Deep tech innovation in smart connected technologies

A comparative analysis of SMEs in Europe and the United States

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Europäisches Patentamt
European Patent Office
Office européen des brevets

European Investment Bank
The EU bank

Foreword

The Fourth Industrial Revolution (4IR) has triggered sweeping transformations in value creation and consumer behaviour. A constellation of disruptive technologies – such as the internet of things, cloud computing, big data, 5G communication and, of course, artificial intelligence – is paving the way for a new, data-driven economy. The world is already filled with billions of smart devices that can all collect and share data in real time and make autonomous decisions. In terms of value creation, the boom in 4IR technologies is expected to contribute over two trillion euros to the EU economy by the end of this decade.

With this report, the European Investment Bank (EIB) and European Patent Office (EPO) are teaming up for the first time to offer key insights into the small businesses driving innovation in 4IR technologies. This partnership stems from a shared awareness of the crucial part such businesses play in Europe's future prosperity. It also draws on our respective experiences of the unique challenges facing businesses seeking to bring new technologies to market and how to address them.

Patent protection is vital for the small and medium-sized enterprises (SMEs) that invest in innovation. Patents enable enterprises and individuals to reap the rewards of their creativity and hard work. As the patent office for Europe, the EPO provides high-quality patents to protect innovations in up to 44 member states (including all EU member states). It is also positioned at the cutting edge of technical progress, with millions of patent documents classified across a wide variety of fields. But patent protection is not just for large multinational corporations. Applicants at the EPO range from teams of scientists collaborating in university spin-offs to sole inventors with brilliant ideas. European patents also help small deep tech businesses to raise funding, set up collaborations, and eventually scale up in Europe and beyond.

Favourable financing conditions are another vital precondition for firms developing 4IR technologies to flourish. The European Investment Bank Group, composed of both the European Investment Bank (EIB) and the European Investment Fund (EIF), is the largest multilateral financial institution in the world. In 2021, the EIB Group made available almost EUR 95 billion worldwide. Almost half the Group's financing, EUR 45 billion, went to SMEs. At the same time, the EIB Group has intensified financing for innovation. Last year, EUR 20.7 billion of the EIB Group's financing went to support innovation, including investment in digitalisation and cutting-edge technologies. From start-ups, to scale-ups, to well established firms, the EIB Group supports innovation and growth via funding for lending and guarantees for banks to target SMEs, direct finance and guarantees to innovative companies, seed capital, business angels and venture capital support, as well as venture debt.

Our study draws attention to SMEs that are developing new 4IR technology in Europe. It provides data-driven analysis of the specific challenges they are facing compared to other SMEs in Europe and in the US. 4IR SMEs have strong potential to unlock growth and deliver added value. In the global race to digital transformation, it is paramount that both investors and decision-makers recognise their potential.

Debora Revoltella
Chief Economist EIB

Yann Ménière
Chief Economist EPO

About the report

The purpose of this study is to provide a comprehensive inventory and analysis of small and medium-sized enterprises that invest in the development of new technologies linked to the Fourth Industrial Revolution (4IR) in the EU27. The study quantifies and analyses the contribution made by these small businesses to the European Union's performance in 4IR innovation over the past decade. By benchmarking these companies against similar 4IR businesses in the US and other European countries, it aims to inform policymakers, private decision-makers and investors of the specific challenges of growing 4IR deep tech businesses in Europe.

About the European Investment Bank Economics Department

The mission of the EIB Economics Department is to provide economic analyses and studies to support the Bank in its operations and in defining its positioning, strategy and policy. The department, a team of 40 economists, is headed by Director Debora Revoltella.
www.eib.org/economics

About the European Patent Office

The European Patent Office was created in 1977. As the executive arm of the European Patent Organisation, it is responsible for examining European patent applications and granting European patents, which can be validated in up to 44 countries in Europe and beyond. As the patent office for Europe, the EPO is committed to supporting innovation, competitiveness and economic growth across Europe by delivering high-quality products and services and playing a leading role in international co-operation on patent matters. The EPO is also one of the world's main providers of patent information. As such, it is uniquely placed to observe the early emergence of technologies and follow their development over time. The analyses presented in this study are a result of this monitoring.

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List of abbreviations

4IR	Fourth Industrial Revolution
AI	Artificial intelligence
CAGR	Compound annual growth rate
CATI	Computer-assisted telephone interviews
CAWI	Computer-assisted web interviews
EISMEA	EU's Executive Agency for Small and Medium-sized Enterprises
EIB	European Investment Bank
EIBIS	EIB Investment Survey
EPC	European Contracting States (member states of the European Patent Organisation)
EPO	European Patent Office
EU27	The 27 European Union countries
GDP	Gross domestic product
ICT	Information and communication technologies
IoT	Internet of Things
IP	Intellectual property
IPFs	International patent families
IPO	Initial public offering
PROs	Public research organisations
R&D	Research and development
RTA	Revealed technology advantage
SMEs	Small and medium-sized enterprises
VC	Venture capital

List of countries

AT	Austria
BE	Belgium
CH	Switzerland
CN	People's Republic of China
DE	Germany
DK	Denmark
ES	Spain
EU	European Union
FI	Finland
FR	France
IE	Ireland
IT	Italy
JP	Japan
KR	Republic of Korea
NL	Netherlands
NO	Norway
PL	Poland
SE	Sweden
UK	United Kingdom
US	United States of America

Executive summary

In recent years, the Fourth Industrial Revolution (4IR) has massively accelerated the process of digital transformation. Technologies such as the Internet of Things (IoT), cloud computing, 5G and artificial intelligence (AI) are already altering the way we live, work and interact. By paving the way for a data-driven economy, they are disrupting many European industries. As one of the six headline priorities of the EU Commission's 2020 Work Programme, its digital strategy is designed to keep Europe on a par with the rapid pace of 4IR innovation observed in the US and Asia. By enabling "a vibrant community of innovative and fast-growing start-ups and small businesses to access finance and to expand", it specifically aims to foster the emergence of new European players in the global race to digital transformation.

Aim of the study

This study seeks to guide policymakers, industry and the public in this endeavour by providing a comprehensive inventory and analysis of SMEs that have been developing 4IR technology over the past decade. It focuses on deep tech SMEs that have actively patented 4IR technologies, as opposed to the larger population of small businesses that are simply implementing and making use of such technologies. By benchmarking these companies against their counterparts in the US and other European countries, the study provides insight into the specific challenges of growing deep tech businesses in Europe for decision-makers in the public and private sectors, as well as investors.

Key findings

There are twice as many SMEs with an international portfolio of 4IR patents in the US than in the EU27, adding to the overall leadership of the US in advanced digital technologies.

Figure E1

Share of 4IR IPFs contributed by SMEs (average of years 2010-2018)

Source: Crunchbase and Orbis, authors' calculation.

- In the EU27, over 2 600 European SMEs generated 3 181 international patent families (IPFs [1]) related to 4IR technologies between 2010 and 2018, contributing 10% of the EU's 4IR patenting in that period. Despite the overall lower proportion of SMEs in the US economy, there are about twice as many SMEs with 4IR IPFs in the US. They contributed 16% of US 4IR patenting in the same period and have significantly larger 4IR patent portfolios on average.
- Within the EU, Germany (570), France (400) and Italy (273) have the largest number of 4IR SMEs – most of which are, in fact, concentrated in a limited number of regions (such as the greater Munich and Paris areas). Outside the EU, the UK has the largest number of 4IR SMEs (950).
- Relative to their size, smaller EU countries like Finland, Sweden, Ireland and Denmark are outperforming other EU member states and even the US. The particularly high concentration of 4IR SMEs in Finland and Sweden denotes the existence of strong local ecosystems, including world-class 4IR companies. Outside the EU, Switzerland and Norway have a relatively high concentration of 4IR SMEs.

1 Each international patent family (IPF) covers a single invention and includes patent applications filed and published at several patent offices. It is a reliable proxy for inventive activity because it provides a degree of control for patent quality by only representing inventions for which the inventor considers the value sufficient to seek protection internationally. The patent data presented in this report refer to IPFs.

Although 80% of EU 4IR SMEs have 50 employees or less, only 41% have been operating for ten years or less, in line with the long development cycles typically observed in deep tech. US 4IR SMEs have a similar age/size distribution but tend to focus more on core hardware, software and connectivity technologies.

Figure E2

Size and age of 4IR SMEs

Small (1-50 employees) Large (51-250 employees)

Young (10 years or less) Old (older than 10 years)

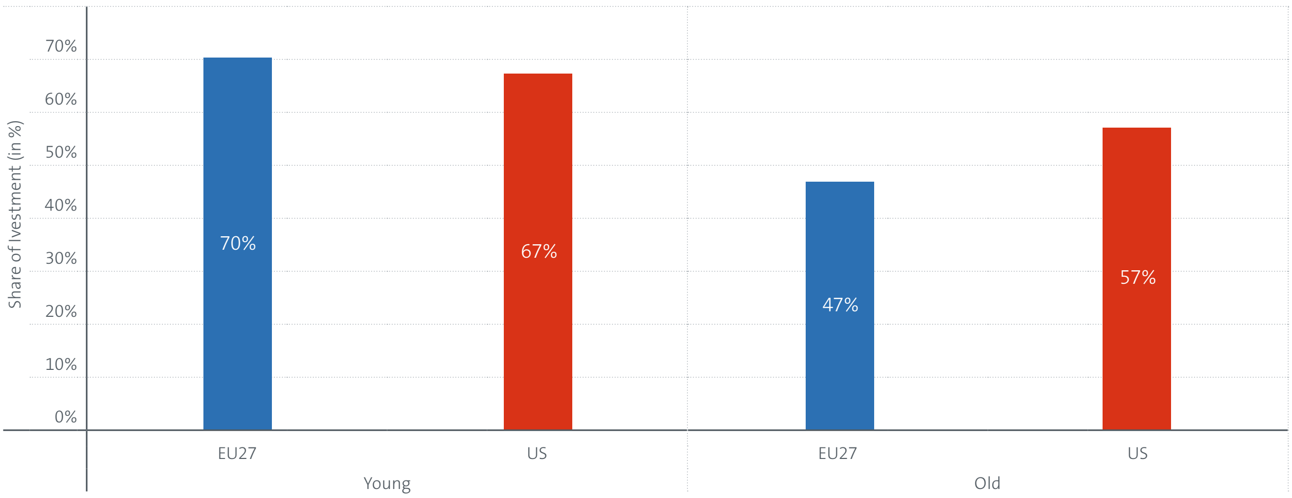
Source: Orbis and Crunchbase, authors' calculation.

- Over 90% of the EU's 4IR SMEs have already implemented their 4IR technologies in products and services or in their own business, with applications spanning the healthcare, transport and cleantech sectors, as well as data analytics. In addition, 4IR SMEs are more likely (44%) to be involved in manufacturing hardware products (developing, building and selling physical devices) than other SMEs.
- More than a third of the EU27 and US SMEs have filed patent applications related to data mining and exploration. The patents filed by US 4IR SMEs are also frequently related to core hardware, software and communication technologies. 4IR SMEs in Finland and Sweden likewise stand out with an even stronger focus on core hardware and communication technologies.
- Almost 60% of EU 4IR SMEs plan to invest more in 4IR-related innovation in the future, while almost 25% regard their current investment as insufficient. However, the current COVID-19 pandemic has had a negative impact on the turnover of more than half of EU 4IR SMEs.

EU 4IR SMEs show a higher investment intensity than other EU SMEs, with up to 70% of total investment targeted at 4IR innovations among young 4IR SMEs.

Figure E3

Share of investment related to 4IR technologies (in %)



Source: 4IR survey.

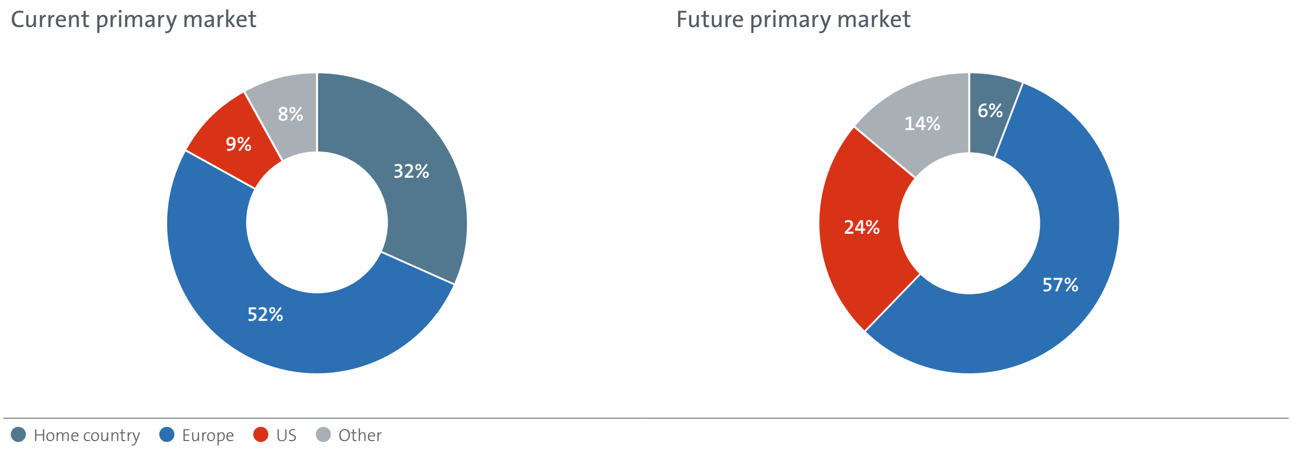
Base: Firms that invested in innovation (excluding don't know / refused responses).

- About 70% of total investment by young 4IR SMEs in the US and EU was specifically targeted at 4IR innovation. For 4IR firms operating for more than 10 years, this proportion drops to less than 50% in the EU27 and less than 60% in the US.
- On average, the subgroup of 4IR SMEs from the US and Europe listed on Crunchbase, one of the largest start-up repositories, received significantly higher funding than a benchmark group of SMEs, especially during the build and growth stages.
- However, the proportion of these 4IR start-ups reporting formal funding sources is higher in the US (68%) than in the EU (59%). In addition, more EU27-based 4IR start-ups rely on public funding.
- Almost half of all 4IR SMEs (49%) consider patents as very important to secure financing and a large majority (80%) report that IP strategy was of relevance to their investors.

More than every second 4IR SME in the EU sees its future primary market in Europe.

Figure E4

Geographical markets of 4IR SMEs in EU27



Source: 4IR survey.

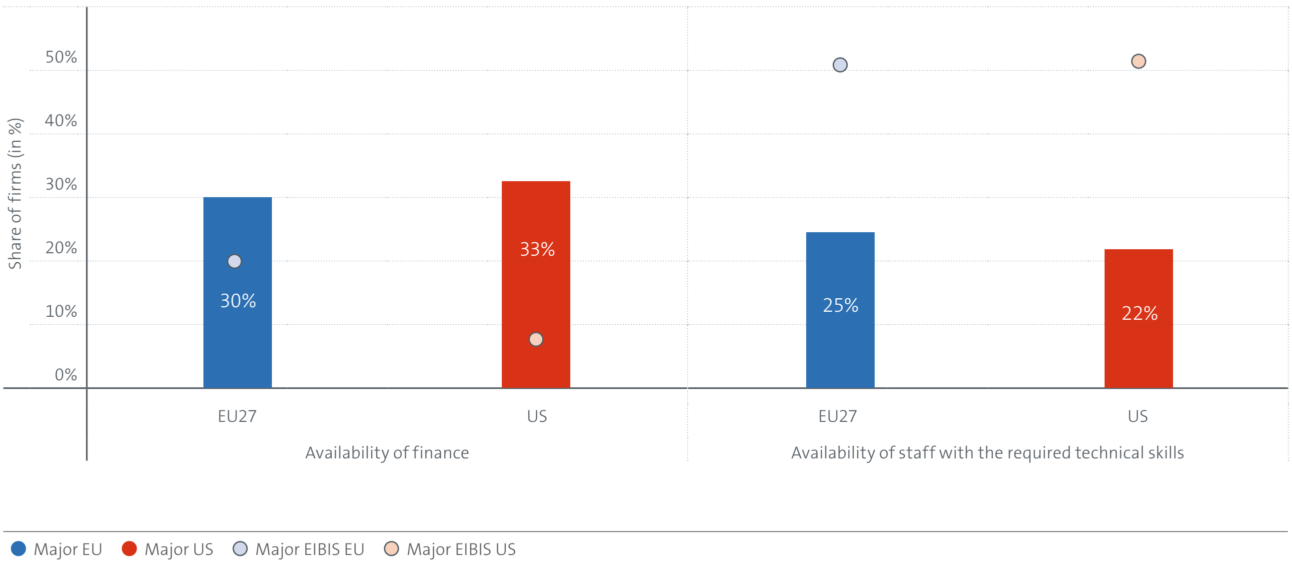
Base: 4IR innovators in 4IR survey (excluding don't know / refused / no obstacle responses).
Note: Europe is defined as all EPC member states, including the EU27, the UK, Switzerland, Norway and other countries.

- Currently, 32% of EU SMEs are still focused primarily on operations in their home country. However, their growth plans tend to be targeted towards the European market (57%), as also reflected in the geographical scope of their patent portfolios. By contrast, US 4IR SMEs cite the entire US domestic market as a priority for both current and future growth, as well as for patent filings.
- While only about one in ten US SMEs sees their future primary market in Europe, more European firms regard the US as their future primary market (24% of EU27). In particular, the EU27 SMEs considered to be dominant players in their market report more frequently that they expect the US to be a future primary market (38%).
- European 4IR SMEs listed on Crunchbase are almost twice as likely to be acquired than a benchmark group of European SMEs (15% vs 8%), and more than every third EU 4IR SME is acquired by a US company.

A large proportion of 4IR SMEs in both the EU and US cite the availability of finance (73% and 77% respectively) and the availability of staff with the required technical skills (73% and 76% respectively) as business barriers.

Figure E5

Major obstacles of 4IR SMEs



Source: 4IR survey, EIBIS (2021).

Base: 4IR innovators in 4IR survey, SMEs in EIBIS (excluding don't know / refused / no obstacle responses).

- The most cited policy support that would encourage SMEs to further introduce or develop 4IR technologies is the availability of finance (54% of the youngest and smallest firms indicate that this is the most helpful support).
- Compared with other categories of SMEs, 4IR SMEs also report the availability of finance more frequently as a major issue. By contrast, the lack of technical skills and other obstacles are less likely to be deemed a severe issue by 4IR SMEs than by other SMEs.
- More than half of US and EU 4IR SMEs complain about the availability of government support, although EU 4IR SMEs are liable to consider this to be a major obstacle to their activities.

Policy perspective

- Fostering the 4IR innovations of small businesses, together with digital skills and infrastructure, should be a policy priority to ensure Europe's competitiveness in advanced digital technologies.
- The creation of the Unitary Patent will support the growth of 4IR SMEs in Europe by helping them secure patent protection in a larger number of national markets.
- Direct policies (such as targeted grants or early-stage deployment policies) provide a tool to foster innovation in technologies that have not yet become cost-effective.
- Access to adequate growth funding remains insufficient to enable scale-up and thereby develop more global 4IR leaders. Further development of the European start-up ecosystem is needed to enable larger funding rounds (in particular for the later stages) and make listing start-ups on European stock markets an attractive option.

1. Introduction

1. Introduction

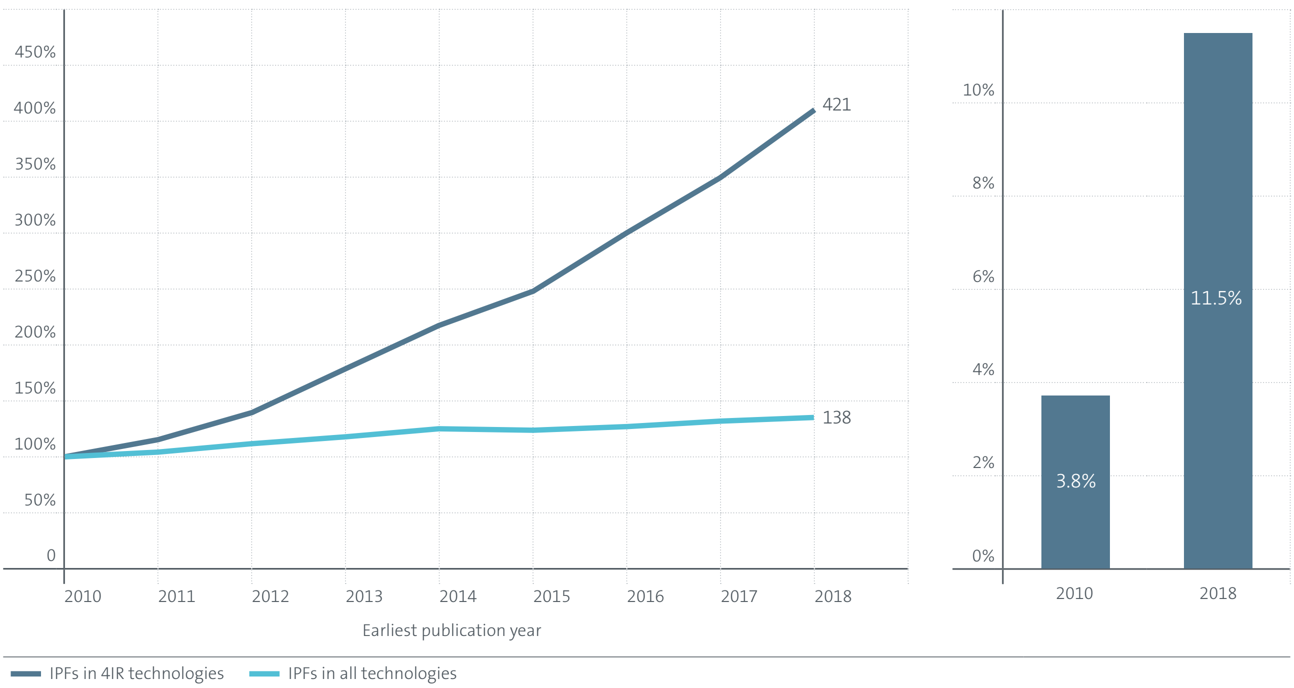
In recent years, the Fourth Industrial Revolution (4IR) has been driving the digital transformation. Characterised by a combination of technologies that blurs the lines between the physical and digital spheres, it is altering the way we live, work and interact, and has already disrupted many industries.

According to a 2020 study by the European Commission, over 29 billion devices will be connected to Internet Protocol networks across the globe by 2023, most of which will be creating data in real time. Once combined with other technologies, such as artificial intelligence (AI), big data, advanced robotics, the Internet of Things (IoT), cloud computing or 3D printing, they enable the automation of entire business processes, including repetitive intellectual tasks previously performed by humans. It is estimated that the cumulative additional GDP contribution of these new digital technologies could amount to EUR 2.2 trillion in the EU alone by 2030, a 14.1% increase from 2017.

This revolution is primarily driven by innovation in technology, as illustrated by the impressive growth of worldwide patent applications in this field (EPO, 2020). The pace of international patenting related to smart connected objects accelerated strongly during the last decade, with an average annual growth rate in patenting close to 20% from 2010 to 2018, compared with 12.8% between 2000 and 2009. The annual increase in international patent families (IPFs) [2] for 4IR technologies has been nearly five times greater than the growth of IPFs in all fields since 2010 (4.2%). As a result, smart connected objects accounted for more than 11.5% of all patenting activity worldwide in 2018 (with nearly 40 000 new IPFs in 2018 alone), pervading most sectors of the economy (Figure 1.1).

Figure 1.1

Global growth of IPFs in 4IR technologies versus all technologies and the proportion they make up of all technologies (in %), 2010-2018



Source: EPO, authors' calculation

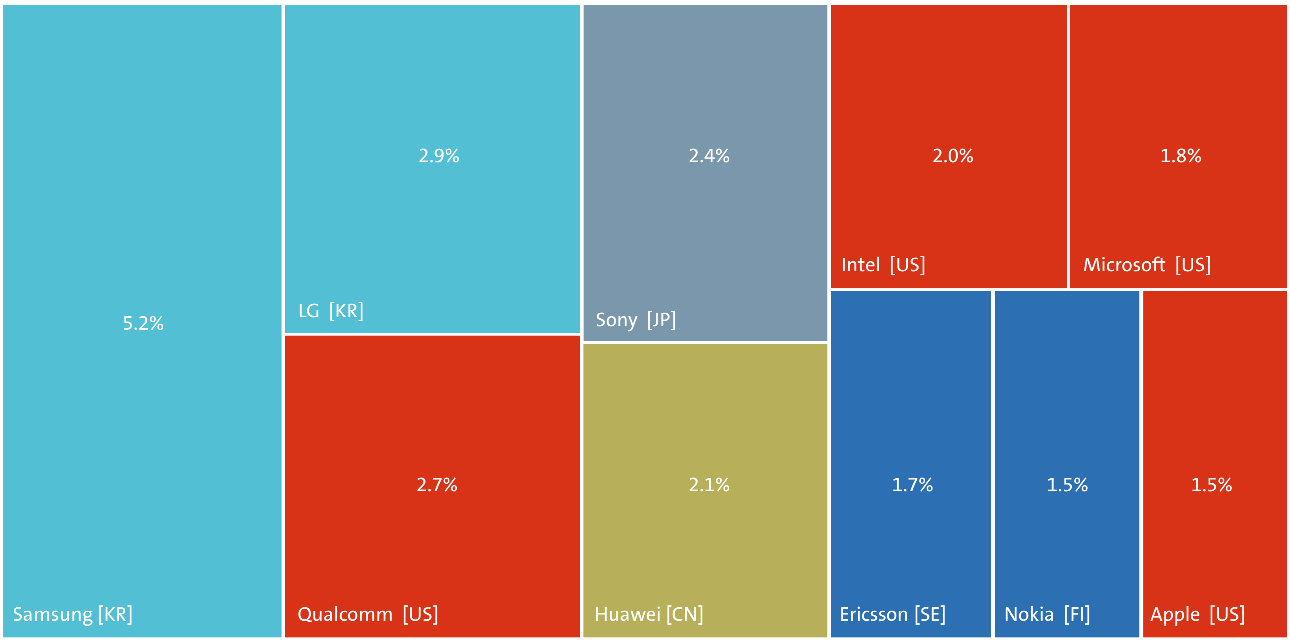
2 Each international patent family (IPF) covers a single invention and includes patent applications filed and published at several patent offices. It is a reliable proxy for inventive activity because it provides a degree of control for patent quality by only representing inventions for which the inventor considers the value sufficient to seek protection internationally. The patent data presented in this report refer to IPFs.

