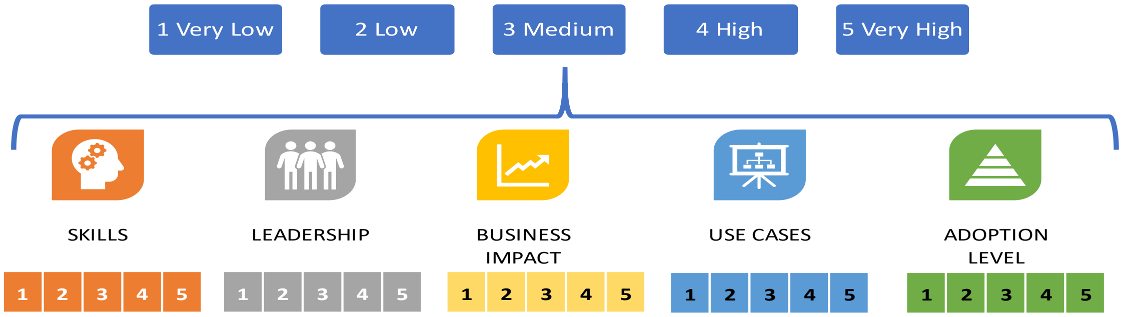
The index is measured on a scale from 1 to 5, where 1 means very low digital maturity and 5 equates to full maturity. The index results from the simple average of 5 sub-indicators (Figure 36), normalised on a common scale, reflecting the mix of factors needed for successful technology innovation. Analysing the level of each of the sub-indicators by industry provides useful insights on each industry's ability to achieve digital maturity and their respective strong and weak points.

All sub-indicators are sourced from the latest ATI survey, consisting of more than 1 500 interviews with enterprises of more than 10 employees in 7 EU Member States. For two sub-indicators, Eurostat data is considered as well.

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 EU as a whole, without breaking down the sample into sub-categories. This corresponds to high reliability and confidence levels.

[13] https://ec.europa.eu/digital-single-market/en/integration-digital-technology

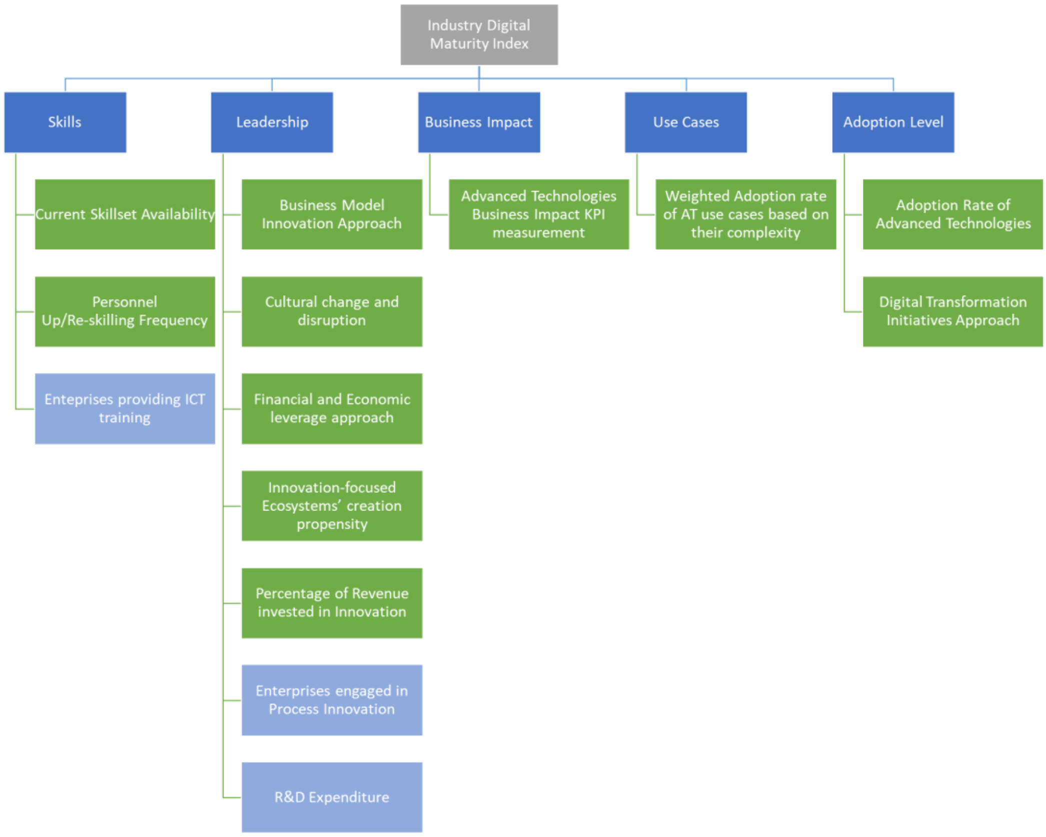
Figure 36: Industry Digital Maturity Index measurement scale



Source: IDC – Industry Digital Maturity Index, 2021

The Industry Digital Maturity Index is a well-established business indicator with well-understood key components: availability of skills, leadership, business impact, use cases and level of adoption of advanced technologies and digital transformation initiatives. Figure 37 shows the pyramid of indicators that were aggregated to measure each of the main components of the index, and then the index itself. The main methodological steps underpinning the Industry Digital Maturity Index are highlighted below. Further details are described in the ATI methodological report[14].

Figure 37: Structure and components of the Industry Digital Maturity Index



Source: IDC – Industry Digital Maturity Index, 2021

Note: Green Inputs are sourced from the latest ATI Survey (November 2020) – Light Blue Inputs are sourced from Eurostat

[14] https://ati.ec.europa.eu/reports/eu-reports/advanced-technologies-industry-methodological-report

Skills

The availability of skills is a critical enabling factor for enterprises to adopt new technologies. In the Industry Digital Maturity Index, this is measured through data about the current skillsets' (perceived) availability and the actions put in place to reskill and upskill personnel across organisations. The data is sourced from the latest ATI survey and Eurostat.

Leadership

Vision and entrepreneurship are necessary for enterprises to become innovators and lead in digital transformation. A strong leadership, able to chart a solid and forward-looking digital road map and infuse a change-ready company mindset, is crucial for digital maturity. To understand industries' capabilities in this dimension, we combine several ATI survey questions around: business-model innovation, cultural change and disruption, financial and economic leverage, propensity to create cross-organisation and cross-industry digital ecosystems, and proportion of innovation investments in organisational budgets. Eurostat indicators measuring the percentage of organisations engaged in process innovation initiatives and business expenditure on R&D have been considered as well. A weighted average of all these inputs determines an industry's 1-5 score for the leadership sub-indicator.

Business Impact

This composite indicator measures the proportion of enterprises that experienced relevant business benefits from the adoption of advanced technologies. This indicator was assessed in the survey by investigating the following seven highly industrially relevant KPIs: 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 KPIs, it reflects 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 final selection of indicators for the maturity model composite was normalised to a standard range and mapped to a five-point scale.

Use Cases

This composite indicator measures the level of adoption of use cases enabled by advanced technologies. A weighted scoring method provides higher ratings to more complex (e.g. difficult to implement from a technical point of view due to the need to integrate with legacy hardware/infrastructure) and forward-looking use cases that focus on improving the customer experience or creating new products and services (rather than those focused on costs savings and process efficiency).

Adoption Level

This is a composite indicator of the current level of uptake of advanced technologies and approaches to digital transformation initiatives, providing a comparative measure of industries' technology innovation capability.

Figure 38: Industry Digital Maturity Index: weights and data sources by component

Index Component	Weight	Measure	Data Source
Skills	55%	Current Skillset Availability	ATI Survey (November 2020) – Question F2
	30%	Personnel Up/Re-skilling Frequency	ATI Survey (November 2020) – Question F3
	15%	Enterprises Providing ICT Training	Eurostat - European Enterprises provided training to their personnel to develop their ICT skills (% - 2019)
Leadership	20%	Business Model Innovation Approach	ATI Survey (November 2020) – Question D2
	20%	Cultural Change and Disruption	ATI Survey (November 2020) – Question D3

Index Component	Weight	Measure	Data Source
	20%	Financial and Economic Leverage Approach	ATI Survey (November 2020) – Question D4
	7.5%	Innovation-Focused Ecosystems' Creation Propensity	ATI Survey (November 2020) – Question E3
	20%	Percentage of Revenue Invested in Innovation	ATI Survey (November 2020) – Question G1
	7.5%	Enterprises Engaged in Process Innovation	Eurostat - European Enterprise engaged in Process Innovation (% - 2019)
	5%	R&D Expenditure	Eurostat - Business expenditure on R&D (% of GDP - 2018)
Business Impact	14%	Business Model Innovation	Composite from ATI Survey (November 2020) - Question E1
	14.3%	Cost Reduction	
	14.3%	Customer Satisfaction	
	14.3%	Number of New Products or Services Launched	
	14.3%	Product/Service Quality	
	14.3%	Revenue and/or Profit Growth	
	14.3%	Time Efficiency	
Use Cases	100%	Weighted Adoption Rate of AT Use Cases Based on Their Complexity	ATI Survey (November 2020) – Weighted Average of Questions C3-12 based on each technology current adoption – For that, a weighted (based on use case complexity) average of use cases adoption for each technology has been used
Adoption Level	60%	Adoption Rate of Advanced Technologies	ATI Survey (November 2020) – Question B1
	40%	Digital Transformation Initiatives Approach	ATI Survey (November 2020) – Question D1

