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Advanced Technologies for Industry – Sectoral Watch

Technological trends in the agri-food industry

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Introduction

This sectoral report has been prepared in the framework of the '*Advanced Technologies for Industry'* (ATI) project, initiated by the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises.

It analyses **trends in the generation and uptake of advanced technologies, related entrepreneurial activities and skills needs in the agri-food sector** with a specific emphasis on Industrial Biotechnology, Robotics, Big Data and Internet of Things (including e-commerce and app design). 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.

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 (AI), augmented and virtual reality, big data, blockchain, cloud technologies, connectivity, industrial biotechnology, Internet of Things (IoT), micro and nanoelectronics, IT for mobility, nanotechnology, photonics, robotics, security.

The relevance of these specific technologies in the agri-food 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: https://ati.ec.europa.eu.

This report is structured as follows:

- The first section sets the industrial context.
- The second section analyses technological trends in advanced technologies applied in the agri-food 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 in the agri-food industry.
- The fifth section concludes with a short future outlook.

Section 1

1. Setting the scene: industrial context

Key messages

The **agri-food sector** is composed of both agriculture & farming and food processing activities. In the face of global change, including demographic change and climate change, the challenge remains to **deliver a sustainable food and agricultural production system**. Advanced technologies are essential in enabling the agri-food industry to **increase efficiency in production**, while limiting the global impact of food production on the environment.

Through developments in **precision agriculture** and farming, as well as **smart food processing,** the agri-food industry is responding to these challenges with increased digitalisation and the uptake of advanced technologies. Changes in the agri-food industries are also driven by **consumer demand** for food **safety, security, traceability** and **higher quality,** and the value of food products.

The **EU is an agricultural production leader** and exporter of products, creating over **44 million jobs in the EU** in the wider agri-food industry. The EU draws from strengths in technical and industrial skills, combined with networks of supporting stakeholders such as innovation intermediaries.

1.1 Towards precision agriculture and smart food processing

Technology and the transition to Industry 4.0 are increasingly important in the agri-food sector. The agri-food sector comprises both agriculture and farming, and food processing. The role of technology in farming includes the use of farm management systems and the uptake of technologies towards smart and precision farming. In food processing, through increased mechanisation and automation, production and processing of food are transitioning towards smart food processing. Advanced technologies are essential in enabling the agri-food industry to increase efficiency in production, while limiting the global impact of food production on the environment. As global population rises to over 7.7 billion inhabitants[1], the challenge remains to deliver a sustainable food and agricultural production system.[2] Climate change, natural hazards and pest and disease outbreaks put even more pressure to improve agricultural systems to ensure food security and sustainable production, while limiting emissions and reducing food losses and waste.

Precision agriculture and farming at the heart of the future of agri-food. Precision agriculture refers to modern farming practices that rely on digital techniques to monitor and optimise farming practices through optimised resource consumption and agricultural output.[3] The precision farming market is estimated at €6.46 bn[4] in 2020, and is estimated to grow to a size of €11.8 bn by 2025 at a Compound Annual Growth Rate (CAGR) of 12.7%.[5] Precision farming, also referred to as smart farming[6], allows for the increased use of Internet of Things (IoT), sensors and farm management systems to support decision making, monitor yield, scout crops, and includes so-called variable rate application, which refers to the targeted use of water for irrigation, planting of seeds, application of fertilisers and pesticides, among others.[7] The Internet of Things (IoT) facilitates smart water management applications that allow for precision irrigation in the agri-food sector, leading to increased crop yield and decreased cost, hereby contributing to environmental sustainability. Sensors make up an essential element in a smart farming system, and enable data flow across the value chain. Measurements include temperature, humidity, electrochemistry, mechanical movement, airflow, optics, pressure, water, and soil as well as levels of antibiotic use, fat content, geographic location and pH levels, among others. In 2018, the global

[1] Worldometer (2020, March 20) Current World Population, https://www.worldometers.info/world-population/
[2] FAO (2017) The future of food and agriculture: Trends and challenges, http://www.fao.org/3/a-i6583e.pdf
[3] https://op.europa.eu/en/publication-detail/-/publication/40fe549e-cb49-11e7-a5d5-01aa75ed71a1/language-en
[4] All currencies are based on exchange rate of 1€ = $US 1.08313, 26 March 2020
[5] https://www.marketsandmarkets.com/Market-Reports/precision-farming-market-1243.html
[6] https://www.wur.nl/en/Dossiers/file/dossier-precision-agriculture.htm#:~:text=Precision%20agriculture%20or%20Smart%20Farming,sensor%20technology%2C%20ICT%20and%20robotics.
[7] https://www.marketsandmarkets.com/Market-Reports/precision-farming-market-1243.html

agricultural sensor market was valued at €1.12 bn[8], with a Compound Annual Growth Rate (CAGR) of 11.04%, reaching a value of €2.34 bn by 2026.[9]

Smart food processing in the agri-food industry. Smart food processing involves transitioning towards the use of Advanced Manufacturing technologies, IoT, sensors, Robotics and other technological solutions in food processing activities. Building on the smart agri-food value chain depicted in Figure 1, application areas cover the entire food industry from meat and fish, to dairy, fruit and vegetables and bakery, and can range from the management of resources to the automation of processing through the use of Robotics, and the implementation of smart packaging sensors to detect temperature and other conditions of food products. Specifically, Robotics can cover a range of processes ranging from packaging, palletising and logistics, to handling of the food including deboning, portioning, decoration and assembly of food objects such as sandwiches, pizza, etc. Also, advanced manufacturing technologies can be applied and include additive manufacturing for personalised products based on ingredients, which is already carried out in the field of chocolates. Overall, the global food processing and handling market is valued at €126.5 bn in 2019 and is expected to grow to €181.9 bn by 2025 at a CAGR of 6.2%.[10]

Figure 1: Precision and smart agriculture and smart food processing value chain

Source: Flanders' Food, 2018

1.2 Changes in consumer demand

Consumers are increasingly demanding higher quality food products, such as organic food, but are also developing more exotic tastes that put increasing demands towards the agri-food industry.[11] Hence, the uptake of IoT, Advanced Manufacturing and Robotics, among others, is driven by a key set of drivers, particularly related to the consumer.[12] These include: the safety of the product, quality and value of the product, origin of the product, nutrition and well-being, sustainability, resilience and food security.

Food safety and security is also driving technology uptake. Technologies can be instrumental in ensuring and monitoring process flows, in detecting foreign objects in food, as well as for the cleaning and disinfecting of machines. Especially sensors are key in these processes through the monitoring of temperatures. For example, for frozen foods, the maintenance of the cold chain is key, and sensors support in ensuring this is the case. Regarding food security, technology supports the fulfilment of aims such as assuring efficient and resilient manufacturing and distribution, minimising waste and delivering safe and compliant products. In addition, technologies support in dealing with scarce resources, and contribute to the reduction of food waste and losses.

