Europäisches Patentamt
European Patent Office
Office européen des brevets

New frontiers in oncology: an evolving innovation ecosystem

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Foreword

Cancer is a pervasive crisis that touches lives, families, and societies. One in twenty Europeans will confront cancer firsthand – an alarming statistic that is set to rise as populations age, making the fight against the disease one of the most urgent health challenges of our time.

This challenge demands a holistic, innovative approach that integrates advanced technologies, collective action, patent trends, and well-resourced, data-driven efforts to ultimately spur targeted advancements in cancer care. It is a mission that transcends individual expertise and requires a free, accessible flow of actionable knowledge to the frontlines where it can make the most impact.

Patents, in particular, play a vital role in forging this innovative ecosystem. They enable diverse stakeholders to engage in the development and dissemination of next-generation cancer-fighting technologies. Besides mobilising investment, patent protection enables cooperation and technology transfer between highly specialised research institutions and industry, including universities and SMEs, driving the next big breakthrough to combat cancer effectively.

This new study – New frontiers in oncology – builds upon the EPO's longstanding commitment to health-related innovation, shedding new light on the high-growth technologies transforming cancer diagnostics and therapeutics. Drawing on the power of patent information, this report deepens the insights from the EPO's Observatory on Patents and Technology's first study on the topic, published in February 2024, which systematically examined global trends since the 1970s.

Focusing on a new framework for identifying high-growth technologies, the study delves into emerging fields such as healthcare informatics, liquid biopsies, and gene therapy, while offering fresh insights into established yet fast-moving areas like immunotherapy and other alternative, cutting-edge approaches. As the findings reveal, these breakthrough technologies have driven a surge in oncological inventions since 2015, thanks to diverse innovation ecosystems that continue to evolve.

While Europe has witnessed an increase in patent applications, it struggles to maintain a competitive edge in high-growth areas. The study also highlights a critical gap: Europe is home to many innovative startups but falls short in scaling them to advanced growth stages. To tackle this, the study is backed by the EPO's Deep Tech Finder, a free tool that tracks European investment-ready startups, including some 1 800 active across various oncology-related fields.

Building on the landmark EU reports on competitiveness by Mario Draghi, and on the future of the European single market by Enrico Letta, the findings of this EPO study serve as another critical addition, highlighting urgent challenges within Europe's oncological innovation system. To remain at the forefront of global cancer research and fast-paced technological advancements, European stakeholders must respond with agility and foresight. To aid this dynamic landscape, the EPO offers a free online platform: Technologies combatting cancer, providing innovators, researchers, and policymakers with the tools to navigate and harness the potential of emerging innovations.

The second edition of this study reflects an expanded collaborative effort between experts from the EPO's Observatory on Patents and a broader team from 20 national patent offices across our member states including. Doubling participation of the first study, it stands as a testament to the power of cooperation in advancing healthcare.

With the right technologies, tools, perspectives, and collaboration, the vision of a world where cancer is no longer an impossible fight but a challenge we can win, draws closer to reality.

António Campinos
President, European Patent Office

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List of abbreviations

AI	Artificial intelligence
ARIPO	African Regional Intellectual Property Organization
ASR	Age-standardised rates
ATMP	Advanced therapy medicinal products
CAGR	Compound annual growth rate
CAR-T	Chimeric antigen receptor T-cell
CRISPR	Clustered regularly interspaced short palindromic repeats
CT scan	Computed tomography scan
DNA	Deoxyribonucleic acid
DSA	Norwegian Radiation and Nuclear Safety Authority
EAPO	Eurasian Patent Organization
ECL	European Cancer League
EFTA	European Free Trade Association
EMA	European Medicines Agency
EMAN	European Medicines Agencies Network
EML	Essential medicines list
EPO	European Patent Office
FDA	Food and Drug Administration (US)
GCCPO	Patent Office of the Cooperation Council for the Arab States of the Gulf
HDAC	Histone deacetylases
ICT	Information and communications technology
IP	Intellectual property
IPF	International patent family
IPR	Intellectual property right
MRI	Magnetic resonance imaging
mRNA	Messenger ribonucleic acid
NCA	National competent authorities
NPO	National Patent Office
OAPI	African Intellectual Property Organization
OCE	Oncology Center of Excellence
OPS	Open Patent Services
PDT	Photodynamic therapy
PET	Positron emission tomography
PRO	Public research organisation
R&D	Research and development
SME	Small and medium-sized enterprise
TIL	Tumour-infiltrating lymphocytes
TTF	Tumour treating fields

List of countries and regions

AL	Albania
AT	Austria
BE	Belgium
BG	Bulgaria
CH	Switzerland
CN	People's Republic of China
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IS	Iceland
IT	Italy
JP	Japan
KR	Republic of Korea
LI	Liechtenstein
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
ME	Montenegro
MK	North Macedonia
MT	Malta
NL	Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
RoW	rest of the world
RS	Serbia
SE	Sweden
SI	Slovenia
SK	Slovakia
SM	San Marino
TR	Türkiye
UK	United Kingdom
US	United States

EU27

27 member states of the European Union

Other Europe

Member states of the European Patent Organisation that are not part of the EU27, (countries) i.e. AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK.

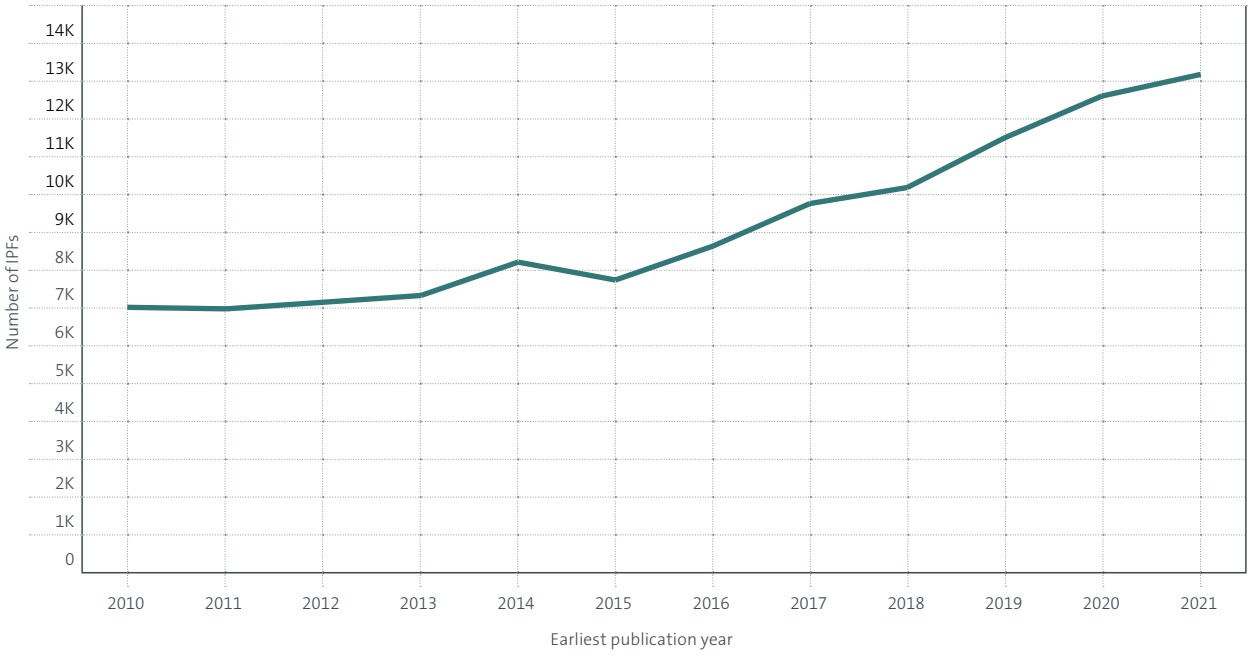
Executive summary

The health sector remains a cornerstone of European competitiveness, as highlighted in the Draghi report on The Future of European Competitiveness (Draghi 2024a, 2024b), underscoring the strategic importance of fostering innovation in this domain. The purpose of this study is to identify the most promising cancer-related technologies. It introduces a framework for categorising 28 distinctive cancer technology fields and deepening our understanding of the recent acceleration in cancer-related innovation. After identifying a set of future growth technology fields, this study evaluates Europe's contribution to them, while examining the pivotal roles played by public research institutions, including universities, public research organisations (PROs) and hospitals and startups. By doing so, it provides new perspectives on the actors and innovations driving progress in cancer-related technologies across Europe.

This study is a crucial extension of a first EPO study on patents and innovation against cancer published in February 2024 (EPO, 2024a). Our initial study comprehensively mapped cancer-related technologies and highlighted the critical role of actors beyond large pharmaceutical companies, such as universities and PROs. It raised important questions about what is driving the recent high-growth phase, how innovation dynamics are evolving at the frontier of cancer research and what strategies the different players are employing. This second study addresses these questions by focusing on the most promising fields of cancer technology and examining the contributions of diverse innovators across various regions and sectors. It provides deeper insights into the trends currently shaping the innovation landscape in the fight against cancer. Based on the lifecycle stage and innovation trajectory indicated by patent activity, it also helps policymakers, researchers and industry stakeholders to target their research and development efforts, investments and policies by equipping them with actionable insights.

Figure E1

Trend in IPFs in cancer-related technologies, 2010-2021



Source: EPO

Key findings

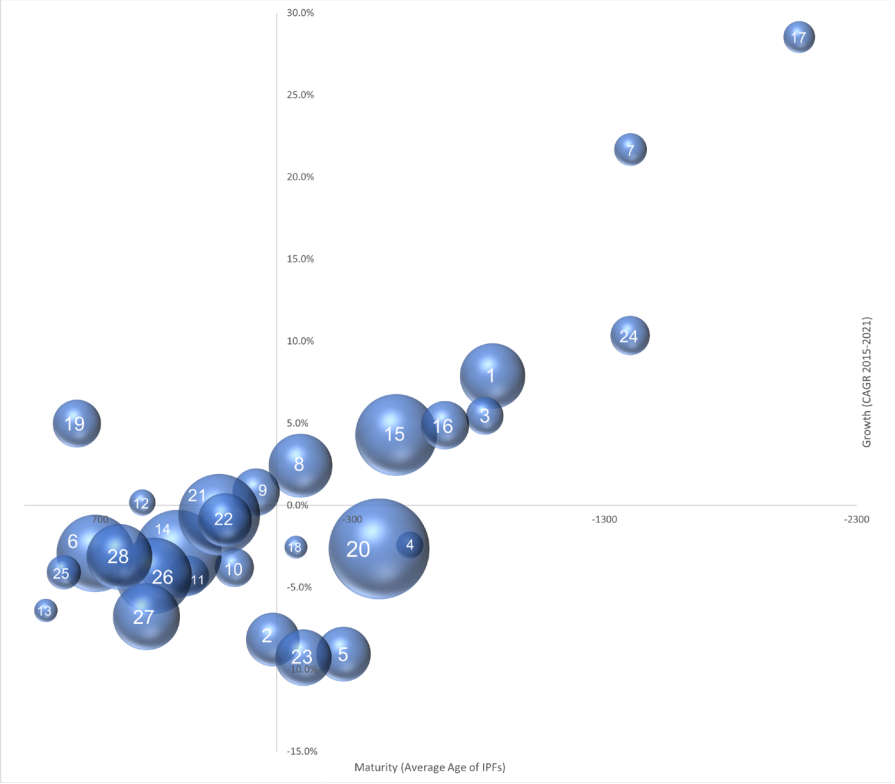
1. Patent data help identify technologies that have been driving the recent surge in cancer-related innovation

After a period of near stagnation with a compound annual growth rate (CAGR) of just 1.7% between 2010 and 2015, patenting activity in cancer-related technologies experienced a significant surge, growing at a CAGR of 9.3% between 2015 and 2021 (Figure E1). This was more than three times faster than the CAGR in all technology fields over the same time period (CAGR in IPFs in all technology areas was 3.0% between 2015 and 2021). Leveraging the expertise of EPO examiners, this study categorises cancer innovation into 28 distinctive technology fields, identifying 11 of them as growing at an even faster pace during this period of accelerated activity (Figure E2).

Among them are the relatively young technologies, as measured by the average age of all international patent families (IPFs) in the field, such as healthcare informatics, image analysis, liquid biopsies, immunotherapy with antibodies, cellular immunotherapy, immunotherapy with small molecule immunomodulators, non-coding nucleic acids and gene therapy, as well as more mature technology fields such as well-established immunotherapy approaches (e.g. cytokines and oncolytic viruses) and certain physical treatments (e.g. photodynamic therapy and tumour treating fields), but also alternative treatments and prevention (e.g. extracts from plants and animal tissue).

Figure E2

Distribution of the 28 cancer technology fields according to growth (CAGR 2015-2021, y-axis), maturity (average age of all IPFs, x-axis) and relative size (number of IPFs and size of the circle)



Cancer technology fields

1 Liquid biopsies
2 Tumour biopsies
3 Healthcare informatics
4 Bioinformatics
5 Personalised medicine
6 Hormonal therapy
7 Gene therapy
8 Non-coding nucleic acids
9 Alternative treatments and prevention (e.g. extracts from plants and animal tissue)
10 Surgery
11 Radiotherapy
12 Other physical treatment (e.g. photodynamic therapy, TTFs)
13 Mitigating side effects
14 Cancer models
15 Immunotherapy - Antibodies
16 Immunotherapy - Small molecule immunomodulators
17 Immunotherapy - Cellular
18 Immunotherapy - Vaccines
19 Immunotherapy - Other approaches (e.g. cytokines, oncolytic viruses)
20 Targeted therapy - Protein kinase inhibitors
21 Targeted therapy - Other small-molecule targeting agents (e.g. HDAC, angiogenesis, proteasome inhibitors, etc.)
22 Targeted therapy - Conjugates
23 Imaging apparatus
24 Image analysis
25 Imaging agents
26 Chemotherapy - DNA damaging agents
27 Chemotherapy - Anti-tubulin agents
28 Chemotherapy - Antimetabolites

Source: EPO

2. While US and Chinese applicants expanded their patenting activity in high-growth cancer technologies, European applicants struggle to keep pace

The recent growth period in cancer-related patenting activity after 2015 was primarily driven by US applicants, who consolidated their dominance in cancer-related innovation, accounting for 44.6% of all cancer-related IPFs between 2010 and 2021. With a share of 9% over the same period, Chinese applicants significantly increased their annual output over time, surpassing the EU27 in 2021 with over 2 000 IPFs filed that year. Europe remains a strong contributor, with EU applicants generating over 17 800 IPFs between 2010 and 2021 and an additional 7 500 IPFs from other EPO member states, collectively representing a 23.9% share over the period 2010-2021.