Source: IDC – Digital Maturity Index, 2021

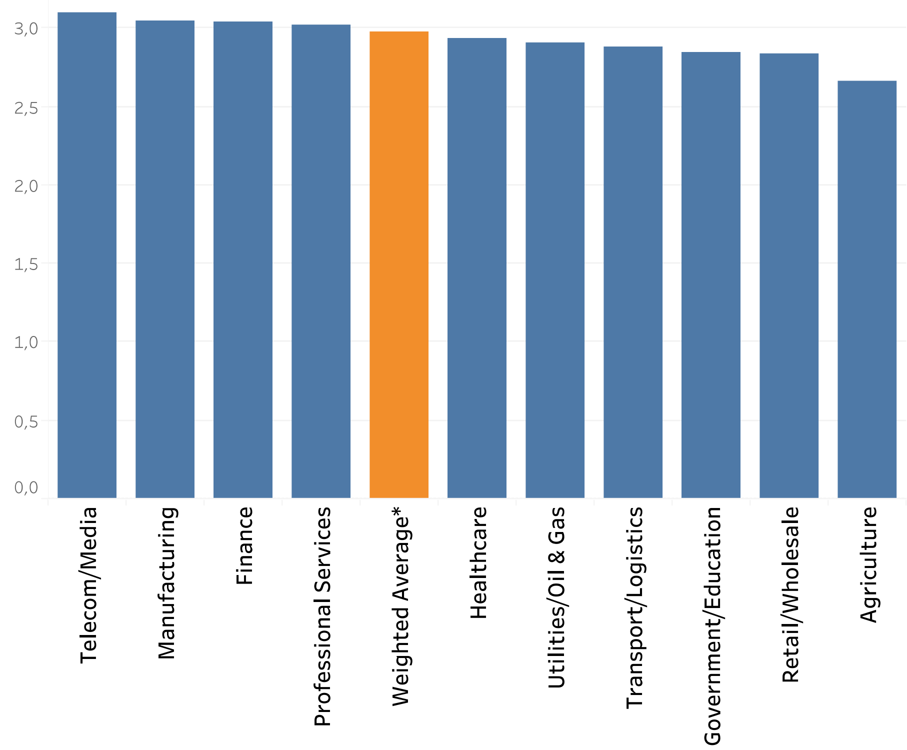
5.2 Main results

Telecom and media, manufacturing and finance, closely followed by professional services, are the most digitally mature EU Industries in comparison with other business and public sectors. Driven by a strong skillsets backbone, mature advanced technologies adoption and a solid leadership propensity to innovate, these four industries — which represent more than 40% of overall European ICT spending (IDC Worldwide ICT Spending Guide Industry and Company Size, January 2021) — lead the way in terms of advanced technologies initiatives and provide some of the clearest best practices in terms of successful digital use cases and innovation-driven ecosystems.

The pandemic has dramatically impacted the full industry landscape in Europe and of these four leading sectors. Manufacturing has certainly been challenged the most. Although the road to recovery for the sector is still long and dependent on other industries' reactions, digital maturity in that sector has been a key response shield, allowing for business-model shifts when required — but digital maturity has also turned to be an important resilience and return-to-growth accelerator, enabling remote management and production scenarios, allowing safe return-to-work initiatives and unlocking effective supply-chain practices.

The healthcare and transport/logistics industries have also been put under extreme pressure by the pandemic, the former due to its vital role in responding to the pandemic and the latter by the tough economic shutdowns that put the sector on the skids. These industries both sit in the middle of the Industry Digital Maturity Index, alongside utilities/oil and gas. While healthcare has been forced to react by accelerating its digital trajectory in the last few months, fully and rapidly implementing some digital use cases and scenarios that would otherwise have taken years to happen, transport/logistics and utilities/oil and gas organisations have had to recalibrate, adapt and (in some cases) postpone their digital road maps in favour of more urgent business-continuity actions.

Figure 39: Industry Digital Maturity Index – 2021 updated results, cross-industry comparison



Source: IDC – Industry Digital Maturity Index, 2021

Note: Weighted average is calculated by weighting individual industries based on their European ICT spending market share (e.g. financial services represent 20% of the overall European ICT spending and therefore a 20% weighting has been applied). Note that simple average would only slightly differ (2.9) from the weighted average value (3.0).

Finally, a few industries have digital maturity scores close to or lower than the EU27 average, namely government/education, retail/wholesale and agriculture.

Retail/wholesale has entered very difficult waters during recent years, due to a dramatic fall in revenue for a sector that has been forced to completely reinvent itself to survive. Therefore, it is no surprise that this has necessarily led to pausing and postponing investments in and plans for advanced technologies, in order to focus limited resources on contingent survival-mode initiatives.

The government/education and agriculture sectors have traditionally lagged other sectors in terms of digital maturity, and this year's Industry Digital Maturity Index is further proof that both sectors need to accelerate their digital road maps to make up lost ground. National recovery plans fuelled by the Next Generation EU instrument represent a key opportunity in this regard, enabling specific investment streams focused on fostering public-sector digitisation and putting the agriculture sector at the core of the green economy revolution.

Figure 40: Industry Digital Maturity Index — 2021 updated results, cross-industry ranking by sub-indicator

Source: IDC – Industry Digital Maturity Index, 2021

Note: The chart shows industry ranking for individual sub-indicators based on their sub-indicator's scoring, from the top (position number 1) to the bottom (position number 10). As an example, when looking at the 'Business Impact' sub-indicator, Utilities/O&G (green icon) leads the ranking while Government/Education (red icon) shows the lowest scoring for 'Business Impact'. The first column 'Composite Index' represents Industry Digital Maturity Composite Index as shown in the previous chart.

The ranking of specific sub-indicators in the Industry Digital Maturity Index highlights a wide variance in sectoral performance in Europe, driven by different competitive positioning and variations in strengths and weaknesses.

The three leading sectors (telecom/media, manufacturing and finance) score highly across all sub-indicators apart from business impact, where telecom/media and manufacturing organisations clearly find it difficult to perceive and measure the impact of advanced technologies in terms of business indicators such as cost reduction, revenue growth and customer satisfaction. This could be explained by temporary pauses to production and services flows due to the long implementation times of new digital projects (especially in manufacturing) and underscores the need for these industries to take the plethora of existing advanced use cases and advanced technologies-driven experiments to the next level, scaling them up so that their impact is company-wide and felt across business units.

Another interesting aspect to the business-impact indicator is the relatively strong position of sectors that score below average in terms of overall digital maturity, such as transport/logistics and utilities/oil and gas, with the latter leading the way in achieving relevant business benefits thanks to the adoption of advanced technologies. Although the two sectors are dragged down by their performance in terms of skills and leadership, they each show a positive level of adoption of advanced technologies with a concrete, measurable business impact.

Healthcare represents another mixed picture, lagging in adoption of advanced technologies and achieved business impacts, but being among the top scorers for leadership and use-case complexity. Leaders in the industry have had to urgently step up in the last year in order to face the tsunami that put the sector under extreme pressure, which also focused attention on a few complex digital use cases that helped to hold the fort during the emergency.

Finally, professional services, among the top industries in terms of digital skills and strong leadership, misses the podium due to falling back on adoption of advanced technologies compared with last year, when it had one of the highest technology adoption rates. The sector has not been spared by the economic shutdown, and some of the investments in emerging technologies that were initially planned for 2020 have inevitably been scaled back due to other business urgencies and contingency plans.

5.3 Comparison with the results of the previous year

Although some industries — healthcare, government/education and agriculture — have been included in the Industry Digital Maturity Index calculation for the first time in 2021 thanks to expanded available data sources, for the remaining industrial sectors a year-to-year comparison provides some interesting insights. A straightforward one-to-one comparison of absolute values on the index may be unhelpful due to some differences in the methodology and a different ATI survey sample but comparing both years' relative rankings is useful to analyse how the past turbulent year has reshaped EU Industries and their propensity for innovation and advanced technologies adoption.

At the top, telecom/media confirms its leading position thanks to its developed skillsets, solid leadership guidance and a mature adoption of advanced technologies. While a high score is also confirmed for finance and professional services, manufacturing represents the most impactful shift in ranking, moving from fifth place last year to second position in 2021. The sector has been particularly exposed to pandemic-related lockdowns and economic shutdowns and is still striving for a rapid return to growth, forcing it to face some challenges that put organisations in the industry in front of a 'accelerate/react or die' crossroads. Innovation and advanced technologies, alongside unwavering leadership, turned out to be key reactive weapons and accelerators along the return-to-growth curve, with multiple examples of manufacturers that were forced by the emergency to experiment (e.g. testing new digital use cases, especially among SMEs in the sector) or to accelerate on their digital trajectories to come through the crisis (e.g. the e-mobility revolution for large automotive players), taking a bold step for a better future.

Figure 41: Industry Digital Maturity Index – comparing 2021 versus 2020 index industry rankings

Source: IDC – Industry Digital Maturity Index,2021 and 2020

Retail/wholesale represents the other side of the coin, having slipped down to the bottom of the industry ranking after being among the front-runners last year. As in the manufacturing sector, the crisis put retail/wholesale organisations on the skids. This dramatic scenario has been ongoing for over a year with little signs of recovery as of today. Unlike in manufacturing, the crisis uncovered an array of digital gaps and challenges for the sector such as resistance to business-model changes (e.g. online shopping and delivery), with most organisations in the sector still struggling to react and find a way through the crisis. Moreover, the fact that budget reserves were limited, if not annihilated, hampered any type of digital investments, with initiatives around advanced technologies postponed until better days.

