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Advanced Technologies for Industry – Sectoral Watch

Technological trends in the medical devices industry and related healthcare

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Introduction

This sectoral report has been prepared in the framework of the '*Advanced Technologies for Industry*' (ATI) project. It analyses **trends in the generation and uptake of advanced technologies, entrepreneurial activities and skills** supply and demand in the **medical devices industry**, and secondly, **it also explores trends in the related healthcare sector** from a demand-side perspective. The analysis interprets data from a list of sources compiled to monitor advanced technologies and their applications in industry across Europe and key competitor economies. Medical devices are defined as any apparatus, appliance, software or material, which is used for the diagnosis, prevention, monitoring, or treatment of diseases, injury or disability[1]. Besides medical devices, it also discusses the related use and uptake of digital technologies in the healthcare sector.

The starting point of this analysis has been 16 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, Internet of Things, micro and nanoelectronics, mobility, nanotechnology, photonics, robotics, security*.

The relevance of these specific technologies in the medical devices industry has been explored through patent analysis and data on private equity investments, skills and technology uptake. The full methodology behind the data calculations is available here:

This report is structured as the following:

- The first section sets the industrial context.
- The second section analyses technological trends in advanced technologies applied in the medical devices industry based on patents and text-mining of company websites.
- The third section presents findings about private equity investment and startup/spinoff activity.
- The fourth section explores the supply and demand of skills related to advanced technologies.
- The fifth chapter concludes with a short future outlook.

[1] European Patients Forum, 2019

Section 1

1. Setting the scene: industrial context

Key messages

The medical devices industry is being radically transformed by digital technologies as the industrial and healthcare ecosystem shifts to **connected healthcare models** and **artificial intelligence** and data enables the development of new solutions.

Manufacturers specialised in medical devices are **challenged with new consumer-goods oriented actors and digital service providers** entering the value chain. Firms are forced to adapt their business models and generate new value by offering complementary services such as data analytics.

The EU27 has a positive medical technology trade balance and employs more than 550,100 people in medical devices, although the US is the largest producer and largest market. EU27 strengths lie in the healthcare system, high research expenditures, quality research centres and highly qualified workforce.

1.1 Towards smart medical devices

With the evolution towards a patient-centred and outcome-based delivery model in healthcare, technological progress allows personalised health to become more and more common[2]. Next generation medical devices embrace today advancements from the Internet of Things, 3D printing technologies, advanced materials, artificial intelligence, data management or blockchain. Within diagnostics, remote, robotic and self-diagnostics are becoming widespread. Areas with particular opportunities for growth include genomics, especially DNA diagnostics in personal medicine, and technologies that involve or facilitate less invasive procedures.

Connected medical devices are products that blend traditional medical devices, diagnostics or sensors with information and communication technologies. Some involve separate devices that can communicate with a smartphone or tablet, whereas others are directly integrated into such consumer devices such as medical apps. New data can be generated through clinical wearables (e.g. blood pressure, glucose levels), physical parameters (sleep patterns, mood); activity levels (e.g. step counters and fitness trackers) and behaviours (e.g. smoking, caloric intake). The data and medical devices are also coined as **Internet of Medical Things** – a "connected infrastructure of medical devices, software applications and health systems and services"[3].

Smart medical devices also include novel products that are enabled by medical technologies but are not necessarily connected. Such smart devices can be for instance smart injectors, smart pills, smart drills, wearables. There is an increasing need for injection devices that support the administration of medicine with intelligent built-in electronics and software such as smart injection devices with supplementary intelligent, built-in functionalities. Smart devices offer expertise in medical diagnostic, help search for a doctor, enable remote consultations or provide shopping features for over-the-counter medicines.

Various digital technologies enable **smart health applications** such as virtual reality, 3D printing, or bio-nanotechnology. Virtual and augmented reality helps creating a simulated environment and improves patient experience, provide psychological relief, data visualisation and advanced diagnostics for doctors.

3D medical printing is a technique that is expected to develop a lot in the area of healthcare and finds application in several segments of the medical industry, with its major implementation seen in 3D-printed prostheses. A further example in this category is minimally invasive surgery delivered by robot technology in combination with endoscopic techniques.

This new value 'ecosystem' of next generation medical devices is becoming more and more complex for the almost 27,000 medical technology companies that are based in Europe. In the race of big data, medical devices firms have to compete with consumer technology companies that have the advantage of being closer to their consumers and more equipped with marketing strategies. These new actors include not just consumer-goods oriented firms but also others that provide IT services at the core and are more experienced in data management

[2] Irish Medtech Association Skillnet, Future skills needs analysis for the medical technology sector in Ireland to 2020

[3] De Jongh, Izsak et Oomens (2019). Analytical report on the Strategic Value Chain on Smart Health

1.2 European strengths in medical devices

Europe has a strong medical devices industry with high-level of R&D and patenting activity. EU27 strongholds of the medical devices industry are located mostly in Germany, France, Italy and Spain[4] (see Figure 1). Germany had a medical technology industry worth €30 billion in 2017 with over 1,250 companies that invested around 9% of their turnover in R&D in the past years[5].

Europe had a positive medical technology trade balance of €19.7 bn in 2017[6] and the EU27 employs more than 550,100 people in medical devices. The global investment landscape in medical technologies is led by the US and Europe takes a second position. The US is both the largest producer and the consumer of medical devices. The capital pool is increasingly expanding with investments from Asia. As economic development unlocks the potential in emerging markets such as in China and India[7], medical devices firms face not only new challenges but new opportunities too.

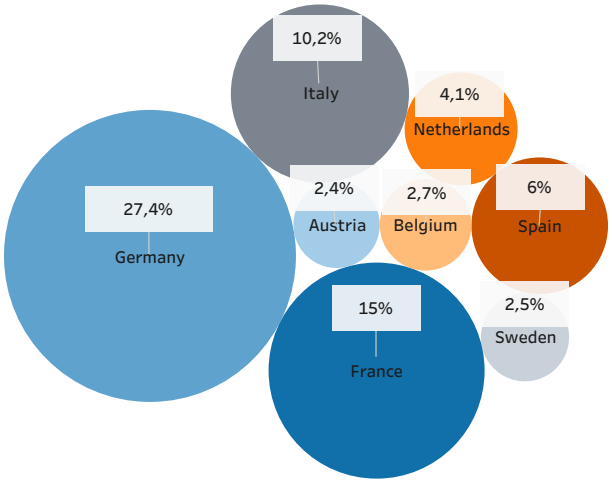
The sector is dominated by SMEs. 99% of enterprises in the medical devices industry employ less than 250 persons in the EU27 (Eurostat, 2017). According to the figures of the Structural Business Statistics, there were 65,189 firms active in the Manufacture of medical and dental instruments and supplies and in Manufacture of irradiation, electromedical and electrotherapeutic equipment in 2017, out of which 257 were large firms[8].

The strengths of the EU27 medical device sector lie in the high expenditures on healthcare and medical technologies, high research expenditures and in the qualified workforce[9]. The EU27 has high quality research centres, business incubators, science and technology research parks with strong activity in the field of medical devices. The European medical technology industry makes up 29% of the world market[10]. The innovative strength is also demonstrated by the fact that one third of the medical devices industry turnover comes from products less than three years old.