Leading innovators in these technologies are already shaping the data-driven economy for the years to come. Meanwhile, others may struggle or even disappear in the wake of 4IR disruptions. Despite being a significant contributor to 4IR innovation (with about 15% of 4IR IPFs between 2010 and 2018), the EU27 lacks specialisation in the field. It also has few of the major digital companies that have been driving 4IR transformations thus far (Figure 1.2). The top ten 4IR applicants in the period 2010-2018 (together accounting for nearly a quarter of all IPFs) include only two European companies (Ericsson and Nokia), compared with four firms in the US (Qualcomm, Intel, Microsoft and Apple). Besides ensuring that its established industries successfully seize the opportunities offered by 4IR technologies, one of the EU's key challenges is therefore to foster the rapid emergence of new, innovative players that can strengthen Europe's position in the global race to digital transformation.

Against this backdrop, the European digital strategy aims to "enable a vibrant community of innovative and fast-growing start-ups and small businesses to access finance and to expand".[3] This objective is particularly relevant for the deep tech SMEs that are developing patentable 4IR technology. While deep tech innovators typically have strong disruptive potential, they face specific issues such as higher development costs and market and technological risks. Most recently, these challenges have been compounded by the COVID-19 pandemic, underlining the need for appropriate measures to support the funding and growth of 4IR SMEs in Europe.

Figure 1.2

Top ten applicants in 4IR technologies (as a proportion of 4IR IPFs)



Source: EPO, authors' calculation.

3 See "Factsheet: Shaping Europe's Digital Future", European Union 2020.

About this study

The purpose of this study is to provide a comprehensive inventory and analysis of SMEs that invest in the development of new 4IR technologies in the EU27. The study quantifies and analyses the contribution made by these small businesses to the EU's performance in 4IR innovation over the past decade. By benchmarking these companies against similar 4IR businesses in the US and other European countries, it aims to inform policymakers, private decision-makers and investors about the specific challenges of growing deep tech businesses within Europe.

Strict emphasis is placed on SMEs that have been actively patenting 4IR technologies, as opposed to the larger population of small businesses that are simply implementing and applying the technologies. These deep tech SMEs typically rely on recombining existing technologies or leveraging emerging technologies rooted in science and advanced engineering that offer significant advances over those currently in use. As a result, they also often face higher upfront R&D investment and a longer transition period from research to actual industry applications. Patent protection is instrumental in securing the legal exclusivity needed to develop and bring new technology to market.

The study documents the distribution and profiles of European 4IR SMEs across EU27 countries and benchmarks them against their counterparts in the US – historically, the leading country in the field – as well as other European countries that are not part of the EU27. To this end, it exploits a holistic set of indicators spanning the business and IP strategies, development trajectories, funding and financial performance of the SMEs. Throughout the analysis, particular attention is paid to the SMEs' plans to grow and commercialise 4IR technologies, and to the factors impacting their ability to fulfil those plans. Furthermore, 4IR SMEs are compared with the SMEs interviewed in the EIB Investment Survey (EIBIS), highlighting the obstacles they face compared with their peers.

Methodology

The analysis is based on the systematic identification of small businesses in Europe and the US that have been filing international patent applications for inventions related to 4IR technologies. The identification of 4IR inventions in patent data is based on expert searches by EPO examiners focusing on all types of inventions relevant to smart connected objects. The focus on international patent families (IPFs, i.e. inventions for which patent protection has been sought in at least two distinct jurisdictions) ensures that the selection of SMEs is based on inventions with a confirmed potential for commercialisation on an international scale. It also enables sound comparisons between populations of SMEs with 4IR patenting activities in different countries.

For the purpose of the analysis, data on 4IR patents were matched to company data from the ORBIS and Crunchbase databases (see Box 3 and Annex 1 for more information) in order to retrieve employment and financial data. The matched dataset of 10 126 companies was also used as a source sample to carry out a survey of 4IR SMEs in Europe (including member states of the European Patent Convention that are not part of the EU) and the US (see Box 3 and Annex 1). Some 625 firms provided complete interviews. All selected firms have fewer than 250 employees. The aim of the interview was to ask firms about their business activities and markets, as well as what hampers their growth. Results from this survey form the basis of the report and are complemented where relevant by those directly derived by analysing the source dataset of matched patent-company data.

Outline

The report contains nine sections. It first looks at where SMEs stand in terms of deep tech innovation and reviews their business profiles. Then it elaborates on the 4IR SMEs' market and IP position, and investment activities. Next, the report shows the investment activities and funding profiles of 4IR SMEs, concluding with policy recommendations.

BOX 1

About patents and patent information

Patents are exclusive rights for inventions that are new and innovative. High-quality patents are assets for inventors because they can help attract investment, secure licensing deals and provide market exclusivity. Patents are not secret. In exchange for these exclusive rights, all patent applications are published, revealing the technical details of the inventions in them.

Patent databases therefore contain the latest technical information, much of which cannot be found in any other source and is freely available for independent research purposes. The EPO's free Espacenet database contains more than 120 million patent documents from around the world and comes with a machine translation tool in 32 languages. This patent information provides early indications of technological developments that are bound to transform the economy, revealing how innovation is driving the Fourth Industrial Revolution.

BOX 2

Technologies for the Fourth Industrial Revolution (4IR)

4IR technologies comprise inventions that are related to smart connected devices and combine computing, connectivity and data exchange. These 4IR inventions are further divided into three main sectors, namely "core technologies", "enabling technologies" and "application domains", each of which is subdivided into several technology fields.

The first sector, *core technologies*, corresponds to the basic building blocks upon which the technologies of 4IR are built. It consists of inventions that directly contribute to the three established fields of information and communication technologies (ICT) inherited from the previous industrial revolution: IT hardware, software and connectivity. The table gives a short definition of these core technology fields.

The second sector encompasses *enabling technologies* that build upon and complement the core technologies. These enabling technologies can be used for multiple applications. They have been subdivided into eight technology fields (Table 1.2).

The third sector, *application domains*, encompasses the final applications of 4IR technologies in various parts of the economy. It has been broken down into eight different technology application fields (Table 1.3).

4IR inventions can be relevant to one or more technology fields within one or more technology sectors, combining features of several 4IR technologies and forming a bridge technology between different 4IR building blocks.

Table 1.1

Overview of core technology fields

Field	Definition	Examples
IT hardware	Basic hardware technologies	Sensors, advanced memories, processors, adaptive displays, smart instruments
Software	Basic software technologies	Intelligent cloud storage and computing structures, adaptive databases, mobile operating systems, virtualisation and blockchain technologies
Connectivity	Basic connectivity systems	Network protocols for massively connected devices, adaptive wireless data systems for short-range and long-range communication

Table 1.2

Overview of enabling technology fields

Field	Definition	Examples
Data management	Technological means to create value from data	Diagnostic and analytical systems for massive data, prediction and forecasting techniques, monitoring functions, planning and control systems
User interfaces	Enabling the display and input of information	Virtual reality, augmented reality, speech recognition and synthesis
Core AI	Enabling machine understanding	Machine learning, neural networks, statistical and rule-based systems, AI platforms
Geo-positioning	Enabling the determination of the position of objects	Enhanced geo-location and satellite navigation, device to device relative and absolute positioning
Power supply	Enabling intelligent power handling	Automated generation, situation-aware charging systems, shared power transmission and storage objectives, smart power-saving management
Data security	Enabling the security of data	Adaptive security systems for devices, services and data transmission
Safety	Enabling safety or physical objects	Intelligent safety systems for theft and failure prevention
Three-dimensional support systems	Enabling the realisation of physical or simulated 3D systems	3D printers and scanners for parts manufacture, automated 3D design and simulation, 3D user interfaces

Table 1.3

Overview of technology fields in application domains

Field	Definition	Examples
Consumer goods	Applications pertaining to the individual	Personal health monitoring devices, smart wearables, smart entertainment and sport devices, smart toys and textiles
Home	Applications for the home environment	Smart homes, alarm systems, intelligent lighting and heating, consumer robotics, climate control systems
Vehicles	Applications for moving vehicles	Autonomous driving, vehicle fleet navigation devices
Services	Applications for business enterprise	Intelligent retail, payment and loyalty systems, smart offices
Industrial	Applications for industrial manufacture	Smart factories, intelligent robotics, energy saving
Infrastructure	Applications for infrastructure	Intelligent energy distribution networks, intelligent transport networks, intelligent lighting and heating systems
Healthcare	Applications for healthcare	Intelligent healthcare systems, robotic surgery, smart diagnosis
Agriculture	Applications for agriculture	Climate monitoring systems, greenhouse automation, smart crop and cattle management, smart farming

2. 4IR patenting and the contribution of SMEs

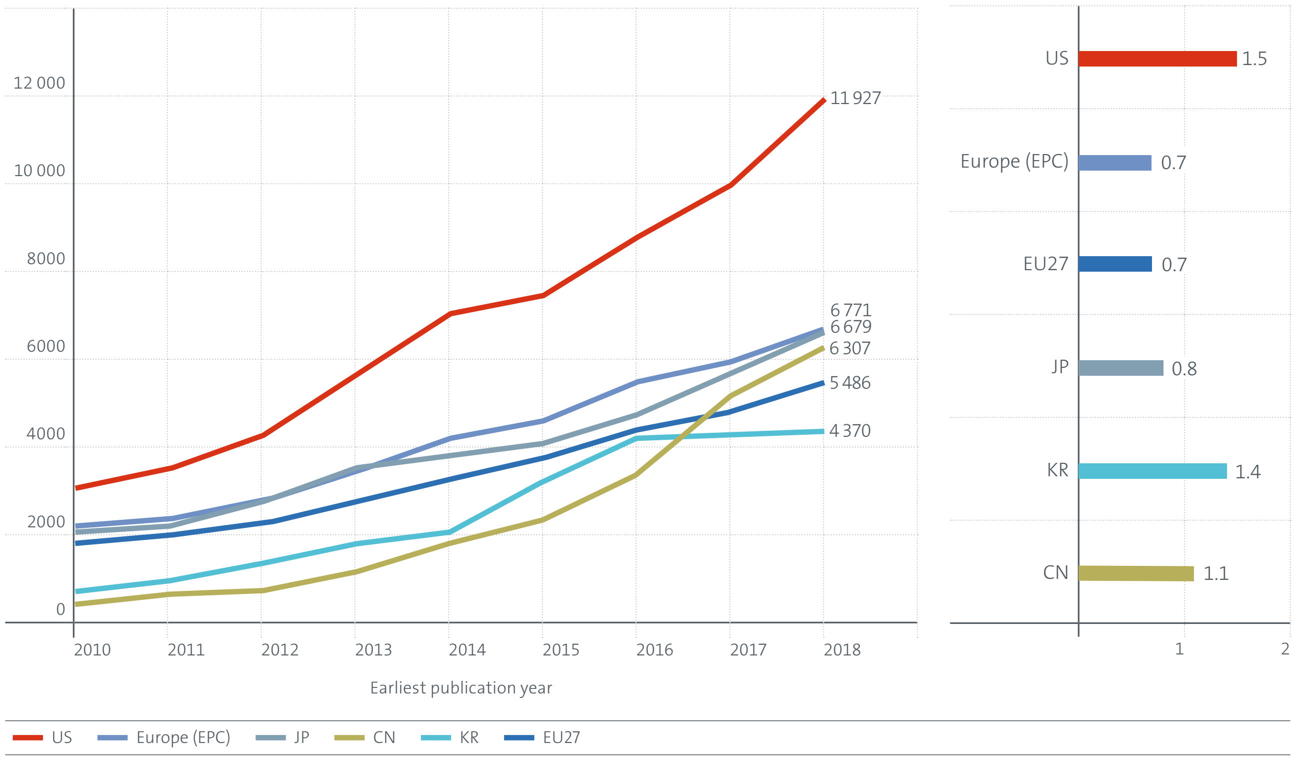
2. 4IR patenting and the contribution of SMEs

Between 2010 and 2018, almost 200 000 4IR inventions were submitted for international patent protection globally. In 2018, they represented more than one tenth of IPFs in all technologies (see Figure 1.1 above). The US was the strongest contributor with 31% of all 4IR IPFs, followed by Japan (18%) and Europe (15% for the EU27 and 19% for the 38 EPC countries). R. Korea (12%) and P.R. China (11%) have been catching up quickly over the last decade.

Of the top five innovation centres, Europe has the lowest specialisation in 4IR technologies over the period 2010-2018 (Figure 2.1). The US shows the highest specialisation with a revealed technology advantage (RTA)[4] value of 1.5, meaning that its proportion of 4IR technologies is 50% higher than its contribution to IPFs in technologies overall.

Figure 2.1

Number of 4IR IPFs by year and country/region, and their revealed technology advantage (RTA) in 4IR technologies, 2010-2018



Source: EPO, authors' calculation.

Note: The right panel shows the average RTA for the period 2010-2018.

4 The revealed technology advantage (RTA) index indicates a country's specialisation in terms of 4IR technology innovation relative to its overall innovation capacity. It is defined as the proportion of IPFs a country has in a particular field of technology divided by the proportion of IPFs a country has in all fields of technology. An RTA above one reflects a country's specialisation in a given technology.

BOX 3

Methodology and data sources[5]

Orbis is Bureau van Dijk's flagship company database, providing information on close to 400 million listed and unlisted companies and entities worldwide, of which 68 million are in North America and 122 million in Europe. It contains detailed financial information and extensive corporate ownership structures. Data are collected from more than 170 providers around the world, treated, appended and standardised to make them more comprehensive and comparable. The version used for this study was downloaded in January 2021. Where information was available, the European definition was applied to identify SMEs[6], otherwise the 250-employee threshold was used. Manual checks were performed as necessary. Companies that have been operating for over 50 years were not considered.

Crunchbase is a commercial database of innovative start-ups and scale-ups maintained by US company Crunchbase Inc. The data are sourced through two main channels: a large network of global investment firms and direct contributions from executives, entrepreneurs and investors who update and revise the company profile pages. The database version used for this study (downloaded in March 2021) lists more than 13 800 different firms operating in the 37 countries covered in this study. For every company, the database reports both the foundation year and the date on which the firm first registered on Crunchbase. Crunchbase is increasingly being used by the venture capital industry as a data source. Where information was available, the European definition was applied to identify SMEs, otherwise the 250-employee threshold was used. Manual checks were performed as necessary. Companies that have been operating for over 50 years were not considered.

The 4IR survey

The main goal of the survey was to collect information on small and medium-sized enterprises (SMEs) in Europe and the US that are developing and/or applying technology in the 4IR category. To achieve this, the population was regarded as comprising all SMEs identified as applicants of an international patent family in the 4IR category in recent years. Finally, N=625 complete interviews were held with the target population between June and October 2021. The interviews, N=455 companies from Europe and N=170 companies from the US, were conducted using mixed methods, namely computer-assisted telephone and web interviews. For the analysis, 27 interviews (14 in Europe and 13 in the US) were discarded as the firms had not carried out any development work in 4IR technologies over the past three years.

EIBIS

The EIB carries out an annual survey of firms in the EU27, UK and US with the aim of monitoring investment and investment finance activities, while at the same time capturing potential obstacles to investment. The survey covers approximately 12 500 companies across the EU and the UK every year, with just over 800 firms in the US for the last three waves. It is administered by telephone (in the local language) and takes an average of 20 minutes. The first wave of the survey took place in 2016 and the survey completed its sixth wave in 2021, with interviews being held between April and July 2021. The results of the latest wave are used as comparison benchmarks.

5 More detailed information can be found in Annexes 1-3.

6 See https://ec.europa.eu/growth/smes/sme-definition_en.

During the same period 2010-2018, **over 2 600 SMEs located in member states of the EU contributed 3 117 IPFs related to 4IR technologies, representing 10% of the EU total** (Figure 2.2). Their patenting activities increased rapidly, at a compound average growth rate (CAGR) of 17% during this period.[7]

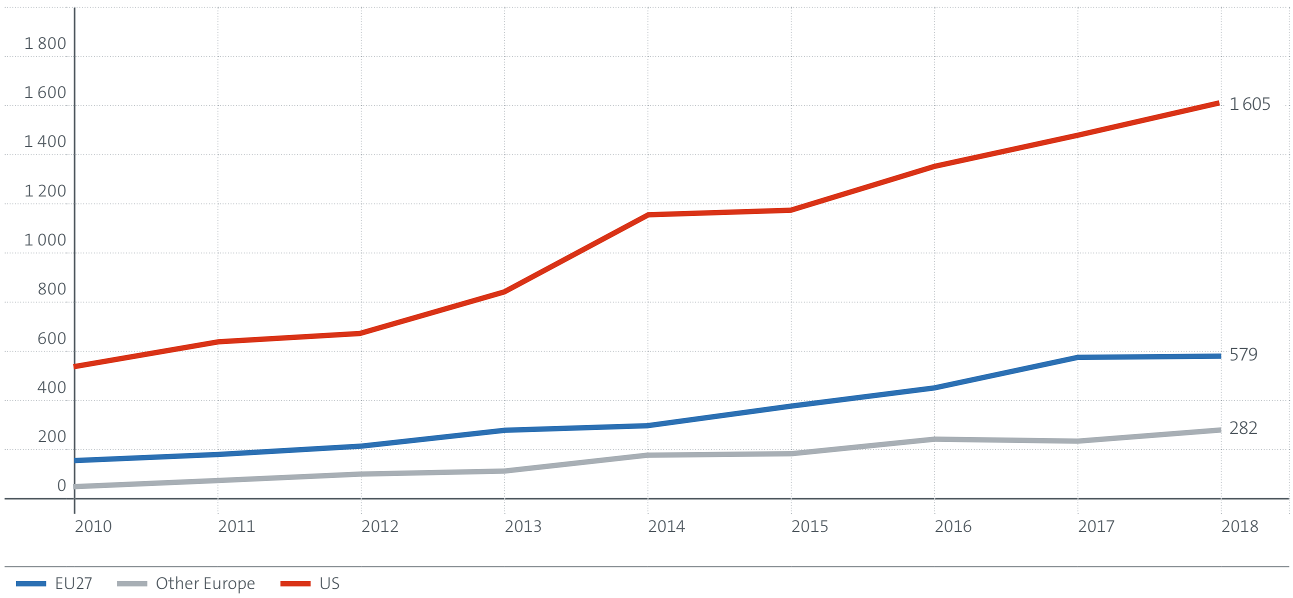
In comparison, the US is home to twice as many 4IR SMEs as the EU27, with a total of 6 157 4IR SMEs. This is remarkable since, overall, fewer SMEs are based in the US than in the EU (see EIB, 2021). **US 4IR SMEs contributed 16% to their country's total innovation output in 4IR technologies between 2010 and 2018; this figure is also significantly higher than their EU27 counterparts and adds to the overall US leadership in 4IR technologies.** However, the number of 4IR IPFs from SMEs rose less dynamically than in Europe, with a CAGR of 15%. As a result, the contribution of SMEs to national 4IR patenting decreased in the US from 17% in 2010 to 13% in 2018, while increasing from 9% in 2010 to 11% in 2018 in the EU.

Figure 2.2

Contribution of SMEs to national 4IR IPFs, 2010-2018

Proportion of 4IR IPFs contributed by SMEs (average of years 2010-2018)

Number of 4IR IPFs contributed by SMEs



Source: Crunchbase and Orbis, authors' calculation.

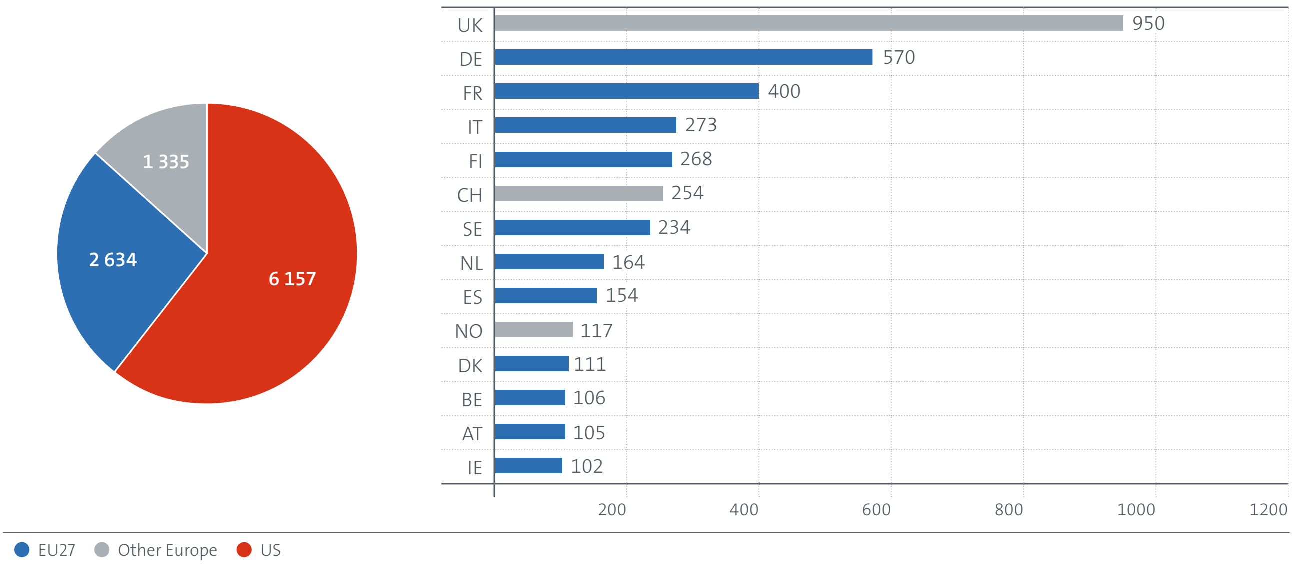
Base: 10 126 4IR SMEs and 14 350 4IR IPFs with earliest publication year between 2010 and 2018.

7 The CAGR is the rate of return that would be required for an investment to grow from its beginning balance to its final one. See above note for the EU definition of SMEs.

Most EU-based 4IR SMEs are located in the three largest member states, Germany (570), France (400) and Italy (273) (Figure 2.3). Scandinavian countries also have a significant number of 4IR SMEs, especially Finland (271) and Sweden (240). Poland is the only Eastern European country in the top 15, with 31 4IR SMEs. In non-EU European countries, SMEs contributed 1 458 IPFs, largely due to the performance of companies in the UK, Switzerland and Norway. The UK in particular has by far the largest number of 4IR SMEs, almost 950. With 254 and 117 4IR SMEs respectively, Switzerland and Norway have comparable numbers to Sweden and Denmark.

Figure 2.3

Geographic origins of the 4IR SMEs



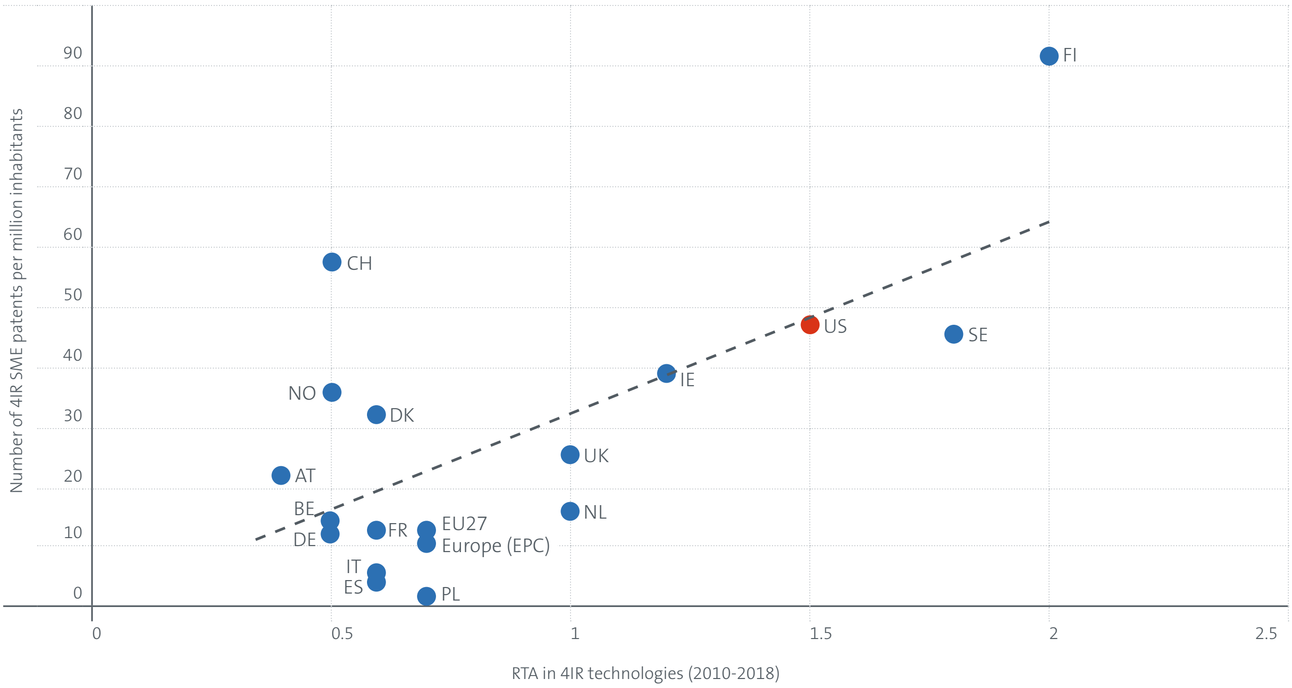
Source: Crunchbase and Orbis, authors' calculation

Note: Only countries with at least 100 SMEs are shown in the right panel.

Figure 2.4 provides further insight into the links between the 4IR specialisation of selected countries in 4IR patenting (RTA) and the number of 4IR SME patents per capita in those countries. It suggests a positive correlation between both indicators, with countries that show overall excellence in 4IR technologies also demonstrating stronger SME performance in 4IR innovation. A few EU countries, namely Finland, Sweden and Ireland, clearly stand out in this respect, with Sweden and Finland even outperforming the US. By contrast, larger countries such as Germany or France exhibit both a lack of 4IR specialisation and relatively low SME impact in 4IR patenting.