However, despite increasing absolute numbers of IPFs, the performance of the EU after 2015 faced headwinds. EU applicants experienced a decline in market share across all high-growth cancer technology fields from 2010-2015 to 2016-2021 (Figure E3). The largest share loss for EU applicants was in cellular immunotherapy (-6.2 percentage points), while the smallest decline was in healthcare informatics and non-coding nucleic acids (-4 percentage points). In contrast, US applicants maintained or increased their shares in most high-growth fields, while Chinese applicants achieved significant growth in shares across all cancer-related technology fields.

Figure E3

Change in shares in IPFs in high growth technology by major innovation centre (2010-2015 vs. 2016-2021, in percentage points)

*AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

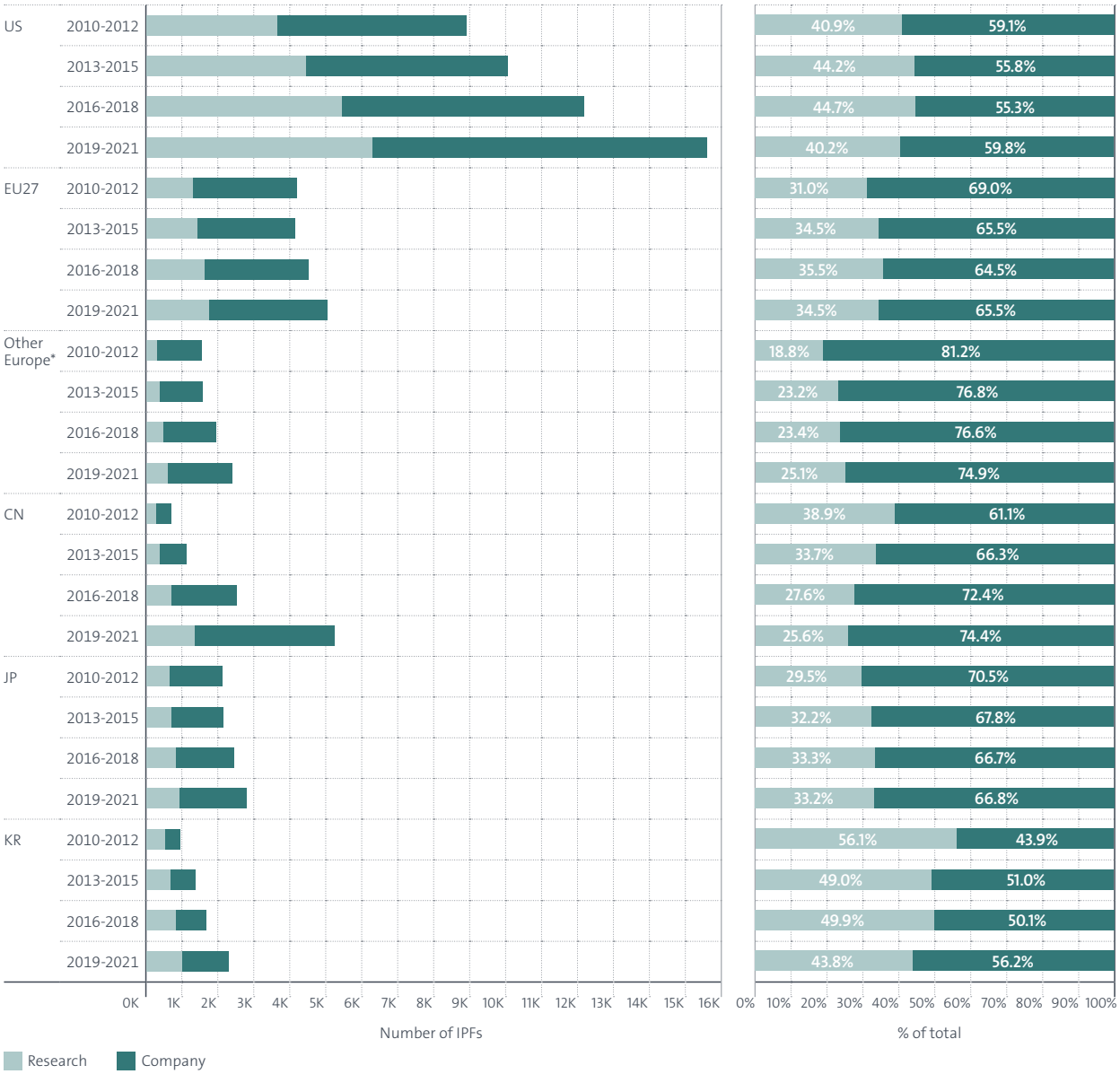
Source: EPO

3. While the research sector drove cancer-related patenting with 37.3% of all IPFs between 2010-2021, their contribution varies widely by country, technology and over time

Cancer-related innovation demonstrates a strong dependence on science-driven research originating from universities, public research organisations and hospitals. As Figure E4 shows, in the US, institutions from the research sector maintained a very high share of its country's cancer-related IPFs, peaking at 44.7% during the initial growth phase (2016-2018). However, their share declined to 40.2% in 2019-2021, indicating that US companies started to expand their cancer-related patent portfolios at a faster pace than US research institutions, especially in high-growth technology fields. Similarly, EU research institutions increased their share of the EU's total cancer-related IPFs from 31% in 2010-2012 to a peak of 35.5% in 2016-2018, before experiencing a slight decline to 34.5% in 2019-2021. Their contributions to individual technology fields generally mirrored the trends observed for EU companies, reflecting a strong alignment in innovation efforts across both the public and private sectors. Conversely, Chinese research institutions saw a sharp drop in their share in cancer-related IPFs from Chinese applicants, from 38.9% in 2010-2012 to just 25.6% in 2019-2021, as companies became the dominant drivers of the P.R. China's patenting surge in almost all cancer technology fields.

Figure E4

Contribution of research institutions to cancer-related IPFs in major innovation centres, 2010-2021



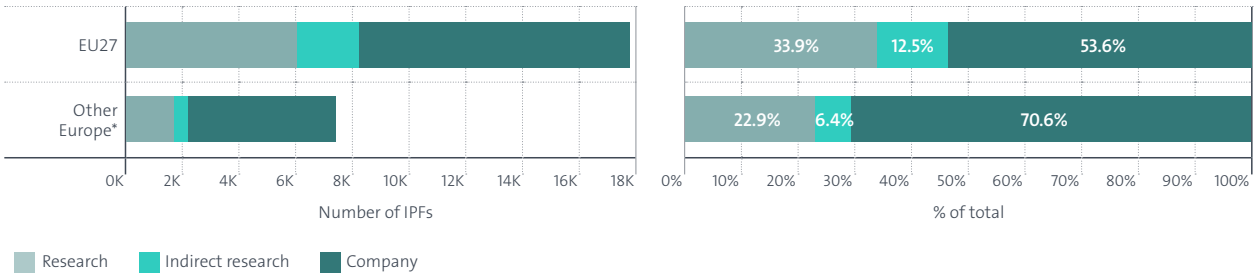
*AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

Beyond direct patenting activity, European research institutions had a significant indirect impact, with 12.5% of all EU cancer-related IPFs and 6.4% of all IPFs from other EPO member states between 2010 and 2021 originating from research institutions but filed by companies (Figure E5). Including these contributions, nearly half of all cancer-related IPFs from EU applicants and nearly 30% in other EPO member states trace their origins to research institutions.

Figure E5

Direct and indirect contribution of European research institutions to cancer-related IPFs, 2010-2021



*AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

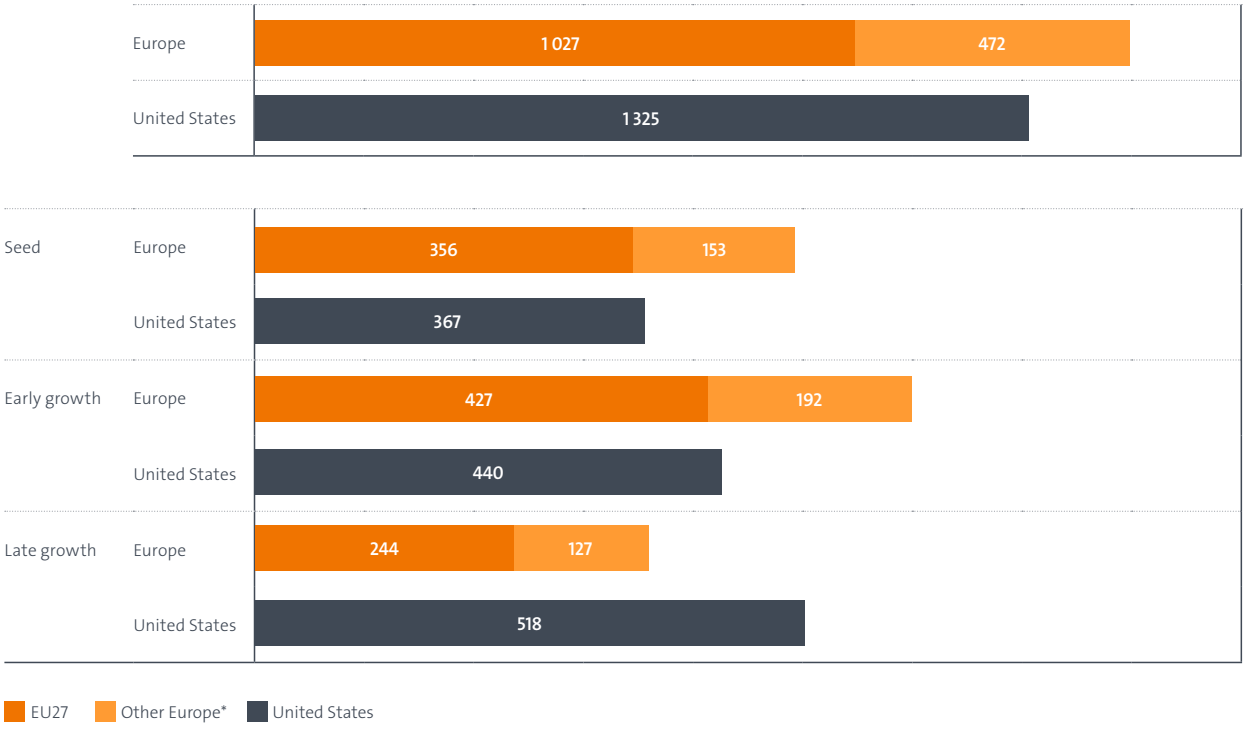
4. With nearly 1 500 entities, Europe hosts a larger number of cancer-related startups than the US, but fewer European startups successfully scale to late growth stages

There are almost 1 500 cancer-related startups, including 1 027 in the EU and an additional 472 in other EPO member states, that are applicants of cancer-related IPFs published in 2010 or after (Figure E6). In comparison, the US has 1 325 cancer-related startups. Among all EPO member states, the UK takes the top spot with 290 startups, while France leads within the EU with 246 startups, followed by Germany with 208, while Switzerland ranks fourth overall with 151.

However, when considering the growth stage of these companies, a stark difference emerges. While Europe clearly exceeds the US in the number of startups in the seed and early growth stages, the US significantly outpaces Europe in scaling startups to the late growth stage. Nearly 40% of US cancer-related startups have reached this advanced stage, compared to just 24% in the EU and slightly under 27% in other EPO member states. In the EU, the largest share of startups (41.6%) remains in the early growth stage, while another 34.7% are still in the seed stage, indicating the challenges European startups may face in scaling successfully.

Figure E6

Cancer-related startups in Europe and the US by growth stage of the company



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

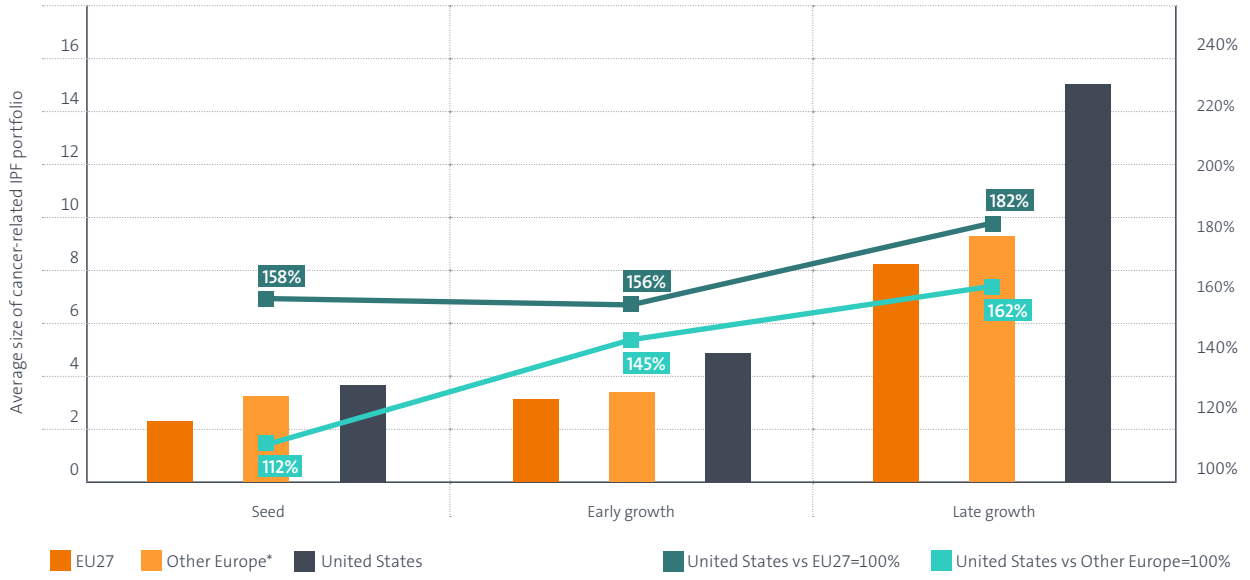
5. US startups hold significantly larger patent portfolios than their European counterparts across all growth stages

US startups have significantly larger cancer-related patent portfolios than their European counterparts, with an average of 8.55 IPFs per company compared to 4.07 in the EU and 4.95 in other EPO member states (Figure E7).