The medical devices sector is highly driven by the wearable devices segment with the development of major advances in medical devices and smartphone-based apps allowing seamless and nearly constant biomarker monitoring[11].

On average approx. 10% of GDP is spent on healthcare in Europe. Out of the total healthcare expenditure, around 7.2% is attributed to medical technologies, which varies significantly across European countries[12].

Figure 1: European medical devices market by country based on manufacturer prices, 2017



Source: MedTech Europe, 2019

The medical devices industry value chain used to be dominated by the manufacturing process where most of the value was captured. In the new era of value-based healthcare firms are forced to adapt their business models and generate new value by offering complementary services and data analytics[13]. Patients, healthcare institutions and insurers play an increasingly important role in the value chain.

[4] MedTech Europe (2019) The European Medical Technology Industry
[5] GTAI, Medical Technology – Europe's biggest market, 2018
[6] ibid
[7] EY, Medical Technology report 2017
[8] https://ec.europa.eu/eurostat/web/structural-business-statistics
[9] Maresova P, Penhaker M, Selamat A, Kuca K. The potential of medical device industry in technological and economical context.
[10] MedTech Europe (2018) The European Medical Technology Industry
[11] https://www.marketresearchfuture.com/reports/wearable-medical-device-market-899
[12] MedTech Europe (2019) The European Medical Technology Industry
[13] KPMG, 2018

Section 2

2. Technological trends

Key messages

The three most relevant advanced technologies in terms of patent applications filed by the medical devices industry were **Industrial biotechnology, Advanced Manufacturing and Artificial Intelligence** in the period of 2015-2017. This pattern means a change compared to the situation a decade ago, when Photonics and Advanced materials had been much more relevant for this industry.

Advanced technologies that have been referenced the most as part of the products and services of medical devices firms include the **Internet of Medical Things** (27% of firms in the sample), **Advanced Materials** (22%) and **Big data** (19%). **B2B platforms** help create collaboration among large firms, SMEs and hospitals, while firms reach out to patients through platform-based health services. The share of medical devices manufacturers offering **services** besides their products **is quite high with a share of approx. 72%** in countries such as Germany and France.

89% of surveyed healthcare institutions have adopted Standard Connectivity solutions but only 27% are using Advanced Connectivity. 75% use Public Cloud to ease collaboration and to transfer data more efficiently among each other. Other digital technologies such as **Big data, IoT or Artificial Intelligence** have been adopted by a much lower share (32, 29, 18% respectively).

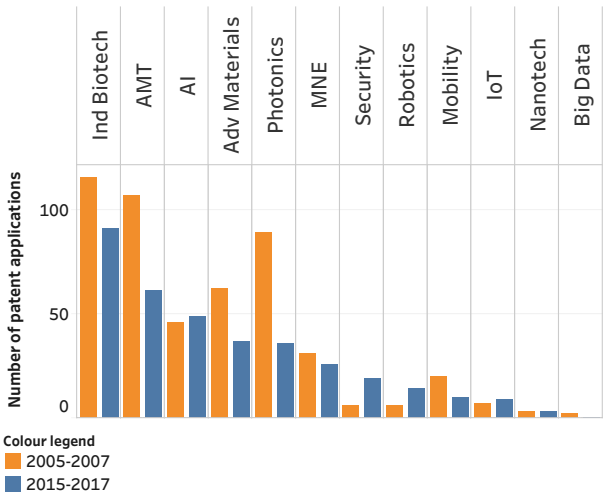
Medical technology is one of the most dynamic fields of research and innovation of our times. The Global Innovation Index 2019[14] revealed that medical technology is now one of the top five fastest growing technology fields (besides IT). In the field of medical technology more than 13,000 patent applications were filed with the European Patent Office (EPO) in 2017[15], where 40% of these applications originated from the EU28, Norway and Switzerland and 60% from other countries, out of which with the majority of applications filed from the US (37%). A positive trend can be observed in medical technologies, where over the last decade the number of EPO filings has doubled.

2.1 Trends in patent applications filed by medical devices companies

Technological trends and development have been captured through patent analysis[16] conducted in the framework of the ATI project. The evolution of patent applications in advanced technologies has been analysed specifically for medical devices. The results indicate that the three most relevant advanced technologies in terms of patents have been **Industrial biotechnology, Advanced Manufacturing and Artificial Intelligence** in the period 2015-2017. Artificial intelligence has a profound impact on diagnosis and imaging, where the combination of nanobots and AI will speed up diagnosis and subsequent care decisions.

This pattern means a change compared to the situation a decade ago in 2005-2007, when Photonics and Advanced materials were much more relevant for this industry. This trend might reflect the rapid advancements in digital technology and especially in AI.

Figure 2: Advanced technology patent applications by the medical devices industry in the EU27



Source: ATI, 2019 Fraunhofer calculations, tableau

14 https://www.wipo.int/publications/en/details.jsp?id=4434

15 MedTech Europe (2019) The European Medical Technology Industry

16 The patent analysis reflects the owner (applicant) of the technology, since patents have been localised based on the location of their legal owner.

Although medical technology patenting overall (by any type of organisations not only by firms classified under the NACE categories of medical devices) is on the rise, we observe a decrease in the number of patent applications of medical devices firms in Industrial biotech, Photonics, Advanced materials and Micro- and nanoelectronics.

On the one hand, there is a shift of priorities. The focus of new knowledge creation has moved to areas related to digital technologies such as Internet of Things, Artificial Intelligence, Robotics and Security.

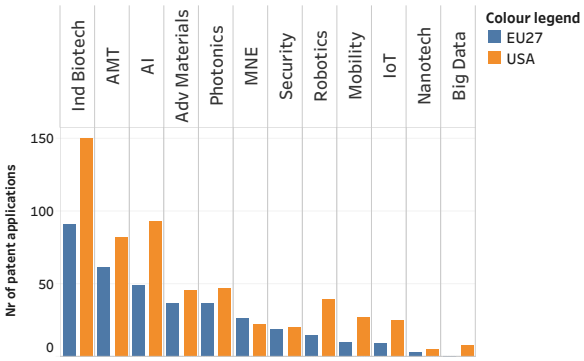
The decrease in the number of advanced technology related patent applications by medical devices firms might also reflect that medical technology is driven by other sectors such as computer, electronics, telecommunications and IT instead of medical devices manufacturers themselves. Some of these new entrants will be also at the forefront of introducing AI into healthcare delivery. For instance, Google[17] is using deep learning (an AI branch) and has been working on an AI model that can spot breast cancer in anonymised screening mammograms with greater accuracy (fewer false positives and fewer false negatives) than experts.

Robotics related patent applications of medical devices companies represented 4% of all advanced technology related patent applications in the EU27 in 2017. Nevertheless, within diagnostics, remote robotic and self-diagnostics are becoming more and more widespread. Innovative surgical inventions include autonomous surgical robots and intelligent balloon catheters that have the potential to enhance outcomes of complex surgeries and enable new forms of minimally invasive surgeries[18].

Through patent analysis it has not been possible to track the relevance of blockchain for medical devices firms, although blockchain's potential on this industry is expected to be even greater than its impact on the financial services sector[19]. New solutions based on blockchain technology can include, for instance, preventative maintenance of devices, a strengthened manufacturing process, digitised business processes and 'smart contracts' with enhanced safety measures and evidence for value-based payments.