Figure 2.4

Number of 4IR IPFs originating from SMEs per million inhabitants and specialisation (RTA) in 4IR technologies in selected countries



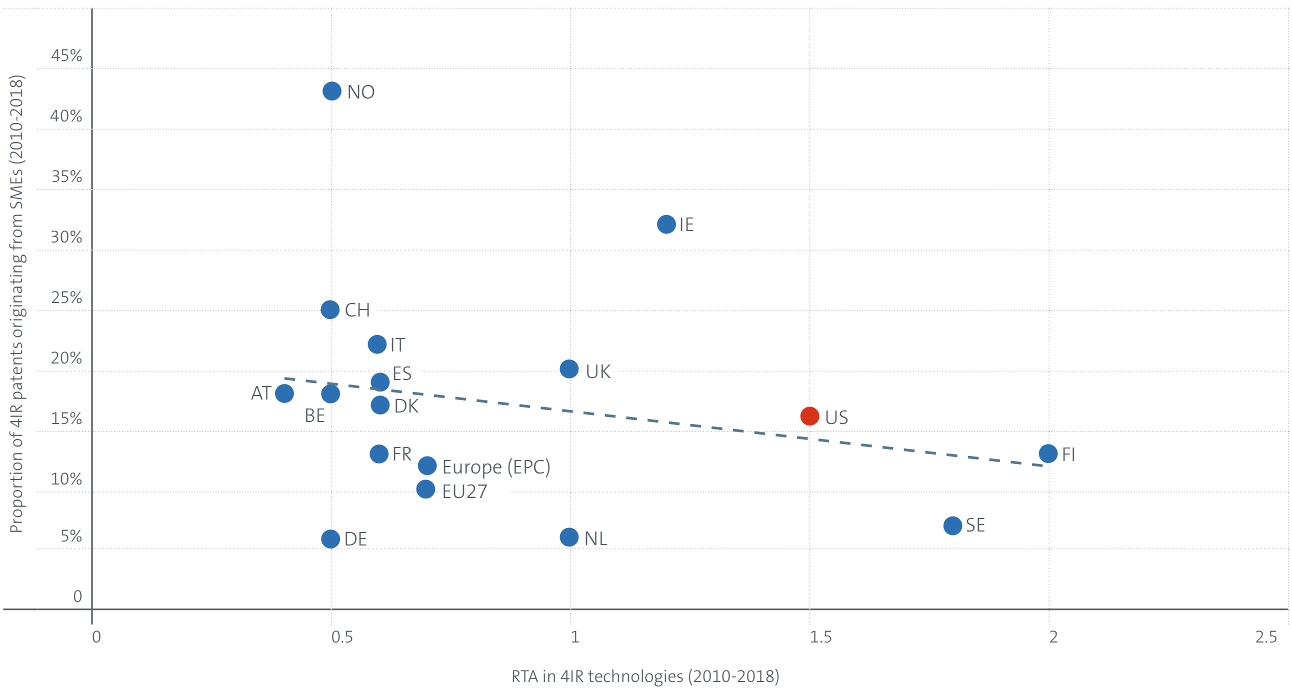
Source: Orbis and Crunchbase, authors` calculation.

Population data for 2020 were retrieved from the World Bank.

Figure 2.5 in turn compares the countries' specialisation in 4IR patenting with the proportion of their 4IR IPFs contributed by SMEs. It shows that SME contribution to overall 4IR patenting is actually lower in countries that are highly specialised in 4IR technologies – such as Finland and Sweden – although the correlation is lower than in Figure 2.4 above. This is due to the significant contribution to 4IR patenting in these countries of other parties in the innovation ecosystem, such as large companies or universities. For instance, Finland and Sweden are the only two EU countries to host some of the top ten 4IR applicants globally,[8] like the US. These large companies contribute to the strength of local innovation ecosystems reducing the proportion of 4IR patents contributed by SMEs. The same pattern applies to the US, where large companies and SMEs both contribute to the country's specialisation in 4IR technology. In contrast, small countries like Switzerland, Norway and Denmark reveal a relative lack of specialisation in 4IR technologies, despite the strong performance of local SMEs (Figure 2.4). This is likely due to the low contribution of large companies to 4IR patenting, as evidenced by the very high proportion of 4IR SME patenting in those countries (Figure 2.5).

Figure 2.5

Proportion of 4IR IPFs originating from SMEs and specialisation (RTA) in 4IR technologies in selected countries



Source: Orbis and Crunchbase, authors' calculation.

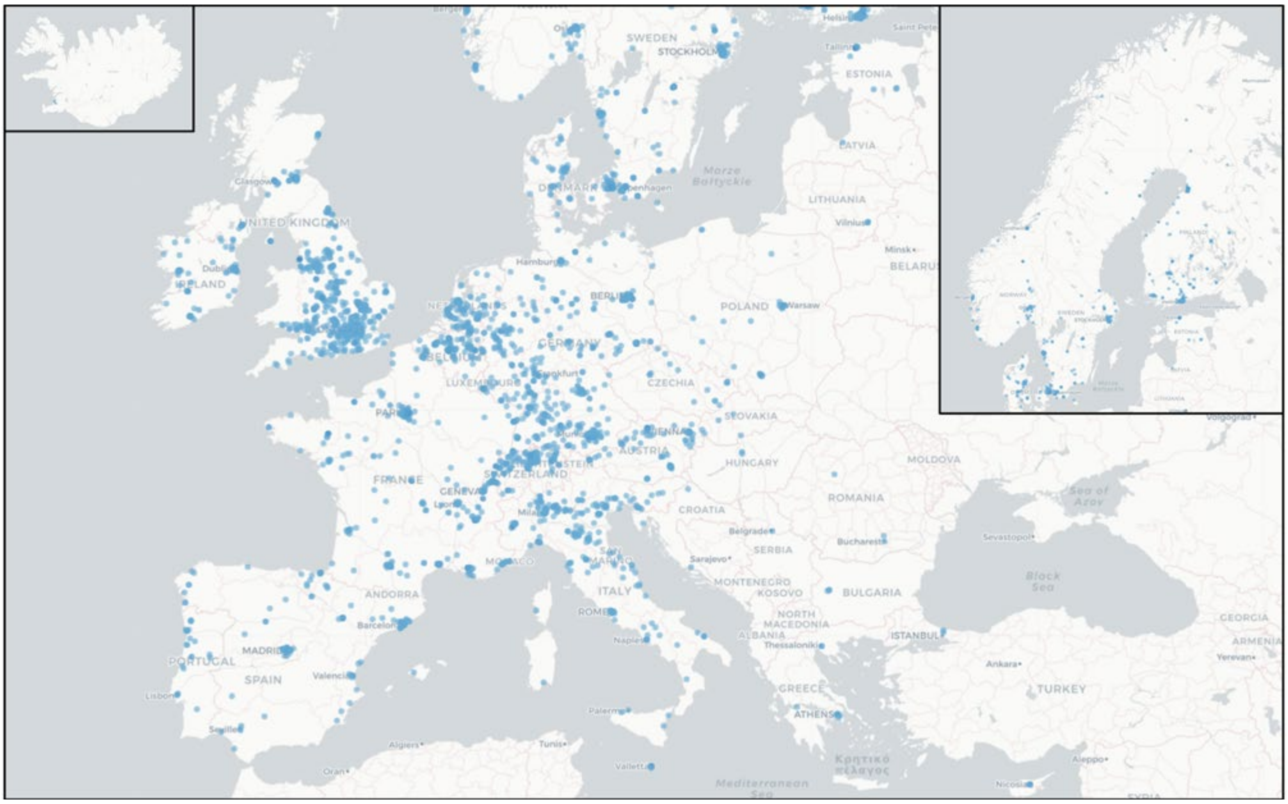
Population data for 2020 were retrieved from the World Bank.

8 Namely Nokia in Finland and Ericsson in Sweden, see Figure 1.2.

As illustrated in Figure 2.6, along with larger companies and research institutions, 4IR SMEs tend to congregate in regional clusters that provide a large pool of technical and entrepreneurial specialists, investors and business partners. The most important clusters are shown in Table 2.1, together with further information on their respective leading 4IR companies, research institutions and technology specialisation. Besides Sweden (Stockholm and Malmö regions) and Finland (Helsinki region), two main EU clusters are located in Germany (around Munich and Stuttgart), one in France (Paris), and one in the Netherlands (Eindhoven). The greater London area also appears as a major 4IR cluster outside the EU.

Figure 2.6

Location of 4IR SMEs in Europe



Source: Crunchbase and Orbis, authors' calculation.

Table 2.1

Top 4IR clusters in the EU27, 2010-2018

Cluster (country)	Global proportion of 4IR IPFs (CAGR)	RTA* > 1.5	Top 4IR applicants** (% of 4IR IPFs)	Proportion of IPFs from research institutions	Top research institution
London (UK)	1.1% (12.9%)	Core AI	Sony (15%)	4.2%	University of London
Eindhoven (NL)	1.2% (15.4%)	Core AI, 3D systems, healthcare, agriculture	Philips (65%), Signify (7%)	2.6%	Eindhoven University of Technology
Munich (DE)	1.1% (16.1%)	Position determination, data security, 3D systems, vehicles	Siemens (15%), Volkswagen group (13%), BMW (12%)	2.8%	Fraunhofer
Stockholm (SE)	1.0% (15.2%)	Connectivity, power supply, agriculture	Ericsson (64%), Volkswagen group (13%)	0.3%***	Fraunhofer***
Paris (FR)	1.0% (8.5%)	Data security, safety, vehicles, infrastructure	Nokia (7%), Valeo (6%)	7.0%	CEA
Stuttgart (DE)	0.9% (11.4%)	Data management, geo-positioning, vehicles, industrial	Robert Bosch (39%), Nokia (7%), SAP (5%)	1.8%	Karlsruhe Institute of Technology
Helsinki (FI)	0.6% (9.6%)	Connectivity, power supply, data security	Nokia (45%), Ericsson (13%)	2.2%	Valtion Teknillinen Tutkimuskeskus
Malmö (DK/SE)	0.6% (17.8%)	Power supply	Sony (26%), Ericsson (21%))	1.4%***	Danmarks Tekniske Universitet

Source: EPO (2020)

* The RTAs in each 4IR sector and field are calculated as the proportion of an innovation centre's IPFs in that sector or field, divided by the proportion of the same innovation centre's IPFs in all 4IR technologies.

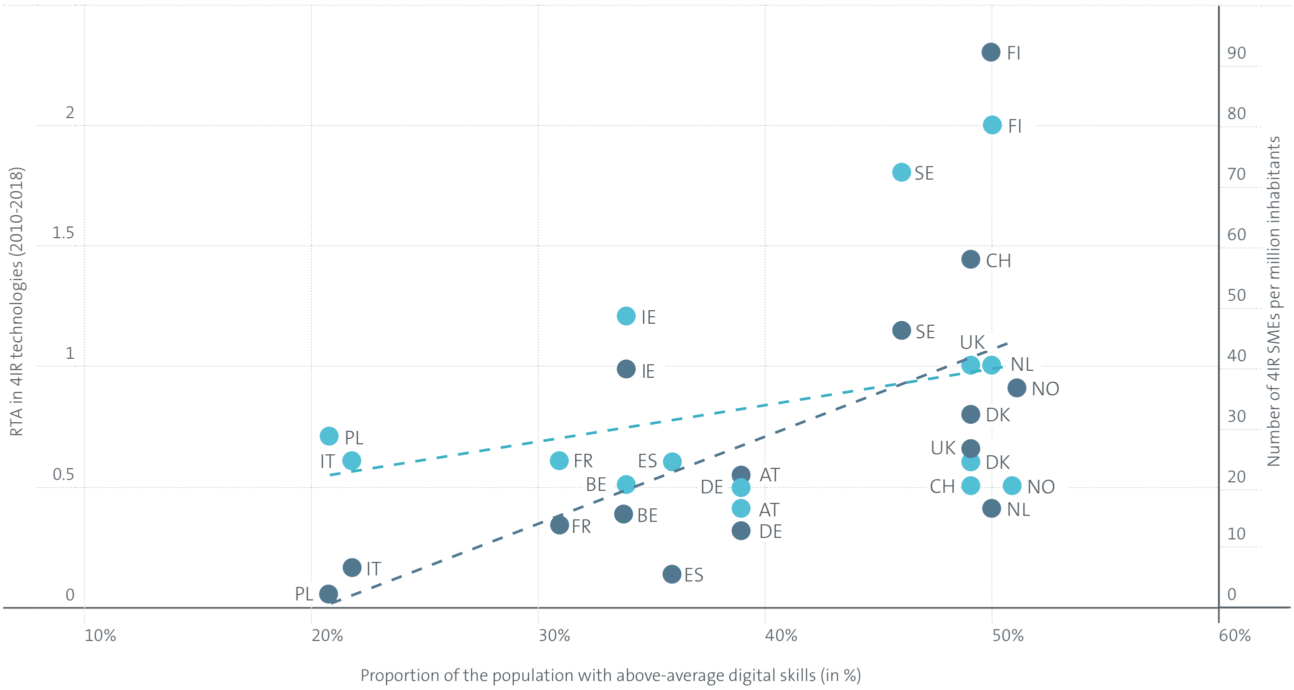
** The top three corporate applicants in each cluster are shown in this column, provided they contributed more than 5% of the cluster's 4IR IPFs. Their respective proportions of IPFs in the cluster are also reported.

*** Due to the system of professors' privilege in Sweden, most IPFs originating from academic inventors are attributed to the individual inventors and not to the research institutions that employ them. Such IPFs are not included in the proportion of IPFs originating from universities and PROs. This explains why a non-Swedish organisation (Fraunhofer) appears as the top research institution in Stockholm according to our data.

The availability of people with digital skills may foster innovation in 4IR. Firms operating in countries where a greater proportion of the population have above-average digital skills tend to have a higher RTA in 4IR (Figure 2.7) and more 4IR SMEs per capita. Reaping the benefits of digitalisation will require improvements in education and vocational training.

Figure 2.7

4IR activities and proportion of the population with strong digital skills



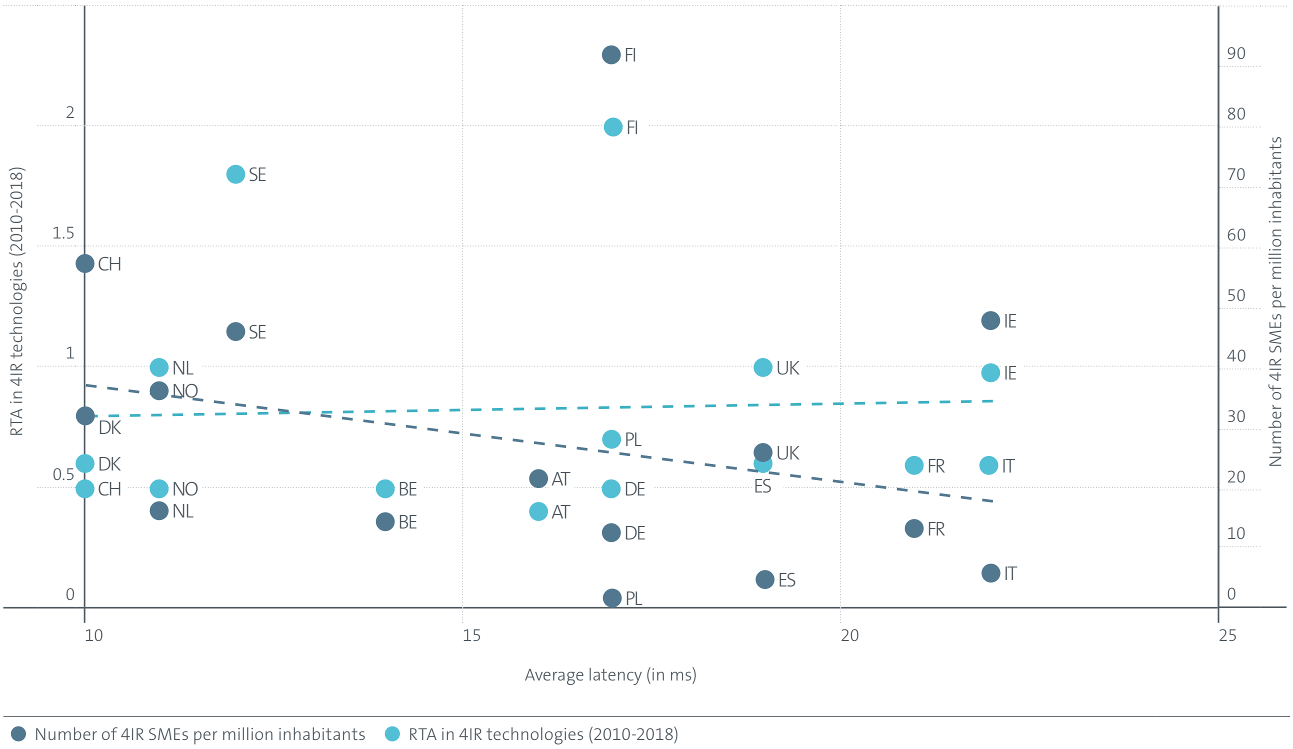
Number of 4IR SMEs per million inhabitants
RTA in 4IR technologies (2010-2018)

Source: Orbis and Crunchbase, authors' calculation. Digital skills data were retrieved from Eurostat.

Digital infrastructure plays a critical role in supporting 4IR SMEs. Firms operating in countries with low average latency (a proxy for good internet connection) tend to have more 4IR SMEs per capita (Figure 2.8). This indicates that many EU regions have the potential to unlock investment in the supporting 4IR SMEs by ensuring wider access to faster broadband. However, broadband connection and RTA do not appear to be linked, possibly due to regional variations in the speed of internet connections in larger countries.

Figure 2.8

4IR activities and quality of digital infrastructure



Source: Orbis and Crunchbase, authors' calculation. Average latency data was retrieved from European Data Journalism Network (2021).

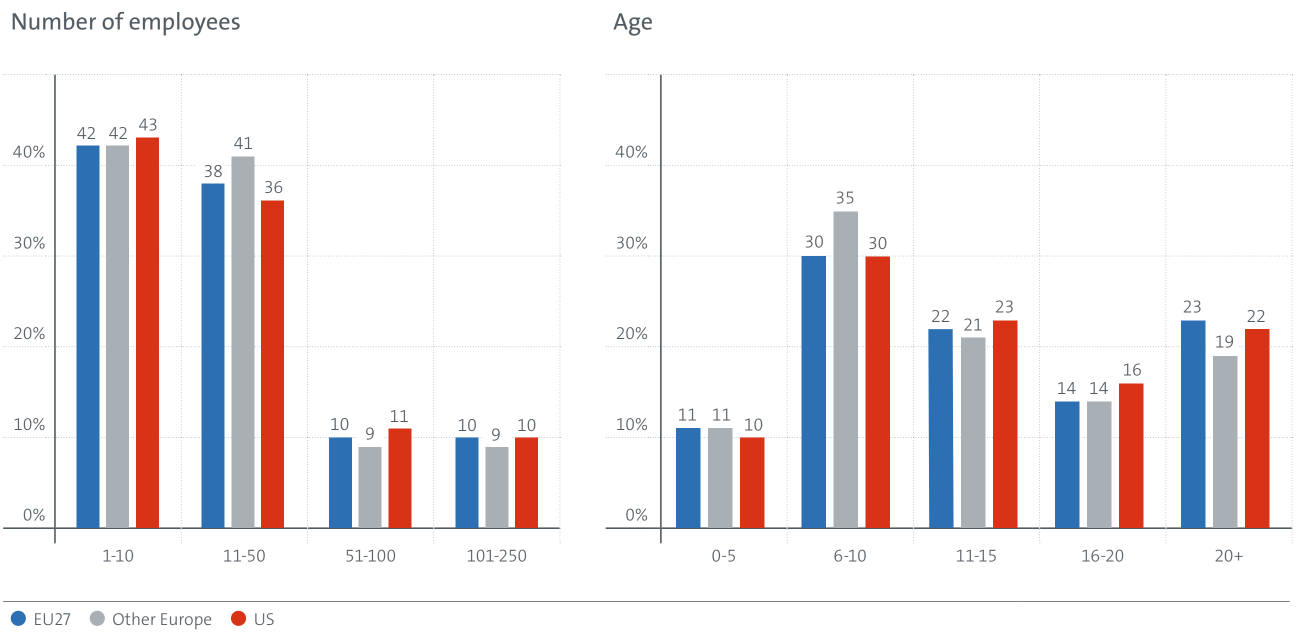
3. Innovation and business profiles of 4IR SMEs

3. Innovation and business profiles of 4IR SMEs

4IR SMEs in the EU27 are mostly small businesses: combining information from Orbis and Crunchbase reveals that four out of five have fewer than 50 employees and over 40% have fewer than ten. However, they are not necessarily young companies, which is consistent with the long development cycles typically observed in deep tech. **Only 41% of 4IR SMEs in the EU27 have been operating for under ten years, while a significant proportion (23%) have been in business for over twenty years.** A similar pattern of size and age distribution can be observed for 4IR SMEs in the US, with a slightly higher proportion of companies over 50 employees (21%) and operating for over ten years (60%) [9].

Figure 3.1

Size and age of the 4IR SMEs



Source: Orbis and Crunchbase, authors' calculation.

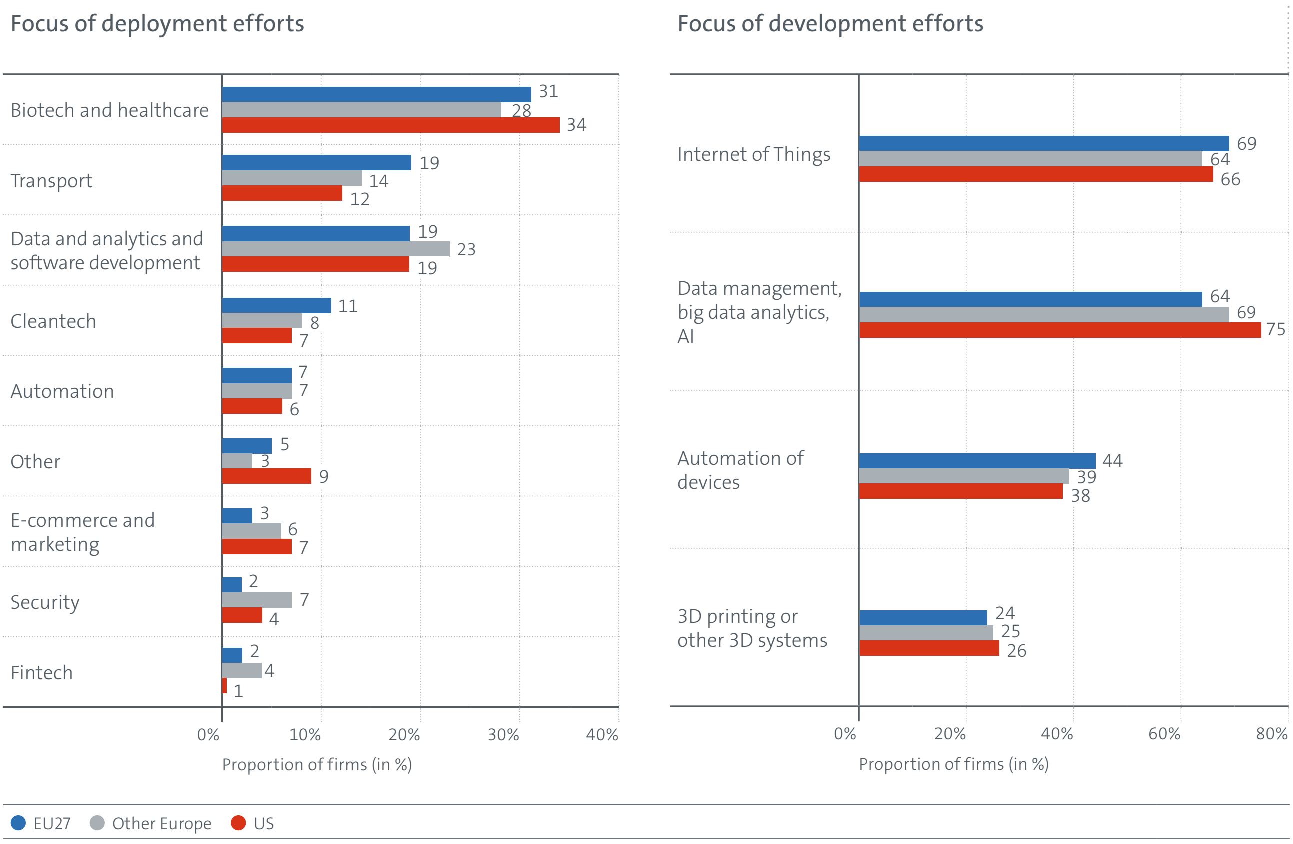
9 Cross-tabulation of 4IR SMEs by age and size shows that there is merely a weak correlation between the two dimensions. Although only 3.2% of EU firms are relatively young and large, with more than 50 employees, the majority of EU 4IR SMEs have been operating for at least ten years and are relatively small. The distribution of US 4IR start-ups is similar, where 42.7% have been operating for over ten years but have a relatively small workforce. Compared with the EU27 and the US, other European countries have a larger proportion of companies that are young and small, namely 42.3%.

Results from interviews with firms (hereafter referred to as the 4IR survey) provide further insight into their market and technology profiles (Figure 3.2). The industry areas in which 4IR SMEs are planning to deploy (or are already deploying) 4IR technologies are highly diverse (Figure 3.1, right panel). **The main target area for EU27 4IR SMEs is the biotech and healthcare industry, cited by nearly one in three SMEs.** However, other important target areas include data analytics and software development (19%), transport (19%) and cleantech (11%). In comparison, only a modest proportion of 4IR SMEs are targeting less tech-intensive sectors such as e-commerce (3%), security (2%) and fintech (2%). Although the deployment profiles of European and US 4IR SMEs are very similar, EU27 respondents are more likely to target the transport sector than US respondents.