Section 6

6. Production and employment related trends

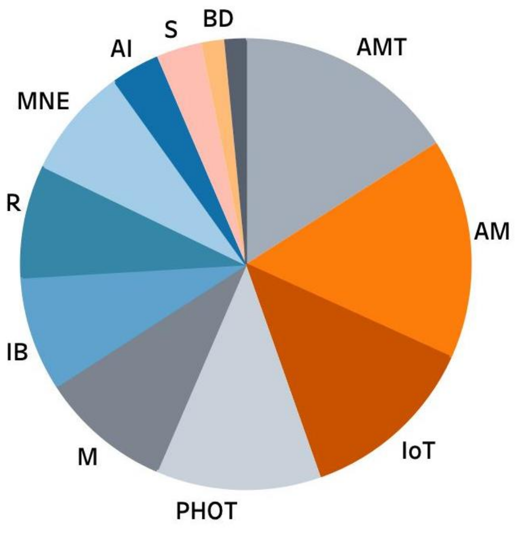
6.1 State of play of EU27 production strengths

Production trends have been captured through the analysis of Prodcom data. Prodcom provides statistics on the production of manufactured goods carried out by enterprises on the national territory of the reporting countries[15]. Production data is analysed in two ways: related to 1) a technology generation and exploitation approach and 2) a technology diffusion approach. The technology generation and exploitation approach refers to the production data that can be associated in whole or in a dominant part with the respective advanced technology. The technology diffusion approach refers to the production data that highlights to what extent the EU27 can use the potential of advanced technologies to improve its competitiveness by manufacturing advanced technology-based products and applying them in the production of manufacturing goods.

EU27 global leadership in Advanced Manufacturing, Advanced Materials and Internet of Things

Figure 42 shows the EU27's country significance of production of technology generation, hence the share of industrial production related to advanced technologies. Europe's strength in the production of components in Advanced Manufacturing and Advanced Materials is clearly demonstrated, while also the production of Internet of Things components proves to be significant. Figure 43 shows the EU27's country significance of production for diffusion, hence the share of industrial production related to advanced technologies. In total, advanced technologies comprise around 24% of industrial production implying that ~1/4 of industrial production is strongly dependent on manufacturing ATI based products and applying them in the production of manufacturing goods. Advanced Manufacturing (6.3%), Advanced Materials (5.5%) and Industrial Biotechnology (2.6%) comprise the largest shares, while the share of Big Data (0.2%), Artificial Intelligence (0.5%) and Security (0.5%) remain low.

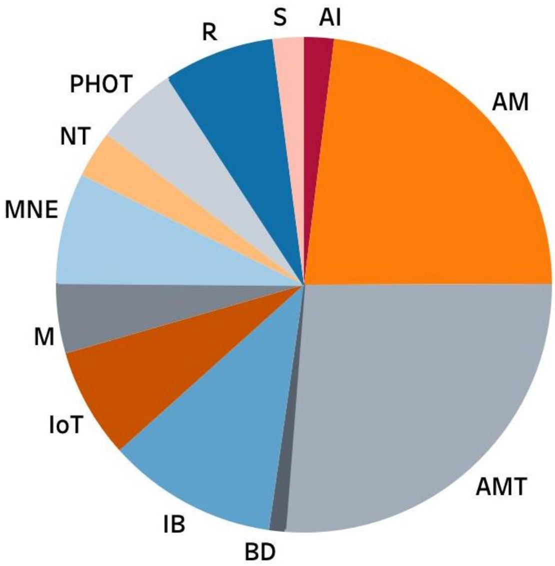
Figure 42: EU27's country significance of production of technology generation in 2019



Source: IDEA Consult calculations based on Eurostat (AMT = advanced manufacturing, AM= advanced materials, PHOT = Photonics, M = mobility, IB = industrial biotechnology, R = Robotics, MNE = micro-and nanoelectronics, S = cybersecurity, BD = big data)

[15] The term comes from the French 'PRODuction COMmunautaire' (Community Production). Prodcom covers mining, quarrying and manufacturing: sections B and C of the Statistical Classification of Economy Activity in the European Union (NACE 2). Prodcom statistics aim at providing a full picture at EU level of developments in industrial production for a given product or for an industry in a comparable manner across countries.

Figure 43: EU27's country significance of production for diffusion in 2019



Source: IDEA Consult calculations based on Eurostat (AMT = advanced manufacturing, AM= advanced materials, PHOT = Photonics, M = mobility, IB = industrial biotechnology, R = Robotics, MNE = micro-and nanoelectronics, S = cybersecurity, BD = big data)

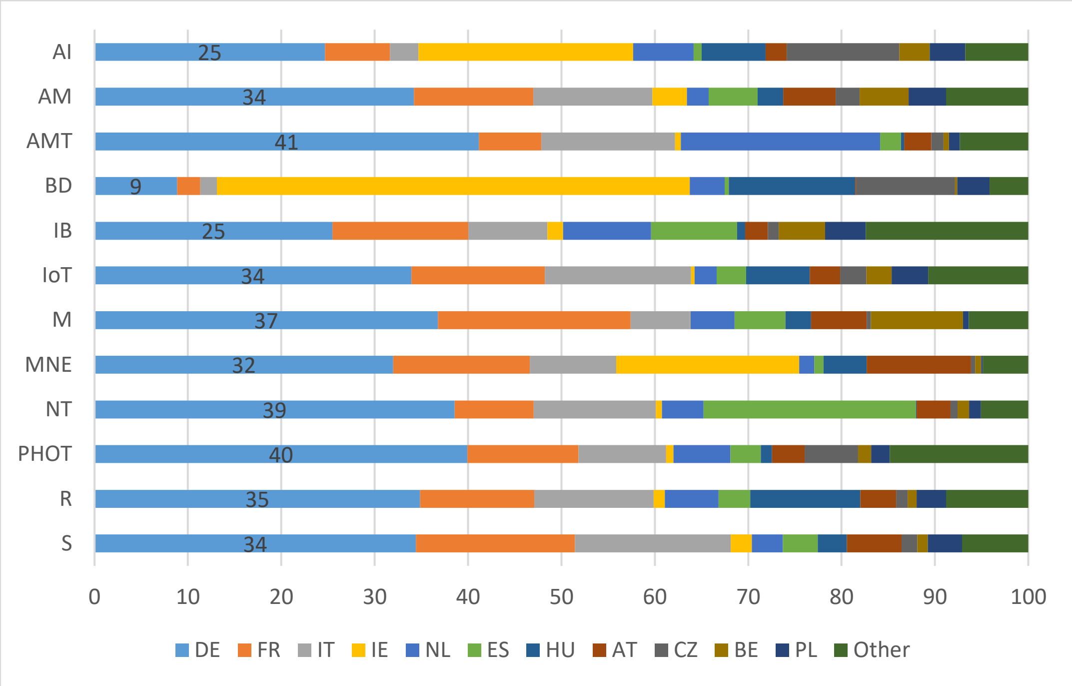
Concentration of advanced technology production in a number of EU Member States

With a view to relevant EU Member States' shares in advanced technology related production, **Germany** dominates the picture in most advanced technologies, with exception of Big Data in the technology generation and exploitation approach and the technology diffusion approach, and Industrial Biotechnology in the diffusion approach where **Ireland** is leading. Already in 2013, the Irish Government's Action Plan identified 'Big Data' as one of the areas where Ireland has distinct advantages compared to other countries[16]. A study of IDC showed that Ireland is well positioned as most of the big players have a significant presence in the country[17]. Ireland also contributes significantly to the production of Industrial Biotechnology. This can be explained by the fact that Industrial Biotechnology includes the production of pharmaceuticals with biotechnological methods. Moreover, Ireland is performing outstanding in this area as it hosts several multinationals which have their manufacturing location for the EU market in Ireland[18].

France and Italy contribute significantly to the majority of the advanced technologies production, with exception of Big Data and Artificial Intelligence. In these two advanced technologies, **Hungary and Czech Republic perform rather well.** In particular, the Czech Republic seems to be able to improve its competitiveness by manufacturing advanced technology-based products in the area of Big Data (22%) and Artificial Intelligence (15%). **Spain** is a central player in the production of Nanotechnology (22%), confirming its strong position already identified in the patent applications.