European medical devices firms have been much less active in terms of patent applications in advanced technologies **than the US** medical devices industry. In the period 2015-2017, US firms filed more patent applications in all technologies except for Micro- and nanoelectronics. The gap is the most pronounced in Industrial biotechnology and Artificial Intelligence. Chinese medical devices firms did not file any digital technology related patents to EPO as this analysis found.

Figure 3: Advanced technology patent applications by the medical devices industry, EU27 and US, period 2015-2017



Source: ATI, 2019 Fraunhofer calculations, tableau

Research and technology development in medical technologies is dominated by the US and the EU. Other countries such as Japan or China stay behind in medical devices. Nevertheless, the recent Global Innovation Index 2019 hinted to the fact that larger emerging economies, like China and India, and even smaller ones, like Indonesia are progressively making their mark on the global health landscape.

2.2 Integration of advanced technologies into products and services of the medical devices industry

A large-scale text-mining[20] of company websites belonging to the medical devices industry shed new light on how advanced technologies are changing the rules of the game in this sector. This analysis reflects about the use of technologies embedded in new products and services and about technological advantages that companies communicate about. It cannot be used, however, to conclude about the adoption of advanced technologies in terms of the more hidden production processes that are being less revealed through online content.

The medical device industry is composed of companies producing medical supplies such as wound care, surgical instruments and healthcare

[17] https://www.blog.google/technology/health/improving-breast-cancer-screening/

[18] KPMG, Collaboration — The future of innovation for the medical device industry, 2016

[19] ibid

[20] Based on a search algorithm, company websites were analysed for links to each specific technology in September-November 2019. The analysis of 3,298 websites of medical devices companies across six European countries, including Denmark, France, Germany, Italy, Netherlands and Spain.

equipment. The level of advanced technology adoption depends on which part of the value ecosystem companies are active since they provide different levels of products and services.

The traditional value chain of the medical device industry has been driven by innovation and research and companies delivered value primarily through manufacturing and selling their products. Nevertheless, medical devices companies are getting closer to customers, payers, patients as personalised medicine and telemedicine are spreading. This is also reflected in the number of medical devices firms promoting services such as client and professional assistance and tailor-made solutions.

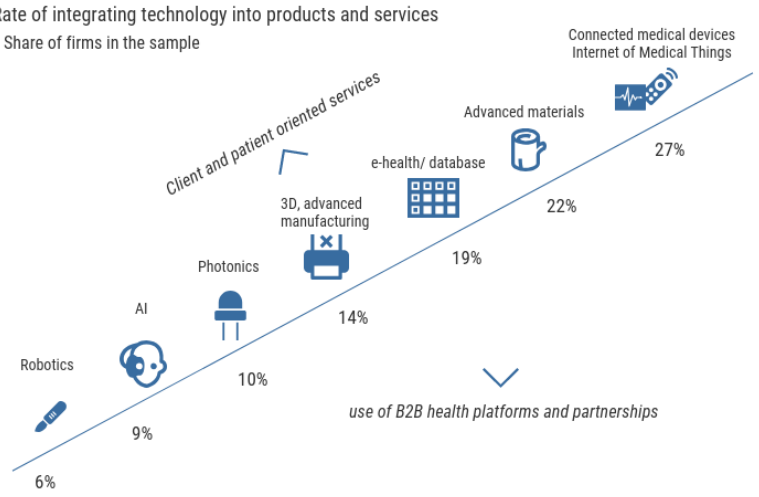
The first finding of this analysis is that the share of firms with services - as observed through the text-mining of company websites - is quite high and around **72% in countries such as Germany and France**. This proves the importance of the trend that medical devices firms offer more and more services besides their products and support hospitals and healthcare institutions directly. The sample signals a potentially upcoming trend where collaborative health gets an increasing attention. Medical device firms lead on collaborative models not only with physicians and hospitals but also with other companies and the rest of the supply chain. These collaborative models are expected to find cost-efficient and innovative healthcare solutions.

According to this analysis the advanced technologies that have been referenced the most as part of products and services are the **Internet of Medical Things** (27% of firms in the sample), **Advanced Materials** (22%) and **Big data** (19%). The latter often includes patient data collection services or support provided to e-health databases (see Figure 4).

IoT technology appears in the references to connected healthcare devices in particular as the Internet of Medical Things (as the fusion of medical devices and applications that can connect to health care information technology systems using networking technologies). The examples include for instance hearing aids that are connected with a smartphone or connected inhalers for chronic respiratory disease management.

The use of **Advanced materials** such as biomaterials and micro- and nanomaterials can create a competitive advantage for medical device manufacturers. Innovation in the composition of the material is driven by quality and longevity requirements but also by sustainability considerations. Although we can assume that the adoption of advanced materials is not necessarily highlighted as part of a product marketing, this analysis found references to new materials in 22% of the sample, which points to the importance of this technology for the industry.

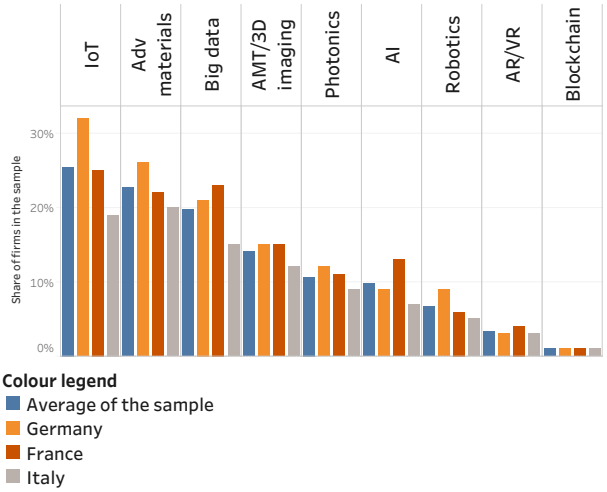
Figure 4: Adoption rate of technology by medical devices firms – measured as a share of companies referencing the technology on their websites



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

Big data is being leveraged by medical devices companies as new intelligence is built into medical equipment. Data and analytics allow companies to stay in contact with healthcare providers and patients and open up new horizons for value added services. Predictive models for patient risk and resource use are also used to predict future behaviour in order to drive better clinical decisions.

Figure 5: Rate of integration of technology into products and services of medical devices firms



Source: Technopolis Group, 2019, tableau

To give some concrete examples, the Navina™ Smart Data developed by the Irish Fannin[21] shares data from users with healthcare professionals in order to support direct overview of treatment progress. In addition to the support of individual patients, data provide input for further extensive research.

3D printing as part of Advanced Manufacturing technology has been identified on 14% of the company websites in the sample. 3D printing technology promises a cost-effective and personalised manufacturing option for a range of medical devices and equipment. As an example, the French Lattice Medical is a biomedical startup founded in 2017 that is specialised in 3D printing of bioabsorbable implants.

Photonics is a technology that enables the production of faster and cheaper medical devices. Biophotonics is a relatively new research domain that will be very important for diagnostics and monitoring[22]. The text-mining of company websites can reflect on the share of firms with light-based medical devices or products that rely on laser, UV lamps, LEDs or lenses. References to these products have been captured on 10% of the websites in the sample.