4IR SMEs tend to develop and deploy the same types of technologies in all sectors, however. Comparable proportions of the 4IR SMEs in the EU27, with 69% and 64% respectively, indicate that they have made technological developments in the areas of the Internet of Things and data management (including data analytics and AI). Automation of devices was also mentioned by 44% and 3D-systems technologies by 24%. These development profiles are remarkably similar among US and European 4IR SMEs.

Figure 3.2

4IR innovation profile of European SMEs



Source: 4IR survey.

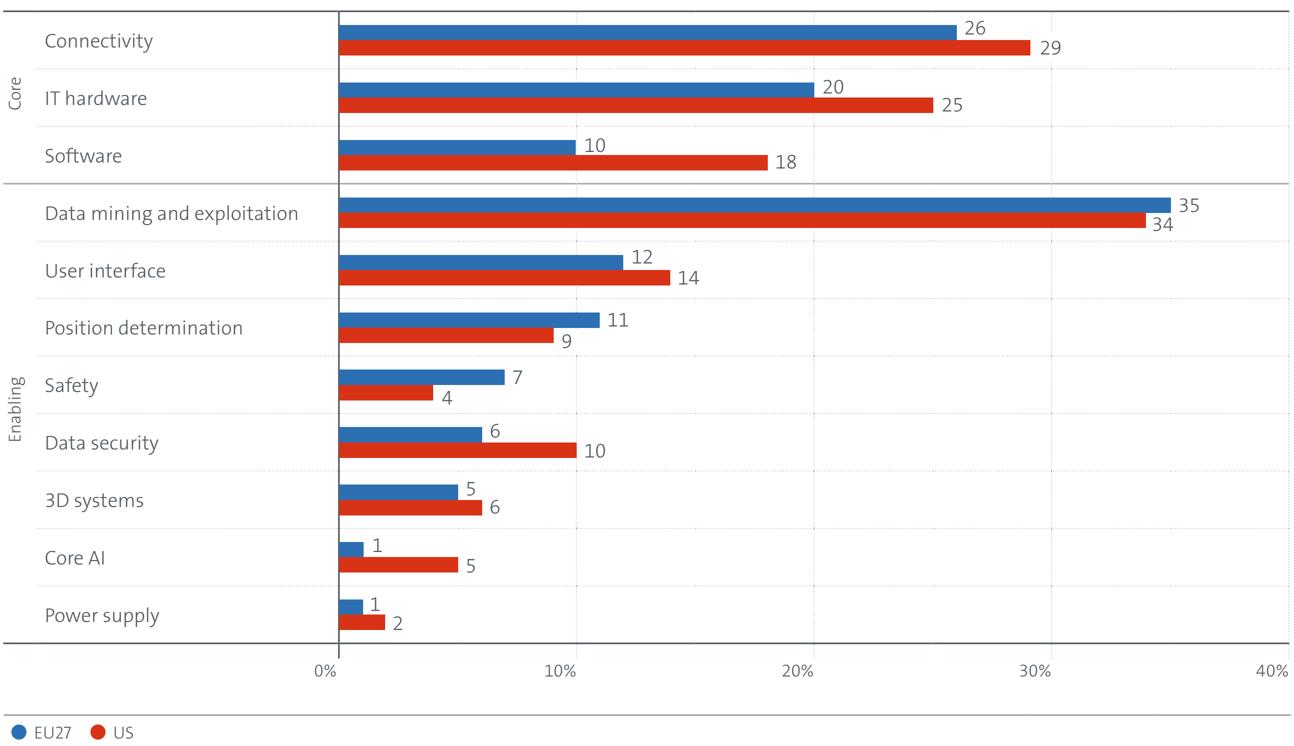
Base: 4IR innovators in the 4IR survey (excluding don't know / refused / no obstacle responses).

A detailed analysis of the 4IR SMEs' patent portfolios from the 4IR survey provides further information on the type of technology that they are developing (Figure 3.3). **More than a third of the EU27 and US SMEs have filed patent applications related to data mining and exploration**, which encompasses all technologies, including AI, that aim to exploit data from the creation, processing and analysis thereof to feedback execution [10]. These technologies, which are also one of the main drivers of 4IR patenting overall [11], offer particularly interesting opportunities for SMEs due to their lower capital requirements and wide spectrum of applications in a variety of sectors (see Figure 3.1 above).

About a quarter of the EU27 SMEs have also patented in the core fields of connectivity (26%) and IT hardware (20%), including sensors. Together with enabling technologies such as user interfaces (12%) and position determination (11%), these two technology fields form the basis of the Internet of Things. However, an even larger proportion of US SMEs have been filing patents relating to core 4IR technologies, even more so in the case of software, which is represented in the patent portfolios of 18% of the US companies, compared with 10% of the EU27 companies. Likewise, 4IR SMEs in Finland and Sweden display a stronger focus on core hardware (24% and 25% respectively) and connectivity (34% and 30% respectively). This reflects the pattern more generally observed in patenting at the country level, where the US, as well as Sweden and Finland, show a specialisation in core 4IR technologies (EPO, 2020).

Figure 3.3

Presence of core and enabling 4IR technologies in SMEs' patent portfolios



Source: Orbis and Crunchbase, authors' calculation.

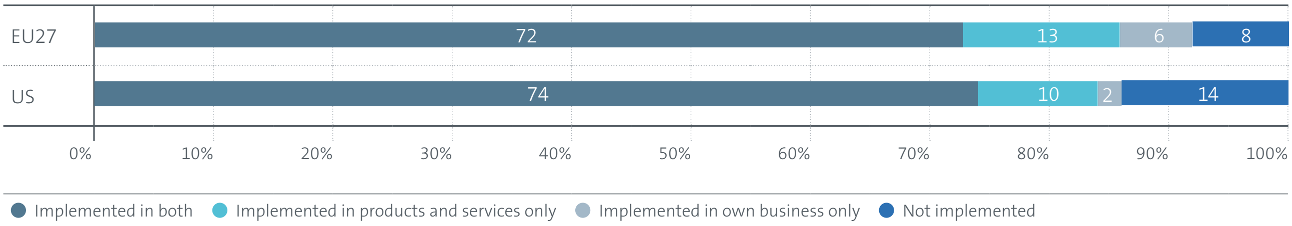
10 The field of data management is pivotal in deriving value from the massive amount of data collected by connected objects. It encompasses all technologies aiming to exploit data, from the creation, processing and analysis thereof to feedback execution. It can be subdivided into four distinct categories, namely monitoring functions (generating data typically by means of sensors), analytics and diagnosis (based on the generated data), planning and control (e.g. automated control systems for enterprises, vehicles or factories), and prediction and forecasting (e.g. wind speed forecasting for electric energy production or business forecasting and optimisation).

11 With about 28% of all 4IR IPFs at the global level in 2018.

Over 90% of SMEs based in the EU27 (86% for US-based SMEs) claim in the interviews to have already implemented the respective 4IR technology [12] (Figure 3.4). Almost three-quarters (72%) of the 4IR SMEs in the EU27 reported implementation in products or services as well as in their own business. Another 13% implemented the technology exclusively in products and services sold, while the technology was used only internally at an additional 6%. Interestingly, younger companies (operating for under ten years) were more likely to implement their 4IR technologies in products, services and their own business than mature companies (78% vs 68%). [13]

Figure 3.4

Implementation of 4IR technologies (proportion of firms in %)



Source: 4IR survey.

Base: All firms (excluding don't know / refused / no obstacle responses).

12 This proportion is remarkably high compared with available evidence on the commercialisation of patented inventions by SMEs in other sectors. In fact, a prior EPO survey (EPO, 2019) found that European SMEs that had filed patent applications with the EPO had managed to commercialise about two-thirds of the corresponding inventions.

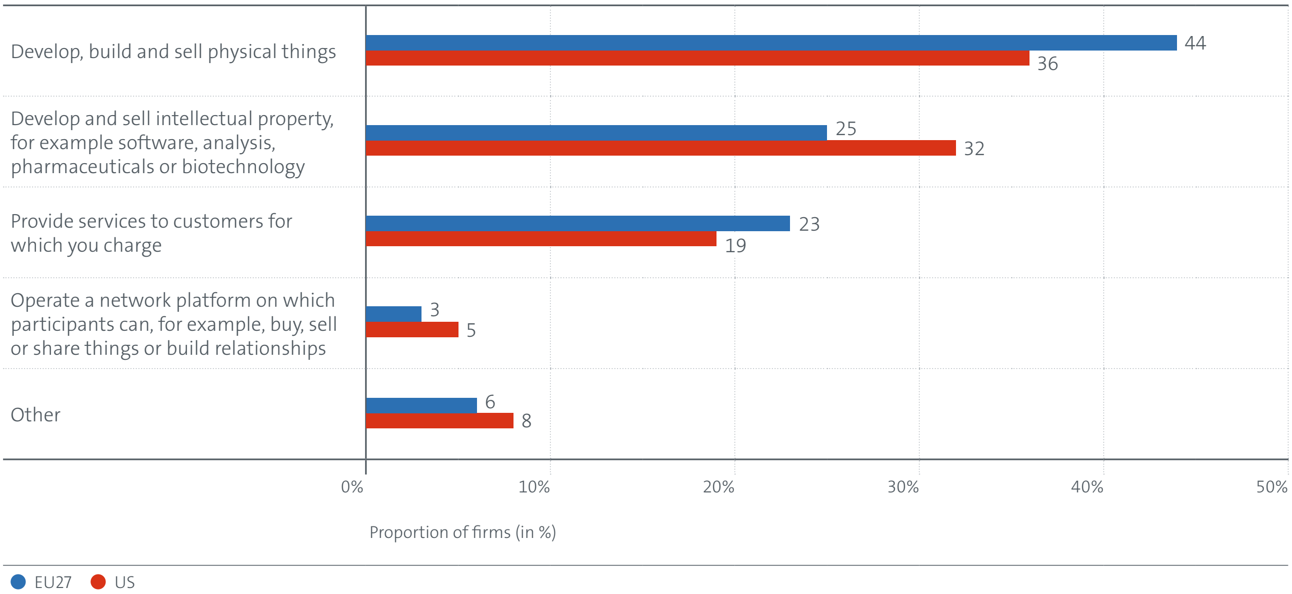
13 Although EU27 and US 4IR SMEs are comparable when it comes to implementing deep tech technologies, there are differences when focusing more broadly on the non-financial corporate sector. For instance, 47% of US respondents have already implemented the Internet of Things (IoT) in their business, compared with 29% of EU respondents (EIBIS 2021).

4IR technologies can support companies' business models in different ways (Figure 3.5). **In the EU27, 43% of 4IR SMEs are involved in hardware manufacturing**[14] **(i.e. developing, building and selling physical products). Another 25% create and sell intellectual property (IP), such as software, analysis, pharmaceuticals or biotechnology, while 23% provide other paid services.** Only a very small proportion of the SMEs surveyed operate network platforms used for online trading or other types of interaction.

Medium-sized companies with more than 50 employees report a larger proportion of activities related to manufacturing, while smaller companies are apt to concentrate on providing services and creating and selling IP (61% of larger SMEs and 39% of smaller SMEs focus on manufacturing). In general, 4IR SMEs tend to favour manufacturing business models compared with other SMEs, as shown in a recent EIB start-up survey (EIB, 2019).

Figure 3.5

Business models



Source: 4IR survey.

Base: 4IR innovators in the 4IR survey (excluding don't know / refused / no obstacle responses).

14 In comparison, the proportion of EU27 start-ups focusing on manufacturing is only 23%.

The design of the survey makes it possible to analyse the business models used by 4IR SMEs in their main deployment sectors, as shown in Table 3.1. In biotech and healthcare, and transport, over 40% of the companies develop and make physical products. By contrast, the business models of companies active in data analytics and software development show a stronger focus on development and the sale or licensing of intellectual property.

Table 3.1

Business models and deployment areas

	Biotech and healthcare	Data analytics and software development	Cleantech	Transport
Develop, build and sell physical things	47%	26%	31%	43%
Develop and sell intellectual property, for example software, analysis, pharmaceuticals or biotechnology	25%	44%	29%	19%
Provide services to customers for which you charge	19%	22%	22%	25%
Operate a network platform on which participants can, for example, buy, sell or share things or build relationships	2%	2%	7%	3%
Other	7%	5%	11%	10%

Source: 4IR survey.

Base: 4IR innovators in the 4IR survey (excluding don't know / refused / no obstacle responses).

Case study:
From the garage to the securities exchange

Invention: Eye-tracking device
Company: Tobii AB
Sector: Human-machine interaction
Country: Sweden

Tobii continually expanded its patent portfolio, enabling it to attract investors, diversify its products, and refine its technology. As a result, the start-up from Sweden became a listed company that dominates its niche.

Neurodegenerative conditions often mean a cruel fate. People who are otherwise healthy with active minds may be unable to express themselves through speech or movement, leaving them trapped in their bodies. Thankfully, rapid technological advancements give those living with conditions such as cerebral palsy or severe paralysis greater independence. Tobii continually expanded its patent portfolio, enabling it to attract investors, diversify its products, and refine its technology. As a result, the start-up from Sweden became a listed company that dominates its niche.

John Elvesjö and Mårten Skogö (European Inventor Award 2015, SMEs, finalists) invented a revolutionary eye-tracking system that recognises the position and gaze point of the pupils and interprets this information in real time. Together with their team at Tobii, they explored uses for their system, ranging from interaction with speech-generating programmes to clinical diagnosis and gaming.

Improving lives in the blink of an eye

At just 24 years old, Elvesjö made a ground-breaking discovery during a lab experiment. He was working with optical sensors designed to track the movements of fruit pulp particles in solution and, peering closely at the vessel, noticed that the sensors detected his own eye movements. He realised the potential of his observation and began working on an eye-tracking device.

The device employs several near-infrared light micro-projectors – optical scanners placed on a screen display. Sensors register and track the reflections of the infrared light from the user's eyes to follow their gaze, where it lands and how it moves. Proprietary software incorporating special algorithms then interprets these eye movements in real time.

An ever-growing number of fields now use eye-tracking. Gamers control the on-screen action with unprecedented realism and researchers see the world through the eyes of their subjects. Marketeers observe how consumers behave online and in-store, while clinicians use new tools to identify tell-tale signs of ocular disease and mental or neural disorders.

Crucially, the invention facilitates touchless human-machine interaction and enables people to control computers with eye movements. For those living with a neurological condition or recovering from a debilitating injury, this enables mobility and improves communication. It empowers people to gain independence and live fuller personal and professional lives. Current assistive technologies can generate speech, connect to devices or to the web, and allow users to write, draw or create music.

Visionary

Tobii was founded by John Elvesjö, Mårten Skogö and Henrik Eskilsson in 2001. The company's iterative development approach required a robust patent portfolio and regular investment. Between 2007 and 2012, venture capitalist firms invested EUR 41 million over several rounds. These funds supported R&D and allowed Tobii to explore new avenues for its eye-tracking devices. It received an additional EUR 13 million in 2014 to finance expansion plans and strategic acquisitions.

Thanks to its market success, the start-up grew quickly and surpassed its status as an SME. Today, the company has split and both Tobii and its subsidiary (Tobii Dynavox) are listed on Stockholm's NASDAQ. The company now employs some 600 people in 14 offices worldwide and reported revenue of almost EUR 60 million (SEK 616 million) in 2021.

The company cites innovation as a vital part of its business model and commands an extensive intellectual property portfolio. This includes rights to protect the design, control and readout of image sensor data; physical integration techniques, calibration methods and system layouts; as well as algorithms and methods to implement eye-tracking. Their patent portfolio extends to industry-specific use cases in areas such as automotive, biometrics, gaming, consumer engagement measurement and wearables. To date, Tobii holds 26 granted European patents, highlighting their consistent focus on intellectual property over two decades.

4. Market and IP positions

4. Market and IP positions

While the previous chapter focused on the technological profiles and innovation strategies of 4IR SMEs, this chapter provides insight into their sales markets and structure. Information from the 4IR survey is complemented by an analysis of patent protection strategies of 4IR SMEs and their role in supporting their business developments.

Figure 4.1 documents the reference geographical markets of 4IR SMEs. **At present, almost every second 4IR SME in the EU27 primarily targets the European market in their commercialisation efforts.** Nevertheless, 32% regard their home country as their core market and 9% primarily target the US. Looking ahead to the next five years, only 6% of SMEs in the EU27 would still consider their national market as their main market. Instead, **4IR SMEs in the EU27 are focusing their growth plans on the European market (from 52% to 57%)** or the US (from 9% to 24%).

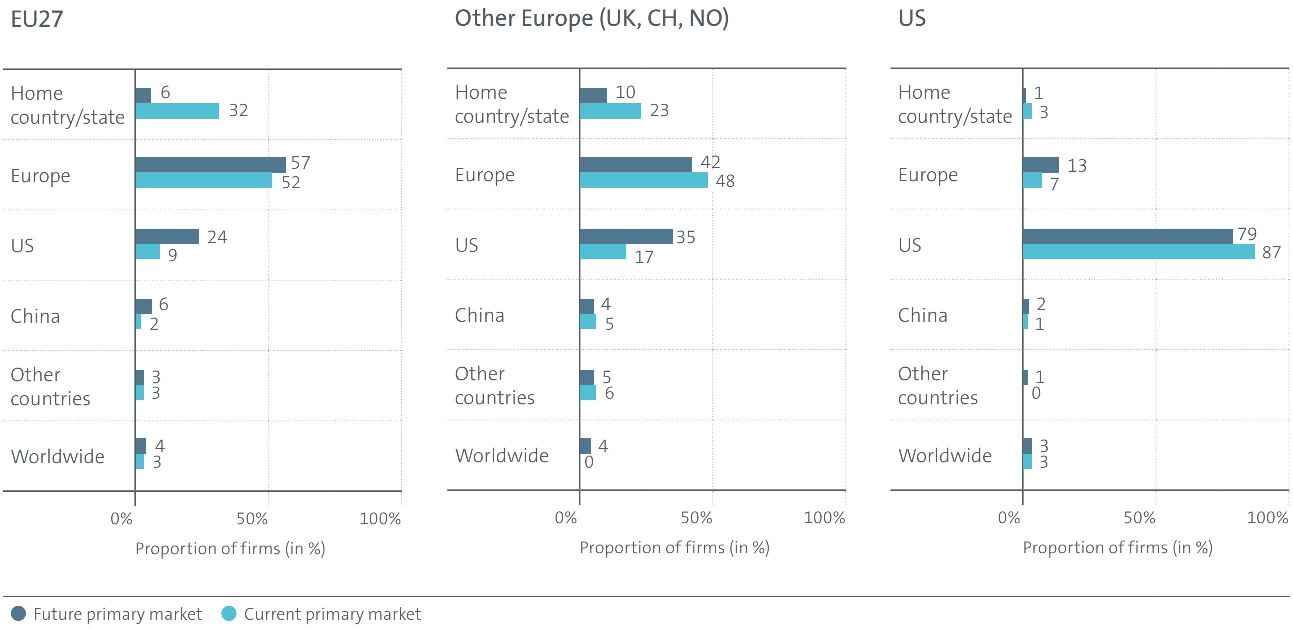
In comparison, virtually no US 4IR SMEs focus their sales activities exclusively on their home state and **87% of all US 4IR SMEs regard the whole US as their primary market.** Only a very small proportion of US companies have their main operations in Europe (7%) or in any market outside the US. Over the next five years, the US will remain the primary market for 79% of US 4IR SMEs. However, the proportion of companies intending to primarily target the European market may increase to 13%. Other markets are likely to remain peripheral for US 4IR SMEs.

It is worth stressing that **more European firms see their future primary market in the US** (24% of EU27 and 35% of Other Europe SMEs) **than vice versa**. Only 13% of US SMEs regard Europe as their future primary market. Moreover, SMEs in the EU27 claiming to be dominant players in their markets are more likely to see the US as a future primary market (38%).

4IR SMEs from the UK, Switzerland and Norway have a similar market distribution to their EU counterparts. Although their primary focus is, and will remain, on the European market, a large proportion of these 4IR SMEs (35%) – especially UK-based firms – will target the US market. Overall, only less than 6% of European 4IR SMEs would consider China as their main sales market in the future.

Figure 4.1

Geographical markets for 4IR technologies



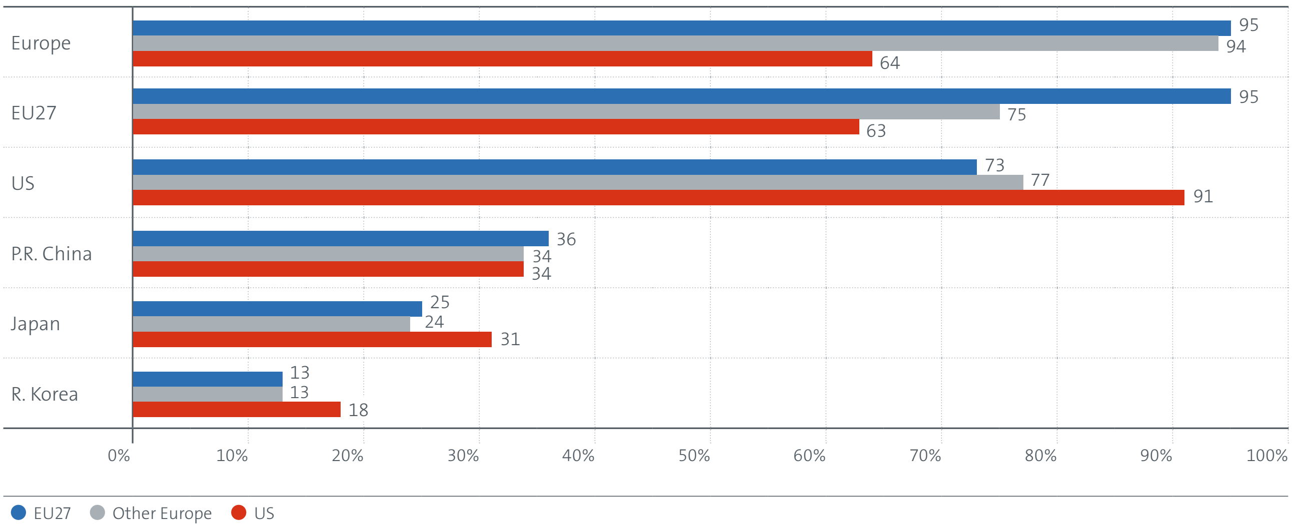
Source: 4IR survey.

Base: 4IR innovators in the 4IR survey (excluding don't know / refused / no obstacle responses).
Note: Europe is defined as all EPC member states, including the EU27, the UK, Switzerland, Norway and other countries.

The countries in which companies seek patent protection for their inventions also provide information on the importance of the different markets for commercialisation. **Almost 95% of European 4IR SMEs seek protection in Europe, followed by the US (73%),** with China (36%), Japan (25%) and R. Korea (13%) quite some distance behind. In turn, **US 4IR SMEs try to protect 91% of their 4IR inventions in their home market, 64% in Europe,** 34% in China, 31% in Japan and 18% in R. Korea. These patent protection strategies reveal the strong integration of the European and US markets, as well as their importance for 4IR technology commercialisation. However, European SMEs seek to protect a larger proportion of their 4IR inventions in the US (73%) than vice versa (63% of US SMEs protect their invention in the EU). This is in line with the survey results, which showed the greater significance of the US market for European 4IR SMEs than vice versa (see Figure 4.1 above). Interestingly, the results apply both to young and mature, as well as smaller and larger SMEs.

Figure 4.2

Scope of international patent protection



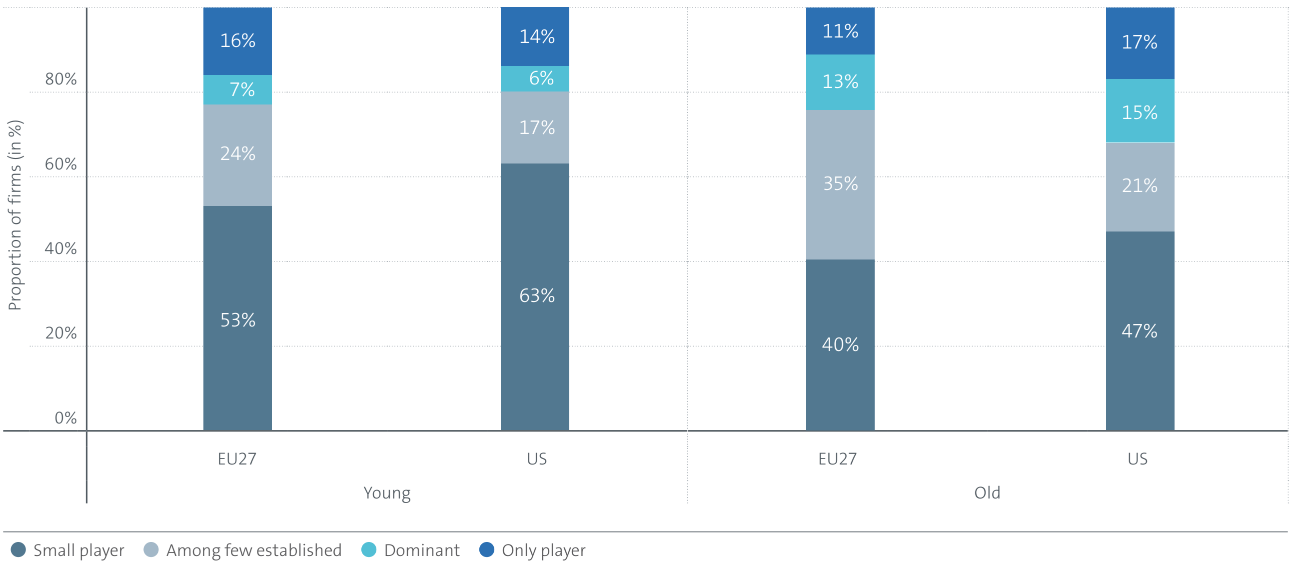
Source: Orbis and Crunchbase, authors' calculation.

Note: The following criteria have been applied to make the results comparable: (a) filtering for patent families with the earliest filing date before 2019 to avoid the issue of the entry into regional/national phase coming from PCT applications; (b) removing all patent families featuring a unique PCT application, since they had not entered a regional/national phase at the time of data retrieval.