This trend holds across all growth stages: US late-growth startups hold 82% more IPFs than EU counterparts, while seed-stage and early-growth US startups exceed EU portfolios by 58% and 56%, respectively. Startups in other EPO member states outperform EU startups, but still lag behind the US. This could highlight the stronger patenting activity and strategic use of intellectual property rights (IPR) by US startups in scaling their innovations.

Figure E7

Comparison of average number cancer-related IPF portfolios of US and European startups across different growth stages, 2010-2024



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

1. Introduction

1.1. The oncology challenge in Europe

Cancer is a leading health threat in all populations and a serious contributor to global mortality. Worldwide, between 2018 and 2022, new cases of the disease grew from 18 to 20 million and deaths from 9.6 to 9.7 million (WHO, 2020 and 2022). The available numbers bring the facts into sharp perspective: oncologic and hematologic malignancies of various types currently cause about one in every six deaths globally, affecting nearly every household. The cancer burden will increase to about 77% by mid-century, putting further pressure on communities and healthcare systems worldwide (WHO, 2024).

Among the main global regions, Europe faces a substantial impact. Europe concentrates almost 25% of global incidence and a little over 20% of global mortality, while having a share of less than 10% of the total population (Ferlay et al., 2019). About one in 20 Europeans has faced a cancer diagnosis in their lives (de Angelis et al., 2024). Predominant forms of the disease in Europe are lung, colorectal, breast, pancreas and prostate, and the number of people who will live with cancer will increase due to ageing (European Commission, 2024).

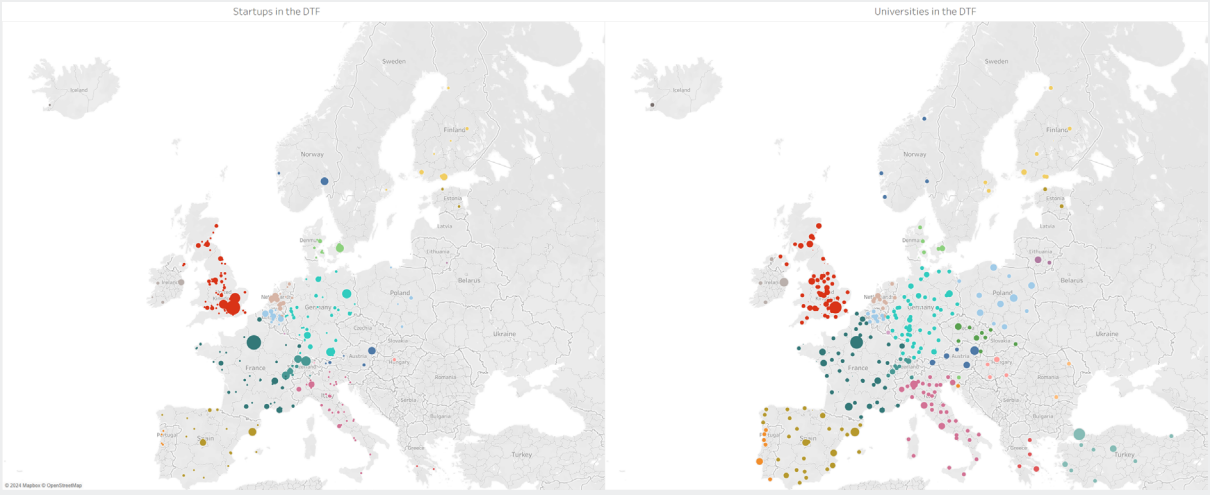
Survival prospects are nonetheless improving. More people are living with and beyond cancer. In European countries, developed healthcare systems are the first line of defence in this battle and offer many examples of excellence in a variety of dimensions, from prevention to patience experience (OECD, 2024). Progress, however, is uneven and hampered by access challenges across systems (Pérez et al, 2017; UICC, 2024).

To meet these challenges, the European Commission launched in 2021 the "Beating Cancer Plan", a comprehensive approach to tackling the cancer burden. This includes a reinforcement of traditional healthcare measures such as promoting healthier lifestyles, cancer prevention and early detection. Emphasis is also placed on improving access to high-quality, affordable and equitable diagnosis and treatment. Complementing these foundational healthcare strategies, the European Commission makes an additional pledge to give support to innovation and to advance the understanding of cancer mechanisms. The EU strategy therefore incorporates ten flagship actions and, together with the EU's Cancer Mission, the goal is to incentivise new technologies. Initiatives such as the development of advanced diagnostic tools and innovative treatments underline the EU's commitment to leveraging technology in the fight against cancer.

The EPO is aligned with these efforts and has contributed recently by adding insights from the technology intelligence perspective. The EPO launched an integrated project in 2024 that included a comprehensive analysis of cancer fighting technologies since the 1970s, an Espacenet technology platform for user exploration of the inventions, a focused webpage pulling together all European Inventor Award nominees in the cancer field, and a dedicated Deep Tech Finder filter for cancer-specialised startups.

This new study makes further use of the unique cartography of cancer-related patents that was originally developed by expert EPO examiners and national patent office (NPO) experts and resulted in a free new online tool, the EPO Deep Tech Finder, that facilitates searches for European universities, their spin-outs and other investment-ready startups with patent applications at the EPO in cancer-related technologies (Box 1). Fundamentally, this new study provides a deeper understanding of the shifting landscape of the latest technological advancements, the diversity of entities involved and the intensity of efforts on frontier oncology innovation in Europe. It focuses on the years after 2010 when technological developments accelerated and concentrates further on the high-growth segments of the technologies beating cancer. It makes use of new quantitative data on startups and further elaborates by presenting qualitative information on illustrative case studies. Overall, this analysis offers policymakers, regulators, researchers and industry stakeholders - from investors to incubator managers - practical baselines to determine where to focus R&D or strategic support, based on the growth dynamics and emergent patterns of oncological innovation as revealed by patent activity.

Box 1: Accessing the European startup scene through EPO's Deep Tech Finder



Source: EPO

The EPO Observatory on Patents and Technology has introduced the Deep Tech Finder (DTF), a digital resource aimed at simplifying the identification and analysis of startups across EPO member states that have filed European patent applications. Drawing on the EPO's extensive patent information, and futher integrating valuable data from a variety of sources, the DTF provides a new strategic window into the evolution of innovations in specific fields and their protection within the European patent framework.

Developed to serve entrepreneurs, investors, researchers, technology transfer offices and other stakeholders in the innovation ecosystem, this free resource enables users to explore industry and technology-specific criteria. By doing so, it helps uncover emerging enterprises with the potential to drive European-scale technological advancements.

The tool also brings to light links between academia and industry as it further facilitates searches for patents filed by universities and their spinouts, offering a comprehensive mapping of European universities with at least one EPO patent application. Finally, the DTF also allows users to identify investors based on the specific technologies behind the patents held by the startups they support.

Since February 2024 it is possible to identify entities with patent applications in 17 different oncology areas, ranging from ICT and cancer models to cancer diganostics and cancer treatment. In total, the DTF provides information on 1 797 European entities with at least one cancer-related EP application, of which 1 333 are startups in various growth stages and 464 universities.[1]

1.2. The innovation vector in the fight against cancer

In recent years, biomedical innovation has sparked public imagination and ignited debate as never before. The race to develop COVID-19 vaccines exemplified this phenomenon, alongside broader advances transforming medical practice and healthcare. Innovation has enabled more people to live longer, healthier and more fulfilling lives. As a result, technology and entrepreneurship have become central priorities for decision-makers and health system stakeholders This is also the case with cancer-fighting efforts.

Investment in research and development (R&D) in non-communicable diseases is significant and growing. Private industry stands paramount in the R&D execution effort and in the clinical phases of research in the field of cancer, but governments, universities and philanthropy are also leading funders of research, especially basic research. Schmutz et al. (2019) identified a total of 4 693 organisations from 107 countries engaged in funding cancer research between 2008 and 2018 with the following distribution: not-for-profit (49%), research sector (21%), private-for-profit (17%) and governments (12%). McIntosh et al. (2023), analysing global public and philanthropic cancer research funding, estimated a total investment of EUR 22.4 billion.

[1] The startups and investors featured in the Deep Tech Finder have been identified through a careful matching of European startups listed in Dealroom – a global data platform for intelligence on startups – with the EPO's own register of patent applicants. A similar approach was applied to universities by matching the European Patent Register to European universities listed in the European Higher Education Sector Observatory (EHESO) microdata.

Another way to access innovation dynamics is through patent data, but this literature has so far been limited. Studies are usually dedicated to particular types of cancer (e.g. Ramos et al., 2017) or specific technologies (Pradeep et al., 2017), rather than systematically covering all types of cancer and cancer-fighting technologies over multiple years and across all geographies. The uniqueness of patent indicators is their consistent coverage over time, their comparability across geographies and the level of detail regarding the specific technologies subject to significant advance. The relative advantage of this evidence base can be used to serve society.

In 2024, the EPO stepped in to assemble and analyse over 140 000 inventions against cancer that had been disclosed to the public from 1971 up to 2021. The observations are based on international patent families (IPFs) and derived from a technology cartography designed and curated by its examiners, i.e. the EPO's experienced internal specialists in cancer-related innovation.[2] The study documented a number of stylised facts for the first time, for instance: a dramatic surge after 2015, the dynamic growth of the US in this field, the relative stagnation of Europe after 2010, and the recent take-off of the P.R. China, which overtook the EU27 in 2021 in total number of IPFs. Within Europe, there are a number of trends: a slow decline in absolute patent filing from Germany starting in the mid-2000s, a shoot-up by the UK in the mid-2010s after some irregular movements, and a steady climb by Switzerland, France and the Netherlands throughout these years.

The robust standing of Europe in the high-tech market for cancer innovation can thus no longer be taken for granted, having lagged behind the dominant US as the world leader and lost protagonism to an emergent China.

1.3. Relaunching the dynamic capabilities of the European health industry

Fears of falling behind are not new, and date back to the 1970s and 1980s. After a couple of decades of post-war catching-up, (Western) Europe was trailing the US and Japan in the new general-purpose field of electronics, and stuck at a relatively slow rate of innovation in sectors in which it had traditional strengths, such as chemicals, machinery and production engineering. It managed to keep its number one ranking only in pharmaceuticals (Patel and Pavitt, 1987). Back then, the role of international competitive performance in terms of productivity growth, R&D investment and high-wage employment opportunities was only beginning to be more clearly understood. Popular policy guidelines among decision-makers and consultants in those years were about increasing entrepreneurial dynamism in the lagging countries and ensuring exploitation of the pervasive applications of information technology.

Is it different this time around? European firms do not hold leading advantages in a range of emergent technologies (Confraria et al., 2021). Apparently, as far as the health industry is concerned, executives and association representatives are sounding the alarm when they say that Europe has to make the sector a strategic priority at the same level as energy or semiconductors (Hudson, 2024), and when they stress that Europe has been losing competitiveness in terms of industry-sponsored clinical trial activities (Wilsdson et al., 2022).

The future of the EU's economic and commercial strategy was the object of two major reports published in 2024 (Annex 1). In April, Enrico Letta (2024), presented a comprehensive appraisal of the future of the single market and, in September, Mario Draghi (2024a, 2024b), presented an analysis aimed at scoping the future of European competitiveness. Both authors give a prominent place to the health sector in their reports and signal its capacity to overcome current challenges and make headway in the world-class opportunities it presents. Taken together, the reports underscore the need for an innovation-friendly regulatory environment to ensure the sustainability of the sector. They also indicate a refocusing on selected segments in fast evolving technologies and nascent markets which are predicated in stronger innovation ecosystems.

While universities, public research organizations (PROs), hospitals, and startups play a critical role in conducting disruptive cancer research and innovation, large pharmaceutical companies are indispensable part of the innovation ecosystem in bringing these breakthroughs to market. Startups often act as intermediaries, translating academic and clinical discoveries into scalable technologies.

[2] An international patent family (IPF) is a group of patent applications filed in multiple countries that protect the same invention. IPFs are a reliable measure of innovation because they focus on inventions deemed significant enough for international protection.

Large pharmaceutical companies take on the significant financial and regulatory commitments of advancing these innovations through clinical trials and securing approvals, a process that is resource-intensive and takes years to complete. By leveraging their complementary assets, expertise, and global reach, these companies further develop promising technologies, ensuring they meet rigorous safety and efficacy standards before achieving market introduction.