Product quality and value drive technology uptake through making use of cost-effective process technologies to maintain and enhance quality and shelf life. This can include the use of photonics technology for the optimal harvest, but also the monitoring and post-harvest treatment of products, especially in the fruit and vegetables value chain. In addition, nutrition and well-being are also drivers of technology uptake related to product quality. Technologies such as photonics can be used to enhance nutritional potential and can also be key in preserving nutritional value, where especially the close monitoring and control of storage temperatures through sensors and IoT is key. In addition, technologies such as sensors can also be important in ensuring ingredients and composition of the foods to meet specific dietary needs and requirements.

1.3 European perspectives in agri-food

The EU as an agricultural production leader. The EU is a leading producer and exporter of agricultural products. This can be attributed to the varied climate and soil conditions, in combination with the strong technical and industrial skills of the farmers and supporting stakeholders, such as innovation intermediaries. These strengths enable further innovation and optimisation of the sector, adopting new technologies such as sensors and farm management tools.

Leading in precision livestock farming. Precision livestock farming includes milk harvesting, feeding management, as well as livestock monitoring and management, which includes hardware, software and services. The EU continues to be a market leader in this specific segment of precision farming technologies.

Overall, the agri-food industry is directly responsible for roughly 44 million jobs in the wider sector, including agriculture, food processing, retail and related services, of which 22

[8] All currencies are based on exchange rate of 1€ = $US 1.08313, 26 March 2020

[9] https://www.reportsanddata.com/report-detail/agricultural-sensors-market

[10] https://www.marketsandmarkets.com/Market-Reports/food-processing-handling-equipment-market-145960225.html

[11] Planet labs (2018) The Top Global Trends Driving the Fourth Agricultural Revolution, https://www.planet.com/pulse/top-global-trends-fourth-agricultural-revolution/

[12] Campden BRI (2018) Scientific and technical needs of the food and drink supply chain 2018-2020, https://www.campdenbri.co.uk/research/pdfs/needs2018.pdf

million are directly found in farming.[13] Most companies (99%) in the sector are SMEs. SMEs are often challenged in the uptake of technologies, due to high risks and technological lock-in, but also owing to gaps in knowledge and expertise on the possible solutions that are applicable for their specific needs. Contributing to this is a disconnect between solution providers and the farmers as well as food processing companies, with information asymmetries going both ways on the challenges faced as well as the specific benefits of the solutions.

[13] COM(2017) 713 final. The Future of Food and Farming, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52017DC0713&from=EN

Section 2

2. Technological trends

Key messages

Technology shifts in agri-food are occurring in line with the shift to Industry 4.0. As industrial processes are becoming increasingly digital, automated and connected, an **agri-food 4.0** is coming into place.

Advanced technologies across the agri-food industry include **Internet of Things**, **Advanced Manufacturing**, and **Photonics -** together with sensors, and include the use of robotics and especially also co-bots. Overall, the **value chain is becoming increasingly digital**, supported by **farm management systems** and tools to manage and oversee activities at farm and production level. **Sensors** are applied in farm and animal sensing as well as in the form of smart **sensors for food packaging**. Consumers are increasingly interested in high quality food, but also in information flows about the origins and impacts of food products and consumer products.

Germany, France and the Netherlands are patent leaders in agri-food in 2017. The EU27 is a leader in patenting activities in the agri-food sector at global scale. Trends in patenting reveal **a downward trend, except in Asia**. According to agri-food company websites that reference specific terms associated with advanced technologies, **Industrial Biotechnology** is the term most associated with the agri-food sector company websites, followed by **Robotics and Big Data**.

2.1 Technological shifts and advances

Technological shifts in agri-food are occurring in line with the shift to Industry 4.0. As industrial processes are becoming increasingly digital, automated and connected, an agri-food 4.0 is coming into place. Advanced technologies across the agri-food industry include the **Internet of Things, Advanced Manufacturing, Photonics (together with sensors) and the use of Robotics (especially also collaborative robots)**. Overall, the value chain is becoming increasingly digital, supported by farm management systems and tools to manage and oversee activities at farm and production level. The Internet of Things (IoT) is, among other, used to optimise crop water use and support the development of irrigation schedules and monitoring, water stress monitoring, etc. The introduction of advanced manufacturing has led to automation, improved process control and robotics within the agri-food processing chain. Additive manufacturing techniques and low-cost, user-friendly electronics allow for SMEs and farmers to build low-cost custom instrumentation for specific purposes in real- or near-real time.

Sensors are applied in farm and animal sensing as well as in the form of smart sensors for food packaging. Consumers are increasingly interested in high quality food, but also in information flows about the origins and impacts of food products and consumer products. The information flow should be transparent, relying heavily on traceability and big data flows through apps that are supported by digitalisation of the entire value chain.

2.2 Agri-food patenting in the EU and internationally

Technology developments can be tracked by patenting activities related to the specific sectoral activities based on patent-based classifications.[14] In order to understand the specific patenting activities, an analysis of agri-food patenting was carried out by selecting **patents in the food, agriculture and bioeconomy** areas, based on a classification developed by Fraunhofer ISI et al. (2016).[15] This classification includes a comprehensive schematic for the classification of patents in the area of food, agriculture and bioeconomy that allows to identify the specific patents and patent areas in the International Patent Codes (IPC codes) that are specific to the sector and its developments. By using this

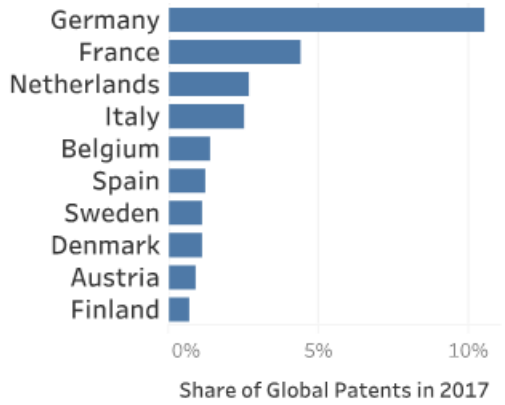
[14] This approach differs from the other Sector Watch Reports due to the specific nature of the Agri-food sector and companies in their patenting activities, which are observed to be low in the NACE-based approach applied in the other reports. Hence a different approach is applied in this report in order to best capture the unique practices of this sector.

[15] Fraunhofer ISI et al (2016) Study on EU Positioning: An Analysis of the International Positioning of the EU using Revealed Comparative Advantages and the Control of Key Technologies. Prepared for the European Commission.

approach, we can representatively capture the patents and patenting activity at EU and global level in the agri-food sector and observe trends in distribution and development as indicated in this section.

Germany, France and the Netherlands are patent leaders in agri-food in 2017. Looking at the EU, the greatest share of agri-food patents in global patents can be found in Germany, followed by France, the Netherlands, Italy and Belgium as depicted in Figure 2. The figure confirms the dominance of Germany in taking patent in the agri-food area. The strong research position of the Netherlands in agri-food is also worth mentioning.