Although a large proportion of the EU's 4IR SMEs are small companies with fewer than 50 employees (see Figure 2.4), the majority have established a strong, competitive position in their respective markets. **31% of 4IR SMEs in the EU27 are among a few established players, another 11% are one of the dominant players and 13% are the sole player in their market.** As Figure 4.3 shows, larger and more mature SMEs are more likely to occupy a dominant position in their market, or be one of a few established players, than smaller and younger SMEs. However, smaller SMEs more frequently indicate that they are the only player in the market, in other words they create new markets or occupy niche markets. Compared with EU companies, a larger proportion of US 4IR SMEs consider themselves as small players (56% vs 45%), while a minority claim to be one of a few established players (18% vs 31%).

Figure 4.3

Market position of 4IR SMEs



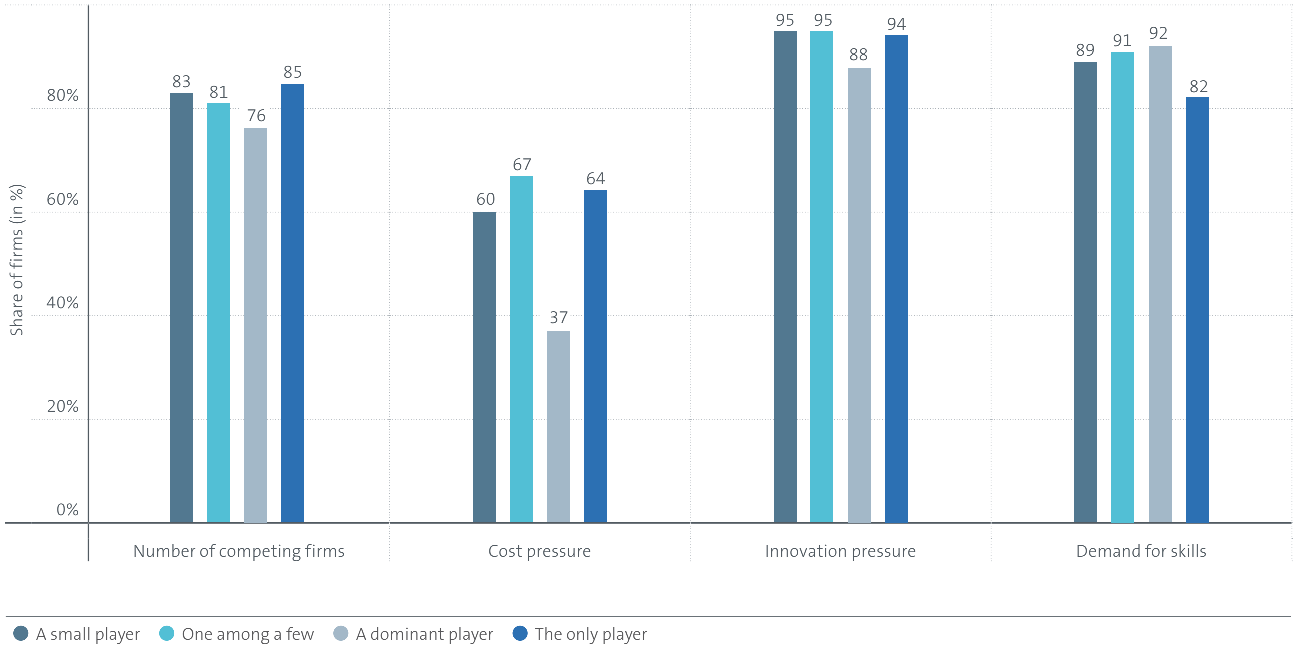
Source: 4IR survey.

Base: 4IR innovators in the 4IR survey (excluding don't know / refused / no obstacle responses).

Survey results also suggest a positive effect of 4IR innovation on competition, as measured by the reported pressure on costs and firm entry. Overall, US and European SMEs that expect the importance of 4IR technologies to increase in their market also anticipate stronger competition. The most common perception is that the greater dominance of 4IR technologies will lead to more cost pressure, more market entry as well as a higher demand for skilled staff. The main difference is that dominant SME players in their markets expect less cost pressure to follow from the further importance of 4IR technologies.

Figure 4.4

Effect of 4IR technologies (net balance), by market position



Source: 4IR survey.

Base: 4IR innovators anticipating that 4IR technologies will gain in importance (excluding don't know / refused / no obstacle responses).
Note: Net balances show the differences between firms expecting an increase and firms expecting a decrease.

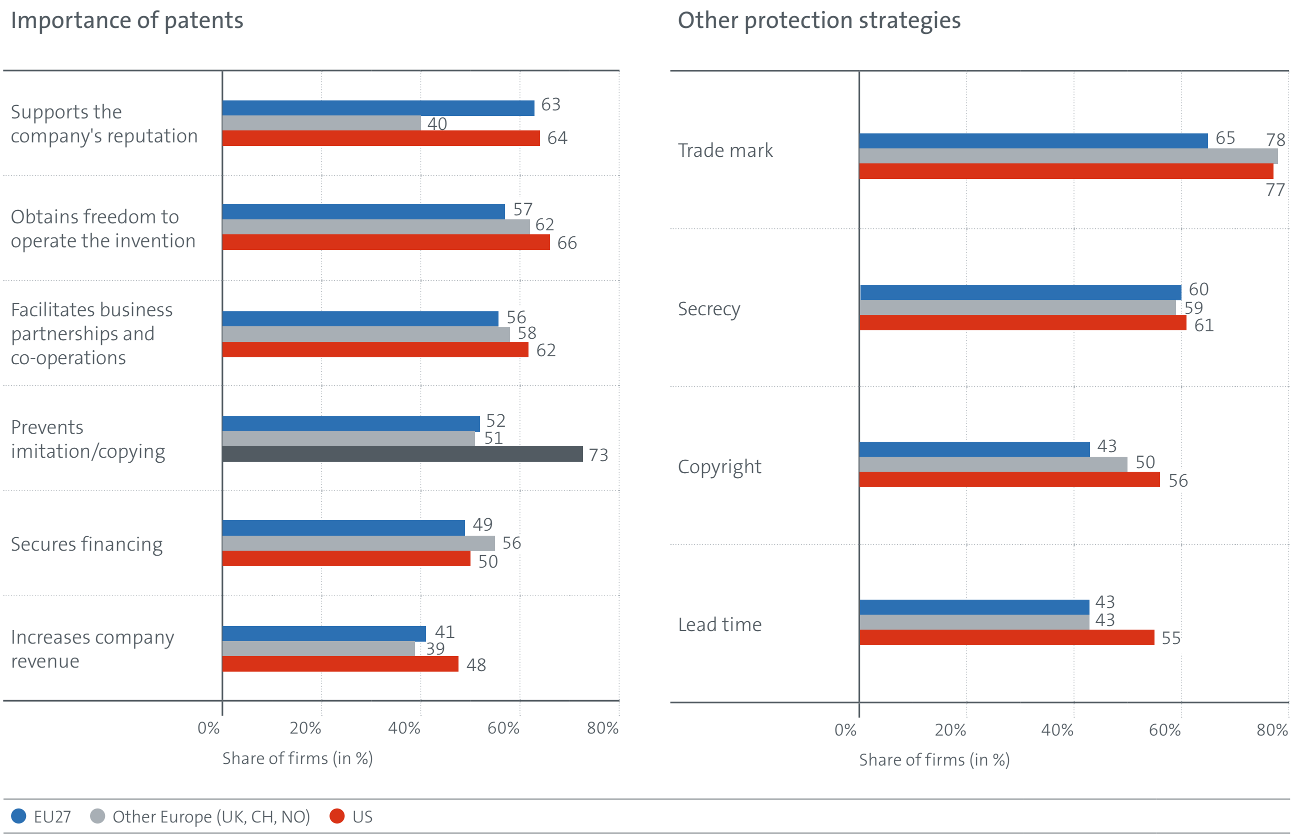
Given their focus on deep tech innovation, securing IP rights in their key geographic markets is of strategic importance for 4IR SMEs. The survey shows that **EU27 companies use patents for a variety of business-related purposes** (Figure 4.5). The reputational benefit from owning patents is considered indispensable by most SMEs (63%), closely followed by obtaining the freedom to deploy the invention (57%), facilitating business partnerships and co-operations (56%), preventing imitation and copying (52%), and securing financing (49%). Interestingly, only 41% regard patent protection as a high priority in increasing the company's revenues.

The importance of the different benefits of patent protection does not differ significantly between locations. **Preventing imitation is the only notable exception, considered essential by a much larger proportion of US SMEs (73% for the US vs 52% for Europe).** However, there are some key differences, depending on company size and age. For example, the role of patents in securing financing is a higher priority for younger and smaller 4IR SMEs, while securing the freedom to deploy seems to be more important for larger SMEs than for smaller.

In addition to patents, most 4IR SMEs in the EU27 use other IP protection mechanisms, especially trade marks (65%) and secrecy (60%), to protect 4IR technologies. Copyright protection and lead time are vital protection mechanisms for 43%, in each case, of the EU27's 4IR SMEs. Interestingly, both are more important for US 4IR SMEs than for SMEs in the EU27. In addition, **all types of protection mechanisms are generally adopted by larger SMEs, perhaps explained by their having better IP management processes in place, rather than by smaller firms.** A recent joint study by the EPO and EUIPO (EPO and EUIPO, 2021) found that European SMEs that own combinations of IP rights tend to outperform other companies in terms of revenue-per-employee. The use of different IP rights is probably a sign of good IP management practices.

Figure 4.5

Protection of intellectual assets



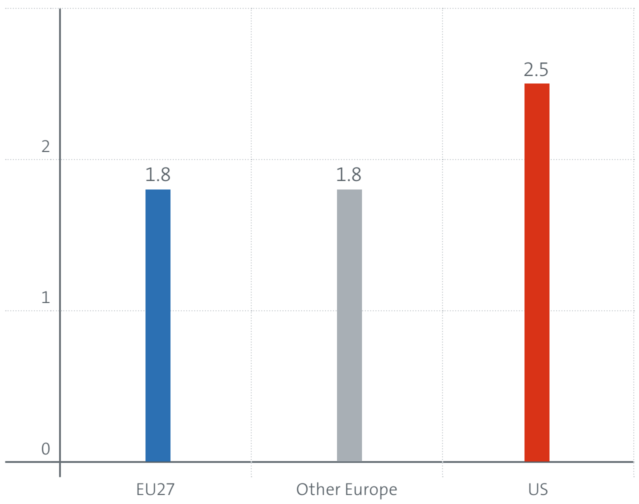
Source: 4IR survey

Base: 4IR innovators in the 4IR survey (excluding don't know / refused / no obstacle responses).

An analysis of the patent protection strategies of 4IR SMEs for the full Orbis and Crunchbase sample is presented in Figure 4.6. **While a European SME owns 1.8 4IR IPFs on average, their US counterparts own 2.5 IPFs.** The higher number of 4IR SMEs in the US is therefore compounded by their, as a rule, significantly larger 4IR patent portfolios. The regional difference persists for younger and mature 4IR SMEs, as well as for smaller and larger companies [15].

Figure 4.6

Average number of 4IR IPFs



EU27

Size	Number of years in operation: 0-10	11-20	20+	
1-10	1.4	1.9	1.9	1.6
11-50	1.8	2.2	1.8	1.9
51-250	3.4	2.3	2.1	2.6
	1.7	2.1	1.9	

US

Size	Number of years in operation: 0-10	11-20	20+	
1-10	2.0	2.1	3.0	2.1
11-50	2.1	2.6	2.5	2.4
51-250	3.7	4.1	4.4	4.2
	2.2	2.7	3.3	

Source: Orbis and Crunchbase, authors' calculation.

15 One similarity between US and European 4IR SMEs is that they tend to increase their patent portfolios in line with company size and less so with the age of the company. While a 4IR SME in the EU with fewer than ten employees owns an average of 1.6 patent families, companies with more than 50 employees own 2.6, and small 4IR SMEs in the US own 2.1 IPFs and larger 4IR SMEs 4.2 IPFs, respectively.

BOX 4

Patents and finance

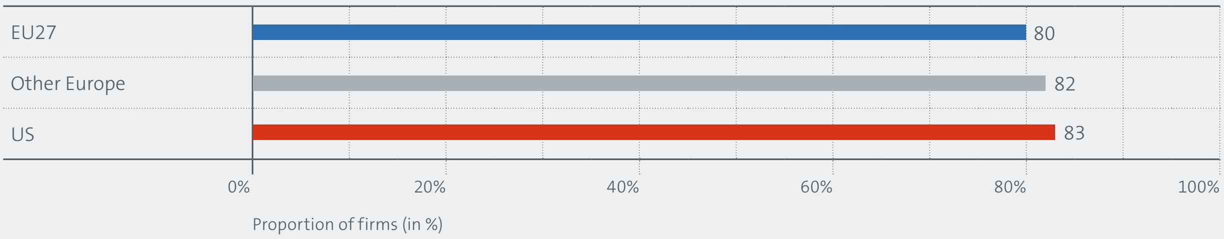
Patents and IP are important assets, enabling technology SMEs to raise capital and finance innovation. They allow enterprises to obtain funding at more favourable conditions. Since they are publicly disclosed, patents help investors assess the quality of the firm's technological capabilities, reducing asymmetric information between them and the company. As legally protected and enforceable property rights, they are also likely to give the company a competitive advantage and increase its expected profitability. In addition, patent rights can be separated from the business and sold in case of financial distress, thus increasing the salvage value of the company, should it fail.

A recent survey by the EUIPO (EUIPO SME scoreboard, 2019) found that, in general, few European SMEs leverage their IP to get access to finance. According to the EUIPO SME scoreboard, only 13% of SMEs owning IP rights tried to use intangible assets to obtain finance: 9% successfully and 4% unsuccessfully. However, the picture changes if only companies using patents to protect their innovations are considered. According to the EPO's Patent commercialisation scoreboard (EPO, 2019), using European patent applications to secure financing is regarded by over one third (35%) of European SMEs as an important motive for maintaining their patent. This proportion is even higher among European 4IR SMEs.

According to the 4IR survey, almost 50% of 4IR SMEs in the EU27 consider that helping to secure financing is one of the chief benefits of patent protection, especially if the firms are very small (see Figure 4.5 above). An even larger proportion of interviewees agreed that the company's IP strategy was of relevance to their investors. 80% of EU27 4IR SMEs reported that investors pay attention to the company's IP strategy; this figure largely reflects the experience of US 4IR SMEs. Interestingly, the percentages do not vary significantly by size, age or industry sector of EU 4IR SMEs.

Figure 4.7

Relevance of IP strategy for investors



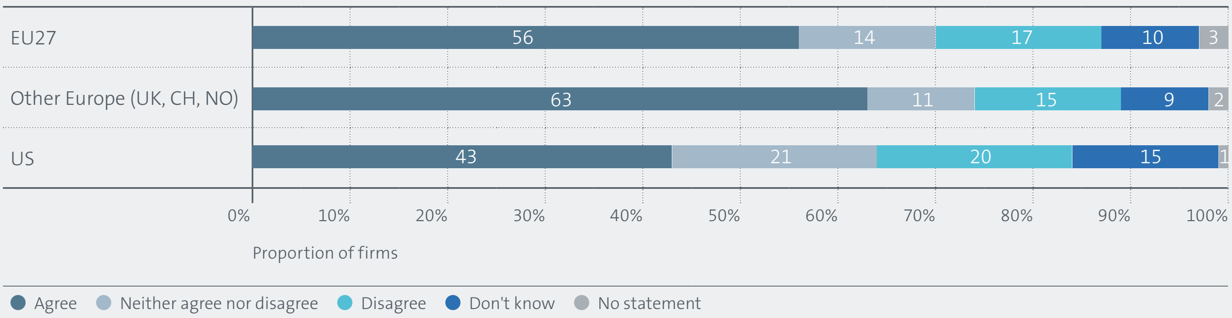
Source: 4IR survey.

Base: 4IR innovators in the 4IR survey (excluding don't know / refused / no obstacle responses).

IP may also be used as collateral for loans or to back equity investments. **Over half of 4IR SMEs in the EU27** and 63% of 4IR SMEs from the three other European countries (UK, CH and NO) **reported that IP was considered collateral by investors,** while just 17% disagreed with this statement. However, 10% and 9% of respondents respectively revealed that a relatively large proportion of companies did not know the answer. The proportion of SMEs in agreement with the statement was high in biotech and healthcare (67%) and significantly lower in data analytics and software development, with only 43% of the 4IR companies concurring and 14% unable to say. Interestingly, variation by age and company size was relatively low. The proportion of SMEs declaring that IP was considered collateral by investors was lower among US 4IR SMEs, with 43% agreeing and 15% declining to respond.

Figure 4.8

Use of IP as collateral



Source: 4IR survey.

Base: 4IR innovators in the 4IR survey.

Case study: Broad patent protection paves the way to commercialisation

Invention: Video-based technology for surgical navigation
Company: Perceive3D (P3D)
URL: epo.org/case-studies
Sector: Medical instruments
Country: Portugal

Spinning out from a university proved the best option to commercialise this flexible, scalable medical imaging technology. Broad patent cover protected the invention and secured continuous investment throughout the development and approval phases.

Healthcare providers have used systems combining computers and cameras for approximately three decades. For example, endoscopy systems comprise thin, flexible tubes fitted with a camera. The camera transmits images onto a screen in real time, enabling the physician to examine a patient's internal organs. Some scopes are equipped with tools that allow doctors to perform keyhole surgery. While these systems can improve patient outcomes, they are often expensive, bulky and closed, and therefore useful in a limited number of procedures.

University of Coimbra Professor João Pedro Barreto and Rui Melo, one of his PhD students, were researching camera calibration and real-time image processing for endoscopy systems. They soon developed early prototype software and knew that their work had potential. However, they were also aware that larger companies are often unwilling to invest directly in technology emerging from universities. With their own capital and an exclusive licensing agreement with the university, Barreto and Melo founded P3D to commercialise their image-processing software. Today, the company develops video-based technology to assist surgeons in navigating around the human body. Their systems are accurate and solve several ergonomic and economic problems.

Towards new surgical concepts

During its first development stage, P3D focused on new camera calibration methods, applying pixel value and pixel position techniques to improve visualisation and correct camera lens distortion, or "fish-eye" effect. The company then developed image-based surgical navigation, combining a pre-operative 3D surgical planning tool with real-time, intra-operative guidance based on augmented reality technology. This enables a surgeon to see the "real" image of a joint, bone or organ, overlaid with additional digital information or projections, all in one view. The device included the first navigation system for Computer-Assisted Orthopaedic Surgery (CAOS) in arthroscopy (keyhole joint surgery). The system adds overlays in the intra-operative video with exceptional accuracy and control.

The solutions currently provided by P3D are simple and cost-effective, reducing the amount of sterilised material needed for each surgery and enabling quicker, more cost-effective procedures. Their software is universal and can be used with off-the-shelf devices such as smartphones, tablets or mixed reality headsets, as well as with existing surgical cameras. This "open surgery" concept bypasses the need for more capital-intensive equipment that is not portable and takes up valuable operating room space.

Navigating the field

In 2013, Portugal Ventures became the first venture capital (VC) fund to invest in P3D via a seed round. The investment covered early patenting costs and secured a minority share for Portuguese Ventures, leaving the founders as the major shareholders. While IP-related expenses consumed a large percentage of early funding, it would have been more difficult to fund such an early-stage R&D project without IP. Then, in 2017, the EU's Executive Agency for Small and Medium-sized Enterprises (EISMEA) granted VC funds to help P3D upscale.

Initially, P3D showcased its technology to practitioners at fairs and other events. However, the company planned these demonstrations (where technical details would be revealed) to follow their patent filings to safeguard them from novelty-destroying prior disclosure. More recently, P3D licensed its navigation system for hip surgery to a global implant manufacturer. The development phase was successful and the system is expected to enter the market in early 2022, almost ten years after P3D's incorporation. In parallel, the company is also preparing to launch its own branded product – a navigation system for total knee arthroplasty that runs on a small device like a smartphone or tablet.

P3D's technology is scalable to many procedures and anatomies in orthopaedics (hip, spine, shoulder). The total market potential is estimated at EUR 4.2 billion, considering both open and minimally invasive surgeries. The company's navigation technology could also reduce surgical revisions. Each year, some 312 000 patients undergo procedures to correct failed knee implants. Improved navigation could reduce this figure by 20% and save healthcare operators EUR 2 billion. For patients, however, the saving is invaluable.

5. Investment activities

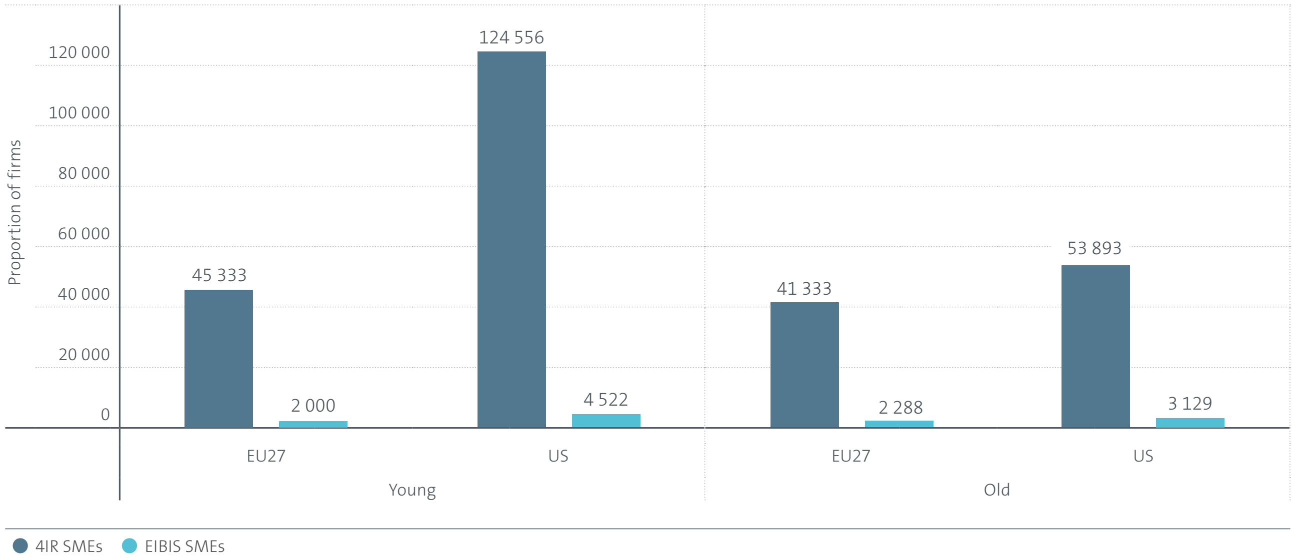
5. Investment activities

4IR SMEs are drivers of investment: they consistently have a higher investment intensity (defined as investment spending per employee) than the SMEs that were interviewed in the EIB Investment Survey (Figure 5.1). When comparing young 4IR SMEs and those that have been operating for over ten years, we find a higher investment intensity among younger firms, both in the EU27 and the US. The investment intensity is also higher in small firms than medium-sized firms. Firms use strategic business monitoring – a proxy for managerial skills – invest more than their peers without monitoring in place.

To a large extent, the higher investment intensity of 4IR SMEs is driven by greater investments in intangibles and, more specifically, R&D. This confirms the high technological nature of these companies. When asked directly, 4IR SMEs also confirmed that a large part of their investment is linked to innovation. Young 4IR firms estimate that about 80% of their investment is related to innovation. For 4IR firms operating for over ten years, this proportion drops to just over 60% in the EU27 and the US.

Figure 5.1

Median investment intensity, in EUR



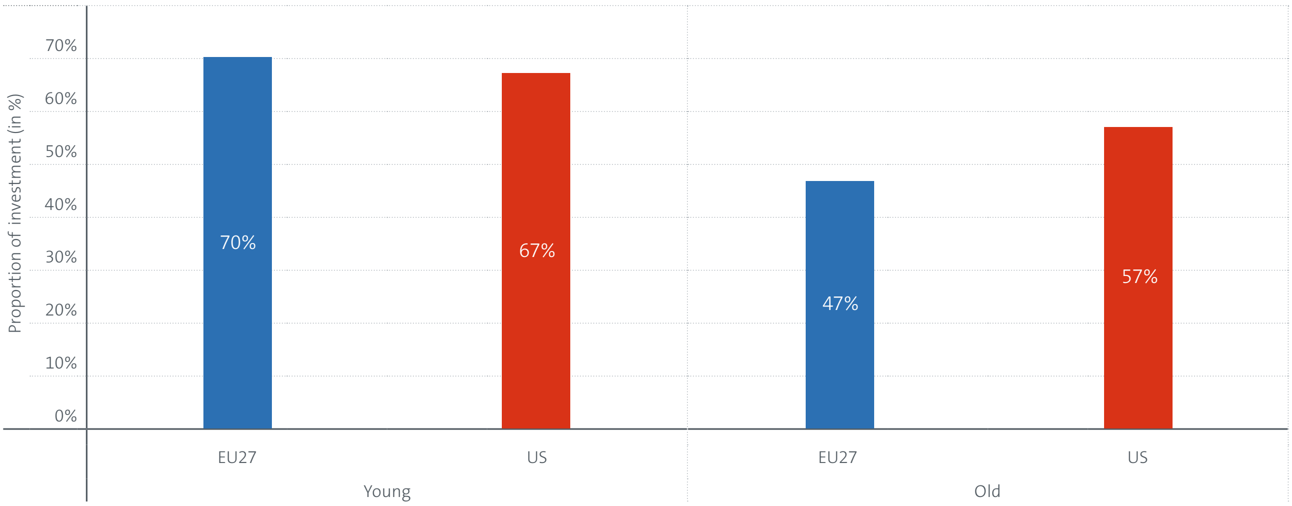
Source: 4IR survey, EIBIS (2021).

Base: Firms with fewer than 250 employees (excluding don't know / refused responses).
Note: Investment intensity defined as investment spending per employee.

Not surprisingly, a large proportion of the innovation-related investment of 4IR companies was in 4IR technologies. Up to 70% of the total investment of young 4IR SMEs was targeted at 4IR innovations. For 4IR firms operating for over ten years, this figure drops to less than 50% in the EU27 and less than 60% in the US.