Artificial intelligence and the use of related machine learning and deep learning algorithms have appeared in 9% of the cases text-mined. This digital technology is used for instance to support AI-based cardiac ultrasound analysis. It also appears in the example of hearing aids that are enhanced by machine learning and driven by the user's preferences and intentions. A simple interface uses the hearing aid user's smartphone. Step by step, the machine is guiding the user to better hearing by using simple comparisons. The user has to choose what sounds best each time. The machine learning algorithm helps predict the preferred setting.

Robotics appears to be a niche technological field with a small share (6%) of the medical devices firms that moved into this direction as observed in this analysis. To give an example, the MMI - Medical Microinstruments is an Italian company specialised in teleoperated robotic micro instruments and platforms for open surgery.

There are a couple of other advanced technologies such as augmented and virtual reality or blockchain that are relevant for the medical devices industry, however, they could not be captured under this analysis. The use of AR/VR is instrumental for instance in deep brain stimulation.

In addition to the set of advanced technologies in the focus of this report, **B2B health technology platforms** have been also analysed through text-mining. Although a very low share of firms uses this model, several interesting examples have been identified where manufacturers offer their partners and also customers a technology platform to develop new improved equipment. These platforms enable a next generation product development process and better risk management. This might also set a new trend in the future. For instance, the Italian Esaote that develops ultrasound and MRI medical diagnostic systems has established partnerships for an integrated IT platform dedicated to cardiology.

2.3 Technology adoption in healthcare

With the aim to examining the role of advanced technologies in shaping industrial transformation in Europe, the Advanced Technologies for Industry (ATI) survey was conducted between July and September 2019[23]. This survey investigated the take-up of advanced technologies, including their level of adoption, the associated industry-specific use cases, the digital transformation drivers that are sustained by these technologies, their expected business impacts as well as the enabling conditions.

Organisations active in the healthcare sector were surveyed about their use of advanced technologies. The survey found that 89% of the institutions have adopted standard Connectivity solutions but only **27% are using advanced Connectivity[24]**. 75% apply Public Cloud to ease collaboration among doctors and departments and to transfer data more efficiently among each other. Cybersecurity is also a concern that is shown by the 60% adoption rate and the large share of organisation to adopt it in the coming months.

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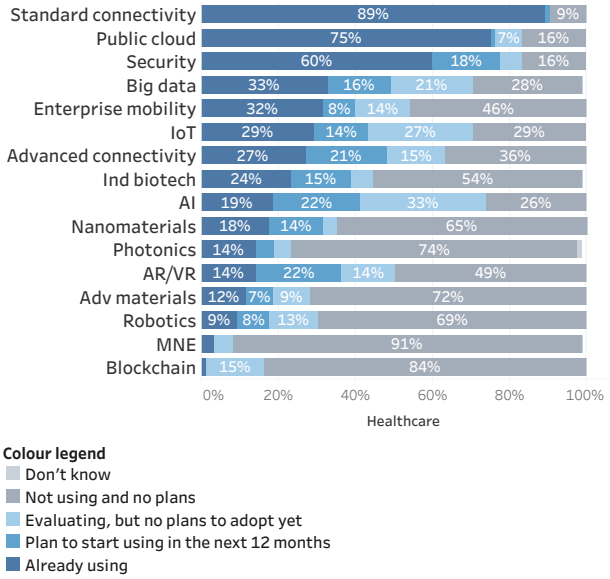
[21] https://www.fannin.eu/

[22] Imec, 2017

[23] The Advanced Technologies for Industry Survey sample consisted of 900 interviews of European organisations with more than 10 employees in the Czech Republic, Denmark, France, Germany, Hungary, Italy, the Netherlands, Poland, Spain, Sweden and United Kingdom. The survey was carried out between July and September 2019. A computer-aided telephone interviewing (CATI) system was used. Additional information on survey methodology can be found in the Advanced Technologies for Industry Survey - Methodological Report.

[24] Standard connectivity refers to all those technologies and services that allow end-users to connect to a communication network. It encompasses an increasing volume of data, wireless and wired protocols and standards, and combinations within a single use case or location. Advanced connectivity technologies expand beyond wired and cellular (e.g. 3G, 4G, 5G,...) services to Low Power Wide Area Network (LPWAN), Satellite, and Short Range Wireless technologies (e.g. Bluetooth, zigbee,..).

Figure 6: Share of organisations in the sample having adopted advanced technologies in the healthcare sector



Source: ATI survey, IDC calculations, 2019, tableau

Other digital technologies such as **Big data, IoT or Artificial Intelligence** have been adopted by a much lower share (32, 29, 18% respectively). Robotics is a niche technology with an adoption rate of 9% of healthcare institutions in our sample.

The most important purposes behind the adoption of the advanced technologies differ.

41% of respondents **apply IoT for Clinical care such as sensors remotely tracking vital signs of patients**, particularly in critical care/intensive care units and 35% for Sensor-based staff identification and location. 29% report the use of IoT to support smart pharmacy and laboratory and diagnostics such as sensors and devices transmitting via-network patient health information to clinical and administrative information systems.

In **Big data, 50% of respondents reported the use of data to drive innovation in medical research**, 40% for clinical decision support/evidence-based medicine and 40% for reporting on quality of care.

Artificial intelligence is mostly used for **IT automation** (31%). 25% of the respondents have already adopted AI technology to support **Clinical decisions** while the adoption rate is **20% in the case of Predictive workforce management**.

Section 3

3. Venture capital investment in medical devices and related advanced technologies

Key messages

Although the majority of VC-backed medical devices companies innovate in the field of **Industrial Biotechnology**, digital technologies in particular **Artificial Intelligence**, followed by the Internet of Things, Big Data, Robotics, m-health and 3D technology are key topics of venture capital investment in the medical devices industry. Some firms also combine the above-mentioned technologies in order to deliver healthcare solutions with increased quality and drive personalised healthcare.

VC investment in medical devices companies with a digital focus has been the highest **in France followed by Germany and Sweden in the period of 2009-2019.** Italy, Netherlands, Spain, Austria, Denmark, Finland, Belgium and Ireland are also among the top countries.

Comparing venture capital investment in medical devices, US-based medical devices firms received more venture capital investment in the past decade than the EU27 and they also have a higher average deal value.

Private equity, venture capital investment and related innovative startup creation have been explored based on a merged dataset available in Crunchbase and Dealroom. Crunchbase provides information on venture capital backed innovative companies. Dealroom contains the same type of information but with a better coverage for Europe. The investment figures presented in this section refer only to the funding rounds where a value has been disclosed.

3.1 Investing in medical devices firms developing and applying advanced technologies

Venture capital investors have been active in the past ten years in investing in medical and health technology. The majority of these VC-backed medical devices companies are innovating in **Industrial Biotechnology,** including life sciences and electronics such as for instance biosensors, bio-artificial systems, innovative diagnostic tools and the use of medical devices to deliver gene therapy.

Nonetheless, a growing share of medical devices firms are active in the application or development of **digital technologies** (21% of the sample). Investors see ample opportunities in fields such as:

- combination of medical devices and artificial intelligence with the objective to develop non-invasive monitoring capabilities,
- the internet of implanted medical devices,
- innovative medical devices for telemedicine applications,
- robotics technology and
- 3D printing of medical devices.

Given the high impact of digital transformation in the medical devices industry, Figure 7 highlights the number of active VC-backed medical devices firms that focus in particular on digital technologies and have been identified in the dataset[25]. The chart compares the EU27 and the US.