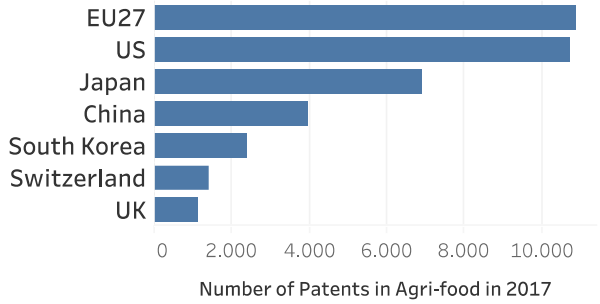
Figure 2: Share of agri-food patents over total agri-food patents globally in 2017, top 10 EU countries



Source: ATI, 2019 Fraunhofer calculations

The EU27 is a leader in patenting activities in the agri-food sector at global scale. It is closely followed by the US which is also quite active in taking agri-food patents. Japan follows at a third place. China occupies the fourth position, before South Korea.

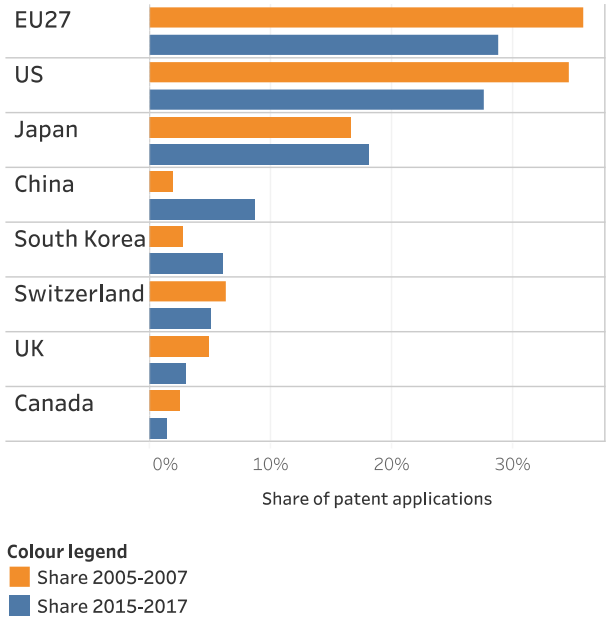
Figure 3: Total number of agri-food patents in global comparison



Source: ATI, 2019 Fraunhofer calculations

Trends in patenting reveal a downward direction, except in Asia. Looking at the trends in patenting in the agri-food area, containing food, agriculture and bioeconomy, it appears that a downward trend can be observed in EU27 and the US. From 2005 to 2007 the average number of patents, as a share of global patents, was higher than in the period from 2015 to 2017 across most of the top 14 patenting countries, including the EU27. The exception during this period appears to be China, which increased considerably its world share in agri-food patents in the 2015-2017 period. In addition, Japan and South Korea also show increases, demonstrating the rise of Asian activities in agri-food patenting. A possible explanation could be the fact that Asian players are increasingly active in the agri-food market as this market has undergone significant changes in the last two decades.

Figure 4: Share of agri-food patent applications over total agri-food patent applications at country-level and EU27 (2005/7-2015/17)



Source: ATI, 2019 Fraunhofer calculations

2.3 Technology adoption by agri-food companies

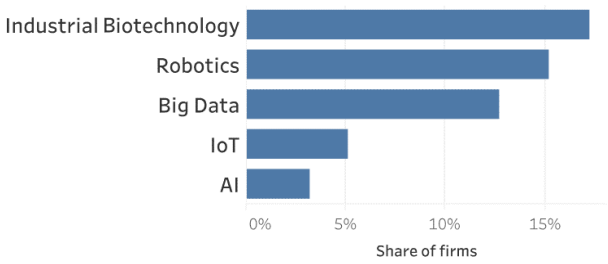
Through a large-scale text-mining[16] of company websites belonging to the agri-food sector, insights could be obtained on current developments related to the advanced technologies in this sector. This analysis provides information on the use of technologies that companies communicate about through the web. It cannot be used, however, to draw conclusions about the adoption of the technologies that are not

[16] Based on a search algorithm, company websites were analysed for links to each specific technology in September-November 2019. The analysis of 2,153 websites of agri-food companies was conducted across seven European countries, including Denmark, France, Germany, Italy, Netherlands, Poland and Spain.

mentioned, e.g. behind the scenes processes, or to capture the technology adoption by stakeholders that are not present in online content, such as the uptake of technologies by the agricultural sector.

Figure 5 presents the share of agri-food company websites that reference specific terms associated with advanced technologies. **Industrial Biotechnology** is the term most associated with the agri-food sector company websites, followed by **Robotics and Big Data**.

Figure 5: Share of agri-food company websites referencing advanced technologies



Source: Technopolis Group based on text-mining company websites

Industrial Biotechnology can play a major role in providing the world with nutritious, safe, and healthy food. Industrial Biotechnology activities in the agri-food sector include the use of enzymes and micro-organisms to make bio-based products. Among other, they aim to improve the resistance of crops to insects and diseases, so that a higher yield can be realised. They also support the increase of resistance of animals to antibiotics as well as infectious diseases and contribute to sustainable agricultural production systems. Industrial Biotechnology related developments have contributed to modifying or enhancing properties such as taste, aroma, shelf-life, texture and nutritional value of food products.

Robotics are of importance in smart food processing in the agri-food sector. Robots and co-bots can support activities requiring a range of motion including packaging, palletising and logistics, to handling of the food including deboning, portioning, decoration and assembly of food objects such as sandwiches, pizza, among others. Recent developments also see a role for Robotics in agriculture for harvesting, seeding and milking to name a few applications, however these are still in development.

Big Data is important for many aspects of the agri-food industry, both at farm level, but also for the purpose of sharing information throughout the value chain towards retailers and consumers. Traceability as well as food safety are enabled through Big Data and related technologies such as blockchain, while relying on IoT sensors to input data. Big Data can be used to support apps that provide information on the origin of products to consumers, as well as logistics and supply of food and beverages, among others. Data sharing remains a challenge for the agricultural segment, as farms and farmers are technically data owners, who both embrace the usefulness of Big Data such as satellite data for environmental monitoring, but also fear that data can be misused to penalise or misinform consumers about farming practices, e.g. about pollutants such as fine dust or nitrogen.

Section 3

3. Venture capital investment and startup creation

Key messages

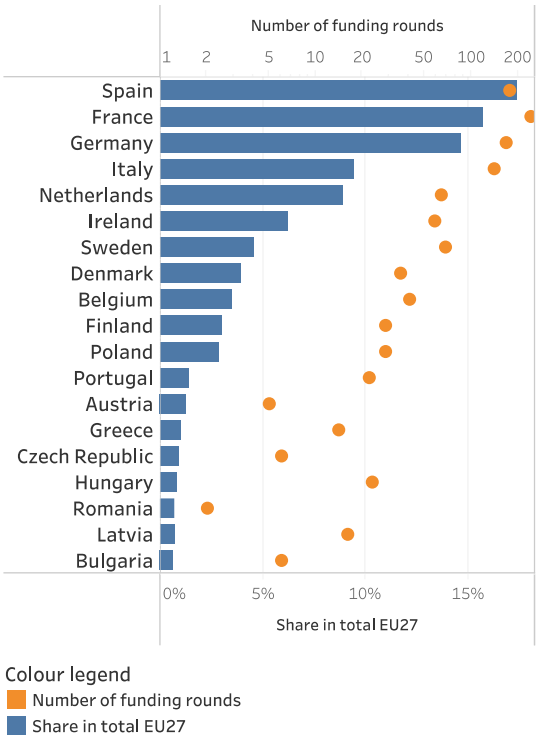
Zooming in on **food and beverage** as well as **food processing companies**, the analysis reveals that there are certain hotspots of activity in Europe, such as Spain, France and Germany. **The EU27 is well-positioned in the global scale**, with high numbers of last funding rounds, and equally over €3 bn in total sum of last funding. The types of funding to fund these companies that play a dominant role at EU27 level include seed funding, venture capital, equity crowdfunding and private equity.