Figure 5.2

Proportion of investment related to 4IR technologies (in %)



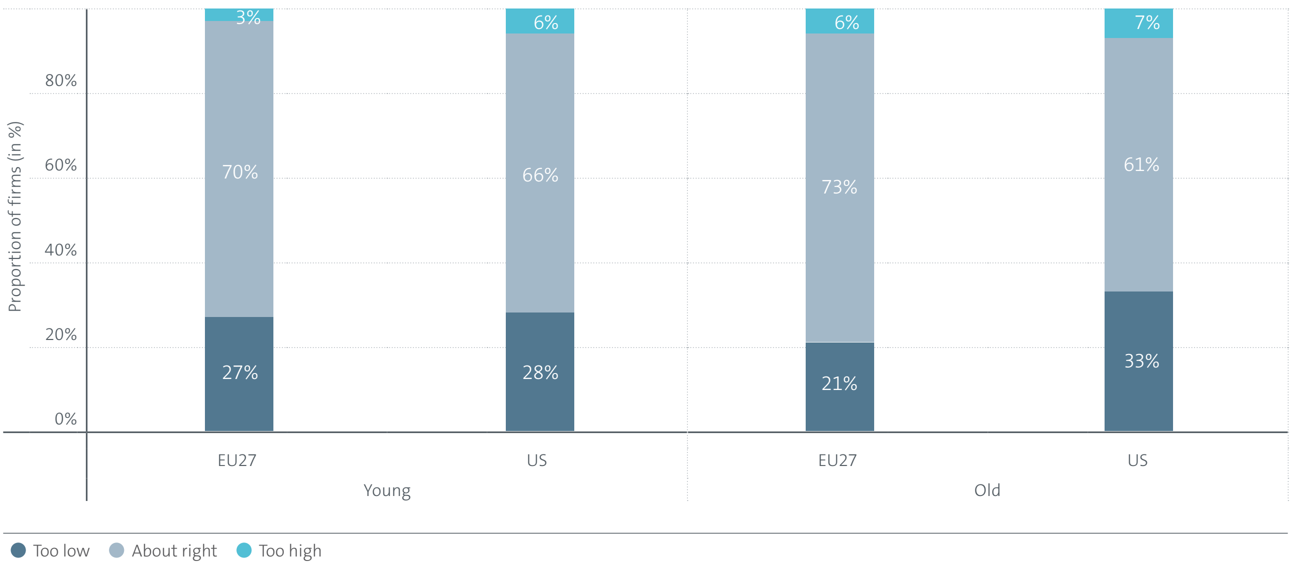
Source: 4IR survey.

Base: Firms investing in innovation (excluding don't know / refused responses).

Despite a high investment intensity, over **25% of firms consider their past investment activities related to 4IR activities insufficient.** Looking back at their investment activities over the past three years, 27% of young EU27 and 28% of US 4IR SMEs stated that their investments were too low to ensure business success. Among firms operating for over ten years, 21% of EU27 firms and 33% of US firms rate their investment activities as inadequate. Given their market position, reported investment gaps were highest for firms claiming to be the sole player in their market and lowest for firms professing to be dominant players.

Figure 5.3

Perceived investment gaps related to 4IR technologies



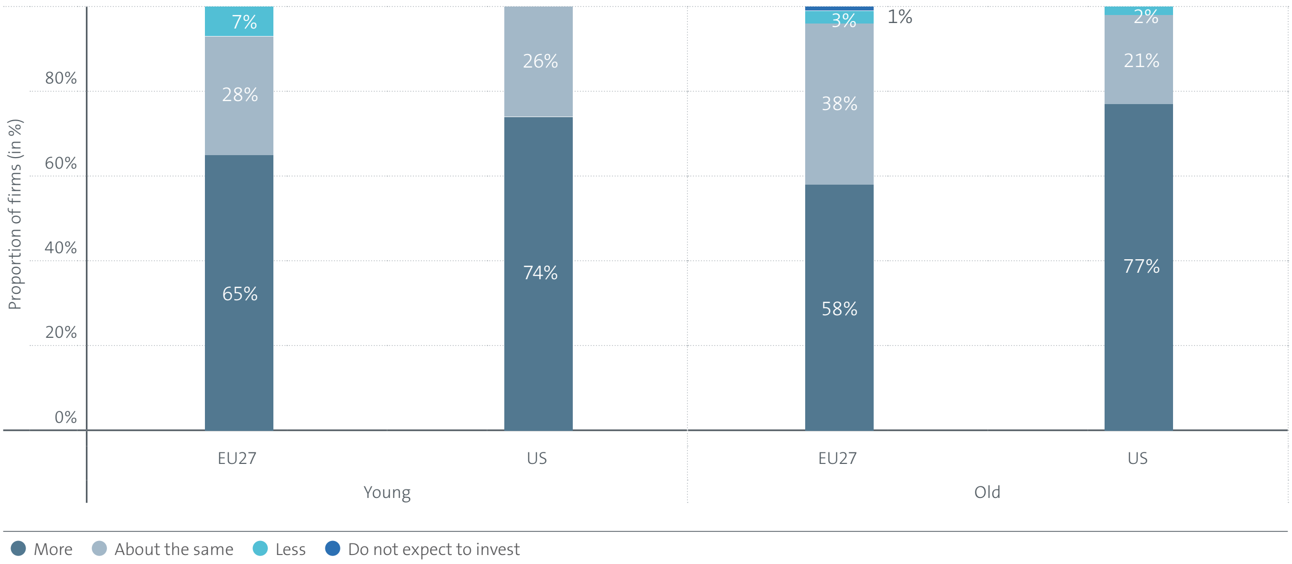
Source: 4IR survey.

Base: Firms investing in 4IR innovation (excluding don't know / refused responses).

The vast majority of firms predict that 4IR technologies will progressively dominate their market in the future. On balance, about 56% of EU27 and 74% of US firms anticipate an increase in investments related to 4IR innovations in the next five years. When asked whether they expect their investment in 4IR innovation to increase, decrease or stay the same over the next three years, the answer was overwhelmingly: increase. Regional differences reflect variations in firms' expectations of changes in the importance of 4IR innovation, with firms in the US standing out as the most buoyant.

Figure 5.4

Investment outlook



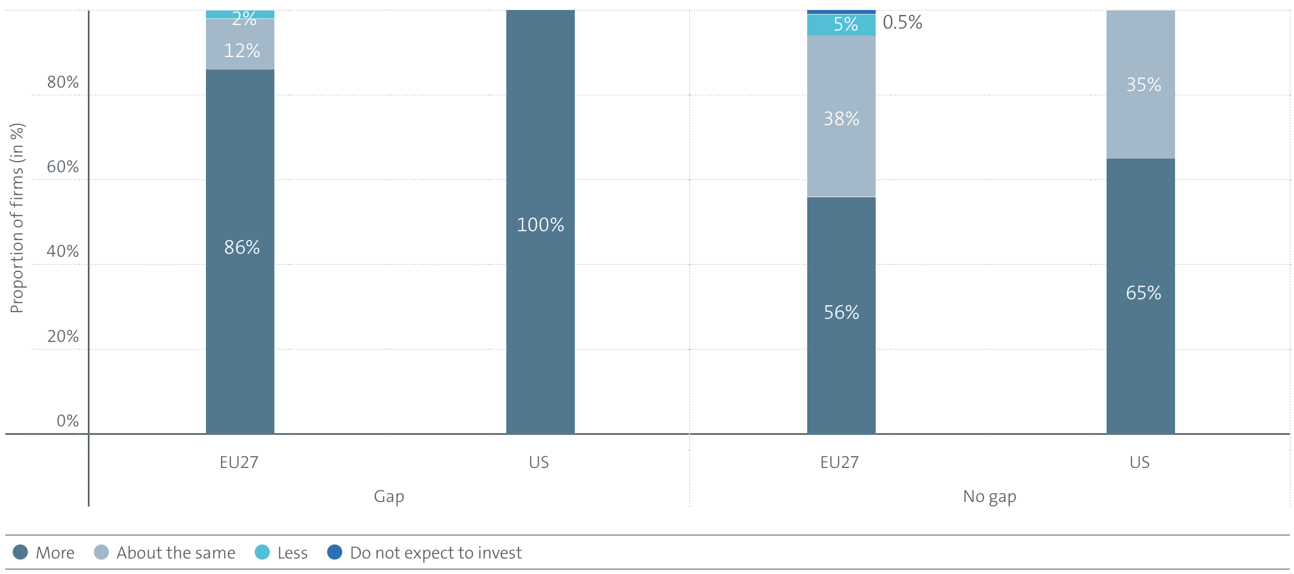
Source: 4IR survey.

Base: Firms investing in 4IR innovation (excluding don't know / refused responses).

Firms' predictions of increasing investment prospects are related to their past investments. On balance, firms considering their investment to have been inadequate are more likely to announce greater investments in 4IR innovation over the next five years than firms investing in line with their needs. This suggests that **underinvestment has implications insofar as it pushes firms to catch up with peers whose investments met their needs** (see Figure 5.5). Furthermore, firms that are well managed tend to report an intention to increase investment in the future.

Figure 5.5

Investment outlook, by past investment



Source: 4IR survey.

Base: Firms investing in 4IR innovation (excluding don't know / refused responses).
Note: Firms with inadequate investments in 4IR innovation in the last three years are labelled gap.

BOX 5

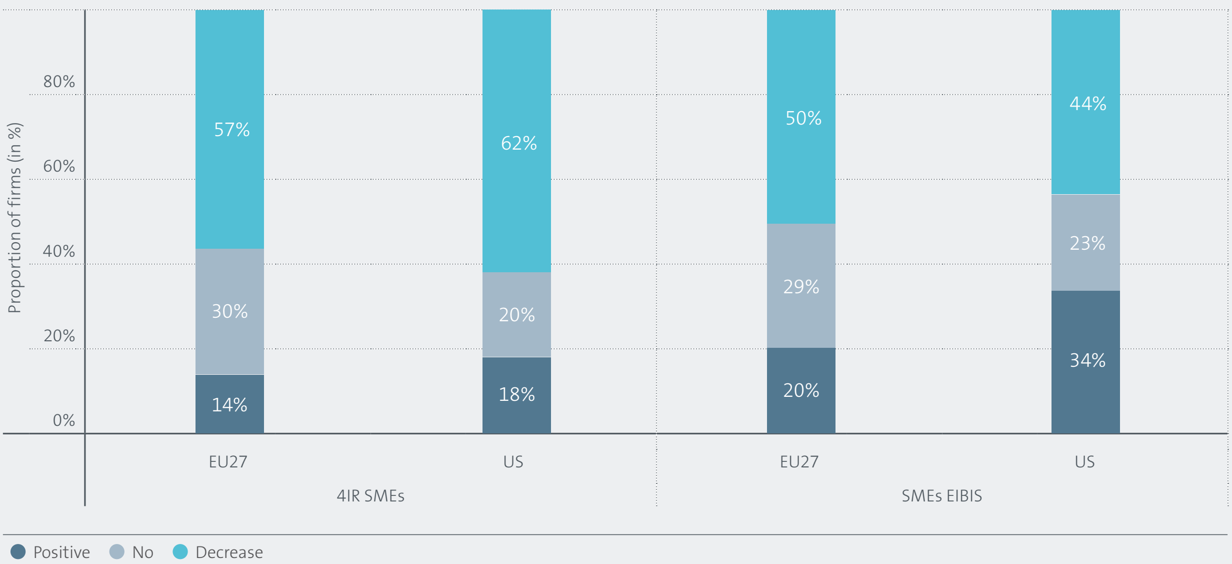
The impact of the COVID-19 pandemic on 4IR SMEs

COVID-19 has undeniably had a large impact on many firms. Nevertheless, **when asked about the impact of the pandemic on their turnover, 4IR SMEs were more likely than SMEs in general to report a negative impact.** In addition, US 4IR SMEs in particular were more likely to experience a negative impact on their sales than their peers in a wide variety of sectors. Given that COVID-19 led to a slowdown in the adoption of advanced digital technologies (see EIB (2022)), it is not surprising that firms active in deep tech saw a larger drop in sales than SMEs in general.

Apart from affecting companies' turnover, COVID-19 had an enormous impact on their various activities. Although most 4IR SMEs did not perceive any impact of the pandemic on their innovation activities in general, more **4IR firms state that the COVID-19 crisis allowed them to innovate more rather than less.** Compared with EIBIS EU SMEs in manufacturing and services overall (based on the AOM module of the EIB Investment Survey), 4IR SMEs seemed slightly less likely to perceive this positive impact on innovation. This difference also applies when focusing exclusively on EU 4IR SMEs.

Figure 5.6

Impact of the COVID-19 crisis on firms' turnover



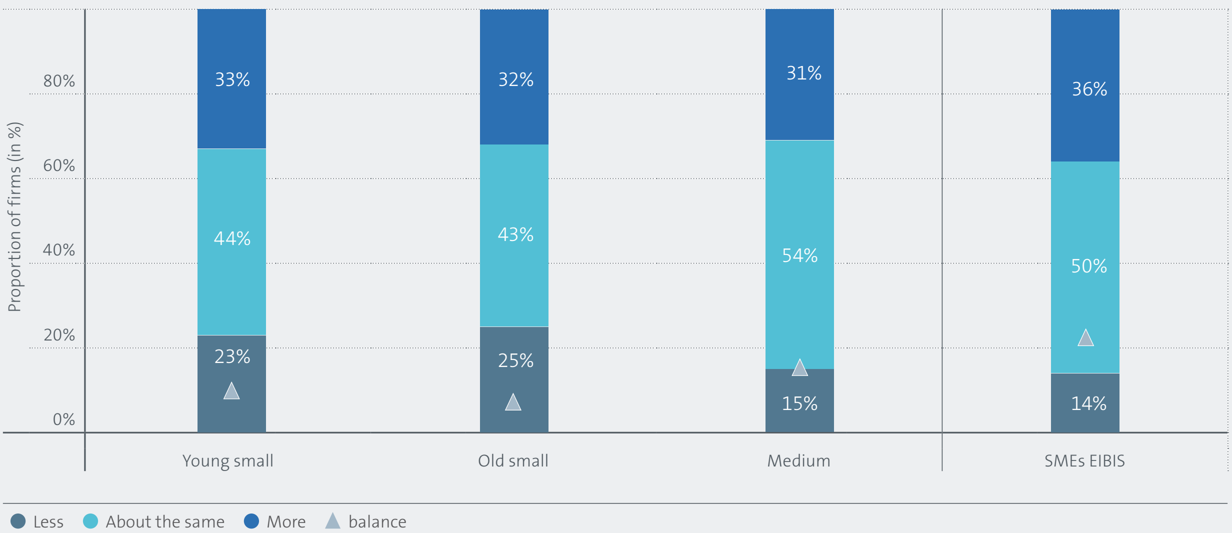
Source: 4IR survey, EIBIS (2021).

Base: 4IR innovators in the 4IR survey, SMEs in EIBIS (excluding don't know / refused / no obstacle responses).

When asked about the impact of COVID-19 on their 4IR-related innovation investment plans, **especially young and small 4IR SMEs indicate that the pandemic led them to revise their investment plans upwards.** At the same time, just under 20% of all 4IR SMEs anticipate a downward revision of their 4IR-related investment plans. Among young firms, US-based 4IR SMEs in particular expect an upward revision of their future investments, while their EU counterparts were more likely not to change their 4IR investment plans.

Figure 5.7

Impact of the COVID-19 crisis on firms' innovation activities

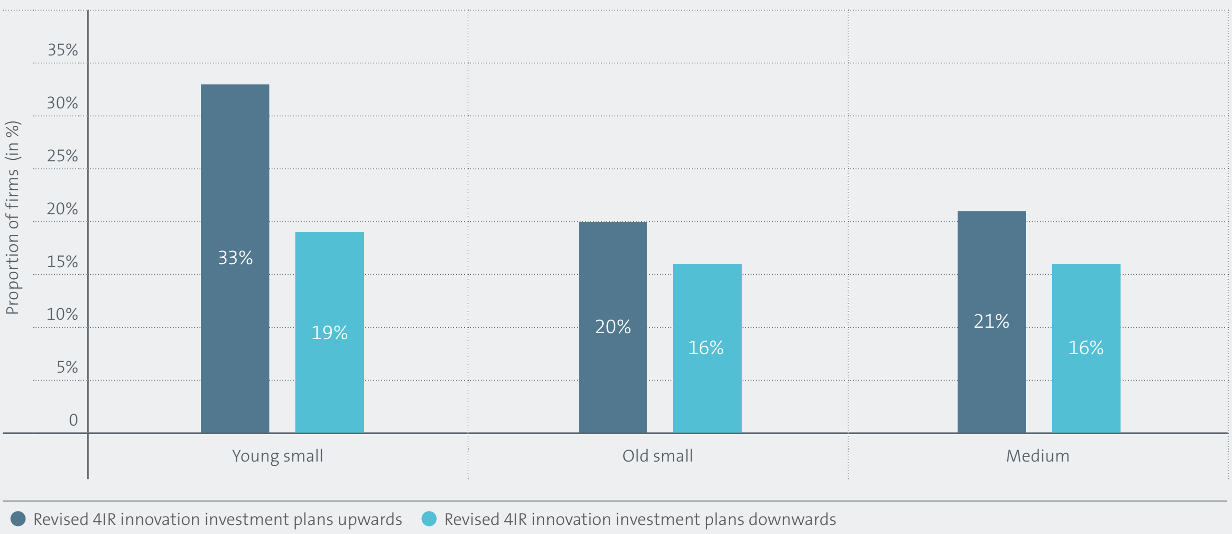


Source: 4IR survey, EIBIS 2021 add-on module (AOM) – sample of EU SMEs in manufacturing and services (2021).

Base: 4IR innovators in the 4IR survey, SMEs in EIBIS (excluding don't know / refused / no obstacle responses).

Figure 5.8

Impact of the COVID-19 crisis on firms' innovation plans



Source: 4IR survey.

Base: 4IR innovators in the 4IR survey (excluding don't know / refused / no obstacle).

Case study: Strong patent position attracts major investment for growing SME

Invention: Lasers and AI for healthier salmon
Company: Stingray Marine Solutions
Sector: Marine technology
Country: Norway

A strong patent position scooped investments of EUR 2.5 million for this Norwegian marine engineering company. The capital injection helped grow a business now supplying technology to over 100 salmon farms.

Norway is the world's largest Atlantic salmon producer and the country's salmon industry is worth over EUR 6.4 billion annually. However, the industry faces a massive threat from a miniscule enemy: sea lice. Each year, salmon farmers spend over EUR 800 million on measures to control outbreaks. Current delousing techniques may involve chemicals that pollute the environment. Over time, parasites can become resistant to these treatments, rendering them ineffective. Fish also need to be starved and handled physically, which may kill them or stunt their growth – resulting in financial losses for farmers who sell by weight.

Esben Beck (European Inventor Award 2019, SMEs, finalist) decided to use technology to tackle the problem. He developed a robot that can spot sea lice on salmon or trout and zap them with lasers. The Norwegian entrepreneur founded Stingray Marine Solutions to take his invention from the basement to the market.

A smart combination

The invention, called Stingray, combines artificial intelligence (AI), 3D computer vision and simulation algorithms that can identify the dark sea lice (typically no larger than 12 mm) on the silvery skin of salmon up to several metres away. The device is also equipped with stereo cameras and uses AI to examine video footage.

An onboard computer scans the fish and can pinpoint the shade and shape of sea lice in just seven milliseconds. The software then models the path of the salmon in the water to predict the future location of the targeted sea louse. The Stingray then directs its movable mirrors to focus the laser beam onto individual sea lice and fires a short pulse of intense light (100-150 milliseconds). The green wavelength of the laser transmits effectively underwater while providing enough energy in each burst to kill the parasites.

The system can kill tens of thousands of sea lice a day and operates 24/7 with no need for human intervention. It keeps fish healthier and heavier, reduces deadly physical contact and ensures that no toxic chemicals enter the marine environment.

When one door closes, another opens

In the early 2000s, the Tromsø-born inventor founded Beck Engineering AS to provide engineering expertise and equipment such as pipeline robots. In 2009, however, the financial crisis threatened his livelihood. Beck read about sea lice infestations and immediately thought about burning the parasites with lasers – much like burning ants with sunlight and a magnifying glass. Thanks to his marine welding knowledge, he knew green laser light would work best.

A patent database search showed that his laser solution was unique and he applied for patents to protect his robot. From 2011 onwards, Beck relied on his then pending applications to raise over EUR 2.5 million in government funding and venture capital. He established a subsidiary, Stingray Marine Solutions, and with his own capital and additional support from employees, launched the robot commercially in October 2014.

Today, the Stingray is used in more than 100 salmon farms in Norway, collectively monitoring around 40 million fish. Mortality has more than halved in pens fitted with the device and farmers yield an extra half a kilogram of meat per fish. With no similar solutions available and the original patents still in force, Stingray Marine Solutions is set to expand its market share locally and abroad.

6. Financial profile and structural barriers

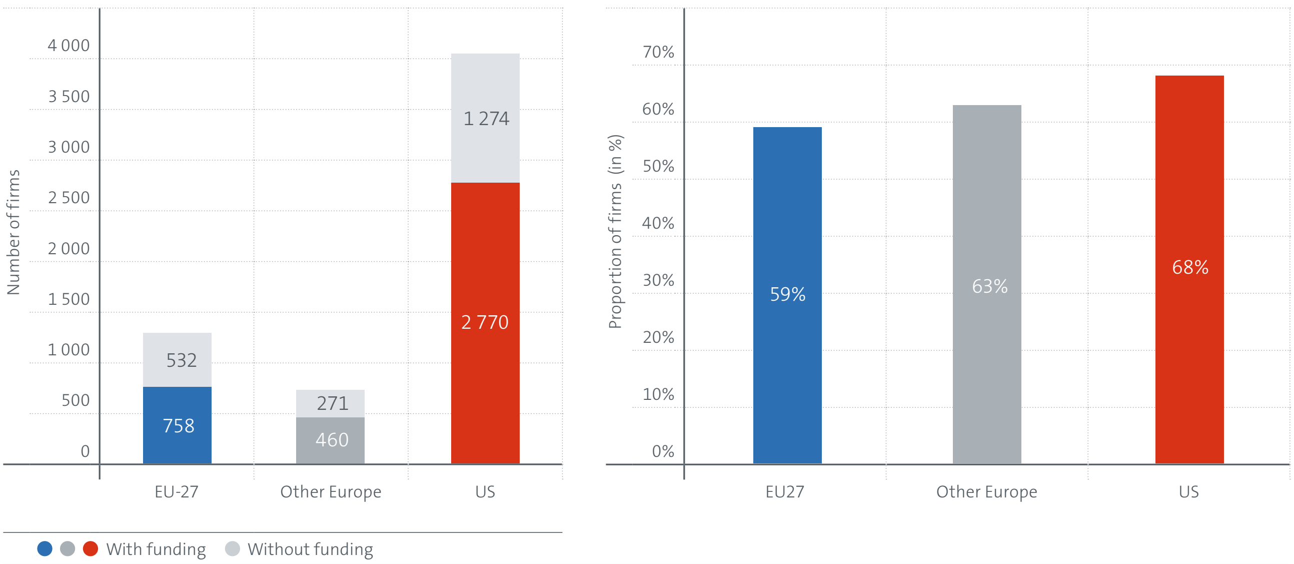
6. Financial profile and structural barriers

6.1. Funding 4IR SMEs

The proportion of funded 4IR SMEs is higher than reported in other studies (EIB, 2019). However, the EU27 has a relatively low number of 4IR start-ups and scale-ups listed on Crunchbase. This is true in absolute numbers (Figure 6.1.1) and as a proportion of the total population. The gap is relatively big, with the EU27 having only about one third the number of young, high-growth firms of the US. Moreover, according to Crunchbase data, **4IR start-ups and scale-ups in the EU27 are less likely to list that they received formal funding (59%) than their US peers (68%).**

Figure 6.1.1

Number of firms with and without funding, and proportion of firms with formal funding



Source: Crunchbase, authors' calculation.

Base: See Annex 1 for a definition of 4IR SMEs.
Note: Crunchbase lists firms that have already received some type of formal funding (with funding) as well as firms that have not yet received formal funding (without funding).

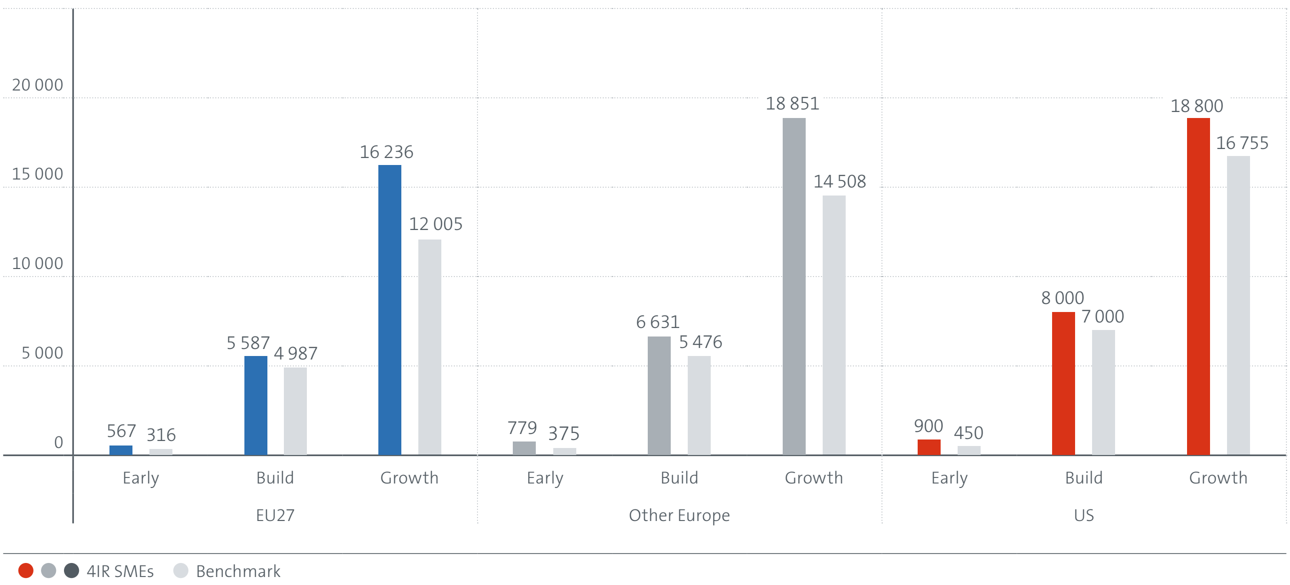
The benchmark for Europe and the US is based on all Crunchbase companies with 250 or fewer employees, which were founded between 1971 and 2018, and based in the respective countries.