The growth of tomorrow's pivotal technologies is thus vital. An example of how this can be achieved in the field of cancer is through "combination solutions", that is, by bringing together dynamic capabilities on diagnostic and therapeutic offerings that draw on bodies of knowledge underpinning digital and biopharmaceutical sciences while deploying real-time big data resources and AI approaches. A case study on the iLoF startup gives an illustrative example of strategically positioning in an expansive niche in cancer-related value chains (see below).

1.4. Why this study?

The present report on cancer-fighting technologies succeeds a first project by the EPO, which included a pioneering patent-based landscaping study. That study rested upon a longstanding, but recently reinforced commitment, to sustainability and societal engagement. Health has been a prime mover of this orientation, and the EPO fully supports the UN Sustainable Development Goal "Ensure healthy lives and promote well-being for all at all ages" (SDG 3).

This new study provides a deeper and complementary follow-up to past EPO efforts on the health agenda (Annex 2) by focusing on the fringes of the oncological landscape, namely by identifying the most promising technologies and highlighting the roles of key players in those emergent opportunities. This new contribution marks a step forward by offering a global mapping and measuring the emergent drivers of technological and organisational activity in the fight against cancer. Examining the actors, factors and sectors behind the recent renaissance in oncological innovation may have instrumental value for those strategists and policymakers guiding research and entrepreneurial decisions, especially in Europe.

Credit: iLoF

Case study: iLoF

Headquarters/Offices: London, Porto and New York City
Products: Digital library of disease biomarkers

AI for biotech, accelerating personalised drug discovery and development

A new wave of ICT-based research tools is bringing new life to precise, patient-centric drug development. While, not long ago, industrial innovation in pharmaceuticals still arose from systematic trial-and-error experimentation with many bio-chemical methods and materials, the discovery and development process today are now being guided by a more data-driven understanding of phenomena.

Beginning at the Atlantic Ocean and expanding its reach

iLoF, which stands for "Intelligent Lab on Fiber", is a born-global biotech company that "enables a world where all biomarkers have a fingerprint." With corporate headquarters based in London, its offices bridge the Atlantic Ocean from the US to Portugal. The company, founded in 2019 and meanwhile grown to 30 employees, has filed three PCT patent applications at the EPO and features in the EPO Deep Tech Finder tool. It has received multiple rounds of funding, including EUR 4.89 million in 2022 and strategic investment from the Hamamatsu Corporation, a Japanese manufacturer of photonic devices and image analysing systems.

iLoF creates and curates a digital library of disease biomarkers. The focus is on cancer and Alzheimer's disease, where personalised medicine can make significant impact. Its capabilities consist of deriving value from a cloud infrastructure by integrating expert knowledge from physicists, biologists and data scientists. The promise of iLoF is the sizeable reduction in cost and time to be achieved in clinical trials. Such outcomes would enable the downstream pharmaceutical industry to streamline their discovery and development of new products.

Precision procedures for tailored therapies

iLoF's approach involves deploying photonics (laser light) and artificial intelligence (AI) to assemble and analyse biological big data. The combination of AI and photonics is used to build an evolving cloud-based library of disease biomarkers and biological profiles. These assets are leveraged by multidisciplinary teams to detect label-free nano-sized biomarkers in biological liquid samples, thus generating specific patient or disease signatures.

Results at the speed of light

Screening and tracking biological data at iLoF are done in a number of ways. Firstly, by optical fingerprinting: small amounts – such as microlitres – of blood samples are scanned using light-based technologies to generate optical signals that reflect the molecular and cellular composition of the sample. Secondly, by bio-digital twins: the collected optical signals are transformed into virtual representations of the patient samples, i.e. essentially digital versions of the patient's unique biomarker profile. Thirdly, by AI-powered analysis: running machine learning algorithms through the bio-digital twins provides an enhanced ability to detect emergent features in the data and helps identify specific disease subtypes.

The system in place is thus minimally invasive, and the high-quality information can be reused multiple times without further need of additional biological samples. The process is low-cost, as it does not need expensive chemical reagents and consumables. The process is also reliable and fast, requiring merely up to 10 seconds to generate results.

Spinning out from the University of Porto, a hub of knowledge networks

The company was established by three co-founders: Luis Valente, Mehak Mumtaz and Paula Sampaio, who now hold the positions of Chief Executive Officer (CEO), Chief Operation Officer (COO) and Chief Strategy Officer (CSO) respectively. The company is a spin-out from the University of Porto where Paula Sampaio researches and teaches. The University of Porto i3s research centre specialises in state-of-the-art optical microscopy for the study of cellular systems in life science research areas such as cell biology, oncobiology, neurobiology, immunology and biomaterials. i3s is also a core facility of the Portuguese Platform of BioImaging (PPBI), which Sampaio serves as national co-ordinator and which is a node of the European research infrastructure Euro-BioImaging (ERIC).

2. Revitalising Europe's leadership in oncological innovation

2.1. The burden of cancer in the European region

Cancer is the second leading cause of death in the European Union, accounting for 21.6% of all deaths (Eurostat, 2024). The burden from the disease in Europe is significant. The European region accounts for almost a quarter of new cases worldwide, despite containing less than one tenth of the global population (Ferlay et al., 2019). By 2018, the total cost of cancer was already verging on EUR 200 billion (Hofmarcher et al., 2018).

The predicted number of cancer deaths in the EU plus the UK was 1 281 436 in 2011 and 1 443 700 in 2040 (Malvezzi et al., 2011; Santucci et al., 2024). Moreover, the number of lives lost in Europe to oncology-related causes are rising due to population growth and ageing. In the horizon to 2024, cancer diagnoses and cancer deaths are expected to increase by 19% and 27%, respectively, in the EU/EFTA countries (European Commission, 2024). Meanwhile, cancer-related healthcare spending is trending to increase faster than the actual incidence of cancer (Hofmarcher et al., 2018).

Nonetheless, absolute numbers of cancer deaths mask important positive underlying developments. Total cancer mortality rates have trended favourably since the 1980s. Age-standardised rates (ASRs) for all cancers computed using World Health Organization (WHO) and Eurostat databases point to a fall of 6.5% and 3.7% in total cancer mortality rates in men and women, respectively, between 2018 and 2023 in the EU27 (Malvezzi et al., 2023). Progress is also apparent in the number of lives saved: an estimated total of 6 183 000 in the EU and 1 325 000 in the UK in the 36 years between 1989 and 2024 (Santucci et al., 2024).

Differences in patterns exist across cancer types. The most commonly diagnosed cancers among the European population are breast, colorectal, lung and prostate cancers, while the most common cancer-related causes of death are from lung, colorectal, breast and pancreatic cancers (Dyba et al., 2021). Progress is being achieved in the detection, treatment and death prevention of all cancers with the exception of pancreatic cancer, which remains the fourth leading cause of cancer-related death for both sexes (Santucci et al., 2024; see also Siegel et al., 2024).

2.2. Factors driving the constant fight against cancer

Cancer research and innovation are challenging activities. They must contend with a diverse and complex set of diseases influenced by a variety of social and geographical factors. Variability in cancer incidence is shaped by behaviours and lifestyles, including diet, alcohol consumption, smoking, physical activity and occupational exposures, as well as broader societal aspects such as screening awareness and healthcare access (Munoz-Pineiro et al., 2023). These interconnected variables highlight the need for tailored approaches to cancer prevention and treatment across different populations.

The individual risk of dying from cancer has nonetheless declined in all countries for which reliable data are available, i.e. in the more developed countries. This phenomenon may be related to more structural factors affecting the most common types of specific cancers like liver cancer and lung cancer, and which constitute a priority for prevention and assistance (Hashim et al., 2016). The general downward pattern has been largely attributed to healthcare access and management of disease, including prevention, testing, removal of lesions and investment in care infrastructure for timely and appropriate treatment and long-term follow-up (Dalmartello el., 2022; Malvezzi et al., 2023).

Yet, sustaining the fight against cancer requires more than the availability of healthcare assets and services. Long-term strategies and dynamic capabilities are also taken to be drivers of persistent downward trends in cancer mortality (Santucci et al., 2024). Although caution should be taken in the interpretation of statistics, progress in prognoses and survivability is furthered by new methods of early detection, accurate diagnostics under unspecific symptoms and signs, innovative treatments of complex and later-stage situations, and multimodal and multidisciplinary approaches, etc. (Gatta et al., 2015). Research indicates that new technologies may reduce cancer mortality by up to almost seven-fold (when compared to factors that reduce incidence), the impact of different solutions like improvements in drugs and imaging may vary by a certain factor, and the social value of the reductions in cancer mortality attributable to medical innovations is much greater than the monetary cost of these innovations (Lichtenberg, 2014).

2.3. Developing high-quality oncology through excellence in next-generation care

Europe is a global region offering high standards in cancer care, control and cure. But much work remains to be done. The agenda is therefore vast for practitioners, administrators, elected officials, health policy advocates, scientists and entrepreneurs. Addressing cancer is bound to involve team-work, with some players focused on direct response and others on the long-run development of next-generation solutions. That is, the actors of the sectoral health research and innovation system are a part of a wider network of players and institutions.

Many wide and persistent gaps in equity and adequacy exist across and within individual countries (WHO, 2020). Responses are uneven, and Europe is no exception. Asymmetries include public information about prevention, access to affordable and high-quality monitoring and treatment, continuous control and support, investment in screening and surgical systems, and education and training levels of medical workforce, etc. (OECD, 2024). Even in places with strong traditions in healthcare, it still matters where cancer patients live. Their economic status, education level, ethnicity, age, gender, sexual orientation, nutrition, physical and mental state, alongside other socio-economic factors (UICC, 2024) also have a role to play, with excess risk not homogenous among cancer types (Singh and Jemal, 2017). Pragmatic, efficient, continuous and contextually-applicable improvements in practice and management are needed (Are et al., 2023).

Progress in the fight against cancer is also critically contingent on new knowledge and technologies. Indeed, breakthroughs have the real potential to improve the whole oncological cycle, from prevention and early detection right through to quality of life (OECD, 2024). Integration of research data, translation of research discoveries, expediency in novel clinical trials and promotion of innovation are among the core factors (Lawler et al., 2014; Sullivan et al., 2015; Pérez et al, 2017). As Lawler et al. (2021, p. 14) summarise:

"Research and innovation have underpinned improvements in outcomes for cancer patients in recent decades, with long-term survival increasing to over 50% of cancer patients in many European countries. Further improvements will depend substantially on appropriate implementation of research and innovation discoveries."

By definition, research and innovation are future-creating endeavours. As science and technology move forward, it is important to monitor new and emerging developments. Studying the progress being made is a first step towards better understanding how it can be made available to for the benefit of all (WHO, 2023).

2.4. Outcomes of first EPO study on cancer-fighting technologies

The first EPO study on cancer-related innovation, published in 2024, performed a comprehensive analysis of patenting trends. A set of stylised facts were outlined uncovering a renaissance in oncological innovation that has occurred in recent years.

Throughout the 1970s and 1980s, progress was mostly along invasive lines. Imaging technologies, like X-ray and biopsy techniques, saw significant advancements. These improvements in diagnostics enabled earlier and more precise detection, location and characterisation of tumours. In terms of treatment, major advances were verified in classical chemotherapy in particular, with antimetabolite drugs inhibiting the replication of cancer cells.

The 1990s saw rapid development of new cancer therapeutics. These methods adopted different cancer-fight heuristics, namely targeted and immunotherapeutic approaches. Soon the number of inventions was at the level of conventional chemo technologies. Towards the end of the decade, cancer models and personalised medicine became vibrant fields.

By the 2000s and through the early 2010s, oncological innovation plateaued. There was nevertheless robust growth in ICT-related innovations, notably healthcare informatics and ultrasound technologies. By 2015, patenting activity accelerated across a broad spectrum of cancer technologies. Immunotherapy, gene therapy and non-coding nucleic acids increased at above average rates. Diagnostics were mostly led by liquid, i.e. non-invasive, biopsies. In 2021, following an average growth rate of over 9% a year, there were over 13 000 IPF applications, equivalent to 3% of the world's patent activity.

Among the top ten applicants, large R&D-intensive corporates dominate. Six of these top applicants are large pharma companies, two are diversified healthcare electronics providers, and two are from the research sector (a university and a public research organisation). Of these ten actors, six are headquartered in Europe and four in the US.

In general, American players have accounted for the largest share of IPFs, and they renewed their momentum after 2015. By 2021, P.R. China rose to become the second-leading contributor to cancer-related innovation, especially through universities, hospitals and PROs. Among the largest regions, Europe has been the slowest after 2015.

The current report builds on the extensive range of cancer-related technologies that were mapped in the previous EPO study, drawing on the recent policy emphasis to focus on innovative contributions and the most promising and fast-growing cancer technologies.

2.5. Key issues in the European health policy agenda

Recent years have witnessed a growing convergence between health policy and innovation policy. This inter-penetration of agendas is reflected in a variety of aspects at the policymaking level, ranging from competitiveness to development (Thune and Mina, 2016), from security of supply (Beran et al., 2019) to global entrepreneurship (Mishra and Pandey, 2023). Evidence also suggests that the greater attention to global monitoring and new indicators by international organisations may be conducive to innovative efforts in the fields of both communicable (Campos et al., 2024) and non-communicable diseases (Santos et al., 2023).

Countries hold primary responsibility for organising and delivering health services and medical care. In the case of the EU, common health policy serves to complement national policies at different levels to ensure health protection in all EU countries and to work towards a "Health Union". One example are the EU's actions through the European Medicines Agency (EMA), which implements and supports scientific evaluation, regulatory supervision and safety monitoring of medicinal products.