For the purpose of this report, startups are defined as those companies founded between 2009-2019. Startups represent the most recent trends of technology development in the industry and target a rapid response to industry needs. The most common related field for food and beverage and food processing startups is in **e-commerce, internet-related activities and apps**. These trends highlight the importance of especially digital technologies for startups creation. Overall, **nearly 50% of the startup creation** in food and beverage and food processing in the EU27 comes from Germany, Spain and France.

3.1 Venture Capital and private equity investment in food and beverages and food processing

The scale of Venture Capital (VC) and private equity investment were tracked using combined Crunchbase and Dealroom datasets. From the overall database, companies were selected by filtering for 'food and beverage' and 'food processing' categories.[17] The analysis reveals that there are certain hotspots of activity in Europe, such as **Spain, France and Germany** as depicted in Figure 6. Although Spain only obtained the sixth position regarding patenting, they rank number one in share of companies that are obtaining VC and private equity investment. In addition, the number of funding rounds in those same countries appears to correlate to overall funding.

Figure 6: Number of funding rounds and companies in food and beverages and food processing in top EU27 countries (2000-2019)

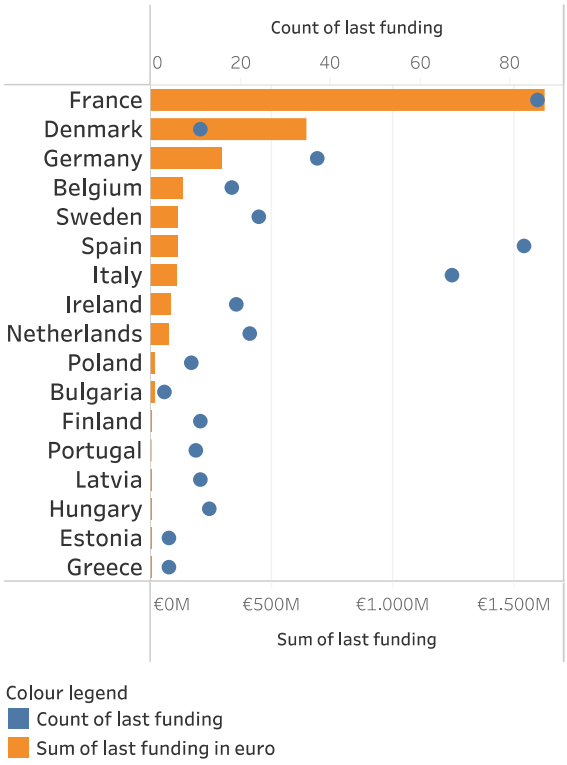


Source: Technopolis Group based on Crunchbase and Dealroom data

[17] Due to an underrepresentation of agricultural stakeholders in the database, the analysis focusses on the food and beverage and food processing stakeholders only.

The amounts of the last funding rounds, as indicated in Figure 7, provide an overview of the countries with above average funding, i.e. **France and Denmark**. Especially the excellent position of France is worth noticing.

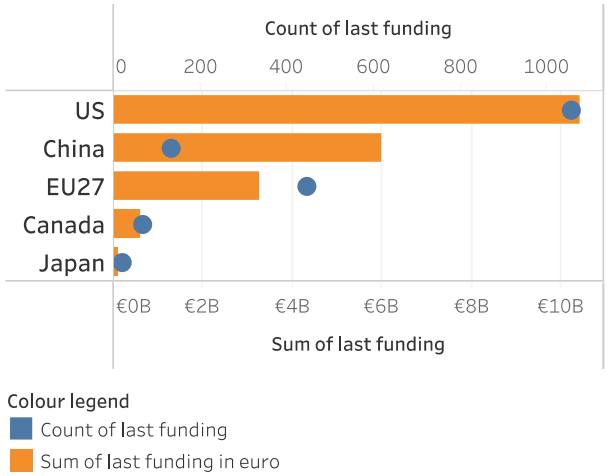
Figure 7: Total amount of last funding and count of last funding in food and beverages and food processing in million € in top EU27 countries (2010-2019)



Source: Technopolis Group based on Crunchbase and Dealroom data

The EU27 is well-positioned in the global scale, with high numbers of last funding rounds, and equally over €3 bn in total sum of last funding as presented in Figure 8. In this international comparison, using the last funding amount as a metric, differences between the EU27 and key players such as the US and China are evident. Interestingly, also Canada appears as important player. This highlights the **North American dominance in the food and beverage and food processing industry**, which builds on a strong agricultural sector. At the same time, China and Japan remain important at global scale in funding food and beverage as well as food processing companies.

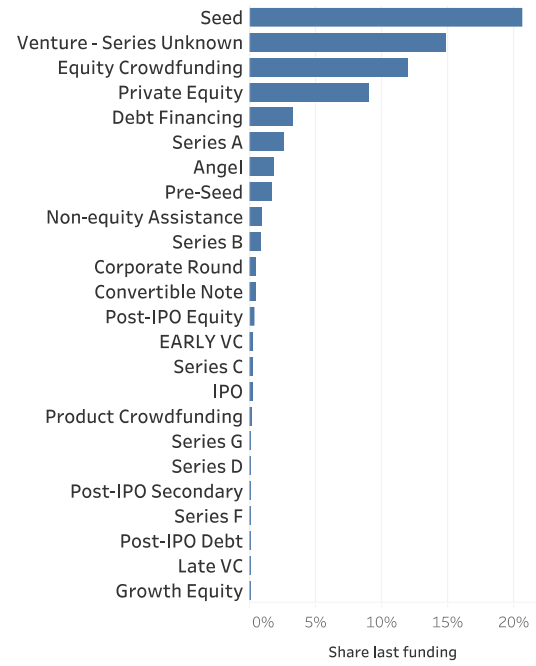
Figure 8: Total amount of last funding and count of last funding in food and beverages and food processing in billion € in international comparison (2010-2019)



Source: Technopolis Group based on Crunchbase and Dealroom data

The types of funding to fund these companies are presented in Figure 9. Notably, seed funding, venture capital, equity crowdfunding and private equity play a dominant role at EU27 level.