Figure 7: Share of VC-backed medical devices firms with a focus on digital technologies in total, 2019

Source: Technopolis Group, 2019, based on Crunchbase and Dealroom – category and business descriptions

[25] Digital technologies have been identified with the help of text-mining the business descriptions included in Crunchbase and Dealroom and based on a category search including AI, machine learning, 3D printing, Big data, m-health, Internet of Things

The analysis of the EU27 investment data (2009-2019) shows that venture capital investment targeted mostly medical devices firms that are engaged in **Artificial Intelligence** (including machine learning and deep learning). AI is not only used to support more reliable decision-making, but it also enables the development of mobile and portable medical tools[26].

Among the highest average investments are Medicus AI that is an Austrian company designing and developing an artificial intelligence-based platform. The firm converts health data in the form of cryptic numbers and medical language into an understandable explanation. Medicus AI has raised a total of €24.1 m in funding over 4 rounds. Their latest funding was raised on Dec 6, 2019 from a Series B round. Founded in 2015, the company has its headquarters in Vienna.

The second most important area from an investment perspective is connected medical devices with the **Internet of Medical Things**, where the EU has a relative advantage over the US. One example is the Irish PMD Solutions that is a medical device company developing CE marked respiratory diagnostic wearables for the hospital and home market. The company changed the traditional method of respiratory monitoring with a discrete, body worn, wireless sensor that comprehensively and continuously monitors patients' respiratory rate from administration to discharge.

When compared with the US, we can observe that the **European VC investment landscape** is concentrated more on **IoT,** however, the **US** has seen more VC investment **in AI** driven medical devices and Big Data services. The difference in the area of Big Data is important since the future take up of AI-based medical solutions will depend on the availability of high-quality datasets and capabilities in big data manipulation.

Robotics is the fourth most relevant digital technology when looking at the type of medical devices firms venture capital funds invested in. For instance, the French Robcath raised €5 m to fund its R-One robotic coronary angioplasty platform in Europe.

Although 3D technologies and 3D printing enabled several medical device breakthroughs in the past years, their relevance for VC investors is behind of other combinations of medical and digital technologies.

The comparison between the EU27 and US points out a relevant **gap in the field of m-health[27] and remote monitoring solutions**. US firms are more active in the area of mobile communication devices for health, the related well-being services and patient information systems as the VC investment landscape suggests.

Among the highest amount of VC investment in m-health/medical devices in the EU is the Austrian SteadySense, an innovative startup collecting medical data. The company develops sensor patch and near field communication solutions to simplify medical routines in homecare and in hospitals. SteadySense has raised a total of €6 m in funding. This was a Series A round raised in 2019.

Many of the VC-backed firms combine the above-mentioned technologies in order to deliver healthcare solutions with increased quality. Indeed, as experts also highlight, diagnostics, genomics, AI and data technologies will be more and more integrated and will reinforce each other, driving personalised care[28].

The number of startups established in the field of medical devices and related medical technologies have increased dynamically especially over the period of 2005-2016 (see Figure 8 on the next page). The lower number of firms established in 2017 or more recently is due to the nature of the database since there is a reporting lag and companies are included in the database when they become relevant for venture capital investment.

Raising money especially for digital medical device startups is, however, not easy. A challenge is to find investors that are ready to take the financial risk associated with such products and have a long-term horizon. As a result, startups are under strong pressure to provide proof-of-concept and demonstrate clinical safety for regulatory approval.

[26] See also in EY (2019)

[27] Mobile health or m-health refers to medical practices supported by mobile devices.

[28] EY (2019)

Figure 8: Evolution of VC-backed medical devices startups over time (2005-2019)

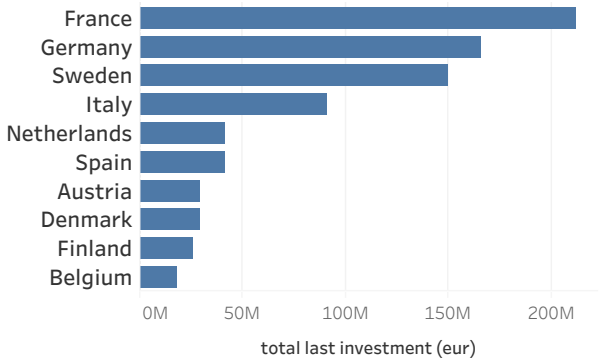
Country	Year 2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU27	42	40	42	36	44	62	57	66	111	114	102	101	59	39	10
France	7	10	6	7	12	13	12	11	8	19	16	13	4	5	2
Germany	7	5	6	4	4	13	9	6	9	11	8	16	10	6	1
Spain	5		7	4	5	4	2	8	10	18	18	10	12	3	1
Netherlands	4	3	2	3	6	4	11	10	12	11	13	12	8	2	3
Ireland	2	4	3	5	6	3	6	1	11	14	9	9	5	3	1
Sweden	7	4	7	2		6	2	8	10	10	6	6	1	2	1
Italy	3	1	1	1	4	5	5	6	10	3	5	4	2	6	
Denmark	2	5	1	1	2	4	3	2	4	9	3	4	3	3	
Poland		1		2			3	4	10	4	6	5	3		
Belgium		1	5	3	2	5	1	1	5	3	3	2	1	1	
Finland	2		1	2	1		2	3	3	2	4	7	1	1	
Austria		1	2	1			1	1	5	3	5	4	1	1	
Portugal	1	1	1		1	2			6	2	3	4	1	2	1
Hungary	1	1		1	1			1	2	1		1	3	3	

Source: Technopolis Group, 2019 based on Crunchbase and Dealroom

3.2 Venture capital investment in medical devices – country and international comparison

VC investment in medical devices companies with a digital focus (notably involved in IoT, AI, big data, m-health, robotics, digital apps) has been the highest in **France** followed by **Germany and Sweden** in the period of 2009-2019. Figure 9 displays the top 10 EU countries.

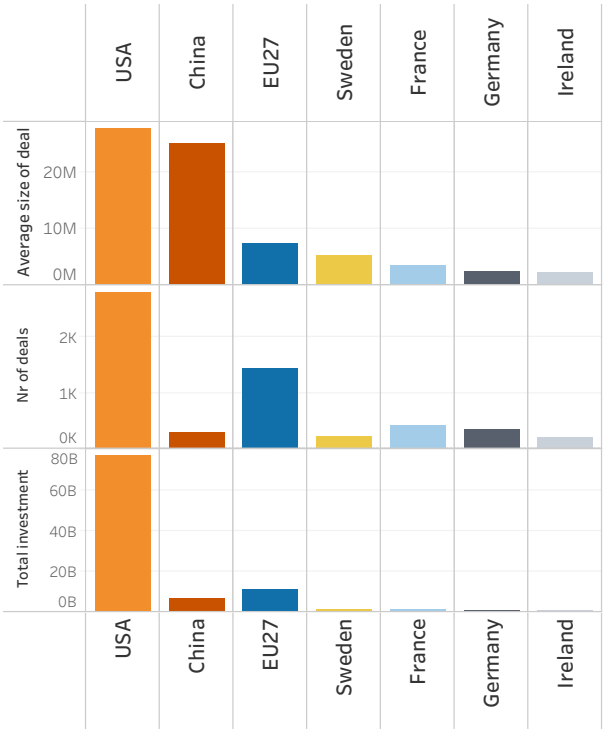
Figure 9: Total last Investments in medical devices and technology, 2009-2019



Source: Technopolis Group, 2019 based on Crunchbase and Dealroom, tableau

Comparing venture capital investment in medical devices globally, we observe a large difference among the US and the EU27 especially in the scale of funding and average size of funding deals. Despite the fact that the data (even with the integration of Dealroom) has a somewhat better coverage for US firms and investment deals, it is evident that US-based medical devices firms received more venture capital investment in the past decade in this field. Within Europe, France, Germany, Spain, the Netherlands, Sweden and Ireland are leading in terms of the number of investment deals.