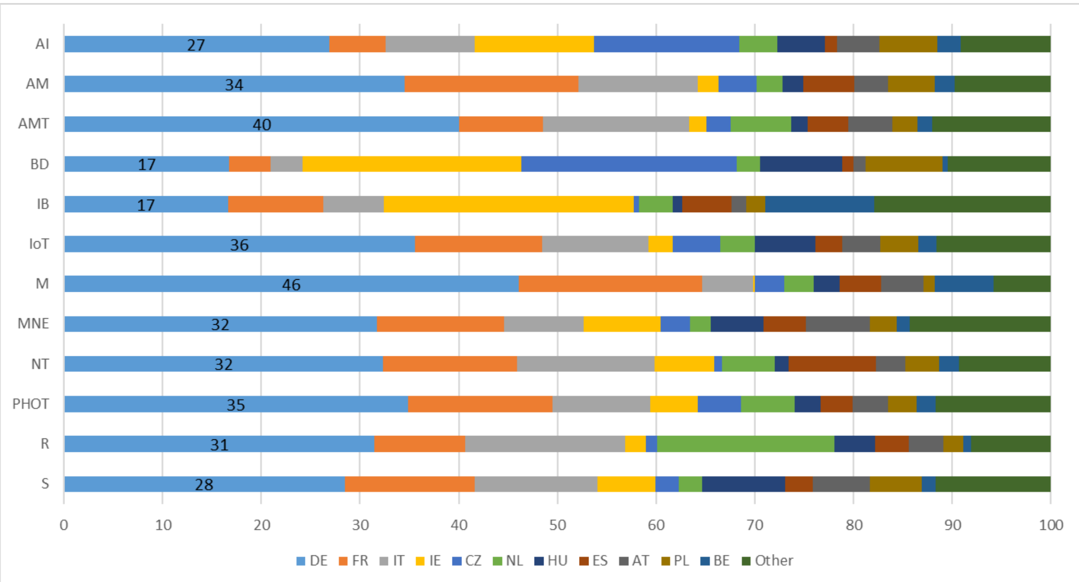
[16] https://www.enterprise-ireland.com/en/funding-supports/Company/Esetablish-SME-Funding/IPP-Big-Data.html
[17] A Study on harnessing Big Data for innovation led growth: an assessment of Ireland's progress and further policy requirements, IDC, 2015
[18] https://www.pharmaceutical-technology.com/products/ireland-biopharma-manufacturing/

Figure 44: Share in total production of technology generation in 2019



Source: IDEA Consult calculations based on Eurostat (AMT = advanced manufacturing, AM= advanced materials, PHOT = Photonics, M = mobility, IB = industrial biotechnology, R = Robotics, MNE = micro-and nanoelectronics, S = cybersecurity, BD = big data)

Figure 45: Share in total production for diffusion in 2019



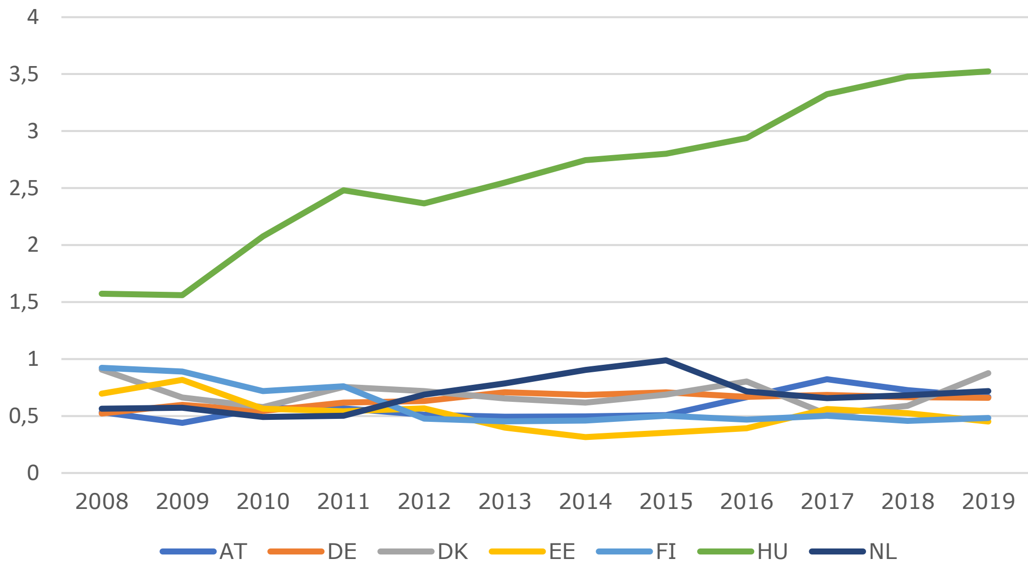
Source: IDEA Consult calculations based on Eurostat (AMT = advanced manufacturing, AM= advanced materials, PHOT = Photonics, M = mobility, IB = industrial biotechnology, R = Robotics, MNE = micro-and nanoelectronics, S = cybersecurity, BD = big data)

Trends over time: focus on Robotics

The production data allows for a longitudinal view as Eurostat monitors the production data yearly. Zooming in on the production developments over time in Robotics, the country significance of production of technology generation shows a significant increase for Hungary. This implies that Robotics has become more important in the country's production portfolio. The high score of Hungary can mainly be attributed to various robots that are being used in the automotive industry. According to RoboticsBiz, the average number of robots in Hungary was 281 per 10 000 workers in 2016, while the European average was 99[19]. The trend analysis in the country significance of production for diffusion in Robotics confirms the increasing importance of Robotics in the production activities of Hungary. It also reveals a strong growth in the production capacity of the Netherlands, indicating that an increasing part of the country's resources are used to produce products related to Robotics.

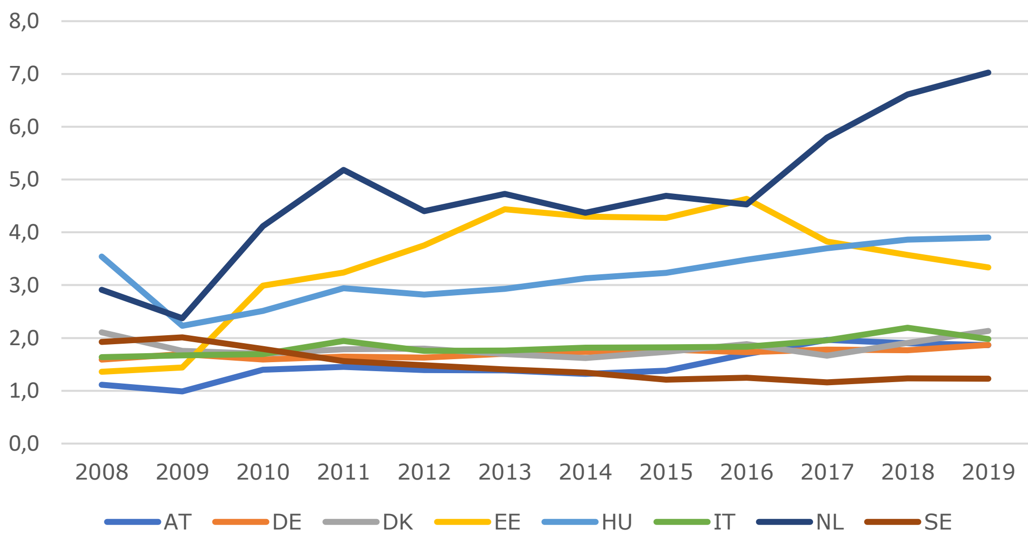
Figure 48 confirms the specialisation of Hungary and the Netherlands in the production for diffusion in Robotics. A high value of specialisation indicates that a country devotes a higher share of its resources to the production of products related to Robotics than other countries on average do. While Estonia witnessed a strong increase in specialisation in Robotics during the time period 2009 to 2016, the specialisation is less pronounced in the last years.

Figure 46: Country significance of production of technology generation in Robotics, 2008-2019



Source: IDEA Consult calculations based on Eurostat

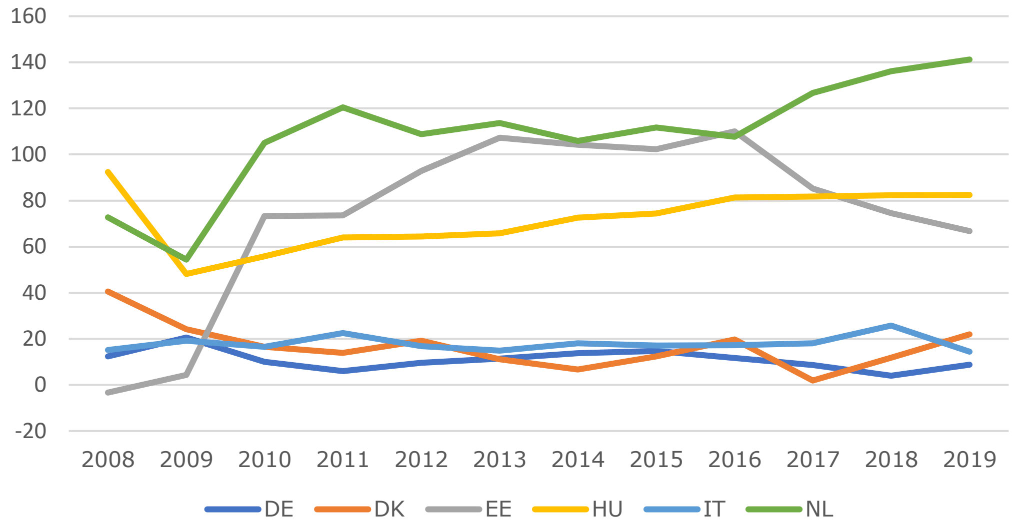
Figure 47: Country significance of production for diffusion in Robotics, 2008-2019



[19] https://Roboticsbiz.com/top-Robotics-research-institutions-and-labs-in-hungary/

Source: IDEA Consult calculations based on Eurostat

Figure 48: Country specialisation in production for diffusion in Robotics, 2008-2019