Figure 9: Type of funding in food and beverages and food processing EU27 (2010 - 2019)

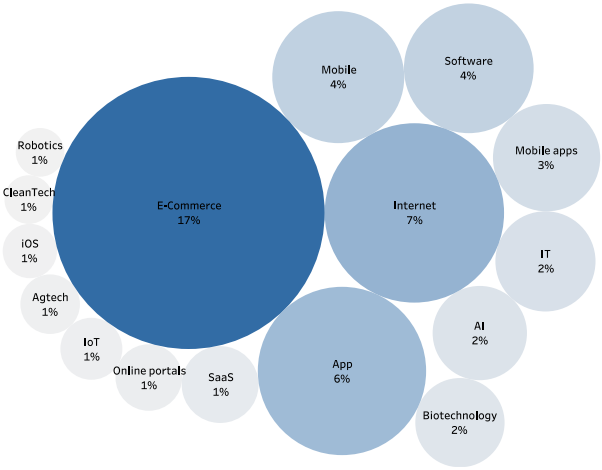


Source: Technopolis Group based on Crunchbase and Dealroom data

3.2 Food and beverage and food processing startups

Zooming in on **startups in the food and beverage and food processing** segment of the agri-food sector, a selection of companies from 2009-2019 are used from both Crunchbase and Dealroom data. Startups[18] represent the most recent trends of technology development in the industry and target a rapid response to industry needs. Hence it is interesting to look at which categories of activity specific startups are active in. Looking at advanced technologies in the company activities reveals, as depicted in Figure 10, related fields of activity. The **most common related field for food and beverage and food processing startups** is in **e-commerce, internet-related activities and apps**. These trends highlight the importance of especially digital technologies for startups creation in this sector.

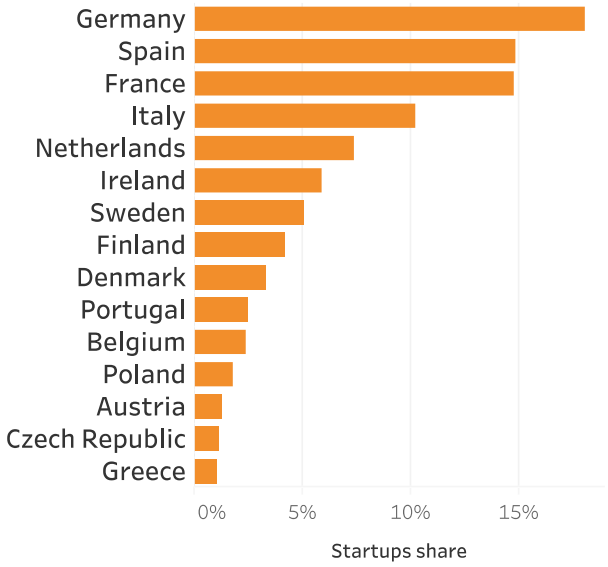
Figure 10: Type of related fields of food and beverages and food processing startups (2009-2019)



Source: Technopolis Group based on Crunchbase and Dealroom data

In terms of startup geography in the EU27, most startups reflected in the data set originate from **Germany** (18%), **Spain** (14.9%) and **France** (14.7%), together making up **nearly 50% of the startup creation** in food and beverage and food processing in the EU27. Other important players are Italy, the Netherlands and Ireland.

Figure 11: Startup creation in food and beverages and food processing industry in the EU27 (2009-2019)



Source: Technopolis Group based on Crunchbase and Dealroom data

[18] In this report start-ups are defined as companies that have been created between 2009 and 2019

Section 4

4. Skills supply and demand

Key messages

Transformations and fundamental shifts in agri-food require **diverse advanced skills**. According to the analysis of LinkedIn data, professionals with technological skills in **Industrial Biotechnology** represent the highest share among all advanced technology professionals in the EU27. Further prominent categories include **Advanced Manufacturing and Cloud technologies**.

It can be observed that **France, Spain and Italy** are leading in terms of absolute number of professionals with advanced technology skills employed in the agri-food sector.

The results emphasise the **growing importance of digital technologies and digital skills** in the agri-food industry. The five technological skills that showed the highest growth within the last year (from 2018 to 2019) include **AI** followed by **Security**, **Blockchain**, **IoT** and **Big Data**. According to the available data, the rise in AI professionals was remarkable especially in Ireland, Poland, the Netherlands and Italy.

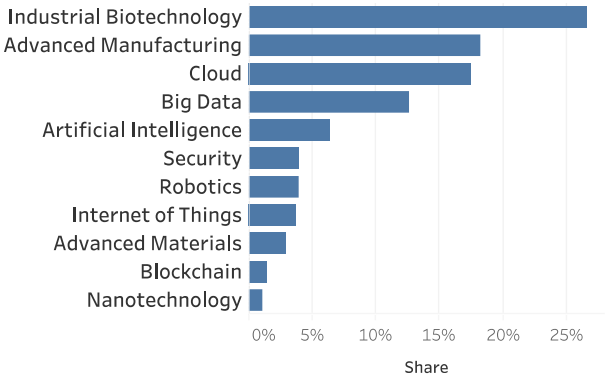
Based on the **skills requirements** of the **online job advertisements** posted on LinkedIn by European agri-food industry firms, we observe that the fields with 'very high hiring demand' as captured in LinkedIn data and analysis include **IoT and Big Data.**

4.1 Availability of new technological skills

Figure 12 visualises the currently available supply of professionals with advanced technological skills relevant in the agri-food sector in 2019 based on the analysis of LinkedIn[19] data. Within the registered professionals on LinkedIn employed in the agri-food industry, **Industrial Biotechnology** represents the highest share in the EU27, reflecting a particularly important role of this field of technology for this sector.

The second largest professional group is linked to relevant skills in **Advanced Manufacturing technologies**. Other technologies include Cloud, Big Data and AI. The least number of professionals among all advanced technologies are employed with skills in Nanotechnology, although there are examples of Nanotechnology in agri-food applications such as nano-encapsulated flavour enhancers or nanocapsules for efficient delivery of pesticides and fertilizers.

Figure 12: Share of professionals with advanced technological skills in the agri-food sector, EU27, 2019

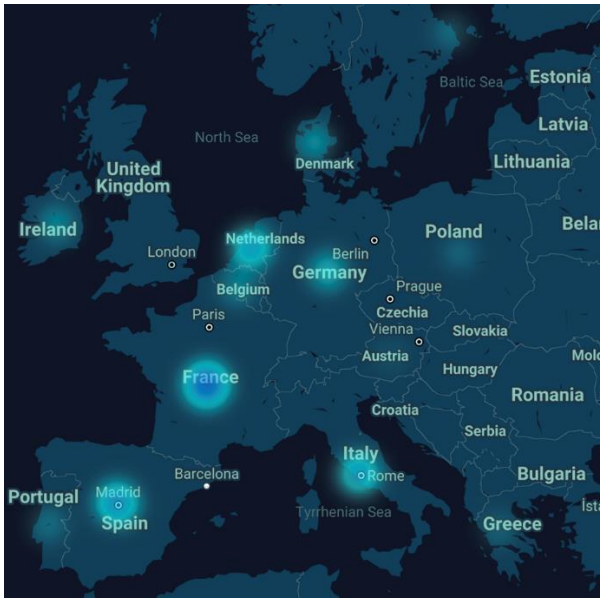


Source: Technopolis Group based on LinkedIn analysis

While Figure 13 illustrates the general distribution of technological skills in the agri-food sector across all EU27 countries, Figure 14 displays the geographical distribution of technological skills applied in the EU27 countries with above median total professionals.