Figure 10: Investment trends in medical devices and technology (eur), 2009-2019



Source: Technopolis Group, 2019 based on Crunchbase and Dealroom, tableau

Section 4

4. Skills supply and demand

Key messages

The currently employed professionals in the medical devices industry possessed the following advanced technology related skills the most often: **Advanced manufacturing, Industrial Biotechnology, IoT, Advanced materials and Artificial Intelligence**. In the hospital and healthcare sector, the most common skills are related to **Industrial Biotechnology, Cloud technology, AI and IoT**, but these patterns are more nuanced when looking at country specific patterns. 6% of professionals in healthcare and 15% in medical devices in the EU27 are skilled with digital technology skills.

Countries with the highest share of professionals with skills in digital technologies employed in the healthcare sector and medical devices industry include **Finland, Denmark, Sweden and the Netherlands**. In the hospital and healthcare sector, the top countries with digital skills include Germany, Finland, Ireland, France and the Netherlands.

In terms of 1-year growth (2018-2019), both in medical devices industry and the healthcare sectors, **skills related to Big Data and Connectivity grew the most dynamically**. We observe high growth rates in Eastern European countries, especially in AI skills. Besides technologies, **soft skills** such as healthcare management, health promotion and personalised healthcare are also among the most demanded skills. This may reflect the ongoing shift towards value-based care.

4.1 Availability of new technological skills

The need for developing digital skills is critical both for manufacturers of medical devices (that use these technologies to offer smart digital devices on the supply side) and for healthcare professionals on the demand side. It is expected that digital medicine (i.a. telemedicine and m-health), AI and robotics, as well as genomics would affect 80% of the health workforce by 2040[29].

The High-Level Expert Group on artificial intelligence underlined the need to upskill the workforce and create stakeholder awareness. Artificial intelligence is a priority focus and digital skills and literacy of healthcare professionals are crucial to maximise the impact of AI. In the case of AI, representatives of the industry recommend arranging pre-certification of medical societies and promote the AI curricula for professionals and hospital managers. But besides digital skills, the lack of soft skills can also represent a problem if not addressed early on. With an ever-more patient-centred care, healthcare professionals need communication skills.

A country-specific report about Ireland highlighted the need to build excellence in electronic engineering for biomedical electronics but also mechanical engineering, biomedical engineering, materials engineering. ICT skills are also playing an increasingly important role in the medical sector in Ireland.

Upskilling the workforce in the areas of data analytics, Internet of Things, collaborative robots, simulation, cloud computing, systems integration, augmented reality and cybersecurity is considered especially imperative. In addition, deep knowledge of regulatory affairs is necessary as professionals would have to become aware of the ethical and patient safety considerations posed by the digital transformation of healthcare.

In the next sections, we present the findings of the analysis based on LinkedIn. 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. Data have been captured in the EU27 in three data points (November, December 2019 and January 2020) for the industry/employer category 'medical devices' and 'hospital & healthcare'.

[29] Irish Medtech Association Skillnet, Future skills needs analysis for the medical technology sector in Ireland to 2020

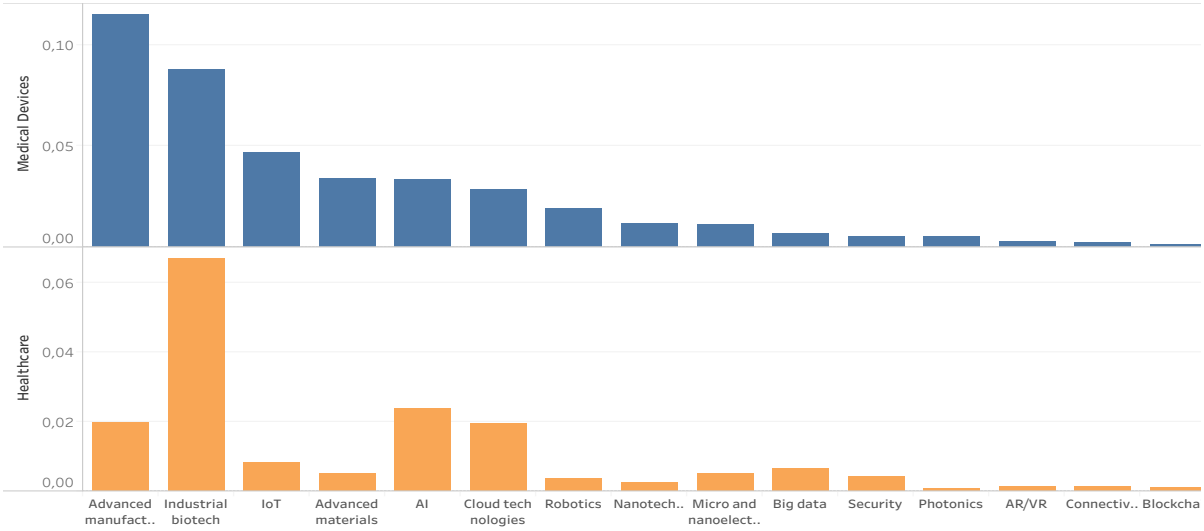
4.2 Availability of advanced technological skills

The analysis of available technological skills within the medical devices industry shows that the top 5 technological skills found among the employed professionals are **Advanced manufacturing, Industrial Biotechnology, IoT, Advanced materials, and interestingly at the fifth place Artificial Intelligence** preceding cloud technologies. While advanced manufacturing and industrial biotechnology professionals are more equally spread among the EU countries, professionals in AI are concentrated in Germany, France, Denmark and the Netherlands (56% of all AI professionals in the medical devices industry and with a profile on LinkedIn).

The next top technological skill in medical devices is **IoT,** which reflects the importance of connected medical devices in the industry. However, this is only the case for Western and Northern European countries such as Germany, France, Finland, Denmark, Sweden, Netherlands. In most Eastern and Southern European countries, IoT professionals are less available in this sector and the most relevant existing technological skills after biotech and cloud technologies are related to advanced materials, nanotechnology, big data etc.