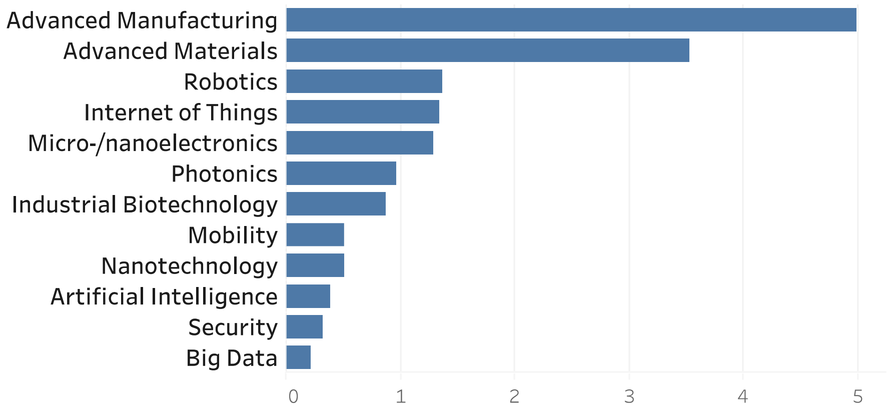
Source: IDEA Consult calculations based on Eurostat

6.2 State of play of EU27 employment strengths

The employment indicators are based on the technology diffusion approach and consider the labour resources needed in the whole technology value chain. They comprise the production stages of the generation and exploitation, the diffusion in application fields and its use in downstream sectors and are valued with the respective employment per country. Hence, these indicators complement the detailed assessment of skills and employment related to core activities and professions in section 2.4 and 4, by enlarging the scope and focussing more on the economic impact and amount of labour resource needed for advanced technologies.

Figure 49 shows the advanced technologies share in employment in the EU27 (significances), hence the share of the industrial employment related to the technologies. In total those advanced technologies comprise around 16% of Industrial Employment, meaning that **1/6 of industrial employment** is strongly dependent on the generation and diffusion of advanced technologies. The lower percentage compared to production for diffusion is due to higher labour productivity in the production and application of advanced technologies. Unsurprisingly, the more mature, rather broadly defined and widely used technologies **Advanced Manufacturing (5%)** and **Advanced Materials (3.5%)** comprise the largest shares of employment in industry. The same as for the whole EU27 applies for almost all EU Member States. On the contrary, some arising digital technologies use less labour resources yet.

Figure 49: Advanced Technologies country significance of employment in EU27 in 2018



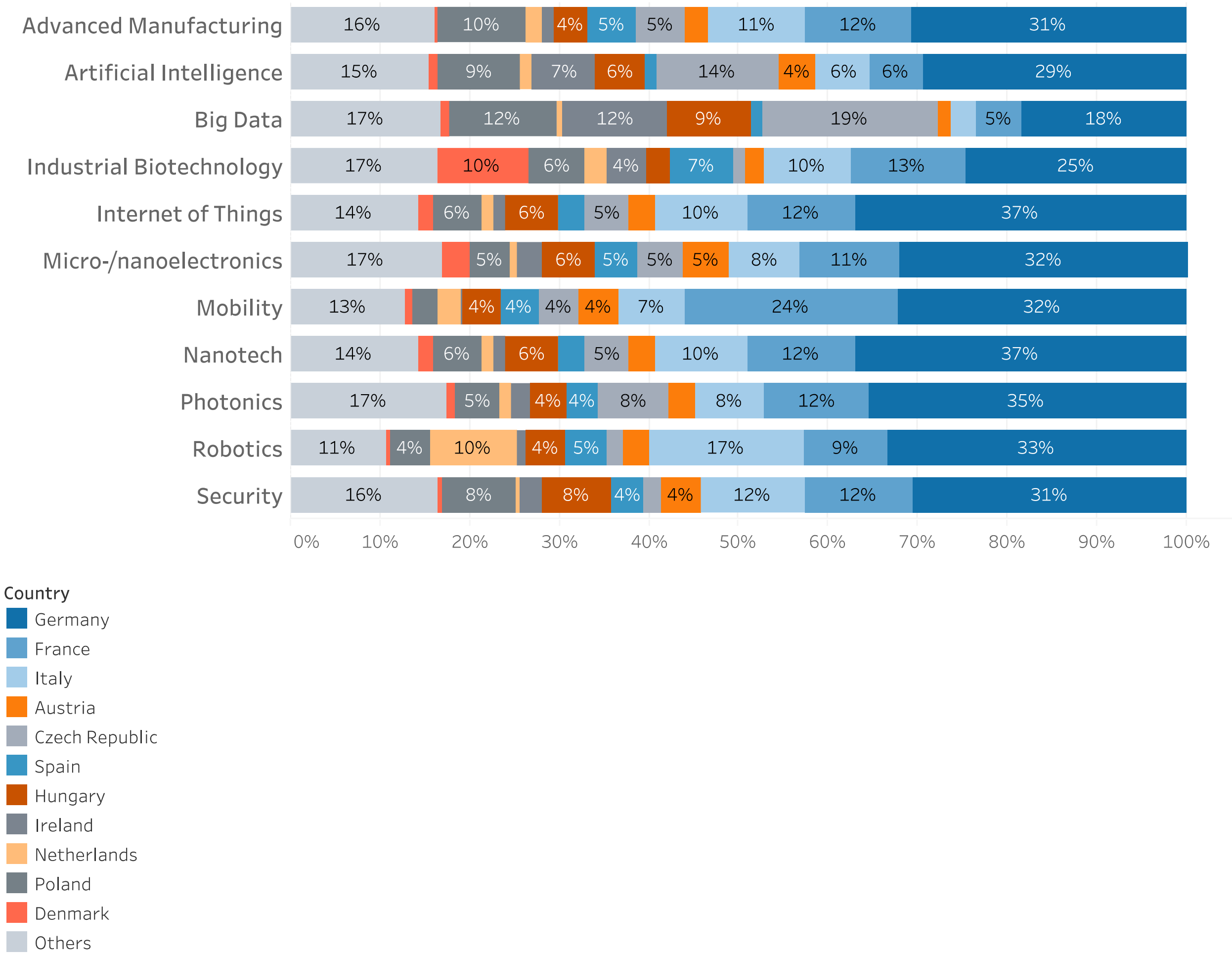
Source: Fraunhofer ISI calculations based on Eurostat

With a view to relevant Member States' shares in employment (Figure 50), **Germany** holds the highest share in all technologies with the exception of **Big Data** in which **Czech Republic** is leading. Overall, large countries like **Germany, France and Italy** contribute to around 45-65% of the EU employment, with the exception of Big Data (~25%) and Artificial Intelligence (~42%).

Poland, Hungary and Czech Republic contribute significantly to employment shares for almost all technologies, only for Industrial Biotechnology and Nanotechnology this is less the case. These countries have a comparatively strong manufacturing industry, among others in electronics and machinery or automotive, which are important user sectors of advanced technologies.

Ireland contributes significant shares in **Artificial Intelligence and Big Data**. In other advanced technologies, Ireland performs rather in average, despite high technology diffusion (see section 6.1), as labour productivity in key industry sectors is rather high and the labour resources needs are limited.

Figure 50: Share of employment of top 10 EU countries in 2018



Source: Fraunhofer ISI calculations based on Eurostat

Specialisation data confirm these results. The larger EU countries **Germany, France and Italy** possess a strong but diversified industrial landscape and use labour resources by applying advanced technologies in all fields. The specialisation values are neither highly very positive or negative in each of the advanced technologies, with the exception of **Big Data and Artificial Intelligence. Here France and Italy** possess strong negative specialisation. Instead, in smaller countries the competencies and activities are more specialised. Many **smaller EU countries** possess high specialisations in one or few technologies, namely the above-mentioned positive performance of **Ireland in Artificial Intelligence and Big Data, Industrial Biotechnology, Micro- and nanoelectronics and Security, Czech Republic for Artificial Intelligence and Big Data, Hungary for Big Data and Security**. Moreover, various countries are highly specialised in one of the advanced technologies. **Estonia** presents the highest specialisation value for **Security and Connectivity, while Netherlands** holds this place for **Robotics, Slovakia for Photonics, Austria for Mobility and Denmark for Industrial Biotechnology.**