[19] To harvest the data from LinkedIn, keywords capturing skills by advanced technology have been defined and reviewed by technology experts. Queries have subsequently been constructed to filter the database by location and industry. To capture agri-food the following categories have been used: farming, food & beverage, food production, wine & spirits, ranching, dairy, fishery.

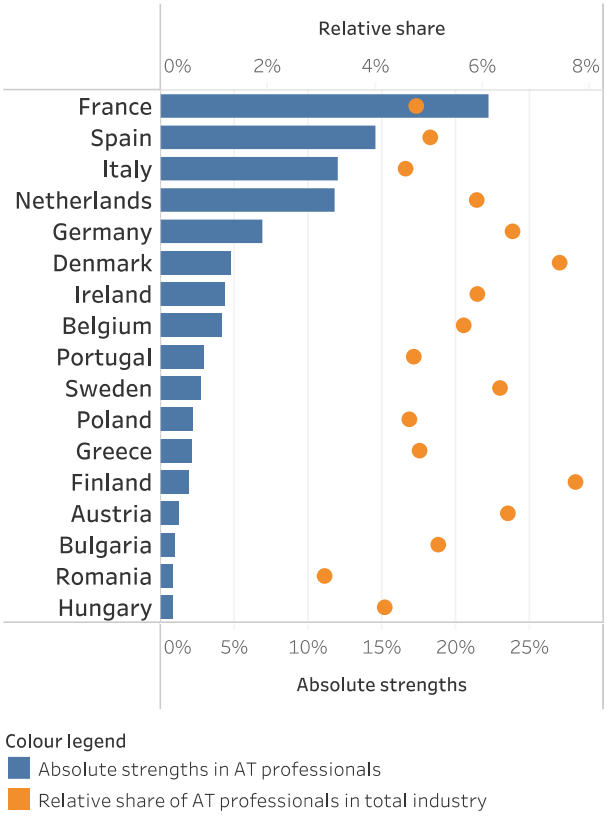
Figure 13: Concentration of professionals with advanced technology skills in the agri-food industry in the EU27



Source: Technopolis Group based on LinkedIn analysis

It can be observed that **France, Spain and Italy** are leading the ranking in terms of absolute number of professionals with advanced technology skills employed in the agri-food sector. When we look at the share of these professionals in the total industry professionals (as captured by LinkedIn), we find that **Finland, Denmark Germany, Sweden and Austria** have the highest share.

Figure 14: Professionals on LinkedIn employed in the agri-food industry and with skills in all advanced technologies, top EU countries

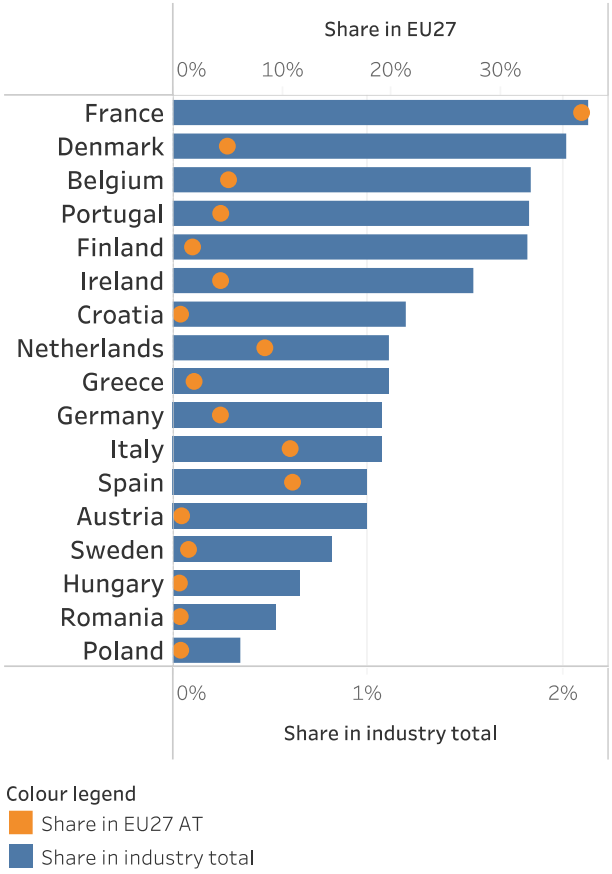


Source: Technopolis Group analysis based on LinkedIn

Note: Only countries with above median total industry professionals are displayed

Zooming in, Figure 15 demonstrates the allocation of the most represented technological skills' supply related to **Industrial Biotechnology** across top performing EU countries. In terms of the relative shares within the total agri-food industry professionals, France is leading the country list, followed by Denmark, Belgium and Portugal. Some of these countries are also those with the highest patent share in Industrial Biotechnology. Denmark for example, is known for its strong position in Industrial Biotechnology.

Figure 15: Agri-food industry professionals with skills Industrial Biotechnology among selected EU countries

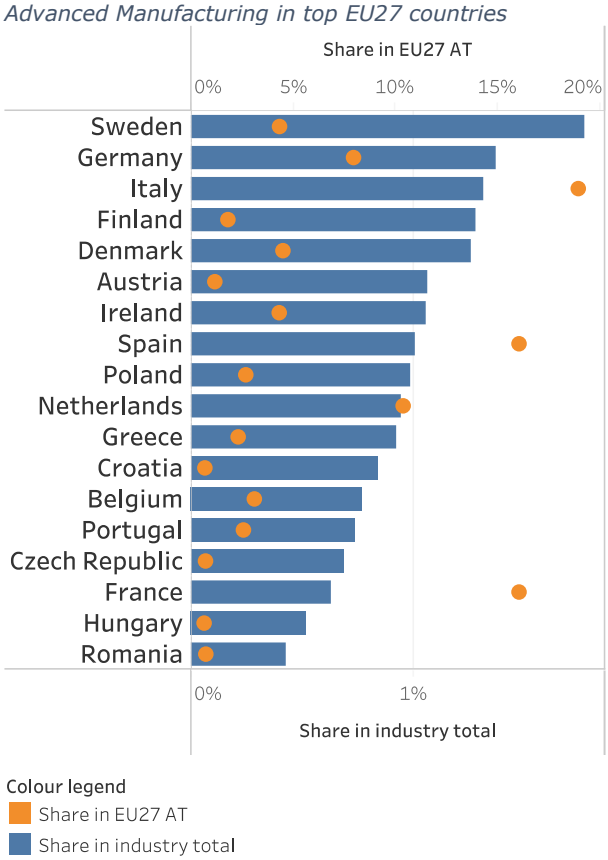


Source: Technopolis Group based on LinkedIn analysis

Note: share of EU27 AT refers to the share within all professionals with advanced technology skills in the EU, while the industry total takes the share within any professionals employed in the agri-food sector as registered on LinkedIn

In terms of skills in **Advanced Manufacturing**, the list as depicted in Figure 16 is led by Sweden, Germany and Italy but when looking at the absolute numbers of professionals within EU27, Spain and France are among the leading countries.