While SMEs in Europe and the US receive relatively similar absolute amounts of early-stage funding, **4IR start-ups and scale-ups benefit more from higher growth funding than their benchmark peers.** This might be linked to the fact that start-ups in this domain invest enormously in R&D, while their projects entail greater risks. Low cash flows, few tangible assets that can serve as collateral and the uncertainty associated with innovating mean that more traditional lenders/investors are hesitant to get involved, so 4IR start-ups depend more on equity-type financing.

We find that EU27 firms raise less funding as they mature. Figure 6.1.2 shows the amount of funding attracted at each funding stage by firms with growth ambitions. While, initially, the differences between the EU27 and the US are modest in absolute terms, as firms move to later funding stages the gap between the EU27 and the US increases.

Figure 6.1.2

Funding received by funding stage, funding amount in thousand USD (median)



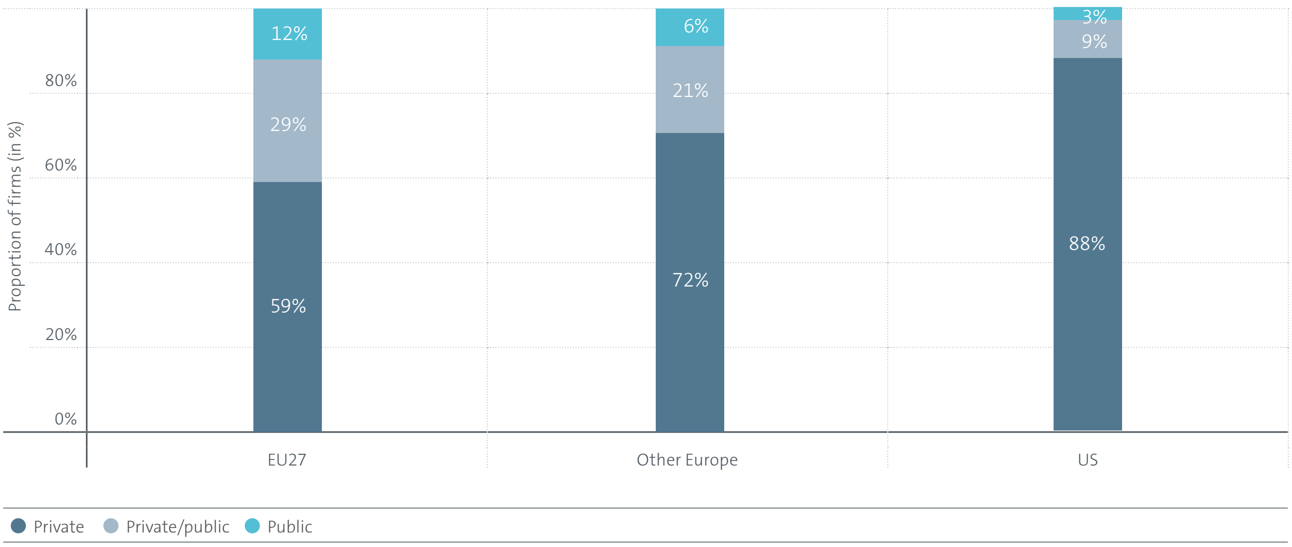
Source: Crunchbase, authors' calculation.

Base: See Annex 1 for a definition of 4IR SMEs.

EU policymakers are already making great efforts to close the funding gap. **At 12%, the proportion of 4IR start-ups in the EU27 receiving funding from public investors is much higher than in the US, with 3%**. In connection with the funding results above, this suggests that public support has been quite effective in closing the early-stage funding gap, but less to help firms to scale.

Figure 6.1.3

4IR SMEs receiving funding, by investor type



Source: Crunchbase, authors' calculation.

Base: See Annex 1 for a definition of 4IR SMEs.

6.2. Structural barriers

To get a better grip on the development and implementation of 4IR technologies, and how policymakers can further enhance this, it is also important to understand the main obstacles faced by 4IR innovators.

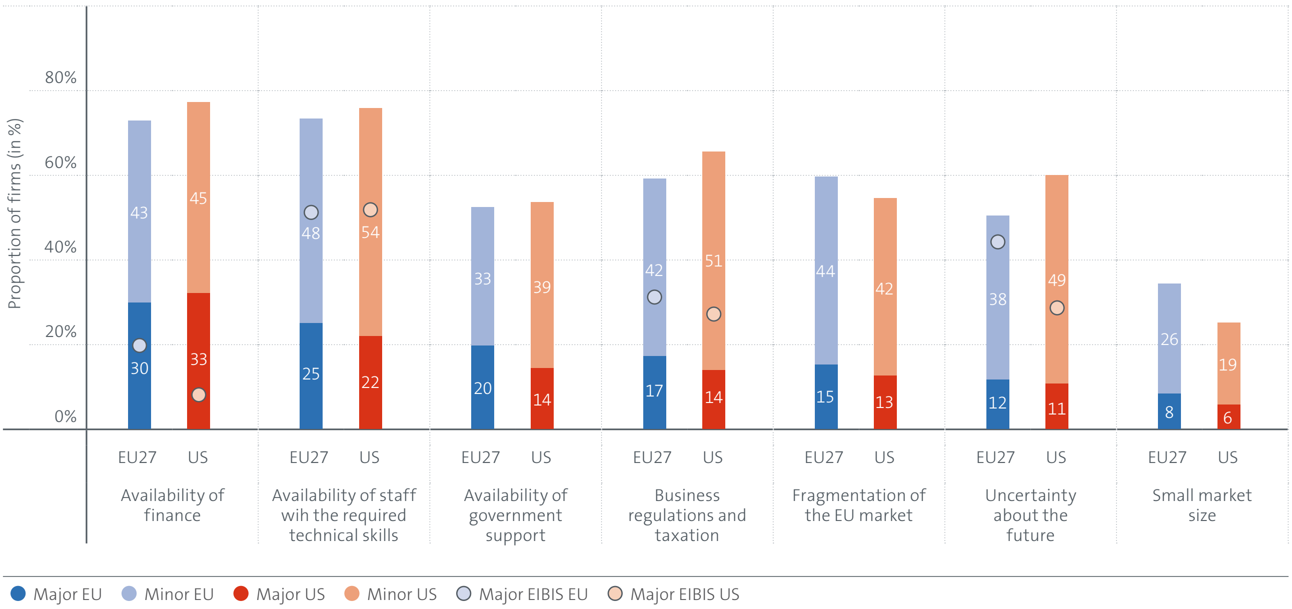
The availability of both finance and staff with the required technical skills are the main obstacles cited by both EU27 and US firms in the survey. More than half of US and EU companies are dissatisfied with the availability of government support, although EU firms are more likely to consider this a major obstacle to their activities.

Overall, firms in both the EU27 and the US seem to face the same barriers, with some noteworthy exceptions. For example, **US firms are slightly less likely than EU firms to perceive the availability of government support, business regulations and taxation, and a small market size as major obstacles.**

Comparing some of the obstacles investigated by EIBIS, we find that 4IR SMEs seem to regard fewer obstacles as major than their peers (Figure 6.2.1). In particular, **4IR SMEs appear to be less exposed than other SMEs to the shortage of skilled staff.** This might be linked to the fact that many 4IR SMEs started with high IT skills, in other words, skills that firms generally lack. However, the availability of finance is an important exception, perceived more often as a critical issue by 4IR SMEs than by other SMEs. In the **EU27, 30% of 4IR SMEs cite the availability of finance as a major obstacle, compared with 20% of SMEs in EIBIS.** In the US, the difference is even greater with 33% of 4IR SMEs reporting it as a major obstacle, compared with 8% of SMEs in EIBIS.

Figure 6.2.1

Obstacles



Source: 4IR survey, EIBIS (2021).

Base: 4IR innovators in the 4IR survey, SMEs in EIBIS (excluding don't know / refused / no obstacle responses).

In particular, firms operating for under ten years face major challenges in raising funds across all regions (Figure 6.2.2). In addition, of these young firms, those with fewer than 50 employees tend to be particularly dissatisfied with their access to finance. This suggests that "newcomers", presumably digital natives, face higher constraints than other companies. These funding disadvantages might be linked to their access to growth capital.

The difference in the availability of growth finance has consequences, not merely for firms' access to funding, it also affects the type of investments they make. Companies aiming to scale up their activities very quickly by means of (new) digital technologies rely on equity-type finance. The risky nature of their project – low cash flows, few tangible assets than can serve as collateral and the uncertainty of a completely new venture – means that more traditional lenders/investors are hesitant to get involved. In other words, funding of similar activities is prone to market failure. It is common knowledge that market failures hamper the innovative activities of firms in general, a factor that may be aggravated in the case of 4IR endeavours, which are perceived as even riskier by the more traditional lenders.

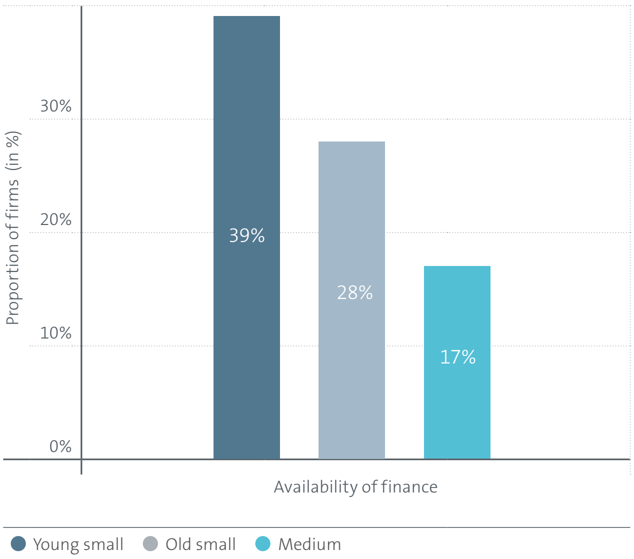
Moreover, access to equity finance not only affects whether firms can access funding for high-risk projects, it also has an impact on what project they pursue. Against this background, it has often been argued that the financial landscape in Europe – heavily skewed towards bank funding – is a barrier for high-growth businesses.

Furthermore, the proportion of firms citing inadequate access to **finance as a barrier to their investment activities is substantially higher among firms taking the view that they underinvested over the past three years** across all regions in our sample (Figure 5.2.3). The difference between firms with investment gaps and no gaps is particularly pronounced for young, small firms.

Therefore, firms that feel they were unable to make sufficient investments to drive their business and achieve their intended success suffer to a greater degree from a lack of financing. This finding is particularly worrisome, given the importance of 4IR in policy debates.

Figure 6.2.2

Obstacles by size and age

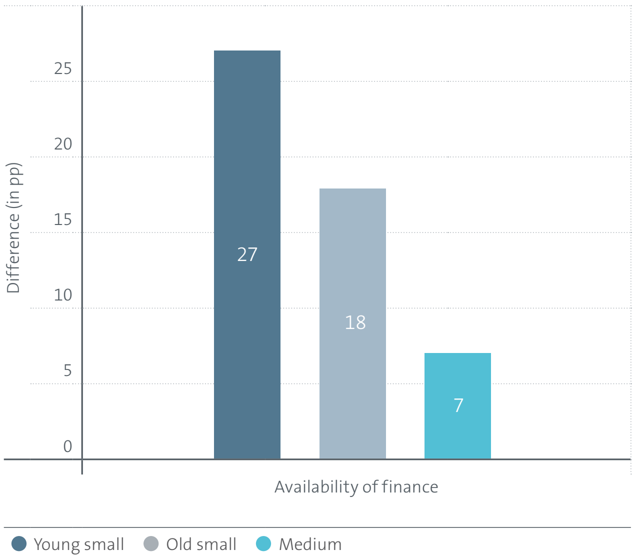


Source: 4IR survey

Base: All 4IR innovators (excluding don't know / refused / no obstacle responses).

Figure 6.2.3

Difference between firms that feel they underinvested and others



Source: 4IR survey

Base: All 4IR innovators (excluding don't know / refused / no obstacle responses).

Case study: From the lab to the market with a solid licensing strategy

Invention: ABS for e-bikes
Company: Blubrake
URL: epo.org/case-studies
Sector: Transport
Country: Italy

Financing and R&D support from a start-up accelerator enabled a small Italian start-up to become the sole "open platform" ABS technology provider for the vast global e-bike and e-cargo bike industry.

The popularity of e-bikes has risen in recent years due to the growing interest in smarter, greener mobility solutions. The pandemic further accelerated this demand: to avoid the risk of infection, many turned to cycling rather than urban public transport. While bicycles remain the preferred mode of transport for many, they are not without risk. Many accidents occur when braking and, until recently, an anti-lock braking system (ABS) for bicycles was not technically feasible. Electronic sensors and computer processors are essential components in ABS. However, these need electricity and only modern e-bikes can provide this power.

Professor Sergio Matteo Savaresi, Politecnico di Milano (Polimi), led a research group that was working on braking control systems for vehicles. In 2015, some members of the research group together with e-Novia, an organisation that helps universities or research institutions develop intellectual property strategies to scale up technologies and create spin-offs, decided to apply their know-how to light electric vehicles, in particular e-bikes. The collaboration led to the development of an open-ended ABS control system for e-bikes and the formation of a company to commercialise the invention: Blubrake. Under the leadership of co-founder Fabio Todeschini, the start-up company developed an ABS product compatible with most of the brakes and batteries already present on the e-bike market.

Open to collaboration

Blubrake provides the only "open-platform" ABS solutions currently available in the e-bike and e-cargo bike market. Their technical solution can be integrated with every third-party braking system and battery kit, uniquely meeting the needs of the original equipment manufacturers (OEMs). The technology comprises both hardware and software: the speed sensor and the phonic wheel measure the front wheel speed in real-time with high precision. A proprietary AI-powered main unit with an ABS actuator continuously and instantly increases or reduces hydraulic pressure in the front brake – guaranteeing smoother braking while preventing the front wheels from locking. Finally, the system incorporates a human-machine interface (HMI) for driver control.

Going global: growing demand for e-bikes

Being a safety device, Blubrake decided to sell its ABS control systems to large OEMs in order to guarantee the highest quality and safety standards. At the same time, the start-up company is also a technology platform provider, supporting OEMs in adapting its technology solutions to specific needs and bike models.

A majority share was granted to e-Novia, who played an essential role in Blubrake's development. The group attracted financing, negotiated with initial investors and supported researchers in filing patent applications and covering procedural fees. At first, Blubrake relied on seed funding, e Novia and a grant from the EU's Executive Agency for Small and Medium-sized Enterprises (EISMEA) to finance four years of R&D. At the end of 2020, the company raised EUR 5.2 million from private investors thanks to its unique innovation, protected by an expanding patent portfolio.

The global e-bike market is worth an estimated EUR 16 billion (USD 18.2 billion) and is expected to grow with an average annual rate of 5% until 2024 (at least). The Asia-Pacific area is the largest market, valued at EUR 11.8 billion (USD 13.5 billion) and around 33.7 million e-bikes sold. However, the Asia-Pacific market is characterised by the slowest growth rate and the lowest average price, with an estimated premium segment that amounts to just 4% of the total. Europe, with 2.9 million e-bikes sold, offers the highest average price and an above-average growth rate, with premium e-bikes (minimum price EUR 1 500) making up 46% of that figure. While growth in North America is high, the market is still relatively small.

7. Exit

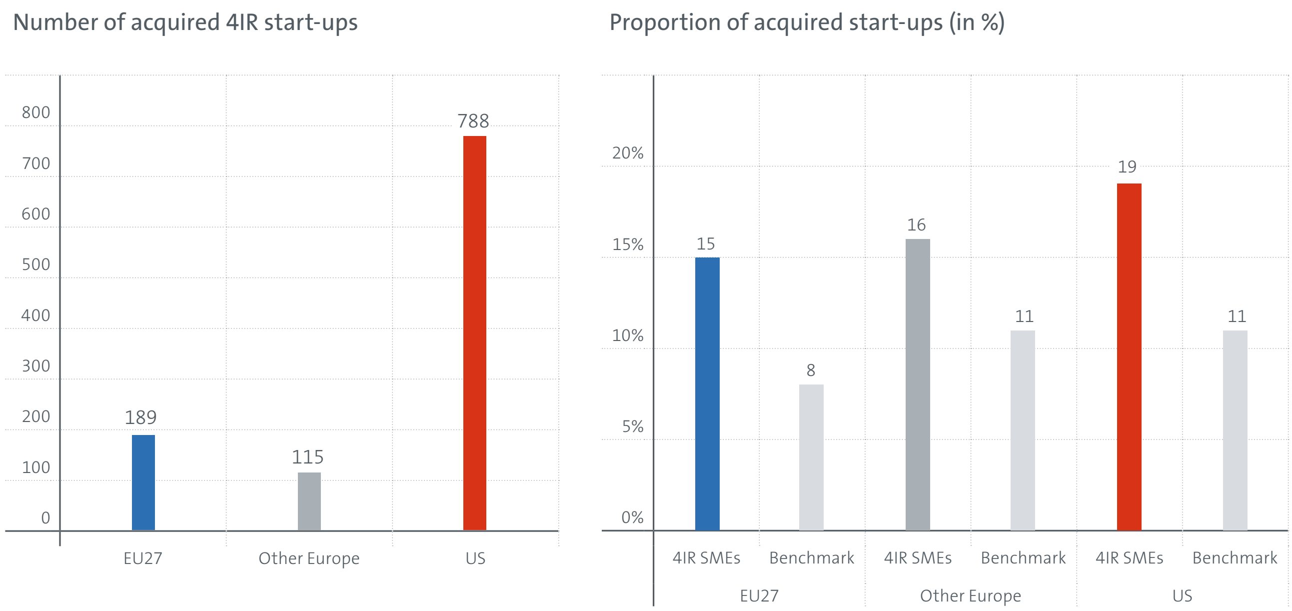
7. Exit

7.1. Acquisitions of 4IR SMEs

The most common types of exits for investors – other than secondary sales to other financial investors – are acquisitions and initial public offerings (IPOs). Acquisitions account for a larger proportion of exits; IPOs are less common when looking at 4IR start-ups. Indeed, **the difference between the acquisition activities of 4IR start-ups in the EU and the US is striking.** EU27 4IR start-ups are less likely to be acquired than US companies (15% vs 19%) and the median acquisition price is considerably lower (USD 81 million compared with USD 102 million).

Figure 7.1.1

Acquired start-ups, comparison to benchmark



Source: Crunchbase, authors' calculation.

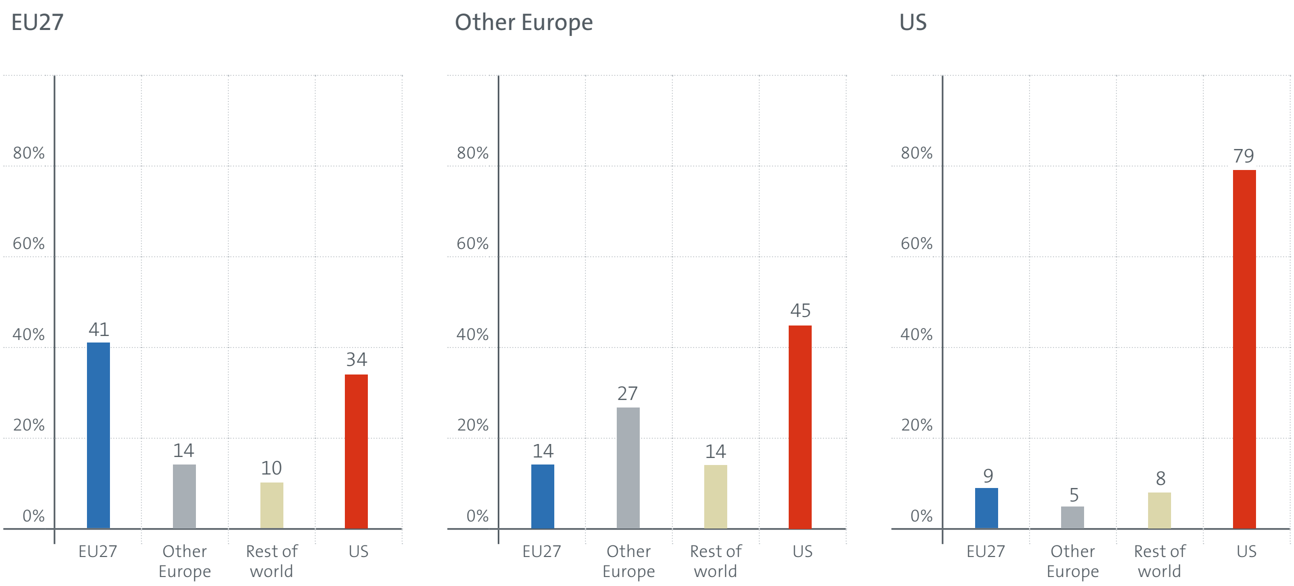
Base: See Annex 1 for a definition of 4IR SMEs.

Successful start-ups often act as acquirers of new start-ups and scale-ups. Despite broadening their geographical focus in recent years, these firms have an overwhelming tendency to acquire start-ups in their immediate vicinity, thereby generating enormous local demand for new start-ups and scale-ups. Mind the Bridge (2016) shows a correlation of 95% between the state of the acquirer and that of the acquiree in the US. The EIF (2017) indicates that, from 2003 to 2015, an average of 44% of exited EIF-backed VC investees were acquired by non-European buyers, particularly from the US. We find comparable patterns for 4IR start-ups (see Figure 7.1.2). **EU27 4IR start-ups are more likely to be acquired by US firms (34%) than vice vers**a (9% of US 4IR SMEs are acquired by firms based in the EU27).

A strong acquisition demand translates directly into a strong incentive for investors to invest in high-growth firms from an early stage. It also increases their willingness to invest large sums in these firms – explaining the earlier finding that investments tend to be higher in the US than in the EU – and invest more "patiently". The greater incentives to invest in start-ups and scale-ups follow the logic that, where there is higher acquisition demand, investors know that there is a good chance that their investee firms will ultimately be acquired by a deep-pocketed corporate, allowing them to exit their investments successfully (see e.g. EIF, 2019).

Figure 7.1.2

Origin of the acquiring companies



Source: Crunchbase, authors' calculation.

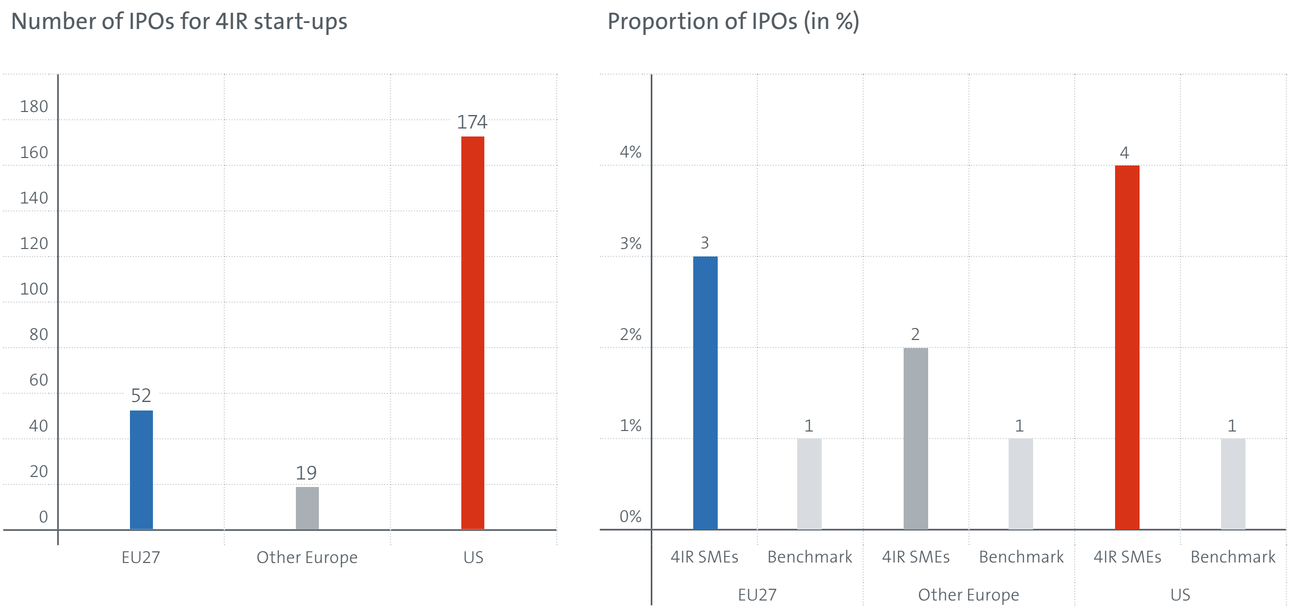
Base: See Annex 1 for a definition of 4IR SMEs.

7.2. IPOs of 4IR SMEs

4IR start-ups are slightly more likely to have an IPO when compared with the benchmark (3-4% of 4IR SMEs compared with 1% of benchmark firms). Moreover, IPO activities are marginally higher in the US. The positive dynamics of past success stories for current IPOs are probably the main reason why among the few European firms that seek a public listing, a significant proportion also does so in the US. US firms are much less likely to seek a public listing in Europe, however.

Figure 7.2.1

Companies with IPO, comparison to benchmark

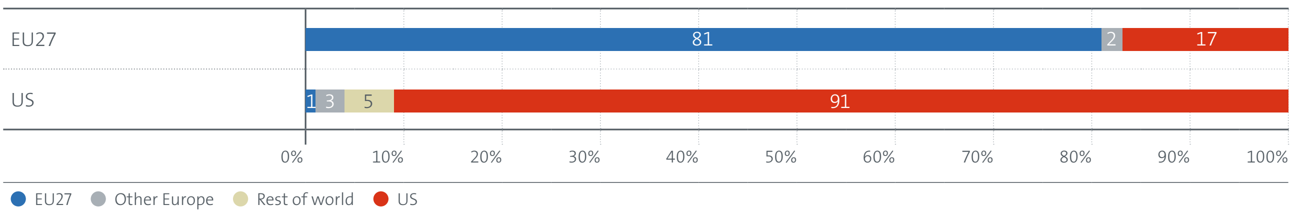


Source: Crunchbase, authors' calculation.