In response to the substantial challenges posed by cancer, the European Commission introduced Europe's Beating Cancer Plan in February 2021. This comprehensive strategy addresses the entire spectrum of cancer care with a primary focus on reducing cancer's incidence and enhancing the quality of life for those affected. To achieve these goals, the plan prioritises prevention by encouraging healthier lifestyles, addressing factors such as tobacco use, nutrition and physical activity. Concurrently, it seeks to strengthen early detection and screening programmes, supporting timely diagnosis and effective treatment. Beyond prevention and detection, ensuring equitable access to high-quality, affordable cancer care is a key issue, with targeted efforts to mitigate treatment disparities across the EU. An emphasis on childhood cancer highlights the plan's inclusive approach to addressing both common and less prevalent cancers.

Supporting this initiative, ten flagship actions are in the course of implementation in the period 2021-2030 which include the establishment of a European Cancer Imaging Initiative, enhanced Health Technology Assessment processes and the release of EU Country Cancer Profiles within the European Cancer Inequalities Registry (European Commission, 2022). Further measures, such as the 2022 European Council recommendation on cancer screening, will bolster the plan as it moves forward. The EU's Cancer Mission complements these efforts, focusing on advancing research, supporting early diagnosis and optimising treatment. Together, these initiatives encourage collaboration among member states and key stakeholders (including patients, healthcare providers and research entities) to foster shared solutions and accelerate innovation in cancer prevention, care and survivorship. The EU Cancer Mission has four pillars: understanding of cancer, prevention and early detection, diagnosis and treatment, and quality of life for patients and their families. In 2024, the EU relaunched its commitment to the fight against cancer as a major priority in health policy, including by establishing targets for 2030 and emphasising the importance of research and innovation. In particular, the European Commission makes a pledge to give "support to innovation and advancing the understanding of cancer mechanisms."

Civil society has also been active in this connection. The European Cancer Organisation issued a manifesto bringing together European members of parliament, called *Time to Accelerate – European Cancer Roadmap to 2023*, that underlined the message "promote innovative approaches to research, treatment and support of cancer patients and their families." The Association of European Cancer Leagues (ECL) also came out in 2024 with a plea for effective implementation of the policy agenda on cancer in Europe. In its *call to action*, the ECL urged stakeholders to "address unmet medical needs and foster multiple pathways for medicines development." In this regard, the ECL stated:

"The pharmaceutical industry is not always willing to invest in developing medicines, including advanced therapy medicinal products, for unmet medical needs because they are intended for a relatively small number of patients and are therefore of low commercial interest. The EU pharmaceutical framework should provide incentives in this area. Furthermore, non-commercial medicine developers, such as academic institutions, have a role to play, however they currently face many hurdles. Therefore, we call on the European Commission to examine the challenges that academic developers of innovative treatments addressing unmet medical needs face and help to overcome them."

As the European Commission launched into a new policy cycle, the health policy agenda at the EU kept being shaped by the impetus that started at the beginning of the decade and by several themes that extend previous priorities. According to the Political Guidelines for the next European Commission 2024-2029, the efforts to complete the European Health Union shall put greater emphasis on: a) a sustainable pharmaceutical sector, b) reduced supply-chain dependencies relating to critical medicines and ingredients, and c) AI and cybersecurity aspects in healthcare, among other aspects. This orientation is bound to encompass the EU Cancer Mission going forward.

Developments have also been forthcoming at the regulatory level. In its latest yearly report, the EMA refers to three strategic areas of focus: "cancer medicines, data-driven medicine regulation, and transparency and communication". In 2023, the EMA increased support to the EU Beating Cancer Plan with the roll-out of a new project called "Cancer Medicines Pathfinder". The initiative aims at "high-quality, robust and rapid assessment of key medicines overall," and cancer was selected as a pathfinder because "it is a therapeutic area with a high rate of innovation and scientific progress, but also a high unmet medical need." The equivalent body in the US, the Food & Drug Administration (FDA), established the Oncology Center of Excellence (OCE) in 2017 to unite its internal experts to conduct expedited review of medical products and substances for oncologic purposes. In its 2023 Annual Report, the OCE documents how it fosters research projects and programs to advance the development of life sciences with academia and companies.

As a complementary organisation to the EMA, the European medicines agencies network, which represents the national competent authorities (NCAs) of the 27 EU member states plus those of Iceland, Liechtenstein and Norway, issued a strategy to 2025 (with a new strategy to 2028 in the works). Here a number of challenging areas are highlighted, including: i) supporting innovation and digitalisation in clinical trials, ii) collaborations with academia and SMEs, iii) post-licensing evidence generation for innovative and precise medicines, iv) governing medicinal product data storage and maintenance lifecycle, and v) developing stronger alliances with relevant regulatory global partners. In the public consultation for this strategy, a variety of cancer-related issues surfaced, such as paediatric cancers, rare cancers, radiopharmaceuticals for targeted cancer therapies, advanced cell therapies, and definition of critical medicines for cancer by using the WHO Model Lists of Essential Medicines Lists (EML) as a starting point, etc. In their responses to the public consultation, participants expressed their support for enacting "new approaches to the lifecycle of innovation", including in the area of clinical trials.

Also turning their attention to innovation, investment analysts and industry observers have pointed to possible sectoral reconfigurations. The rise of longshot technologies in areas such as biopharmacy and nanomedicines, which could redefine the division of entrepreneurial labour between bigger players and smaller players, has been highlighted (Science et Vie, 2024). There has been particular focus on this recently for oncology in connection with promising fields such as immunotherapy or radiopharmaceuticals, or research tools like genetics AI (Financial Times, 2018, 2024a, 2024b, 2024c).

The current view is that new technologies are bypassing Europe, including in the health sector. Mario Draghi (2024a, p. 2) states from the outset: "Europe is stuck in a static industrial structure with few new companies rising up to disrupt existing industries or develop new growth engines." The consequence is that the EU is losing weight on the world stage. Enrico Letta (2024) concurs and issues an explicit call to "Europe's leadership in health", underscoring how Europe's Beating Cancer Plan should be seen as a model to tackle other critical challenges for the future. It may come as an important realisation that there can be a variety of organisational vehicles to overcome the present challenges. For instance, as the Faron Pharmaceuticals case study illustrates, even family-based businesses may find room in the evolving landscape, and prove to be well adapted as a root of high-tech bets to territorially-rooted knowledge bases.

2.6. Patents at the intersection of health policy, innovation, regulation and industrial strategy

Although the EPO and the EU are two separate international organisations, they are part of a web of multilateral institutions that can provide a positive context for research and innovation in healthcare. Patents are an intrinsic component of the context fostering innovation, competitiveness and economic growth.

On one level, patents stand out as a crucial underpinning for R&D investments in the health domain, and have an impact on the access and affordability of diagnosis and treatment of diseases. Invention screening procedures ensure a level playing field, as they are neutral across types of firms, isonomic for non-firms, and independent of geographic origin. In these requirements for efficiency, transparency and predictability, the IPR system is highly complementary of health-related sectoral supranational and national regulatory agencies such as the European Medicines Agency (EMA) or the Norwegian Radiation and Nuclear Safety Authority (DSA).

On another level, advances in big data management, data mining and natural language processing are enhancing patent analysis and providing more leverage for intelligence extraction from past inventions. The informational intersection of patent policy and health policy is recognised by the World Health Organization (2024), which emphasises "the need for patent landscapes for important health technologies." Indeed, well-known innovation indicators (like patents) can map and illuminate technological frontiers in real-time, and thereby directly impact efforts to advance the state of the art.

As to what concerns innovation, it is well acknowledged that patents matter crucially as an incentives system. This is especially the case for a strategic sector in which Europe has retained its leadership: pharmaceuticals (Levin et al., 1987; Cohen et al., 2000; Sampat, 2018). However, the role of exclusivity regulation and appropriability strategies, and of patents in the pharma sector, may have non-linear effects with strong public health implications (Rafols et al., 2014; Gamba, 2017; Shrum et al., 2020; Dosi et al., 2023; Campos et al., 2024).

Credit: EPO

Case study: Faron Pharmaceuticals

Headquarters: Turku
Products: Targeted immunotherapy cancer treatment

Recruiting the body's own defences as a source of new hope

Medical technology experts are finding new ways to redirect the natural strengths already encoded in living organisms to more effectively detect and combat diseases. Within this framework, immunotherapy has emerged as a form of biological treatment that makes use of substances derived from living organisms to fight cancer.

When cancer-fighting breakthroughs are a family business

One particular development in immunotherapy was brought about by Sirpa Jalkanen and Markku Jalkanen. Sirpa has a long track record in the research sector, having been a Professor at the University of Turku, the chair of the Finnish Academy of Science and Letters, Professor at the University of Helsinki, and Research Professor at the National Institute of Health and Welfare. Her husband Markku has a PhD degree in medical biochemistry, but has spent more time interfacing with the market as Director of the Turku Centre of Biotechnology, partner and advisor to a venture capital management company, as CEO of Biotie Therapies, and as the current CEO of Faron Pharmaceuticals. They are partners in life, in life sciences, in biopharma patents and in a family-controlled R&D-intensive enterprise.

This husband-and-wife team have developed the bexmarilimab (also known as Clevegen), a clinical drug. They understand that sustaining a business in the healthcare sector benefits from seamless dialogue between research and clinical practice. Between them, they combine the expertise of a medical doctor, laboratory researcher and business manager. Their children are also following in their footsteps: their oldest daughter is a cancer doctor in Helsinki and full-time clinician; while their son, who served as the COO at Faron and was promoted to CEO in 2024, takes care of the business strategy and manufacturing, as well as overseeing all other corporate activities. Their youngest daughter is also a full-time scientist involved in R&D at the company. Together, they aim to bring bexmarilimab to market by 2027.

Targeted biopharma for patients who have exhausted all other options

Bexmarilimab functions by inhibiting CLEVER-1, a protein present in specific white blood cells. When the CLEVER-1 receptors are deactivated, immune-suppressing cells are transformed into immune-activating cells, rallying additional immune cells for a coordinated attack on the cancer. By targeting and reprogramming immunosuppressive macrophages that are associated with the tumour but are not cancer cells, the approach has an overall effect in the tumour environment. In this way, the body's natural defences are re-educated to work smarter and harder to find and destroy cancer cells. Results have been particularly promising in leukaemia situations.

What distinguishes bexmarilimab is its innovative mechanism, which not only strengthens the body's natural defences but also amplifies the efficacy of conventional therapies for treating solid tumours and haematological malignancies. This breakthrough supports adaptive immune responses and expands the scope of immunotherapy in a variety of ways. Specifically, the drug opens up prospects of immunotherapy to more patients, boosts the potential effectiveness of standard cancer treatments and offers crucial hope for oncological cases that are stubbornly resistant to existing therapies.

Moving therapeutical candidates to the market

According to the company, their programme offers "one of the most advanced myeloid cell-targeting immunotherapy candidates in development." Reaching this level, however, took time and a unique ability to learn. The journey from early insights to a market-ready prototype, to developed product and to market launch is long and risky.

In the first clinical trials, almost all patients showed marked increases in natural killer cells. These trials included patients who had undergone multiple previous treatments and were in the disease's final stages. Subsequent trials demonstrated that the bexmarilimab therapy was not only well tolerated, but also led to significant remission rates among patients with acute myeloid leukaemia (AML) and myelodysplastic syndrome (MDS) who had otherwise proved resistant to other last-resort therapies. Team Jalkanen is working toward securing authorisation from medicines authorities, and hopes to bring bexmarilimab to market by 2026-2027. The fact that the team was a finalist for the EPO European Inventor Awards in 2024 will be surely support their efforts.

3. Understanding the landscape of technological advancements related to cancer

This section builds on the cartography of cancer-related technologies developed in the first EPO study on cancer-related innovations (Box 2). It offers a fresh perspective on the 28 distinct technology fields that form the foundation of this landscape. By introducing a new categorisation, this section highlights the recent growth trajectories of these technologies and assesses their varying levels of technological maturity.

Box 2: Identifying and measuring patenting activity in cancer-related technologies

Efforts to identify patent applications related to the various technologies in the fight against cancer were carried out using the knowledge of the EPO's expert patent examiners, together with scientific publications and studies published by a range of consultants and international organisations. This in-house knowledge has been built up over many years of working within the various fields of technology relevant to cancer diagnostics and treatment, and refined via networks of technology specialists within the EPO. Adding to this core expertise, the initial project leading to this technology mapping benefited from the contributions of experts from national patent offices who provided input and feedback.

Published international patent families (IPFs) are used in this study as a uniform metric to measure patenting activity in the various categories of cancer-related technologies. Each IPF identified as relevant for cancer-related technologies is assigned to one or more technology sector(s) or field(s) of the cartography, depending on the technical features of the invention.

Each IPF covers a unique invention and includes patent applications targeting at least two countries. More specifically, an IPF is a set of applications for the same invention 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.[3] 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 reference year used for all statistics in this report is the earliest publication year of each IPF, which usually is 18 months after the first application within the patent family. In case of multiple applicants, statistics on the country of origin are reported using fractional counting, assigning each country a fraction based on the number of applicants from that country.

The dataset was further enriched with information about the applicants of the IPFs. In particular, data was retrieved from Bureau van Dijk's ORBIS database, Crunchbase, Dealroom, ETER and other internet sources, and was used to harmonise and consolidate applicant names and identify their type. Manual checks were performed to improve the data quality.

3.1. Categorising cancer-fighting technologies

Cancer-related technologies represent a broad and evolving landscape of innovative tools and techniques aimed at diagnosing, treating and managing cancer. The complexity of cancer as a disease, with its diverse molecular and genetic characteristics, necessitates a wide range of technological approaches. In this study, we build upon the framework established in the previous report, focusing on key technology areas that are essential for advancing cancer research and care.

The main technology areas identified in this study are categorised into two primary groups: cancer diagnostics and cancer treatment technologies. This distinction is crucial, as each category serves distinct purposes within the broader context of cancer care. Diagnostic technologies are primarily concerned with accurately detecting and monitoring cancer progression. These tools are vital for ensuring timely interventions and personalised treatment plans. Treatment technologies, on the other hand, encompass a spectrum of interventions designed to target and destroy cancer cells or control their growth, ranging from traditional methods like chemotherapy to cutting-edge immunotherapies and gene editing techniques.