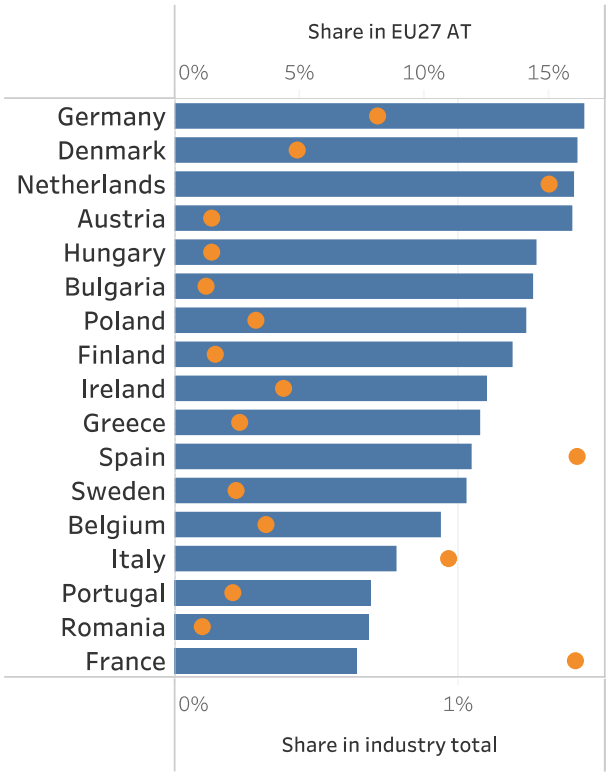
Figure 16: Agri-food industry professionals with skills in Advanced Manufacturing in top EU27 countries



Source: Technopolis Group based on LinkedIn analysis

The share of professionals with **AI and Big Data** skills within the total number of professionals in the agri-food industry is highest in Germany, followed by Denmark and the Netherlands as the analysis of LinkedIn data demonstrates (see Figure 17).

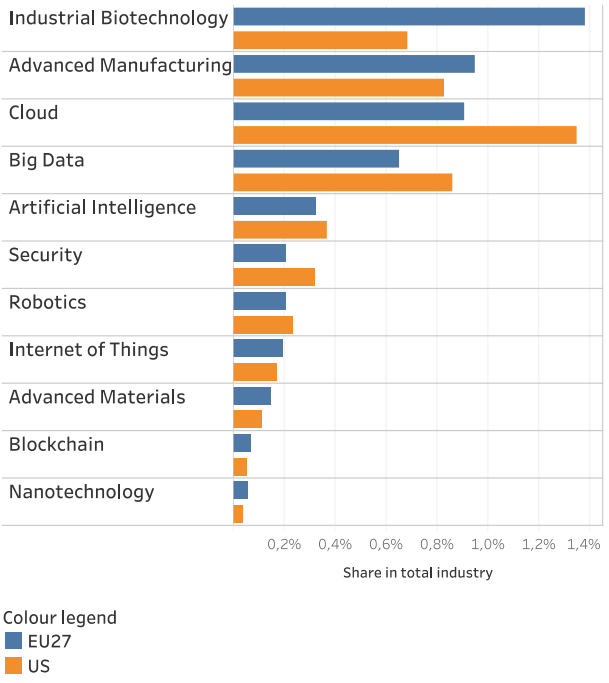
Figure 17: Agri-food industry professionals with skills in AI & Big Data in top EU27 countries, 2019



Source: Technopolis Group based on LinkedIn analysis

LinkedIn data also allows the comparison of the agri-food sector in terms of skilled professionals in the EU27 and the US. This is particularly interesting to compare, seeing the important role of the US in agri-food technologies at global scale. After taking the share of professionals with advanced technology skills employed in the agri-food industry within the total number of agri-food professionals, it can be observed that the **EU27 is leading especially in Industrial Biotechnology**, Advanced Manufacturing, Advanced Materials and Internet of Things as depicted in Figure 18. Nevertheless, the US has a higher share of professionals with expertise and skills in Cloud technologies, Big Data and AI. Overall, the US has an advantage in employing digitally skilled professionals in the agri-food industry.

Figure 18: Agri-food industry professionals with skills in advanced technologies in the EU27 and US



Source: Technopolis Group based on LinkedIn analysis

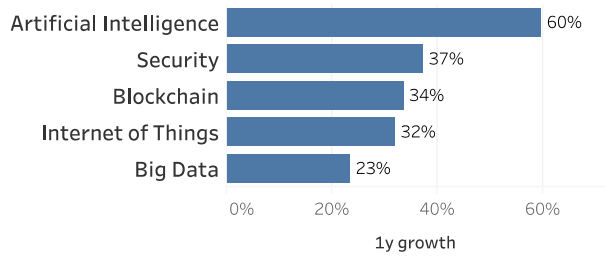
Note: total industry refers to the professionals employed within the agri-food sector as registered on LinkedIn in the same occupations both in the EU27 and the US

4.2 Demand for new skills

After analysing the availability of technological skills in the agri-food industry, it is also important to look at which skills have been the most common in the recent hires. To measure this demand, the 1-year growth rate of technological skills has been analysed by comparing the skills indicated in 2018 and its change to 2019.

Figure 19 visualises the five technological skills that showed the highest growth within the last year (from 2018 to 2019). We see **AI on top followed up by Security, Blockchain, IoT and Big Data.** This result emphasises the growing importance of digital technologies and digital skills in the agri-food industry.

Figure 19: 1-year growth of top 5 skills



Source: Technopolis Group based on LinkedIn analysis

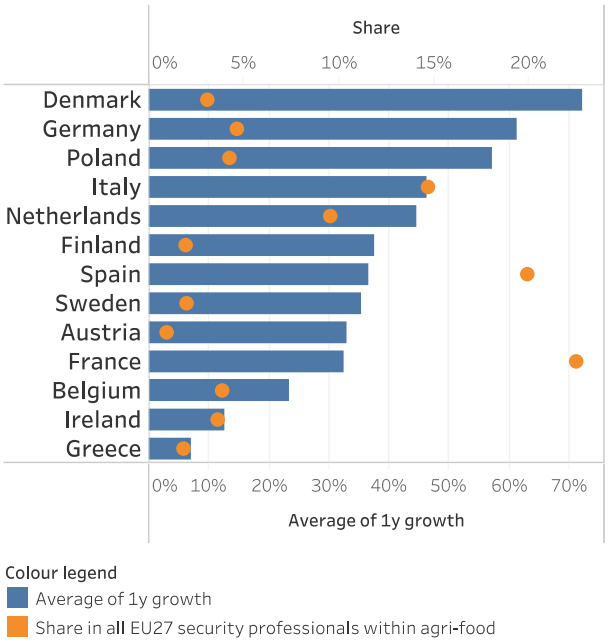
Emerging technological skills linked to **Artificial Intelligence (AI)** are rapidly gaining in importance for the agri-food industry. The LinkedIn data provides evidence for particularly high recent growth rates in these areas. According to the available data, the rise in AI professionals was remarkable especially in **Ireland, Netherlands, Poland and Italy**, as depicted in Figure 20.

Figure 20: EU-countries with highest 1-year growth of AI professionals of agri-food industry

Source: Technopolis Group based on LinkedIn analysis

EU27 countries that have witnessed the highest growth in terms of new hired professionals in Security are **Denmark, Germany and Poland** (Figure 21).