Base: See Annex 1 for a definition of 4IR SMEs.

Figure 7.2.2

Location of the stock exchange for the IPO



Source: Crunchbase, authors' calculation.

Base: See Annex 1 for a definition of 4IR SMEs.

8. Policy recommendations

8. Policy recommendations

Fostering 4IR innovations should be a policy priority and policy should not hesitate to push companies to invest in innovation. Even if innovations have the potential to attract a sufficiently wide market, private investors may still hold back, owing to the higher sunk costs, and delay bringing novel technology to market. The specific risks entailed by R&D investments, such as the risk of R&D failure or of new technology spilling over to competitors, also make it more difficult for firms to find the necessary funding. These knowledge-market failures are not new in the innovation literature and can be addressed by a variety of measures. Nevertheless, the novelty and often experimental nature of innovations in the domain of 4IR suggest that they may be more prone to these failures.

The patent system and intellectual property rights (IPRs) are generally of direct relevance in this context. By ensuring legal protection of their inventions, patents and other IPRs offer businesses incentives to invest in research and commercialisation. They are also a means of organising technology transfers with other SMEs, research institutions and large companies, thereby enabling the development of innovation ecosystems for deep tech SMEs. The publication of patent applications is particularly important in this context as an effective signal of innovation for investors and other business partners.

Ensuring accessibility of the patent system, together with the high and consistent quality of patents related to digital technologies is therefore a key factor of the successful development of 4IR SMEs in Europe (Figure 4.7 above). While the survey of 4IR SMEs highlights the relevance of IP strategy for their investors, other studies [16] point out the need to increase awareness of IP in the broader population of SMEs and the investor community.

The study also shows that European 4IR SMEs prioritise growth within Europe, seeking to align the geographical scope of their patent portfolios accordingly (Figures 4.1 and 4.2 above). Currently, the EPO offers a single uniform grant procedure for Europe, enabling owners of European patents to take up their rights in over forty countries. However, once granted, these European patents must be validated and maintained in force in each individual country to take effect. Similarly, European patents are enforced before the national courts so there is fragmentation at the litigation stage, too. The imminent creation of a Unitary Patent and Unified Patent Court will address these post-grant limitations by giving inventors access to an alternative, simplified and cost-effective route to patent protection and dispute resolution over most of the EU single market. By providing for a more integrated European market for technologies, it will facilitate the growth of European deep tech companies and make them more attractive for international investors.

Direct policies, such as targeted grants or early-stage deployment policies, are another tool to foster innovation in technologies that have not yet become cost-effective. For early-stage technologies, policies are needed to help cross the bridge from research and development to market launch (Howell, 2017). In this context, the EU's flagship research and innovation programme Horizon Europe will direct EUR 100 billion to research and innovation, making it one of the biggest initiatives in the world. In addition, specific innovation programmes and prize-based challenges could benefit innovation.

16 See EUIPO (2019), for example.

Investments in 4IR technologies are mainly hampered by a lack of finance. Survey respondents (Figure 6.2.1 above) cite this as the main obstacle, more so than the overall group of SMEs. In addition, it is chiefly the younger, smaller firms indicating that they had underinvested that express dissatisfaction in this regard. Unsurprisingly, therefore, across all regions, these same firms believe that financial backing would give them the most support (Figure 8.1).

The second-most cited support that would encourage firms to further introduce or develop 4IR technologies is assistance in identifying new markets or customers for the youngest, smallest firms and consistent regulation for the other 4IR SMEs. This suggests that, while smaller and younger firms are still in a growth phase and looking for opportunities, more mature and larger companies are considering different business aspects, requiring a greater focus on regulation and taxation.

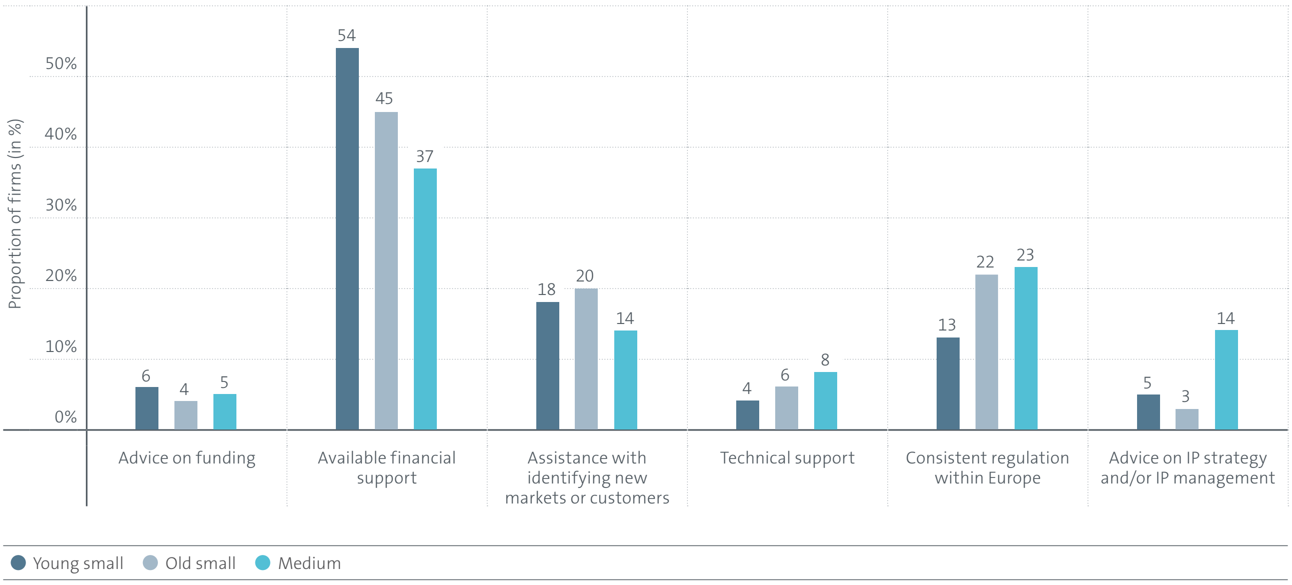
The amount of capital going into the European start-up ecosystem increased substantially over the last decade and numerous political initiatives taken by governments helped in founding European start-ups. This is encouraging but Europe's start-ups are still hampered in terms of later-stage funding. As 4IR scale-ups are essential for Europe's competitiveness and in order to develop more global 4IR leaders, the access of adequate growth funding needs to be improved.

With the lack of late-stage financing slowing the growth of EU start-ups, it will be essential to create a start-up ecosystem that both enables larger funding rounds (in particular for the later stages) and makes listing start-ups on European stock markets an attractive option. Europe needs to do even better in transforming scientific ideas into sound business models. So far the excellence of Europe's research landscape is not duly reflected in the form of 4IR champions. What is more, the collaboration between start-ups and industry incumbents could be strengthened by overcoming cultural barriers on both sides.

Our survey data point towards structural barriers to the growth of 4IR SMEs. These include market fragmentation as well as the availability of staff with the right skills. A smaller effective market size affects adoption of new technologies as it means less room to scale up technologies. The Digital Single Market Strategy championed by the European Commission aims at addressing these broader obstacles and enablers of digitalisation. Lack of staff with the right skills flags a need for policymakers to foster a system of lifelong learning that extends from basic skills in formal education to social and emotional skills in vocational training and higher education, and continuous training throughout working lives.

Figure 8.1

Policy support 4IR SMEs considered most useful (in %)



Source: 4IR survey

Base: 4IR innovators (excluding don't know / refused / no obstacle responses).

9. Conclusion

9. Conclusion

The purpose of this report is to shed light on SMEs that are active in 4IR patenting. As they bring novel and disruptive technology to market, 4IR SMEs are instrumental in shaping the global race to digital transformation. By benchmarking the impact, business profile and challenges of these companies in the EU, the US and other European countries, the report aims to inform policymakers, private decision-makers and investors of the specific challenges of growing deep tech businesses within Europe.

The report highlights that Europe not only lags behind the US when it comes to large ICT companies but also in terms of SME activity in deep tech. The US has roughly twice as many 4IR SMEs as the EU, despite the overall lower proportion of SMEs in the US economy. They contributed 16% of US 4IR patenting between 2010 and 2018, and have significantly larger 4IR patent portfolios on average. Within the EU, over 2 600 European SMEs contributed 10% of the bloc's 4IR patenting. There are significant differences between EU countries, however. Finland and Sweden in particular stand out with a higher concentration of 4IR SMEs than even the US, adding to the presence of global 4IR leaders such as Nokia and Ericsson.

Analysis of the main markets and growth trajectories of 4IR SMEs reveals other differences between the EU and the US. Currently, 32% of the EU's SMEs still focus primarily on operations in their home country, with growth plans mainly targeting the European market (52%), as also reflected in the geographical scope of their patent portfolios. By contrast, US 4IR SMEs cite the entire US domestic market as a priority for both current and future growth, as well as for patent filings. Interestingly, more than every third EU 4IR SME that has been acquired was acquired by a US company.

European and US 4IR SMEs have very similar profiles. A relatively large proportion (43%) of these SMEs are involved in manufacturing (developing, building and selling physical products), as opposed to service-based or platform-based business models for the remainder. Overall, almost 90% of 4IR SMEs have successfully implemented their 4IR technologies in products and services or in their own business.

Crucially, 4IR SMEs differ significantly from other SMEs with respect to their investments and capital needs. For instance, our survey results reveal the higher investment intensity of EU-based 4IR SMEs, as well as their strong investment focus in 4IR-related innovation. On average, 4IR SMEs listed on Crunchbase also received substantially greater funding than a benchmark group of SMEs, especially during the build and growth stages.

Survey data point toward various structural barriers that hamper 4IR SMEs in bringing new technology to market. Specifically, firms consider the availability of finance and shortage of staff with the required technical skills to be their main obstacles in introducing or developing 4IR technologies. They also differ from other SMEs in these respects. Compared with other SME categories, 4IR SMEs more frequently report the availability of finance as a major issue.

4IR SMEs are telling us that financial backing and assistance in identifying new markets and customers would give them the most support. In addition to addressing the structural bottlenecks identified, policymakers should work to ensure strong demand for new generations of 4IR SMEs as well as a flourishing ecosystem overall.

The results of this study open various avenues for future research. The analysis firstly highlights the importance of local 4IR innovation ecosystems involving large, international companies as well as universities alongside 4IR SMEs. Further research is needed to analyse these ecosystems, their respective strengths and dynamics, as well as the structural conditions and policy levers that can support their further development towards a smart specialisation in 4IR technologies.

Further investigation of the funding conditions available to European and US SMEs is also necessary to document the current obstacles to growth that seem to persist in Europe, and available policy levers to address these obstacles. In particular, we find that 41% of 4IR SMEs in the EU27 received funding from public investors, compared with only 12% of US ones. A deeper comparative analysis of these two patterns of funding would help to better understand their impact on the growth and business performance of SMEs.

While the study is based on a comparison between Europe and the US, other potential benchmark countries could also be considered. China and R. Korea in particular have managed to close the gap in 4IR innovation with respect to the other leading innovation centres over the last decade, even overtaking the EU27's contribution to 4IR IPFs in 2017 (see Figure 2.1). A comparison with these two countries could provide additional insights into the role of SMEs in catching-up and in establishing a competitive 4IR innovation landscape.

Annex

Annex 1 Identification of SMEs with international patent families related to 4IR technologies

Identification of 4IR international patent families

Patents are strictly territorial. To protect a single invention in multiple markets, a number of national or regional patents is required. A large number of patents, therefore, does not necessarily mean a large number of inventions. A more reliable measure is counting international patent families (IPFs), each of which represents a unique invention and includes patent applications filed and published in at least two countries. [17] IPFs are a reliable and neutral proxy for inventive activity because they provide a degree of control for patent quality and value by only representing inventions deemed important enough by the applicant to seek protection internationally. A relatively small proportion of applications meet this threshold. This concept enables a comparison of the innovative activities of countries and companies internationally since it creates a sufficiently homogeneous population of patent families that can be directly compared, thereby reducing the national biases that often arise when comparing patent applications across different national patent offices.

In addition, almost all IPFs are classified according to the Cooperative Patent Classification (CPC) scheme (this is not always the case with applications filed solely at one office). Only one scheme is therefore needed to identify relevant inventions and assign them to the different technologies in the cartography, irrespective of where the applications were filed. Each IPF identified as relevant to 4IR technologies is assigned to one or more sectors or fields of the cartography. The date attributed to a given IPF always refers to the year of the earliest publication within the IPF. The geographic distribution of IPFs is calculated using information about the origin of the inventors disclosed in the patent applications. Where multiple inventors were indicated on the patent documents in a family, each inventor was assigned a fraction of the patent family.

17 An IPF is a patent family that includes a published international patent application, a published patent application at a regional patent office or published patent applications at two or more national patent offices. The regional patent offices are the African Intellectual Property Organization (OAPI), the African Regional Intellectual Property Organization (ARIPO), the Eurasian Patent Organization (EAPO), the European Patent Office (EPO) and the Patent Office of the Cooperation Council for the Arab States of the Gulf (GCCPO).

Linking 4IR technology to patent data

The cartography of 4IR technologies was created in three steps.

Step 1: Mapping the cartography to the patent classification scheme

The cartography is based on the in-depth knowledge of EPO patent examiners. Patent classification experts from all technical areas were asked to indicate which field ranges of the Cooperative Patent Classification (CPC) scheme they would assign 4IR inventions to, and to which fields of the cartography these ranges should be attributed. The resulting concordance table contains around 368 CPC field ranges in all technical areas with their respective 4IR technology fields. The cartography was verified by applying ad hoc queries against the EPO's full-text patent database and analysing the results using text mining techniques. Whenever anomalies were identified they were re-assessed by classification experts and corrected/amended where necessary.

Example

CPC range	Description	4IR fields
G16H10/00 - G16H80/00	Medical informatics	Consumer goods, healthcare
B60K31/00 - B60K31/185	Vehicle control, e.g. automatic speed control	Vehicles

Step 2: Identifying 4IR patent applications

On all patent documents in the identified CPC ranges, a full-text search query was applied to identify documents related to the 4IR definition with the highest degree of certainty placed on true positives. As a general restriction, all documents had to contain the concept of data exchange, even if this was not itself the inventive aspect of the patent application. In addition, further subqueries were defined to include the concepts of communication (e.g. internet, mobile, wireless), computing (e.g. big data, cloud, artificial intelligence) and intelligent devices (e.g. sensor networks, Internet of Things, smart homes).

Step 3: Classifying patent applications to the cartography fields

All the patent documents associated with each field in the cartography were extracted and labelled with said field. Finally, all the retrieved patent documents were combined in a final set of unique patent documents with the corresponding cartography fields. The combination of the cartography fields defined the characteristic 4IR technology fields of the patent application.

Examples:

- CPC codes assigned to patent application or cited documents: A61B5/68, B60D1/075
- Corresponding CPC field ranges in 4IR cartography: A61B5/68 – A61B5/6802, B60D1/01 – B60D1/075
- Cartography fields mapped to patent application: Personal, Connectivity, Vehicles

For the purposes of this study, the statistics on 4IR patent applications are based on a simple count method, reflecting the number of patent families, or inventions, assigned to a particular field or sector of the cartography, independently of whether some of these patent families are also classified in other fields or sectors. For example, a patent family assigned to two fields of the same sector is counted as a single invention at sector level and as one invention in each of the technology fields. Accordingly, an invention assigned to two fields in two different sectors is counted as one invention in each of the two technology sectors and as one invention in each of the technology fields.

Identification of SMEs with 4IR international patent families using Orbis and Crunchbase databases

The internal EPO database of patent applications was matched to the Crunchbase and Orbis company databases using a "fuzzy" procedure in line with previously proposed approaches in the literature, such as the one described in detail by Tarasconi and Menon (2017). The matching procedure exploits the available overlapping information across the two databases represented by company name and location. The procedure is based exclusively on the patent applicant information and does not consider inventor information, given the high level of false positives that this approach would have produced.

A final manual consolidation and cleaning step was performed on the matched dataset to avoid false positives and maximise the number of correct matches.

Annex 2 4IR survey methodology

The main subject of the survey was to collect information on small and medium-sized companies (SMEs), which are developing and/or applying technology that can be categorised under the Fourth Industrial Revolution (4IR). Companies were identified based on matching patent applicant data with the two company databases Orbis and Crunchbase.

The criteria of each company in the target population were defined as:

– a company filing at least one patent application in the 4IR technology category that was part of an international patent family (IPF) with an earliest publication date after 2009
– a company fitting the definition of a small or medium-sized company. If information was available, the European SME definition [18] was applied; if not, the 250-employee threshold applied.

The target respondents were defined as individuals who are responsible for operative business and/or technical/financial decisions in patent matters at a specific company.

To ensure high response rates, the target persons were able to answer the questionnaire in CATI or CAWI interviews. Furthermore, the survey was offered in three languages: English, French and German. The interviews were conducted between June and October 2021. On average, the interviews on the "business" part took around 26 minutes in computer-assisted telephone interviews (CATI) version and 17 minutes in computer-assisted web interviews (CAWI).

Sampling

The survey focused on existing and operating companies that had not been acquired at the time of the fieldwork. Therefore, companies not meeting these criteria had to be eliminated from the target population for the weighting of the net sample. Finally, N=7 104 units were established as "valid companies" in the final target population, N=3 270 in Europe and N=3 834 in the United States. Since the aim was to contact each company in the complete final target population, quotas were not applied in the fieldwork.

The response rate (calculated by processed sample units, divided by complete interviews) varied in the European regions from 13.3% to 20.5%, except for the United Kingdom, where the response rate was the lowest at 8.4%. For the United States, the response rate was the lowest overall at 4.5%. The net sample resulted in N=625 complete interviews. N=455 companies from Europe and N=170 companies from the United States contributed interviews to the net sample. N=521 (83%) of the net sample were companies with 50 or fewer employees. N=48 (8%) of the net sample were companies operating for under five years.

Table A 2.1

Breakdown of the fieldwork outcome

Region	Valid companies	Complete interviews	Response rate (%)
Western EU without Germany	691	85	13.4
Germany	353	46	13.3
Scandinavia without Norway	545	103	18.9
Southern EU	493	85	17.5
Remaining EU	114	18	15.8
UK	764	57	8.4
Switzerland and Norway	310	61	20.5
United States	3 834	170	4.5
Total	**7 104**	**625**	

Note: Western EU without Germany (Austria, Belgium, France, Ireland, Luxembourg, Netherlands), Scandinavia (Denmark, Finland, Sweden), southern EU (Cyprus, Greece, Italy, Malta, Portugal, San Marino, Spain), remaining EU (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia).

18 See https://ec.europa.eu/growth/smes/sme-definition_de.

Weighting

The net sample of N=625 cases was adjusted by weighting to best reflect the population in terms of its proportions. The valid companies of the final target population (N=7 104) were used as the basis for the weighting. In general, the weighting factors were moderate as the proportions of the final target population were approximately met by net sample. The exception was the global weight to balance the proportions between the United States and Europe. As the response rate for the United States was significantly lower than for Europe, the US net sample had to be weighted up with relatively high weights to balance the proportion between the United States and Europe. Furthermore, to provide enough cases in each cell of the net sample, western EU and Germany were joined together, as well as Switzerland, Norway and the United Kingdom.

Table A 2.2

Weights: global (adjustment between Europe and the US)

Region (global)	Weights	Weighted N
Western EU incl. Germany	0.69	91
Scandinavia	0.48	49
Southern EU	0.50	42
Remaining EU	0.56	10
Other Europe (UK, Switzerland, Norway)	0.82	97
United States	1.98	336

Questionnaire

The questionnaire is provided in a separate Annex.

EIBIS

The EIB carries out an annual survey of firms in the EU (EIBIS General Module) with the aim of monitoring investment and investment finance activities, and at the same time capturing potential obstacles to investment. The survey covers approximately 12 500 companies across the EU and the United Kingdom every year, with just over 800 firms in the United States for the last three waves. It is administered by telephone (in the local language) and takes an average of 20 minutes. The first wave of the survey took place in 2016 and the survey completed its sixth wave in 2021, with interviews taking place between April and July 2021.

Using a stratified sampling methodology, the EIBIS General Module is representative across all 27 EU member states, the United Kingdom and the United States. It is representative across four firm size classes (micro, small, medium and large) and four sector groupings (manufacturing, services, construction and infrastructure) within the individual countries.

Firms have to have a minimum of five employees in order to be interviewed, with full-time and part-time employees being counted as one and employees working under 12 hours per week excluded. Eligible respondents are senior employees with responsibility for investment decisions.

The survey is designed to build a panel of observations over time and is set up in such a way that survey data can be linked to firms' reported balance sheet and profit-and-loss data (see EIBIS-Orbis matched dataset below). Approximately 40% of the companies interviewed in each wave are companies that took part in the survey in the previous wave.

The EIBIS General Module complements pre-existing information on investment activities in the EU. It adds a firm-level dimension to the macroeconomic data available, thereby allowing for more fine-grained analysis of investment patterns. It also adds to existing firm-level national surveys by providing full comparability of results across countries. The survey complements the European Commission investment survey by asking a much wider set of both qualitative and quantitative questions on firm investment activities and the European Central Bank / European Commission SAFE survey by focusing on the link between firm investment and investment finance decisions.

Table A 2.3

EIBIS at a glance

27	EU member states are all consistently represented in the survey – more specifically, non-financial enterprises with at least five employees and assigned to NACE categories C to J.
4	industry groupings and size classes determine the representativeness of the data in almost every member country.
11 920	firms belonging to the EU participated in the last wave of the survey.
802	US firms participated in the last wave of the survey.
43%	of all firms participating in the last wave responded for at least two consecutive waves.
89%	of firms surveyed in 2021 agreed to be contacted again for next year's survey.

The EIBIS is a powerful instrument, built according to the highest scientific standards. To guarantee this, every step of the survey process is executed and monitored closely by experts in the field. All steps – sampling and weighting, questionnaire development and translation, the fieldwork, and quality control and data processing – are also subject to strict controls and validation. Further information on these technical aspects can be found in the technical report produced by the market research company conducting the survey (Ipsos MORI, 2020). Table A.3.1 presents key facts and figures about EIBIS.

All aggregated data using the EIBIS General Module in this report are weighted by value added to better reflect the contribution of different firms to economic output. The aggregate survey data and a detailed account of the survey methodology are available at www.eib.org/eibis.

Annex 3 4IR-based indicators: country comparison

Table A 3.1

4IR-based indicators: country comparison

	Number of 4IR SMEs per GDP (billion USD)	Number of 4IR SME patents per million capita	Proportion of 4IR patents originating from SMEs (2010-2018)	Average number of 4IR patents per SMEs
EU27	**0.17**	**10.83**	**10%**	**1.8**
Germany	0.15	12.78	6%	1.9
France	0.15	13.46	13%	2.3
Italy	0.14	6.31	22%	1.4
Finland	0.99	91.85	13%	1.9
Sweden	0.44	45.88	7%	2.0
Netherlands	0.18	16.23	6%	1.7
Spain	0.12	4.90	19%	1.5
Denmark	0.31	31.90	17%	1.7
Belgium	0.21	14.97	18%	1.6
Austria	0.24	21.76	18%	1.8
Ireland	0.24	39.44	32%	1.9
Europe (EPC)	**0.20**	**11.60**	**12%**	**1.8**
UK	0.35	25.81	20%	1.8
Switzerland	0.34	57.66	25%	2.0
Norway	0.32	36.25	43%	1.7
US	**0.30**	**47.51**	**16%**	**2.5**

References

EPO, "Market success for inventions: Patent commercialisation scoreboard: European SMEs", 2019. epo.org/scoreboard-smes.

EPO, "Patents and the Fourth Industrial Revolution: The global technology trends enabling the data-driven economy", 2020. epo.org/trends-4IR.

EPO and EUIPO, "Intellectual property rights and firm performance in the European Union", 2021. epo.org/ipr-performance.

EIB Investment Report 2019/2020: accelerating Europe's transformation, 2019. https://www.eib.org/en/publications/investment-report-2019

EIB, "Digitalisation in Europe 2020-2021", 2021. Luxembourg: European Investment Bank. https://www.eib.org/en/publications/digitalisation-in-europe-2020-2021

EIB, "Recovery as a springboard for change 2021/2022", 2022. Luxembourg: European Investment Bank. https://www.eib.org/en/publications/investment-report-2021

EIF, "The European venture capital landscape: an EIF perspective", 2017. Working Paper 2017/41. Available at https://www.eif.org/news_centre/publications/EIF_Working_Paper_2019_55.pdf

EIF VC Survey 2019, "Fund managers' market sentiment and policy recommendations". Working Paper 2019/59. Available at https://www.eif.org/news_centre/publications/EIF_Working_Paper_2019_59.pdf

EUIPO, "Intellectual Property SME Scoreboard 2019", 2019. https://euipo.europa.eu/ohimportal/en/web/observatory/sme-scoreboard#2019

European Commission, "Shaping the digital transformation in Europe", September 2020. A study prepared for the European Commission, DG Communications Networks, Content and Technology. https://op.europa.eu/en/publication-detail/-/publication/917c520f-fd56-11ea-b44f-01aa75ed71a1.

Hochberg, Y. et al., "Whom You Know Matters: Venture Capital Networks and Investment Performance", 2007. Journal of Finance, Volume 62, pp. 251-301. https://onlinelibrary.wiley.com/doi/10.1111/j.1540-6261.2007.01207.x

Howell, S. T., "Financing Innovation: Evidence from R&D Grants", 2017. American Economic Review, 107(4), 1136–64. https://www.aeaweb.org/articles?id=10.1257/aer.20150808

Mind the Bridge, "Startup Transatlantic M&As: US vs. EU", 2016. Available at https://startupeuropepartnership.eu/wp-content/uploads/2016/09/Startup-Transatlantic-MAs_MTB-Crunchbase_2016.pdf.

Tarasconi, G. and Menon C., "Matching Crunchbase with patent data", 2017. Working paper, OECD. https://ideas.repec.org/p/oec/stiaaa/2017-07-en.html

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Authors
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