However, to fully capture the scope of innovation in cancer-related technologies, two additional areas must be considered: cancer models, and information and communications technology (ICT) related to cancer research. Cancer models play an indispensable role in both diagnostics and treatment research. These models help researchers understand the underlying mechanisms of cancer development, explore genetic mutations associated with different types of cancer, and study the

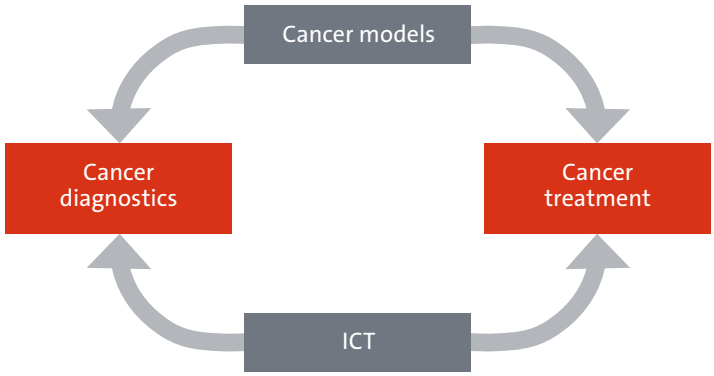
[3] The regional patent offices are the African Intellectual Property Organization (OAPI), the African Regional Intellectual Property Organization (ARIPO), the Eurasian Patent Organization (EAPO), the European Patent Office (EPO) and the Patent Office of the Cooperation Council for the Arab States of the Gulf (GCCPO).

biochemical pathways involved in tumour growth. By providing a controlled environment for experimentation, cancer models accelerate the development of new diagnostic tools and treatment strategies.

Furthermore, ICT is revolutionising cancer care by enabling more efficient data management, early diagnosis through advanced imaging techniques, computational tools to analyse biological data and personalised medicine approaches. ICT facilitates the integration of large datasets from clinical trials, patient records and genomic studies to develop more precise treatment plans tailored to individual patients. It also supports telemedicine platforms that enhance patient access to care and improve treatment monitoring. The interconnectedness between these four technology areas – cancer diagnostics, cancer treatment, cancer models and ICT – is illustrated in the diagram presented in Figure 1.

Figure 1

Overview of main cancer-related technology areas



Source: EPO

Except for **cancer models**, which is one of the largest areas with almost 17 000 IPFs between 2010 and 2021, each technology area is further subdivided into several technology fields. These fields have been refined based on the results and feedback from the first EPO cancer study. The full list of technology fields is presented in Figure 4, alongside the number of IPFs with earliest publication dates between 2010 and 2021. A detailed description of each technology field is provided in Table A1 and Figure A1 in Annex 2.

The **cancer-related ICT** area consists of two key fields: **bioinformatics** and **healthcare informatics**. With approximately 2 000 and 4 200 IPFs, respectively, these are relatively smaller fields compared to others. However, their importance is growing rapidly as bioinformatics plays a crucial role in processing large-scale biological data for cancer research, while healthcare informatics enhances patient care through data management and communication tools that facilitate more personalised treatment approaches.

The **cancer diagnostics** area encompasses a total of 37 368 IPFs, making it a significant field in terms of innovation volume. This area includes six key technology fields. **Liquid biopsies**, which is a non-invasive diagnostic method that detects cancer-related genetic material or cells circulating, for example, in the bloodstream. This field is currently the largest, with almost 14 000 IPFs gaining traction due to its potential for early cancer detection and monitoring. In contrast, **tumour biopsies** is smaller in scope and contains inventions related to traditional tissue biopsy methods, which are still critical for diagnosing cancer types and determining appropriate treatment strategies. Imaging apparatus is the second largest cancer diagnostic field with around 8 500 IPFs, and comprises technologies such as magnetic resonance imaging (MRI), computed tomography (CT) scans and positron emission tomography (PET) scans. These tools are essential for visualising tumours and assessing their progression. Related to imaging apparatus is **image analysis**, which employs advanced software tools that also use AI or other algorithms to analyse medical

images for more accurate diagnosis and staging of cancer. The **imaging agents** field focuses on substances or compounds used to enhance the visibility of tumours during imaging procedures, such as MRI, PET or CT scans. These agents are crucial for improving the accuracy of cancer diagnosis, staging and treatment monitoring. **Personalised medicine**, also referred to as precision medicine, is an approach that customises cancer treatment based on the unique characteristics of each patient. It considers genetic, environmental, and lifestyle factors of each patient to identify and tailor therapies that are more effective and potentially less harmful.

The **cancer treatment** area is by far the largest in terms of patent activity, with a total of over 78 000 IPFs across 19 different technology fields. This reflects the diversity of approaches being developed to combat cancer. The fields include targeted therapies such as **protein kinase inhibitors** (26 452 IPFs), which block specific enzymes involved in tumour growth, disrupting cancer cell growth and division. Targeted therapies aim to attack cancer cells while minimising damage to healthy cells. **Conjugates** (7 496 IPFs), which also belong to targeted therapies, are drugs linked to carrier molecules that deliver the therapeutic agent directly to cancer cells. These carriers can enhance the drug's effectiveness or reduce side effects. Examples include antibody-drug conjugates and peptide-drug conjugates. The group of **other small-molecule targeting agents** (15 706 IPFs) includes therapies that target specific molecular pathways critical for cancer cell survival. Examples include Histone deacetylase (HDAC) inhibitors, angiogenesis inhibitors (which block blood vessel growth), and proteasome inhibitors (which disrupt protein degradation in cancer cells).

Because immunotherapy is such a broad field, it is subdivided into five different technology fields. **Antibodies**, the largest one with almost 19 000 IPFs, are engineered proteins designed to bind to specific targets on cancer cells. Some antibodies mark cancer cells for destruction by the immune system, while others block signals that allow cancer cells to evade immune detection. **Small molecule immunomodulators** (6 501 IPFs) are compounds that modulate the immune system's response to cancer by either enhancing immune activity or suppressing mechanisms that help tumours grow, while cellular immunotherapies (3 639 IPFs) involve using a patient's own immune cells to fight cancer. CAR T-cell therapy is a prominent example where T-cells are engineered to target specific proteins on cancer cells. Cancer **vaccines** is the smallest of the five immunotherapy fields with just over 1 350 IPFs. These vaccines aim to stimulate the immune system to recognise and attack cancer cells by, for example, introducing antigens associated with tumour cells. **Other innovative immunotherapy approaches** such as cytokine-based treatments and oncolytic viruses that selectively infect and kill cancer cells are grouped into one field.

Chemotherapies are subdivided into three fields. The largest is related to **DNA-damaging agents (13 451 IPFs)** which cause direct damage to the DNA of cancer cells, preventing them from replicating. Alkylating agents are a common example used against various cancers. The other two fields are **antimetabolites** (10 026 IPFs), which mimic molecules needed for DNA synthesis in cancer cells but disrupt the process when incorporated into DNA strands, and **anti-tubulin agents** (10 008 IPFs), which interfere with microtubules involved in cell division, effectively halting the proliferation of rapidly dividing cancer cells.

Hormonal therapy is a well-established technology field, with over 12 300 IPFs, that targets cancers driven by hormones like oestrogen or testosterone. It works by either blocking hormone production or interfering with hormone receptors on cancer cells. This method is commonly used for breast and prostate cancers. **Gene therapy** (3 581 IPFs) involves introducing new genes into a patient's cells to treat or prevent disease. In cancer treatment, gene therapy can be used to modify immune cells or directly target tumour cells for destruction through genome editing techniques like CRISPR/CAS. **Non-coding nucleic acids** (10 971 IPFs), such as microRNAs and interfering RNAs, play crucial roles in regulating gene expression in cancer cells. Therapeutic strategies targeting these molecules aim to disrupt cancer cell growth by interfering with key biological pathways involved in cancer progression.

Radiotherapy (3 853 IPFs) and **surgery** (3 829 IPFs) belong to the earliest cancer treatment fields. Radiotherapy uses high-energy radiation to destroy or damage cancer cells while minimising harm to surrounding healthy tissues. It remains a cornerstone of treatment for many cancers and is often used in combination with surgery or chemotherapy. Surgical techniques continue to evolve with advancements such as robotic-assisted surgery and minimally invasive procedures like cryosurgery and laser surgery. These innovations improve precision in tumour removal while reducing recovery times.

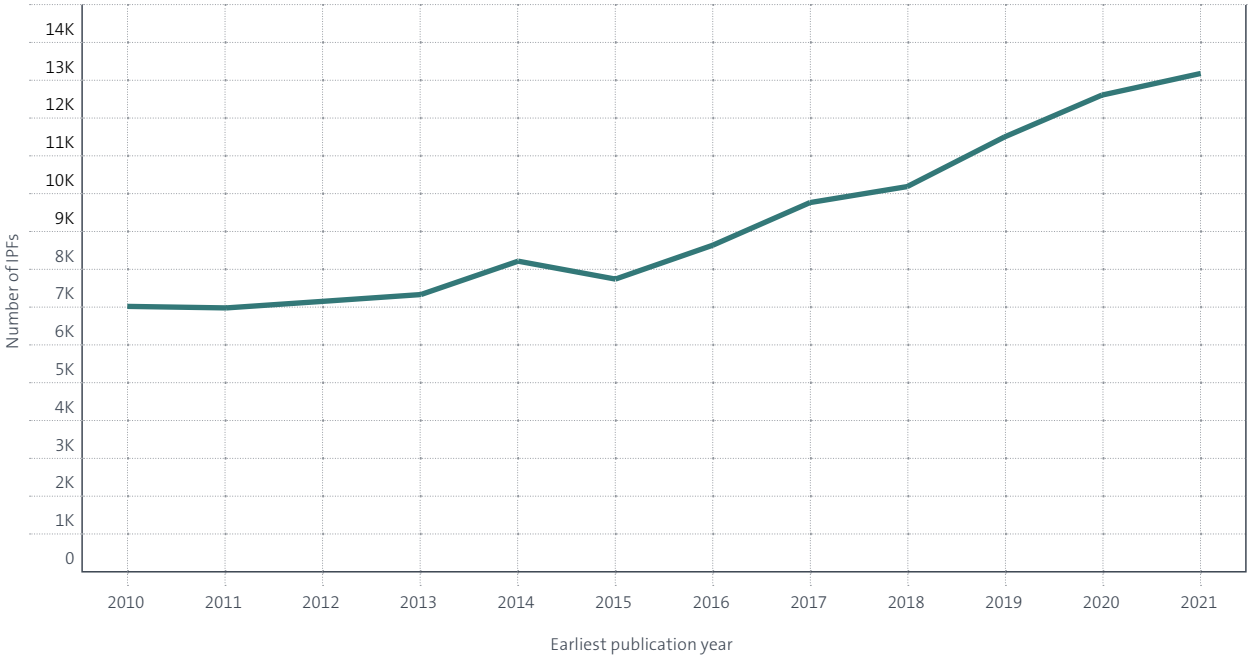
The field **other physical treatments** (1 689 IPFs) includes methods like photodynamic therapy (PDT), which uses light-activated drugs to kill cancer cells, and tumour treating fields (TTF), which use alternating electric fields to disrupt cell division in tumours. **Alternative treatments and prevention** (5 677 IPFs) includes treatments derived from natural sources such as plant extracts or animal tissue. While still emerging, some of these therapies show promise in inhibiting tumour growth or enhancing traditional treatments. Technologies aiming at **mitigating side effects**, with 1 111 IPFs, is the smallest of all 28 fields. They focus on reducing the adverse effects associated with cancer treatments. This includes drugs or devices designed to alleviate symptoms such as nausea or fatigue.

3.2. Cancer-fighting technologies reshuffled

Overall, the patenting activity in cancer-related technologies remained relative stable between 2010 and 2015. After 2015 there was significant and sustained growth, when the number of IPFs per year grew from less than 8 000 IPFs per year to over 13 000 IPFs in 2021 (Figure 2).

Figure 2

Overall trend in cancer-related technologies, 2010-2021



Source: EPO

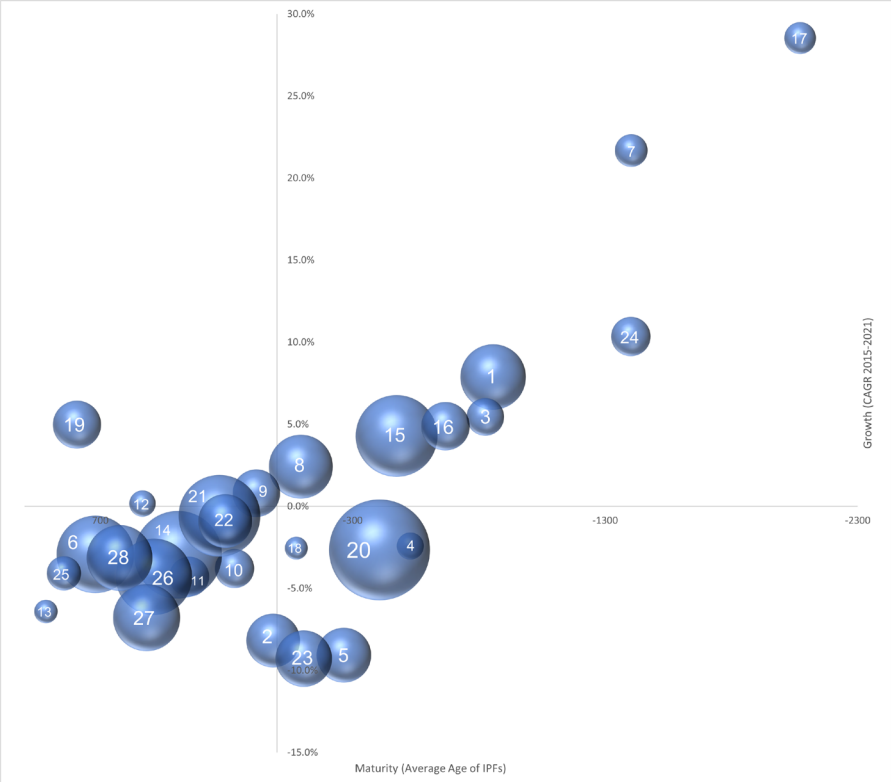
Besides being of different size, the 28 cancer-related technology fields have seen different dynamics in patenting activity over the past years (see the first EPO cancer study). Some technology fields such as tumour biopsies, certain chemotherapeutic approaches or cancer models have seen intense patenting activity and market-ready therapies already decades ago, while other fields are relatively young and still developing, with only some drugs or applications being already available for patients.