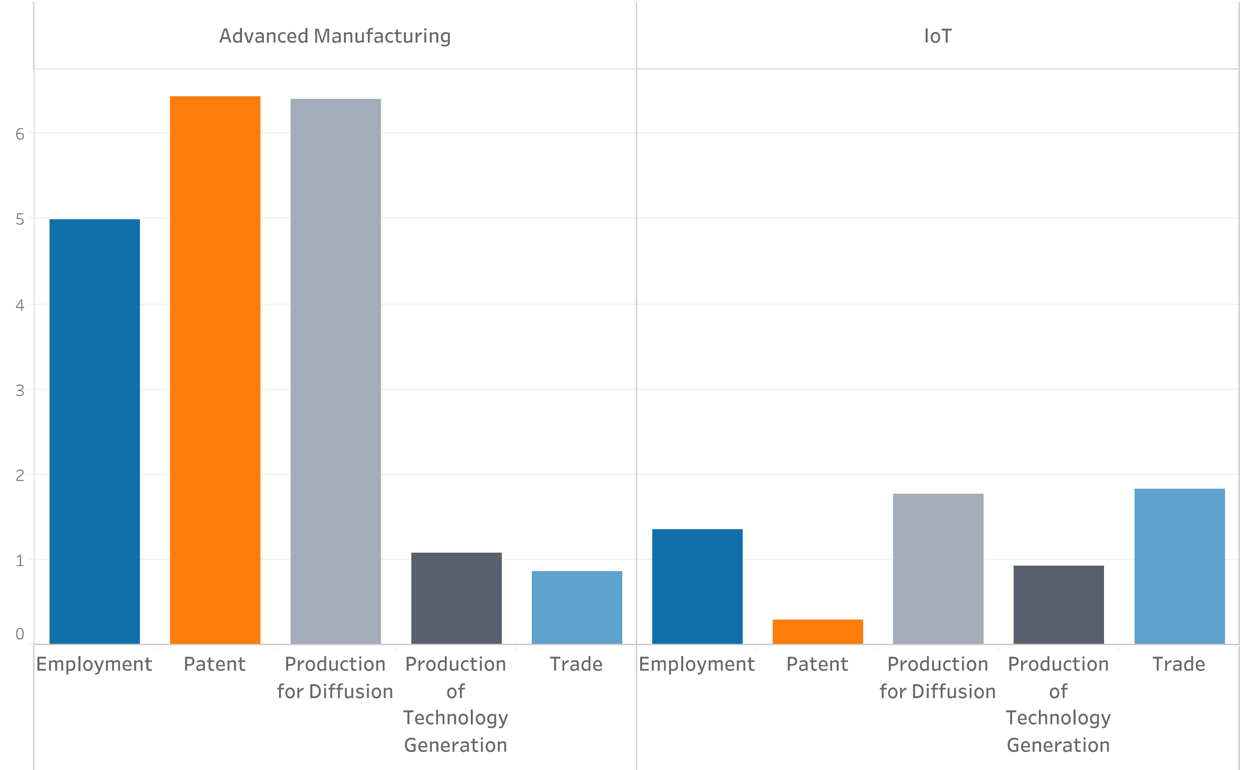
6.3 Cross-indicator analysis

The various indicators in this report for the generation and diffusion of advanced technologies point out the position and competitiveness of countries along the technology value chain. A key question is how the countries perform along these different stages and activities, i.e. to which extent the leading patenting countries are able to transfer technological advantages in competitive products and use embedded knowledge in various applications. Therefore, we combine the results of the five indicators groups namely patents, trade, production for technology generation, production for diffusion and employment for diffusion.

Overall, the different indicators provide a coherent picture, with a somewhat higher differences between the indicators for the digital technologies, probably because they are less mature and moreover higher specialisation patterns of individual countries occur. Moreover, the different stages in the technology value chain relate to different capacities, resources and influences (e.g. investment needs and production skills to transfer intellectual property in successful market products).

Concerning significance, meaning the technology share of total exports in a country, the data shows that advanced technologies have high importance in patenting, but also in technology diffusion and related employment. Unsurprisingly, the significance of trade and production of technology generation is lower, as only a limited set of goods is allocated to these indicators. More precisely, **Advanced Manufacturing** presents **6.4%** of EU27 patent applications as well production for diffusion, and **5%** of industrial employment. For Internet of Things, as another example, patents are less relevant **(0.3%)** as IoT mostly combines technologies, while related trade, production and employment comprise between 0.9 to 1.9% of EU27 totals.

Figure 51: Advanced Technologies significance for Advanced Manufacturing technologies and IoT in EU27 in 2018



Source: Fraunhofer ISI and IDEA Consult calculations based on Eurostat

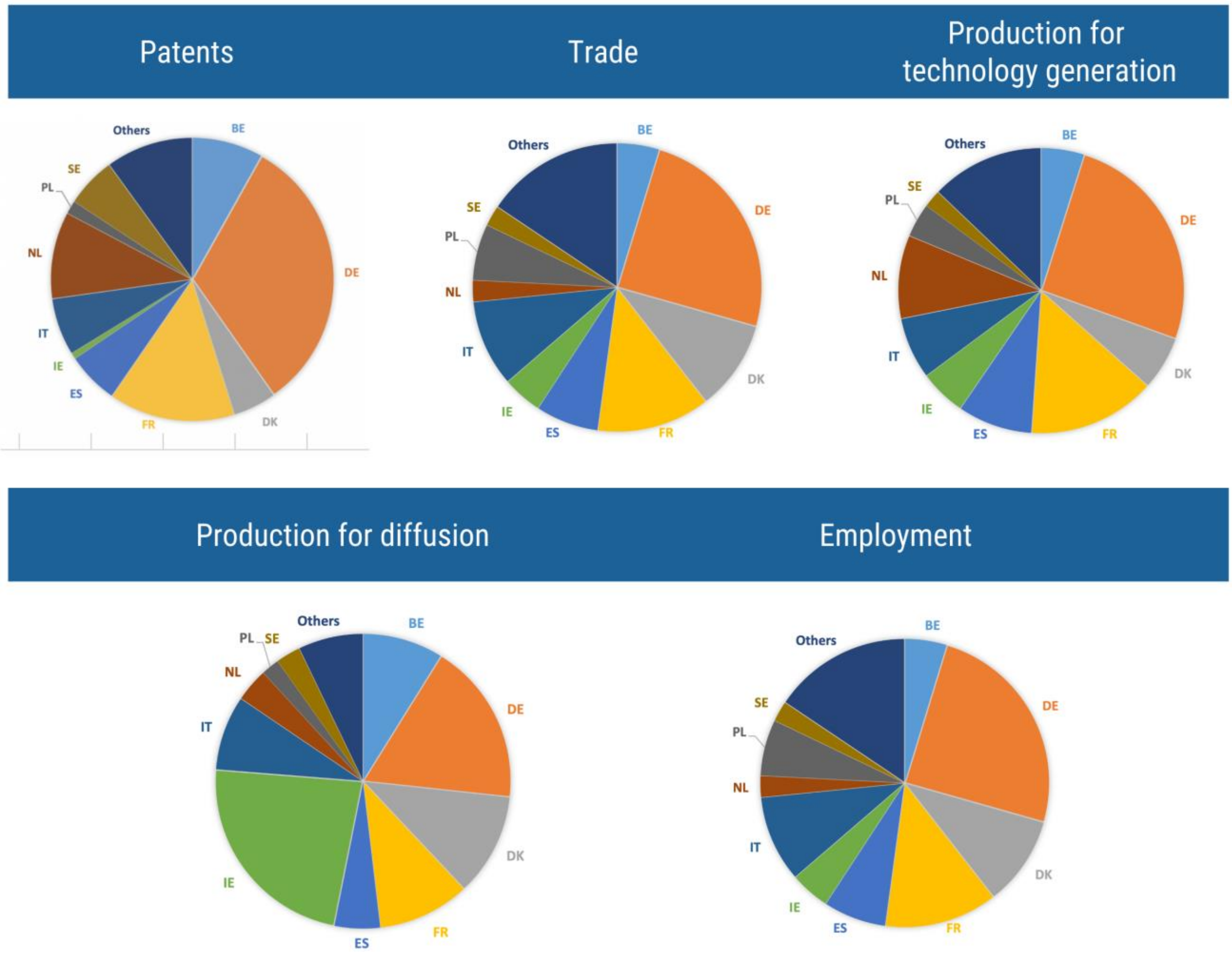
Regarding EU Member State shares of EU27 totals, overall observations are explained and presented for two technologies, namely Industrial Biotechnology and Artificial Intelligence (Figure 52 and Figure 53). Overall, Western and Northern EU countries possess rather high patent shares. For trade and production for technology generation, in many cases similar patterns occur, but some countries show a strong specialisation in certain Advanced Technologies (see below). For production for diffusion and employment smaller countries comprise less shares than for technology generation indicators such as patent, production and trade. This may be due to the fact that less specific competencies and resources in a certain technology field are relevant, such as for Industrial Biotechnology in Denmark. Instead, advanced technology diffusion takes place in several industrial sectors (e.g. electronics, machinery, chemicals), and competitiveness in production in those industrial sectors is of high importance for a broad uptake of advanced technologies components and products in further industrial processing. Hence large countries comprise rather large share in diffusion for production and employment.

In general, Italy, France, Germany, Netherlands and Spain are rather strong in patent, trade, the production indicators and employment for most technologies. This pattern can be seen nicely for Industrial Biotechnology. In Figure 52 only Denmark as hosting country of Novozymes (leading enzyme company) shows significant shares next to the mentioned countries.