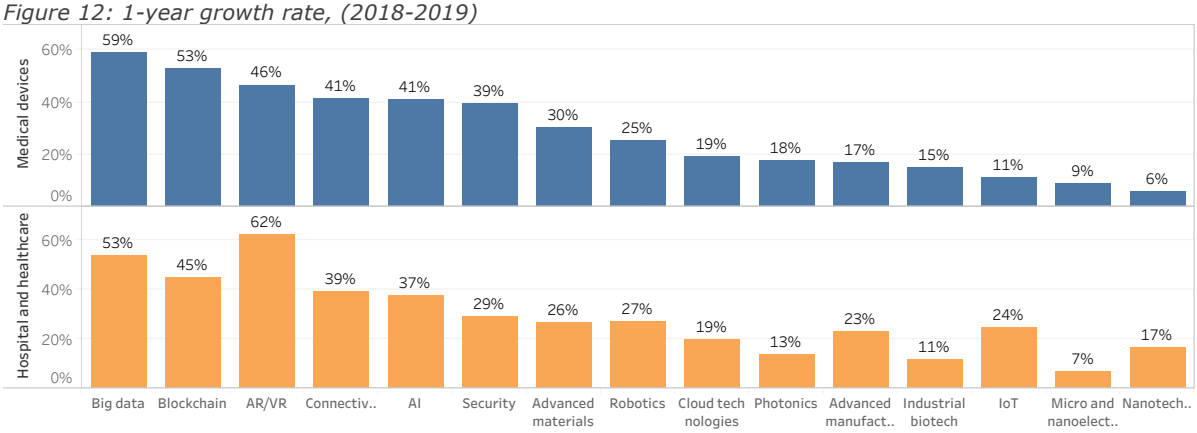
If we look at the demand side (please see Figure 11), in the hospital and healthcare sector the most common technological skills are related to **Industrial Biotechnology** and **Cloud technologies and AI occupy** the second position

Figure 11: Share of professionals with advanced technology skills within medical devices and healthcare, 2019



Source: Technopolis Group based on LinkedIn data

Figure 12: 1-year growth rate, (2018-2019)



Source: Technopolis Group based on LinkedIn data, tableau

(in most EU countries cloud technologies are more relevant than AI and the ranking is somewhat biased by the ranking of countries with a more representative sample in LinkedIn and again by the strong concentration of AI in certain countries as mentioned already above).

IoT is much less prominent, which might reflect that the uptake of connected healthcare devices is not yet fully realised and will need more efforts to match the increasing availability of such technologies.

When we look at the trends over time, the average growth for all skills in medical devices in the EU27 was 27%. This average growth rate is 23% in the hospital and healthcare sector. This reflects the **growing importance of advanced technology skills** in both sectors.

In terms of skills, the highest growth rate was in **Big Data** with +59/53% followed by **Connectivity** with +41/39%. The high growth rates in AR/VR and Blockchain related skills also stand out, however, these are the consequence of a low number of existing professionals in these areas. The growth rate of the two top skills (Advanced manufacturing and Industrial biotech) was approx. +17% which points at a steady growth too.

4.3 Country patterns with highest uptake of advanced technologies

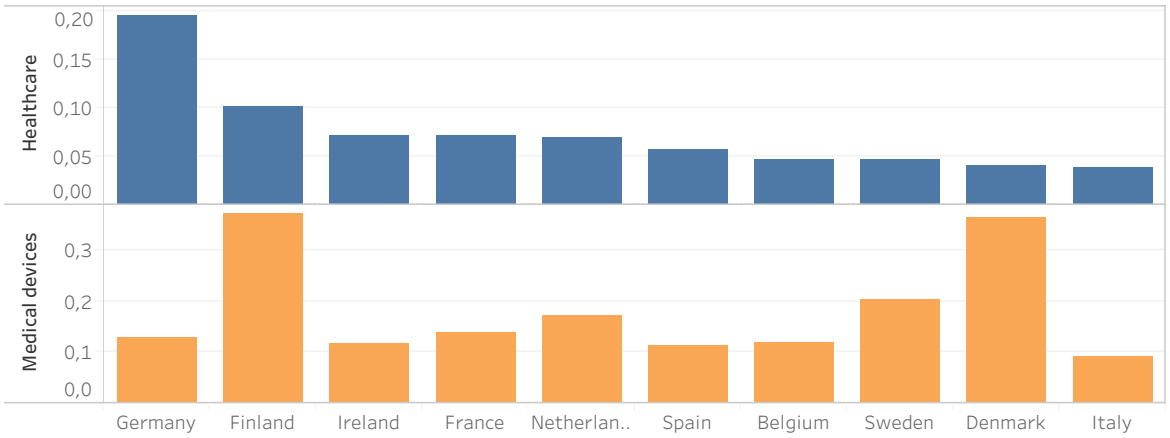
The analysis of skilled professionals can hint at the level of uptake of advanced technologies. When we investigate the share of professionals in all the selected digital technologies (AI, AR/VR, blockchain, cloud, connectivity, IoT, robotics and security), we can reflect about adoption rates in the EU27 Member States.

Countries with the highest share of professionals (as captured via LinkedIn) that possess **digital technology skills and are employed in the medical devices industry include** Nordic countries such as **Finland, Denmark, Sweden** and also **the Netherlands**. When we look at the demand side in the hospital and healthcare sector, the top countries are similar and include **Germany, Finland, Ireland, France and the Netherlands**. The share of professionals in digital technologies in the other EU countries is relatively low but cannot be fully analysed due to the low representativeness of healthcare professionals on LinkedIn.

Specifically, in AI, the share of professionals with AI skills in medical devices has been the highest in **Finland, Denmark, the Netherlands** and **Sweden.** In the healthcare sector, the top performers are the Germany, the Netherlands and Finland. The share of professionals with AI skills in the US is around the same percentage as in the before mentioned countries (although this finding has to be interpreted in the light of the representativeness of LinkedIn users per country).

IoT skilled professionals work most often in **Denmark, France, Germany and Sweden** as the analysis of LinkedIn profiles suggests.

Figure 13: Countries with the highest share of professionals with skills in AI, AR/VR, blockchain, cloud, connectivity, IoT, robotics and security within the healthcare sector and within medical devices industry, 2019



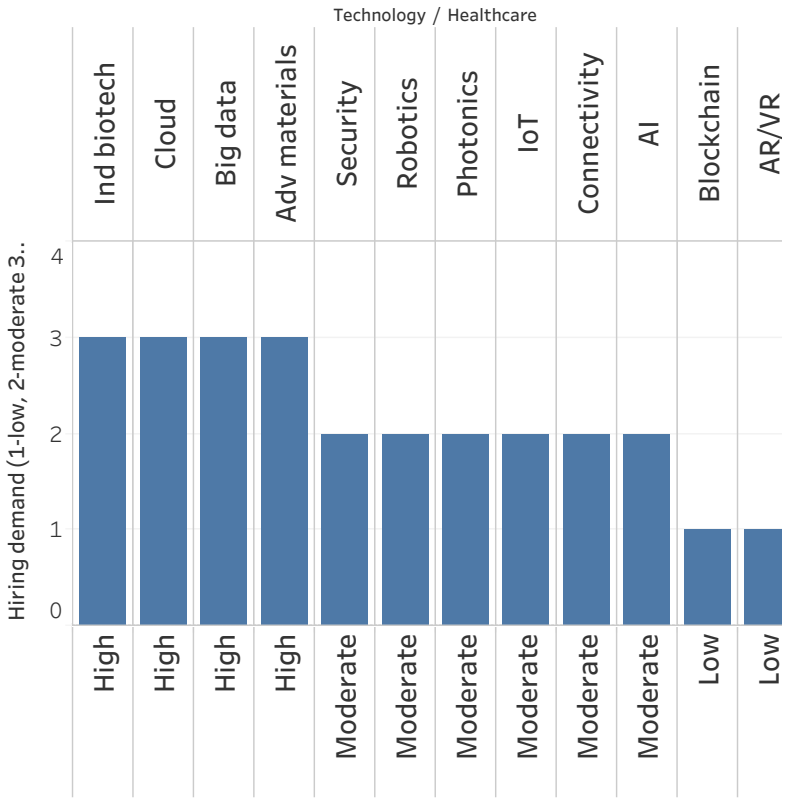
Source: Technopolis Group calculations based on LinkedIn

Turning to the demand for advanced technological skills, we observe that the fields with 'high hiring demand' as captured in LinkedIn include the following in the healthcare sector of EU27: industrial biotech, cloud technologies, big data and advanced materials. Hiring demand is defined as the share of job ads published on LinkedIn and requiring the specific skill.