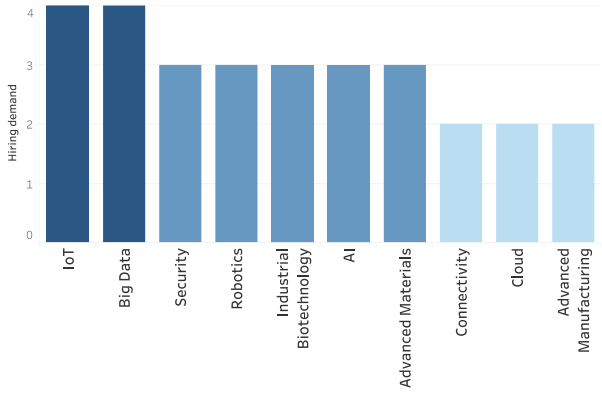
Figure 21: EU countries with the largest 1-year growth of agri-food industry in Security



Source: Technopolis Group based on LinkedIn analysis

Based on the skills requirements of the online job advertisements posted on LinkedIn by European agri-food industry firms, we observe that the fields with 'very high hiring demand' as captured in LinkedIn data and analysis include IoT and Big Data. Hiring demand is also high for skilled professionals in **Security, Robotics, Industrial Biotechnology, Artificial Intelligence and Advanced Materials** (see Figure 22). Hiring demand is defined as the share of job ads published on LinkedIn and requiring specific skills.

Figure 22: Hiring demand in the agri-food industry, Dec 2019 – March 2020



Source: Technopolis Group based on LinkedIn analysis

Section 5

5. Future Outlook: challenges and opportunities

5.1 Innovation and new technologies

The detection of innovation and new technological developments based on certain data sets remains challenging for the area of agri-food. **Agri-food companies do not have the inherent practice to invent technologies** they are developing, but rather focus on applying and adapting technologies for their specific needs and industrial requirements.

Industrial Biotechnology, Robotics and Big Data are important advanced technologies for the agri-food industry. Certainly, also IoT and AI play an important role, seeing the importance of especially digital technologies for the agri-food industry. However, agri-food actors are often reluctant to take up new technologies as it changes the way they currently work, and the outcome of applying the technologies can often be insufficiently demonstrated to the farmer or the food processing company. Hence, the economic feasibility of investing in technologies like Industrial Biotechnology, Robotics and Big Data remains a hurdle.

The agri-food sector is also a highly regulated sector, making the introduction of innovation not straightforward as it needs to comply with existing regulations.

The implementation of innovation and new technologies like Robotics and Big Data have the potential to disrupt the agri-food supply chain. New players active in these areas are entering the supply chain by creating new business models e.g. based on data capturing and processing. This raises issues regarding ownership of data (e.g. is it the data processing actor that owns the data or the agri-food actor that produces the data?) and privacy issues. With the introduction of new players in their value chain, agri-food companies try to safeguard their business activities, while lowering their environmental impact.

5.2 Challenges in the startup scene

Startups are faced with sector specific challenges, such as strict regulatory frameworks relating to health and safety, in addition to cross-national legislative barriers hampering scale-up within Europe**.** The regional specificity of startups, which are created based on circumstances in a specific geographic location, dependent on a specific agricultural or food product often hampers company growth leading and contributing to the long-term creation of SMEs. This is further reinforced by the legislative difference across European Member States, hampering the scaling up and internationalisation of companies, even within Europe. For example, in the dairy sector, technologies to support the detection of certain bacteria are available with a functioning business model in Sweden, however due to different legislative frameworks, as well as a strong veterinarian lobby, the technology and its business plan is not viable in France, despite being able to bring considerable benefits to animal welfare and antibiotic use.

5.3 Digital divide and skills

Across agri-food stakeholders and Member States (MS) it is evident that there is **movement at two speeds.** In the agricultural sector, some, especially smaller and older farms are reluctant to digitalise. Technological solutions are available, but the farmers miss a clear signal on how and what to digitalise. On the other hand, one can observe larger farms, with younger generation farmers that embrace digitalisation and who also rely on technologies to manage their farms due to the large size.

Digital skills need to be reinforced to bridge the gap. Both the agricultural and food processing industry need to bridge the gap of the digital divide to overcome several barriers. Specific skills on the use of advanced technologies are needed. In addition, understanding of the overall benefits, both in terms of addressing consumer needs and addressing the wider sustainability of the agri-food industry are a prerequisite for a sustainable agri-food industry.

In many cases, this also includes the **training and reskilling of field advisors and innovation intermediaries**, who are meant to advise farmers and food processing companies on which technologies to implement. Education programmes are lagging in this respect, with insufficient coverage of latest technological development for agronomists and engineers in the food industry. Focussing on skills and knowledge as a solution, can support in tackling the skills and

knowledge barriers associated with Advanced Manufacturing, IoT, Photonics and other technologies in the food processing industry.

5.4 COVID-19 - impact on the Agri-food sector

As a vital sector, the agri-food sector must continue to operate despite COVID-19. This means that employees are required to continue to be actively working on-site in their jobs throughout the crisis. A strong focus is placed on the importance of ensuring that employees remain in good health and do not contract the virus. Therefore, equipping and training staff on social distancing rules is key.

Guarantee food supply and safety. It is important that exporting/importing activities can continue to ensure that countries with low self-sufficient percentage of food generation can still obtain food. On the other hand, countries with a high self-sufficient percentage can maintain their export and thus sustain their business. Strict hygiene rules are applied to ensure that no contamination of food by the virus is taking place.

Availability of foreign workers. Farms in the EU rely on support from foreign workers for harvesting and support at farms, as well as in the food processing industry. Certain countries have taken the initiative to fly in workers from foreign countries to be able to ensure that harvest can be carried out and food processing is ensured.

Value chain impact. Certain value chain segments are only experiencing a limited impact from the COVID-19 crisis, such as feed suppliers for livestock farming who indicate that raw materials are still available. In the retail value chain segment, there are issues due to transport restrictions, border controls and especially the closure of restaurants and the catering sector. Some of these elements are tackled through the reopening of restaurants, bars and cafés or though delivery services. During the strictest lockdown periods, supermarkets limited capacities jeopardised sales. Over the long term, there is a risk of reduced output due to COVID-19 due to value chain bottlenecks that could potentially lead to increasing costs, with impacts to be felt across the agri-food value sector, that could even result in restricted food availability.

Tackling food waste. During the COVID-19 pandemic, it has become common practice for many households to stockpile food and beverages, however due to improper storage or insufficient attention to expiry dates of food products, there is a high risk of food waste being generated as a result of these practices. Governments such as Germany have pushed for guidelines to shoppers to encourage responsible shopping to prevent food waste due to stockpiling. In addition, shoppers are given clear and detailed information about how to store certain foods to minimise food waste. The Netherlands, Slovenia and Greece are among the countries with similar initiatives in place.[20]

[20] https://ec.europa.eu/food/sites/food/files/safety/docs/fw_lib_gfd_eu-plt-prevent-flw-covid-19.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. 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;
- 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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