In order to capture these different dynamics and the development stage of each technology, they are categorised according to their maturity and growth in the most recent years of observation. Growth is defined by compound annual growth rate (CAGR) between the years 2015 and 2021 in order to capture the recent explosion in patenting activity and identify the fields that contributed to it. Maturity is defined as the average age of all IPFs in a field that were published before 2022.[4]

[4] The results of this study remained relatively robust to the variations of time periods for the calculation of the growth rate and the maturity indicator.

Figure 3

Landscape of cancer-related technology fields displaying maturity, recent growth dynamics and relative size



Cancer technology fields

1 Liquid biopsies
2 Tumour biopsies
3 Healthcare informatics
4 Bioinformatics
5 Personalised medicine
6 Hormonal therapy
7 Gene therapy
8 Non-coding nucleic acids
9 Alternative treatments and prevention (e.g. extracts from plants and animal tissue)
10 Surgery
11 Radiotherapy
12 Other physical treatment (e.g. photodynamic therapy, TTFs)
13 Mitigating side effects
14 Cancer models
15 Immunotherapy - Antibodies
16 Immunotherapy - Small molecule immunomodulators
17 Immunotherapy - Cellular
18 Immunotherapy - Vaccines
19 Immunotherapy - Other approaches (e.g. cytokines, oncolytic viruses)
20 Targeted therapy - Protein kinase inhibitors
21 Targeted therapy - Other small-molecule targeting agents (e.g. HDAC, angiogenesis, proteasome inhibitors, etc.)
22 Targeted therapy - Conjugates
23 Imaging apparatus
24 Image analysis
25 Imaging agents
26 Chemotherapy - DNA damaging agents
27 Chemotherapy - Anti-tubulin agents
28 Chemotherapy - Antimetabolites

Source: EPO

The insights from this exercise are particularly useful for assessing the different dynamics of the 28 technologies in the general landscape of cancer-related knowledge, helping stakeholders identify where to focus research and development efforts, investment or policy support based on the lifecycle stage and innovation trajectory indicated by patent activity. This exercise puts every cancer-related technology into one of four quadrants, depending on whether the recent growth and maturity of the technology field were above or below that of the overall sphere of cancer-related technologies: the CAGR of all cancer-related IPFs between 2015 and 2021 was 9.3%;

and the average age of all cancer-related IPFs was around 4 900 days.[5] This defines the following four quadrants (see Figures 3 and 4):

High-growth, high maturity (quadrant 1): Technologies in this quadrant are well-established with a significant portfolio of older patents, and are also seeing a surge in new patent filings in more recent years. This indicates ongoing innovation and improvements in well-rooted technologies, suggesting strong, continuous market interest and technological relevance.

The technology fields that fall into this quadrant are other physical treatment (e.g. photodynamic therapy and TTFs), Immunotherapy – other approaches (e.g. cytokines and oncolytic viruses), which is one of the fields with the oldest patent families on average, and alternative treatments and prevention (e.g. extracts from plants and animal tissue).

High-growth, low maturity (quadrant 2): Technologies in this quadrant are characterised by a more recent presence in the patent landscape with rapidly increasing new patent filings. This indicates more emerging technologies that are quickly gaining traction, possibly due to breakthrough innovations or newly discovered applications.

The technology fields that fall into this quadrant are gene therapy, Immunotherapy – cellular, which is the field with the youngest IPFs on average and growing fastest, Immunotherapy – small molecule immunomodulators, Immunotherapy – antibodies, healthcare informatics, image analysis, which is the field with the youngest IPFs on average, non-coding nucleic acids, and liquid biopsies.

Low maturity, low-growth (quadrant 3): Technologies in this quadrant are still emerging but have not shown significant recent growth in patenting activity. This may indicate that these technologies are in early exploratory stages, face substantial development challenges, or, despite their low maturity, may have already reached their peak potential.

The technology fields that fall into this quadrant are Immunotherapy – vaccines, bioinformatics, personalised medicine (a field that has hardly been growing in recent year), and Targeted therapy – protein kinase inhibitors, which is also the largest cancer technology field.

Low-growth, high maturity (quadrant 4): Technologies in this quadrant are characterised by a mature patent landscape with a significant number of older patents, and have not experienced above-average growth in recent patent filings. This suggests that the technology is well-established, potentially approaching a plateau in innovation, facing competition from emerging alternatives, or transitioning into a standardised, less dynamic phase of development.

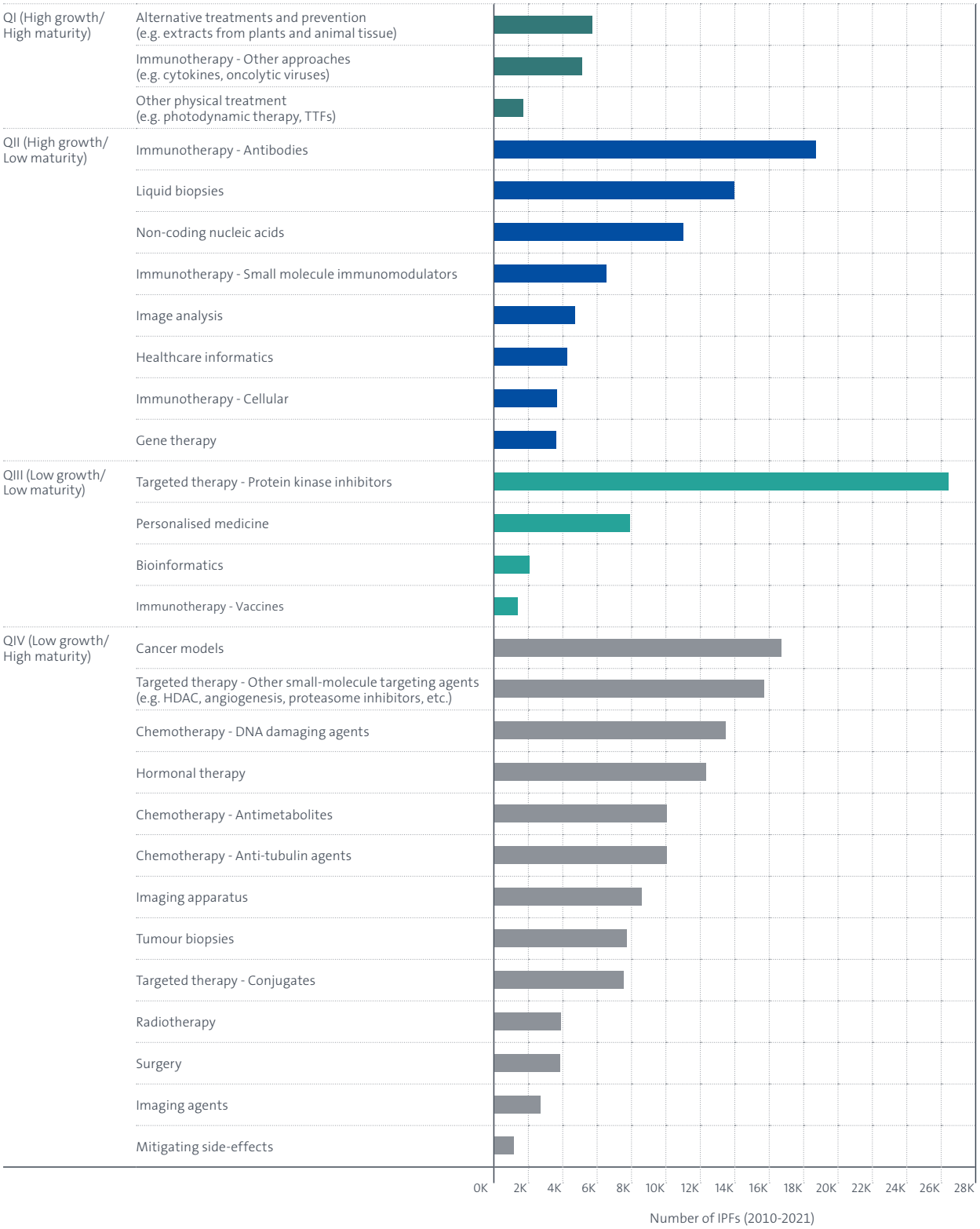
The technology fields that fall into this quadrant are cancer models, Chemotherapy – anti-tubulin agents, Chemotherapy – antimetabolites, Chemotherapy – DNA damaging agents, hormonal therapy, imaging agents and imaging apparatus, the fields with the lowest CAGR between 2015 and 2021, mitigating side effects, the fields with the oldest IPFs on average, radiotherapy, surgery, Targeted therapy – conjugates, Targeted therapy – other small-molecule targeting agents (e.g. HDAC, angiogenesis, proteasome inhibitors), and tumour biopsies.

It is important to note that taxonomies such as this are a methodological device to build analytical perspective. Exciting opportunities may emerge in any technology category, and the AMAL Therapeutics case study provides an apt example of how previously dormant fields have been revamped.

[5] As of November 2024. See Figures A2 and A3 in Annex 3 for the distribution of variable maturity and growth by cancer technology field.

Figure 4

Overview of cancer technology fields and number of IPFs between 2010 and 2021 by quadrant



Source: EPO

Credit: EPO

Case study: AMAL Therapeutics

Headquarters: Geneva
Products: Therapeutic cancer vaccine

Oncological vaccines for policing and protecting the body

The classic treatment of cancer was based on chemotherapy. Its side effects on quality of life are extensive and severe, and its effectiveness is low. The idea of preventing cancer seemed difficult to imagine, let alone by igniting and energising the endogenous protection mechanisms of the organism. Then came a research question: could a vaccine train the body to detect and manage its own abnormal, defective or damaged cells?

Between Switzerland and France

Madiha Derouazi started out in a biology course at the University of Geneva, did her masters in biotechnology engineering in Berlin and a PhD at the EPFL in Lausanne. Years later, she could be found in Grenoble pursuing post-doctoral research at the French National Centre for Scientific Research (CNRS). It was there that she hit upon the vaccine idea, and soon enough her work on antigen delivery system design was gaining traction. It was in 2012, when Derouazi was back at the University of Geneva as a "Maitre assistante", that she launched a startup – AMAL Therapeutics.

The first addition to AMAL Therapeutics was Elodie Belnoue, who had pursued a trajectory from biochemistry to immunology at the University of Paris. When this happened, she was a senior post-doctoral fellow at the University of Geneva with extensive experience in studying the adaptive immune responses of new-born infants suffering from viral infections. She then changed course for something completely new.

On the road from impossible to product you need a proper vehicle

Oncologists once considered the development of a therapeutic cancer vaccine to be nearly impossible. An intuition behind the project leading to AMAL Therapeutics was that a protein vaccine could be effective: the challenge lay in delivering the protein into a cell to provoke a cellular immune response.

The KISIMA platform (a Swahili word that means a water spring or dug water well) was developed by Derouazi and Belnoue to create therapeutic cancer vaccines for a range of cancer types. It provides a new approach to combining the essential components needed and producing a vaccine that can stimulate a strong immune response against the disease.

Vaccines reimagined, the oncology way

Traditional vaccines are designed to be prophylactic, aiming to prevent infection or reduce the severity of a disease if a person becomes infected. In contrast, the focus of AMAL Therapeutics is on developing therapeutic cancer vaccines intended to treat individuals who already have cancer. These vaccines work by instructing the immune system to seek and destroy cancer cells, effectively coaching the body as it combats the disease.

While conventional vaccines typically work by enhancing antibody production to block infections, the approach for cancer patients is different. Here, the goal is to activate the body's tumour-specific T-cell response. This involves stimulating killer T-cells to eliminate cancer cells and helper T-cells to co-ordinate the immune attack. Additionally, the therapeutic vaccines aim to strengthen the immune system's ability to unambiguously identify and rapidly respond to the same cancer cells in the future.

From papers to patents, a movement that paid off

When they first started, projects on vaccines to treat cancer were low priority. But, ten years on, drug development efforts are making headways into the broader arsenal to fight cancer. The vaccines developed using the KISIMA platform are designed to complement, rather than replace, traditional cancer treatments like surgical or radiotherapy cures.

They moved forward, advancing across research fields, from academia to commercialisation, moving from science to entrepreneurship, from publishing into patenting. Their first patent was granted in 2019, and subsequent patent applications build on each other. It all paid off: the company was acquired in 2019 by Boehringer Ingelheim, a global pharmaceutical company headquartered in Germany, for EUR 425 million. Recognition from winning the European Inventor Award came in 2022. Their current focus is on metastatic colorectal cancer and pancreatic cancer, and they are proceeding with human trials for their vaccine.