The moderate level of hiring demand for IoT, connectivity shows as already pointed out above that skills related to connected medical devices are not yet sufficiently widespread in the healthcare sector across Europe, even if the pattern is different in specific EU Member States.

Besides the analysis of the technologies within the focus of this report, the skill demand by EU27 medical devices industry firms hiring through LinkedIn has been also investigated using the skills taxonomy of LinkedIn. This analysis found that skills in demand include molecular biology, bioinformatics, data analytics, programming languages, Matlab, Python and embedded systems. Soft skills are also highly demanded such as healthcare management, health promotion, personalised healthcare and change management that may reflect the ongoing shift towards value-based care.

Figure 14: Hiring demand for professionals with skills in advanced technologies in the healthcare sector in EU27



Source: Technopolis Group based on LinkedIn

Section 5

5. Future outlook: challenges and opportunities

5.1 Megatrends: demographic challenges, value-based healthcare, cost pressure, green medical technology

Demographic trends such as the aging population, the increase in the number of chronic diseases and the changing expectations of patients especially in the middle class are key drivers behind the need for more innovation in medical devices and diagnostic equipment[30].

These trends are coupled with pressures on public healthcare budgets across the world as healthcare costs have been steadily increasing in recent years. As a result, healthcare providers are strictly focused on increased efficiency and reduced prices. New technologies that can help providing more value for money play an important role in providing solutions for the reduction of the soaring healthcare costs[31]. At the same time, they are instrumental in improving patients' lives and health conditions.

Another key megatrend is the shift towards value-based healthcare and reimbursement schemes, which will require a change in the industry business models in the near future[32]. In this context, medical devices companies will need to operate in a new ecosystem and to adopt a system-oriented and value-centred approach. In order to remain competitive, they will need to create new partnerships and collaborate in reconfigured value chains[33].

Sustainability trends also affect medical technology and push them to go green. More and more healthcare institutions are expecting their suppliers to follow environmentally responsible practices and improve both device and packaging sustainability for instance through the use of biomaterials[34].

5.2 Data, AI and cybersecurity

A key challenge and opportunity for the medical devices industry is to build new strategies and form partnerships around the production and use of medical device data. As it has been pointed out in several earlier studies and reports, Europe holds more health data than the US, but its opportunity is constrained by privacy concerns, technical and political challenges[35].

As it has been discussed in the previous sections, artificial intelligence is the technology transforming the imaging sector the most dramatically. AI is the "process of automating automation"[36] and increases quality of care by computer vision in healthcare.

The safe use of AI in medical devices requires cybersecurity measures among others. Data security, as well as software costs and complexities lead to further risks. The recent European strategy for data[37] addresses these challenges by among others creating a common health data space bringing new opportunities for the industry.

New data infrastructure and the developments in connected medical devices will allow remote patient monitoring systems which is an area expected to grow dynamically in the period of 2020-2025[38]. Remote monitoring systems are said to further strengthen patient care and reduce the strain on healthcare providers by cutting down on patient visit times.

5.3 Regulatory compliance

Medical devices companies need to innovate and develop new products faster than the competition, but at the same time they need to comply with the latest needs of end users and ensure high-quality.

The EU represents one of the 'fastest times to market' for medical devices, especially compared to the US. Nonetheless, firms in Europe witnessed higher recall rates[39]. When products are recalled it can become very expensive for the manufacturer. In terms of public health, a faster access to new medical technologies must be carefully weighed against the risks arising from devices that have not yet proved their safety or effectiveness.

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[30] See eg. Bain&Company, 2019 Deloitte, 2019 Bresslergroup, 2019, EC, 2019, PwC, 2018
[31] EXPH (2018). Assessing the impact of digital transformation of health
[32] BCG (2017). Why Every Medtech Company Needs a Value-Based Strategy
[33] Deloitte (2019). Winning in the future of medtech
[34] https://www.med-technews.com/digital-health
[35] See eg. Deloitte (2019), EC, 2019
[36] EY, 2019
[37] European Commission (2019). A European strategy for data, Brussels, 19.2.2020, COM(2020) 66 final
[38] Mordon Intelligence (2019). European remote patient monitoring systems market – growth, trends and forecast
[39] Hwand et al. (2016) Comparison of rates of safety issues and reporting of trial outcomes for medical devices approved in the European Union and United States: cohort study

In 2017, the EU revised the legal framework for medical devices and adopted two new regulations, one on medical devices and the other on in vitro diagnostic medical devices. The Medical Devices Regulation (MDR) enters into force on 26 May 2021. The application date for the In Vitro Diagnostic Medical Devices Regulation is 26 May 2022[40]. These regulations tackle the risks associated with medical products that were historically entering the market rather easily. They strengthen the controls around traceability and transparency within the whole supply chain and include a clarification and guidance on how software is intended to be classified. Although the compliance is expected to become more costly, companies realise that the MDR represents not just a compliance challenge, but an opportunity to add value to the business[41] . Nevertheless, a recent survey[42] found that 57% of respondents are still in the process of renewing their certificates. The main barriers encountered are the lack of internal resources and lack of available timely guidance.

Besides regulatory compliance in Europe, a further challenge is the existence of competing regulatory systems, where medical technology companies will continue to move into markets where they can obtain regulatory approval more quickly.

5.4 Future expected trends in skills

Accessing and leveraging the right skills is of utmost importance for medical devices firms operating in a highly competitive industry. The recent focus on digital skills has several consequences for medical devices companies. On the one hand, medical technology is a highly innovative and technological field that is well-prepared to integrate IoT and AI solutions to its products. As a result, the demand for internalising the related skills is also high. On the other hand, the sector faces difficulty to hire workers with the tailored profiles[43]. In addition, there is a demand for professionals who are also aware of the regulatory limits concerning patient's safety or AI ethics.

The medical devices industry is facing competition from other sectors that may be more attractive for people with digital profiles. There is also a country divide, where stronger economies have more chances to attract and nurture digital talent. At the level of the firm, there is further need for upskilling and reskilling due to fast change. Rapid developments in AI and big data force medical devices firms to be agile and offer life-long learning opportunities for their employees.

[40] https://ec.europa.eu/growth/sectors/medical-devices/new-regulations_en

[41] EY (2016). How the new EU Medical Device Regulation will disrupt and transform the industry

[42] https://institutes.kpmg.us/content/dam/institutes/en/healthcare-life-sciences/pdfs/2019/kpmg-eu-mdr-whitepaper.pdf

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About the 'Advanced Technologies for Industry' project

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

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

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

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

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