Czech Republic and Ireland have limited technological competitiveness, but a strong industrial basis and are leading countries in production and exports for **Artificial Intelligence** (see Figure 53). Similar patterns arise for **Big Data**, and in the case of **Czech Republic** for **Photonics** and for **Ireland** for **Micro- and nanoelectronics.**

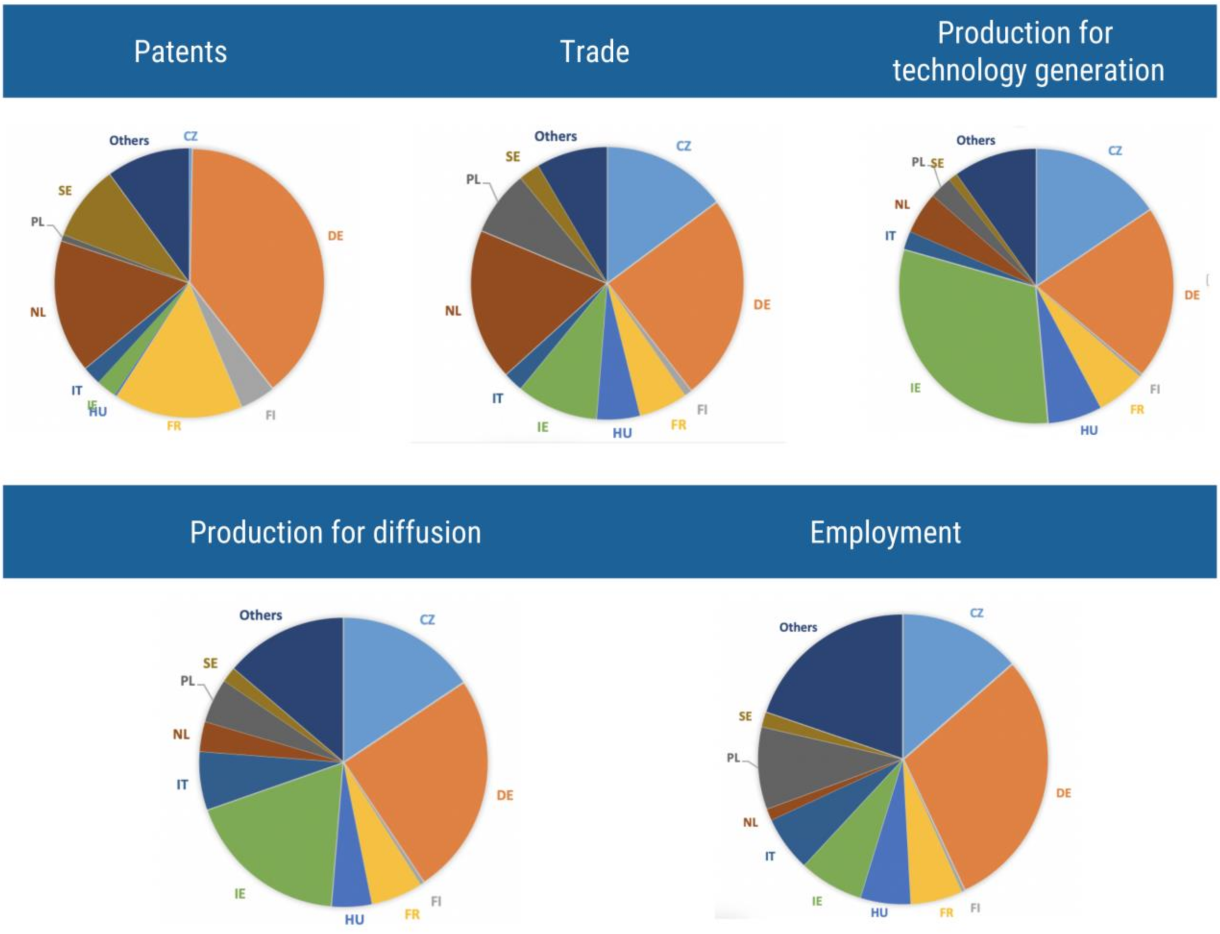
On the contrary, **Sweden and Finland** perform well in patenting in digital technologies such as **Artificial Intelligence**, but less in production, trade and employment. Hence, the strong knowledge base is not transferred in a broad industrial production along the value chain, but as the results in section 4.1. indicate, Sweden and Finland are rather specialised in certain key relevant professions and related tasks for those technologies.

Figure 52: Top 10 country shares in EU27 in Industrial Biotechnology in 2018



Source: Fraunhofer ISI and IDEA Consult calculations based on Eurostat

Figure 53: Top 10 country shares in EU27 in Artificial Intelligence in 2018



Source: Fraunhofer ISI and IDEA Consult calculations based on Eurostat

Section 7

7. Policy recommendations

The EU needs a technological base that can guarantee the prosperity of its industries and citizens in a responsible manner. The analysis of various data sources conducted in the framework of the ATI project highlighted several opportunities but also threats that need policy action at various levels. Based on the findings, this report formulated nine policy recommendations:

1st Recommendation: It is imperative to further bolster the financing of advanced technology development and deployment both at European, national and regional levels in order to sustain and (re)gain EU technological leadership. Current instruments such as the NextGenerationEU and the related Recovery and Resilience Facility should be used explicitly to target all types of advanced technologies relevant for the future of European industry.

The EU27 has technological strengths in the field of Advanced Manufacturing and the Internet of Things but also key deficiencies for instance in Artificial Intelligence and Big Data. Trends over time call the attention to the overall pressure on the advanced technology landscape of the EU. Even areas where it has a competitive advantage are challenged by global competitors and the current position will be hard to improve or keep without bold actions.

2nd Recommendation: Investments must focus both on EU's strengths and on areas that are critical to protect technological independence.

- ***Ongoing European initiatives related to Artificial Intelligence and the European data strategy should be followed up by dedicated EU funds to AI research and technology development and should foster venture capital investment in specific application areas.***
- ***At the same time, a coordinated EU strategy should be also put in place in the field of Advanced Manufacturing including a range of other related technologies in order to maintain current strengths.***
- ***EU policy should also look at the intersection of technologies and how a mix of technologies can make a difference for the competitiveness of industries (e.g. use of AI in circular industrial technologies, combination of Advanced Manufacturing, AI, Cloud and Internet of Things) instead of any narrow focus.***

In recent years the attention of the EU has turned towards Artificial Intelligence and its implications for the economy; rightly so given the transformative nature of these technologies. Efforts have been made to strengthen investment in AI, deal with the ethical consequences and monitor development. The European Commission has set out a European initiative on AI which focuses on boosting the EU's technological and industrial capacity and developing an innovation ecosystem. The ATI analysis has revealed some positive signs such as a growing EU AI startup scene or the increasing awareness of and advancements in AI skills which show that the public efforts start working out on the ground. Nevertheless, the analysis also pointed out key gaps. Besides the attention towards AI, the EU should watch out that its current strengths in other advance technologies are not lost either. Advanced Manufacturing including the Internet of Things and Robotics should be fields to invest in and innovation and entrepreneurship should be incentivised.

3rd Recommendation: Investment into the development of technological excellence and into the deployment of advanced technologies for industry should be better balanced out. EU policy should better focus on concrete application areas and commercialisation pathways of advanced technologies while keeping in mind technological sovereignty at the global level.

In several countries, technological strengths in terms of patent applications are different from strengths in the technological component of trade and production. This calls the attention to the fact that while some countries might be less developed in generating certain technologies, they can be strong in related products and application fields. EU, national and regional policies are often focused on research and technology development, while not enough attention is devoted to the use of technologies.

4th Recommendation: The diffusion of advanced technologies into a broader set of industries and sectors should be better supported in order to facilitate technological transformation across the economy. In this regard, the list of advanced technologies to be monitored should be reassessed and include other emerging technologies relevant for the future of European industry.

The ATI analysis pointed out the disadvantages of a lower level of technology diffusion across the economy that is pertinent in the EU compared to the US. Although certain industries such as automotive, electronics or finance lead the way in technology adoption, other sectors are not benefitting and risk falling behind. This is a particular challenge for regions with a more traditional industrial structure. At the same time, there are a range of further technologies that significantly affect the future of European industry. Low carbon and circular industrial technologies, life sciences and new digital technologies will play a key transformative role.

5th Recommendation: Besides supporting technology development, EU policy should bring back the discussion on service innovation and business models for technology on the policy discussion fora. Policy measures should consider the service innovation element when supporting the generation and deployment of advanced technologies.

Technological advancements are just one side of the coin. One of the critical success factors will be whether organisations, companies and whole industries find the right new business models, innovate in their service portfolio around the technology and adjust their operational processes in order to optimise the return on investment in advanced technologies. The case of many online platforms pointed out the relevance of how they manage to build full customer service and personalised operation with the help of advanced technologies and how this new business model alters the operational logic of whole industries. Another example is in Robotics, where the model of 'robot as a service' can foster technology uptake among manufacturing SMEs.

6th Recommendation: Skills and talent sourcing should remain a priority area of public policies. Skills development both related to the technology itself and about the use of technology, including the understanding of how to deploy advanced technologies in a responsible way, should be further bolstered at all policy levels. The attraction and employment of tech talent in industry is a pertinent policy gap that should be addressed by removing existing barriers and facilitating new opportunities.

The skills challenge has been well recognised at EU level, especially the challenge to supply enough digital skilled professionals. Policymakers have mapped out the pathways for upskilling the existing workforce to balance new digital skills with industrial expertise. Collaboration with education institutes will be critical to ensure curricula are matched with the skills requirements of industrial transformation. Advanced technologies are changing particularly fast and call for flexibility in skills agendas but also for the readiness of the workforce to retrain. To be innovative, companies need to harvest talent, but the demand exceeds the current skills supply, with too few professionals combining tech and industrial skills. The competition among sectors and industries for tech talent should be recognised and addressed.

7th Recommendation: The EU should develop an international strategy for advanced technologies linked to its external economic instruments including international partnerships on the access to critical raw materials, cooperation of technology deployment, access to skills and the promotion of green technologies at a global level.

There are huge opportunities currently unexploited at an international scale. The ATI analysis revealed that the EU27 is less connected globally in terms of technology cooperation in particular in the field of talent scouting and is too much reliant on US relations in an unbalanced way. The EU could benefit from establishing more strategic international partnerships and cooperate on the global technology landscape.

8th Recommendation: The regional and local dimension should be a more accentuated part of future EU industrial technology related strategies. More needs to be done to link the smart specialisation discussion to the fora on developing new industrial pathways.
Regional disparities in the EU technology landscape are striking and will be a key issue to address. The EU cannot afford to leave certain regions behind in the race of fast-paced technological development. Startup and venture capital investment in advanced technologies are far too much concentrated in certain places that can negatively impact European cohesion. A balanced technological landscape across the EU can also ensure that talent and potential in all regions are sufficiently exploited.

9th Recommendation: Public policy at all levels should further strengthen the actions related to SME support to advanced technologies. Initiatives such as the ATI technology centre mapping can become instrumental in this respect but will need to be better connected to other SME related initiatives such as the Enterprise Europe Network, the European Cluster Collaboration Platform and the Digital Innovation Hubs. Capacity building programmes that target SMEs in the field of advanced technologies should be further rolled out.
In particular, SMEs will need support in developing and executing technology-related strategies. While large firms have the power and resources to deploy advanced technologies, small firms are disadvantaged, do not have the computational or production infrastructure to make full use of emerging technologies. There are currently several networks and initiatives operating at different levels (European, national, regional) and with a different technology/application focus. Those SMEs willing to embark on R&D projects might face difficulties finding their way through the multiple initiatives. Better structuring the access and information about these networks and initiatives at EU level could facilitate SMEs access to them. ATI technology centres can play the role of local 'satellites' in the individual countries which can bridge language and national gaps and serve as a gateway to the broader European offer.

Section 8

8. Conclusions

Through an in-depth analysis of traditional data sources and novel metrics, the Advanced Technologies for Industry (ATI) report has analysed in detail the trends in the generation, uptake and diffusion of advanced technologies, the related entrepreneurial activities, and the demand and supply of skills associated with advanced technologies. The analysis has explored the role that advanced technologies can play in the process of Europe's industry modernisation and on the influence that they can exert to shape the current and future digital opportunities for the EU.

The starting point of this analysis has been sixteen advanced technologies that have been identified in conjunction with the European Commission as a priority for European industrial policy. They are the core technologies that enable process, product and service innovation throughout the economy and that can foster industrial modernisation. Advanced technologies have been 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 Cybersecurity (IT for Security).

The study has found areas of excellence across the EU, together with elements that deserve close attention to bridge the gap that Europe has with its most relevant international competitors. All in all, the EU27 has a leading position in various advanced technologies such as Advanced Manufacturing and the Internet of Things and has recently managed to considerably increase investment in Artificial Intelligence. The EU holds the highest share (30.6%) of worldwide patent applications in Advanced Manufacturing technologies and its focus on industrial applications is mirrored by the high share of Internet of Things technologies (28.8%) complemented by a high share of digital technologies for Mobility (26.7%) in line with its strengths in the vehicle and aeronautics industry.

On the other hand, European Union shows weaknesses in Micro- and nanoelectronics inventions and in areas such as Big Data and Artificial Intelligence where the EU27 shares remain low (14.7% and 16.2% respectively) while shares in Robotics, Nanotechnology, Industrial Biotechnology, Photonics and Advanced Materials appear to be in line with world trends, ranging between 17% and 21%. In terms of patenting, the aggregate figures for all advanced technology patent applications in the EU27 display a nearly tenfold rise in China's contribution to worldwide patenting since 2005 with figures having more than doubled since 2012. On top of this, and with few exceptions such as the Internet of Things, the EU is increasingly struggling to match the growing trends that China is consistently exhibiting in most of the advanced technologies, particularly in Robotics and Advanced Manufacturing.

Despite these challenges, the EU managed to considerably increase the level of investment deals in advanced technologies in the year 2020, and this in spite of the pandemic. The increased attention of investors for advanced technologies has been driven by the accelerated digitalisation trends and new demand for various tech-based applications and services. In 2020 private equity and venture capital funding have been invested mostly in firms developing Mobility technologies followed up by Biotechnology and Artificial Intelligence in the EU27. This has been reflected in the number of startups that were founded in the EU after 2015. Countries that have the highest number of startups include Germany, France and the Netherlands. When compared with the size of the country and their economic relevance, Member States like Estonia, Ireland and Belgium stand out from the EU27 average and show promising trends that could be adopted as best practices for the rest of the EU Member States.

In terms of employment, while some European companies continue to register their headquarters in one EU country, they have relevant labour force and developments ongoing in another Member State. This trend goes hand-in-hand with the fact that a considerable portion of European tech firms is increasingly looking for US investors to back their capital growth. This phenomenon has also been linked by a tech migration to the US with some European companies moving their headquarters oversea in order to have access to capital and larger markets. The analysis of the geographical location of professionals employed by Artificial Intelligence companies estimates that 9.9% of AI employment generated by EU27 companies can be attributed to the US. On the other hand, 14.5% of AI employment generated by US AI companies is linked to India and Israel.

The analysis of various data sources conducted in the framework of the ATI project highlighted some of the key worldwide strengths of the EU such as in the field of Advanced Manufacturing and the Internet of Things but also key deficiencies for instance in Artificial Intelligence and Big Data. Trends over time call the attention to the overall pressure on the advanced technology landscape of the EU. Even areas where the EU clearly exhibits a competitive advantage are challenged by global competitors and the current position will be hard to improve or keep without bold actions. For this reason, the report recommends further strengthening the financing of advanced technology development and deployment at European, national and regional levels in order to sustain and gain EU technological leadership. Current instruments such as the NextGenerationEU and the related Recovery and Resilience Facility should be used explicitly to target all types of advanced technologies relevant for the future of European industry. It also calls for investment to focus both on EU's strengths and on areas that are critical to protect technological independence. For instance, the European initiative on AI should be followed up by dedicated EU funds to AI research, technology development and venture capital investment in specific application areas. At the same time, a coordinated EU strategy should be also put in place in the field of Advanced Manufacturing including a range of other related technologies.

The analysis conducted throughout the ATI study pointed out the disadvantages of a lower level of technology diffusion across the economy, which is evident in the EU if compared to the US. Although certain industries such as automotive, electronics or finance lead the way in technology adoption, other sectors are not benefitting and risk falling behind. This is a particular challenge of regions with a more traditional industrial structure. As a result, the diffusion of advanced technologies into a broader set of industries and sectors should be better supported in order to facilitate technological transformation across the economy. However, improved diffusion and technological advancements are just one side of the coin. One of the critical success factors for Europe will be whether organisations, companies and whole industries find the right new business models, innovate in their service portfolio around the technology and adjust their operational processes to optimise the return on investment in advanced technologies. The case of many online platforms emphasised the ability of European companies to build full customer service and personalised operation with the help of advanced technologies and how this new business model alters the operational logic of whole industries. Another example is in Robotics, where the model of 'robot as a service' can foster technology uptake among manufacturing SMEs.

To further modernise its industry basis and enhance its competitiveness on the international scene, the EU policy should bring back the discussion on service innovation and business models for technology on the policy discussion fora. Policy measures should consider the service innovation element when supporting the generation and deployment of advanced technologies. Linked to the ability to deliver innovative services is also the ability to muster the necessary skills associated to the diffusion and deployment of advanced technologies. The skills challenge has been well recognised at EU level, especially the difficulty to supply enough digital skilled professionals. Policymakers have mapped out the pathways for upskilling the existing workforce to balance new digital skills with industrial expertise. Collaboration with education institutes will be critical to ensure curricula are matched with the skills requirements of industrial transformation. Advanced technologies are changing particularly fast and call for flexibility in skills agendas but also for the readiness of the workforce to retrain. To be innovative, companies need to harvest talent, but the demand exceeds the current skills supply, with too few professionals combining tech and industrial skills. The competition among sectors and industries for tech talent should be recognised and addressed. For the same reason, skills and talent sourcing should remain a priority area of public policies.

On the worldwide scene, the EU should develop an international strategy for advanced technologies linked to its external economic instruments including international partnerships on the access to critical raw materials, cooperation of technology deployment, access to skills and the promotion of green technologies at a global level. Conversely, attention should also be devoted inside Europe. Regional disparities in the EU technology landscape are striking and will be a key issue to address. The EU cannot afford to leave certain regions behind in the race of fast-paced technological development. Startup and venture capital investment in advanced technologies are far too much concentrated in certain places which can negatively impact European cohesion. A balanced technological landscape across the EU can also ensure that talent and potential in all regions are sufficiently exploited. For this reason, the regional and local dimension should be a more accentuated part of future EU industrial technology related strategies. More needs to be done to link the smart specialisation discussion to the fora on developing new industrial pathways. SMEs in particular will need support in developing and executing technology-related strategies. While large firms have the power and resources to deploy advanced technologies, small firms are disadvantaged, do not have production infrastructure to make full use of emerging technologies.

Finally, the SME dimension, a clear distinctive character of Europe's economic structure, should be duly considered. Public policy at all levels should further strengthen the actions related to SME support to advanced technologies. Initiatives such as the ATI technology centre mapping can become instrumental in this respect but will need to be better connected to other SME related initiatives such as the Enterprise Europe Network, the European Cluster Collaboration Platform and the Digital Innovation Hubs. Capacity building programmes that target SMEs in the field of advanced technologies should be further rolled out.

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. It 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;
- Analysis of industrial value chains and policy needs;
- 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 and city mapping.

You will 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 European Innovation Council and SME Executive Agency (EISMEA) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

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