4. Europe's cancer-related innovation profile compared to other major innovation centres

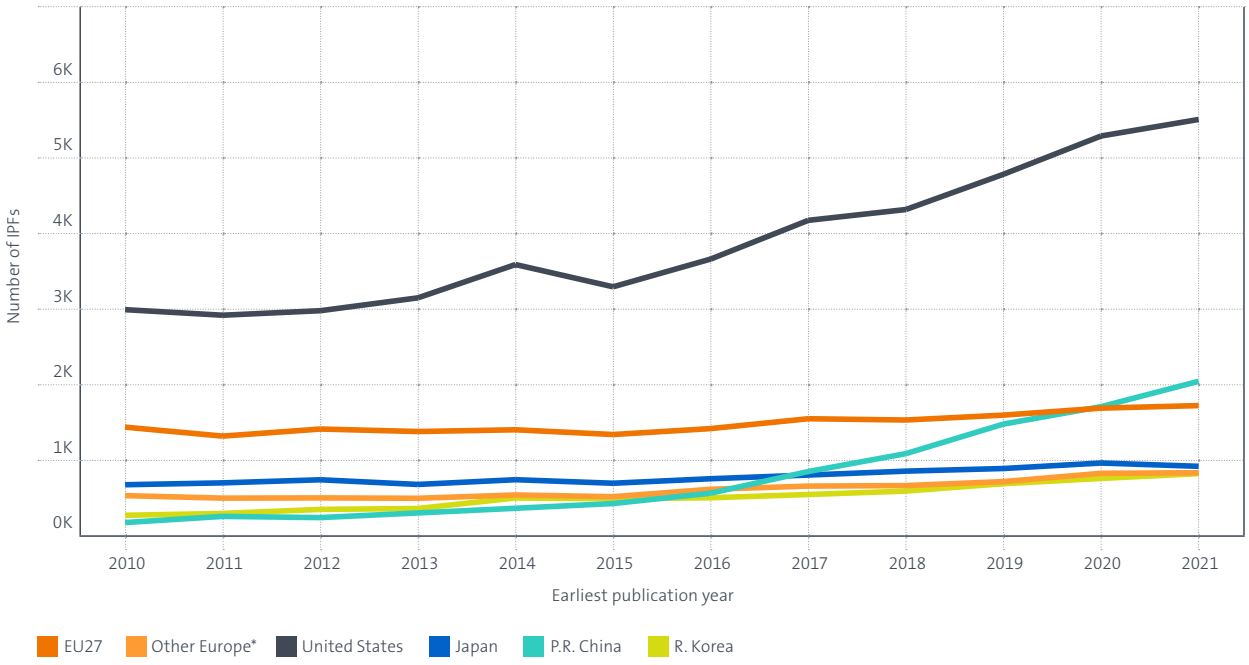
Using the framework for categorising 28 cancer technology fields developed in the previous section, this next section analyses the patenting activity trends across the major global innovation centres: the US, Europe, the P.R. China, Japan and the R. Korea as well as key European countries. It highlights the evolution of these regions' innovation profiles in cancer-related technologies, particularly over the course of the recent boom phase.

4.1. Trends in cancer-related IPFs across major innovation centres

With nearly 47 000 IPFs and a dominant 44.6% share of all cancer-related IPFs, the US led cancer-related innovation between 2010 and 2021. The surge in US contributions significantly drove the growth in cancer-related patenting activity post-2015, with annual IPFs increasing from just over 3 300 in 2015 to more than 5 500 in 2021 (Figure 5). EU-based applicants ranked second over the period 2010-2021, contributing over 17 800 IPFs and holding a 16.9% share, followed by applicants from other EPO member states – primarily the UK, Switzerland, Norway and Türkiye – which accounted for 7 437 IPFs, or 7.0% of the total. While the EU's annual IPF output increased moderately from 1 346 in 2015 to 1 724 in 2021, contributions from other EPO member states grew from 530 to 839 over the same period.

Figure 5

Evolution in all cancer-related IPFs by major innovation centre between 2010 and 2021



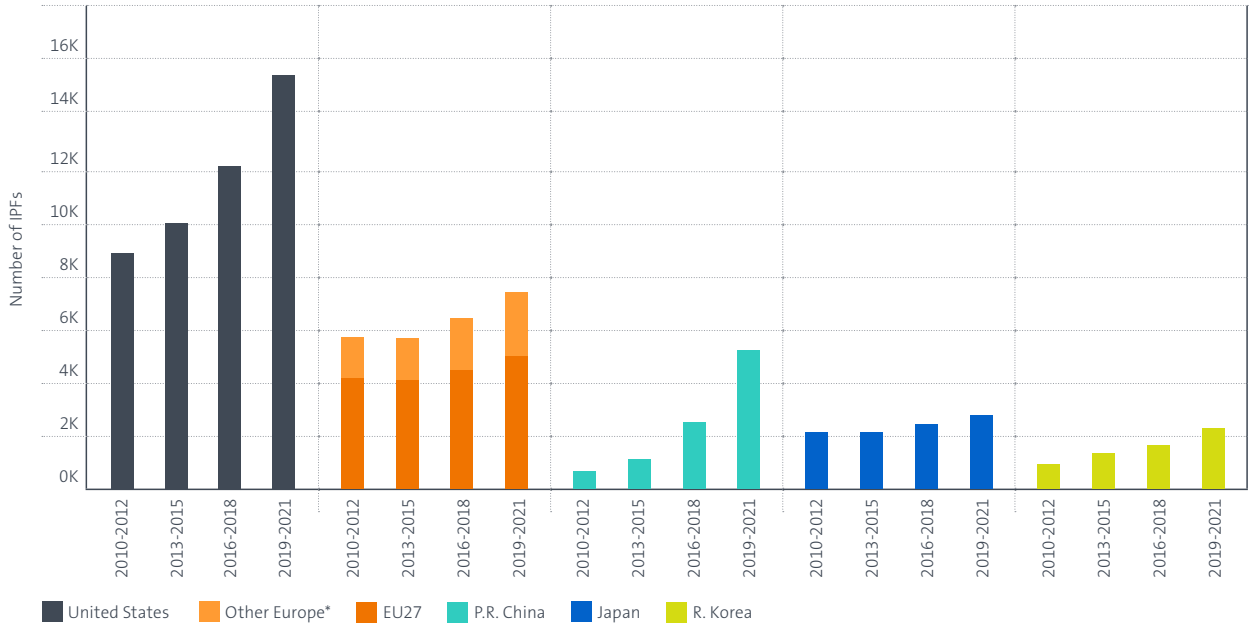
* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

Chinese applicants demonstrated the most dynamic growth, surpassing the EU in annual IPF contributions in 2020 and 2021. Starting with just 430 IPFs in 2015, China rose to over 2 000 IPFs in 2021, making it the second major source of growth next to the US. Over the 2010-2021 period, Chinese applicants held a 9% share, on par with Japanese applicants but ahead of R. Korea whose share stood at 5.9%, due to consistent annual increases in cancer-related IPFs. Figure 6 presents the evolution of absolute numbers of cancer-related IPFs across major global innovation centres over four consecutive 3-year periods between 2010 and 2021.

Figure 6

Evolution in cancer-related IPFs by major innovation centre between 2010 and 2021, by 3-year periods



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

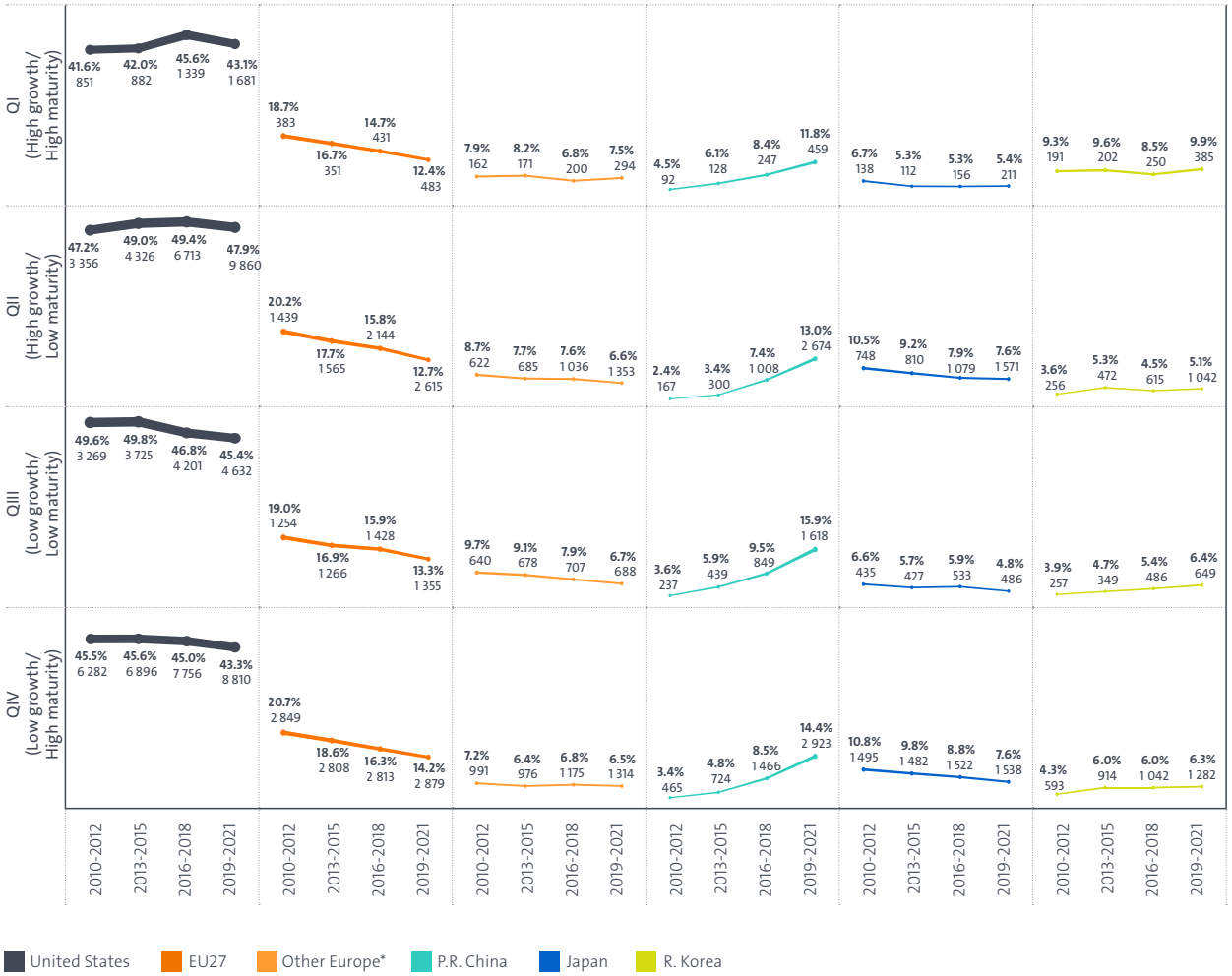
Source: EPO

4.2. Comparative performance in different segments of cancer-related technologies

Analysing innovation trajectories across the 28 technology fields provides deeper insights into recent developments. Figure 7 shows the changes in shares within the four quadrants of cancer-related technologies during the three-year periods between 2010 and 2021, providing insights into regional performance relative to overall IPF growth within the quadrants. Figures 8 and 9 show the trends in the individual cancer technology fields in the high-growth (Figure 8) and low-growth (Figure 9) quadrants.

Figure 7

Trends in shares and absolute numbers of IPFs across the four quadrants of cancer-related technologies (2010-2021) by major innovation centre



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

The US holds the largest shares across all four quadrants, but the dynamics vary significantly over time and by technology field. In quadrants 1 and 2, consisting of high growth technology fields, US applicants expanded their dominance after 2015, reflecting their strong focus on dynamic and rapidly advancing technologies. While these shares dipped slightly in the most recent 3-year period, the US continues to lead in high-growth fields. Conversely, in the low-growth quadrants 3 and 4, US shares experienced a notable decline, suggesting a shift in focus away from more mature or less dynamic technologies. However, the trends differ markedly across specific technology fields, underscoring the importance of examining developments at a more granular level.

Among the three more established high-growth technology fields (quadrant 1), US applicants hold the largest share in immunotherapeutic approaches with cytokines and oncolytic viruses. Their dominance increased from 53% in the periods before 2016 to 58.7% during 2016–2018 and has since stabilised at 56%. In contrast, US shares in the smaller field of other physical treatments, such as photodynamic therapy and tumour treating fields (TTF), have declined significantly, from 47.1% in 2010-2012 to 32.9% in 2019-2021. Meanwhile, in alternative treatments and cancer prevention, US shares grew steadily from 28.9% in 2010-2012 to nearly 35% by 2019-2021.

Among the eight more emerging high-growth fields, US applicants saw the highest gains in non-coding nucleic acids, where their share increased from 48.6% in 2010-2012 to 54.9% in 2019-2021, and in healthcare informatics, rising from 35.0% to 40.8% over the same period. In other rapidly growing fields, such as image analysis (27.6% in 2019-2021), where the US share is the lowest of all technology fields, and liquid biopsies (53.2% in 2019-2021), US applicants managed to maintain their positions. However, in the three immunotherapeutic areas – cellular immunotherapy, antibodies, and small molecule immunomodulators – US shares, though still close to or above 50%, declined slightly in the latest period (2019-2021). Gene therapy remains the field with the highest US dominance, consistently exceeding 65% across all periods from 2013 to 2021.

US shares experienced the greatest decline in the third quadrant, though notable differences exist among the four emerging technology fields with slower development. In the larger fields of personalised medicine and targeted therapy with protein kinase inhibitors, US shares fell from around 50% before 2016 to 43.2% and 45.2%, respectively, by 2019-2021. In the smaller fields of bioinformatics and immunotherapy with vaccines, US applicants reinforced their majority share, increasing from 56.1% in 2010-2012 to 62.3% in bioinformatics and from 46.3% to 50.1% in immunotherapy with vaccines, solidifying their leadership in these areas.

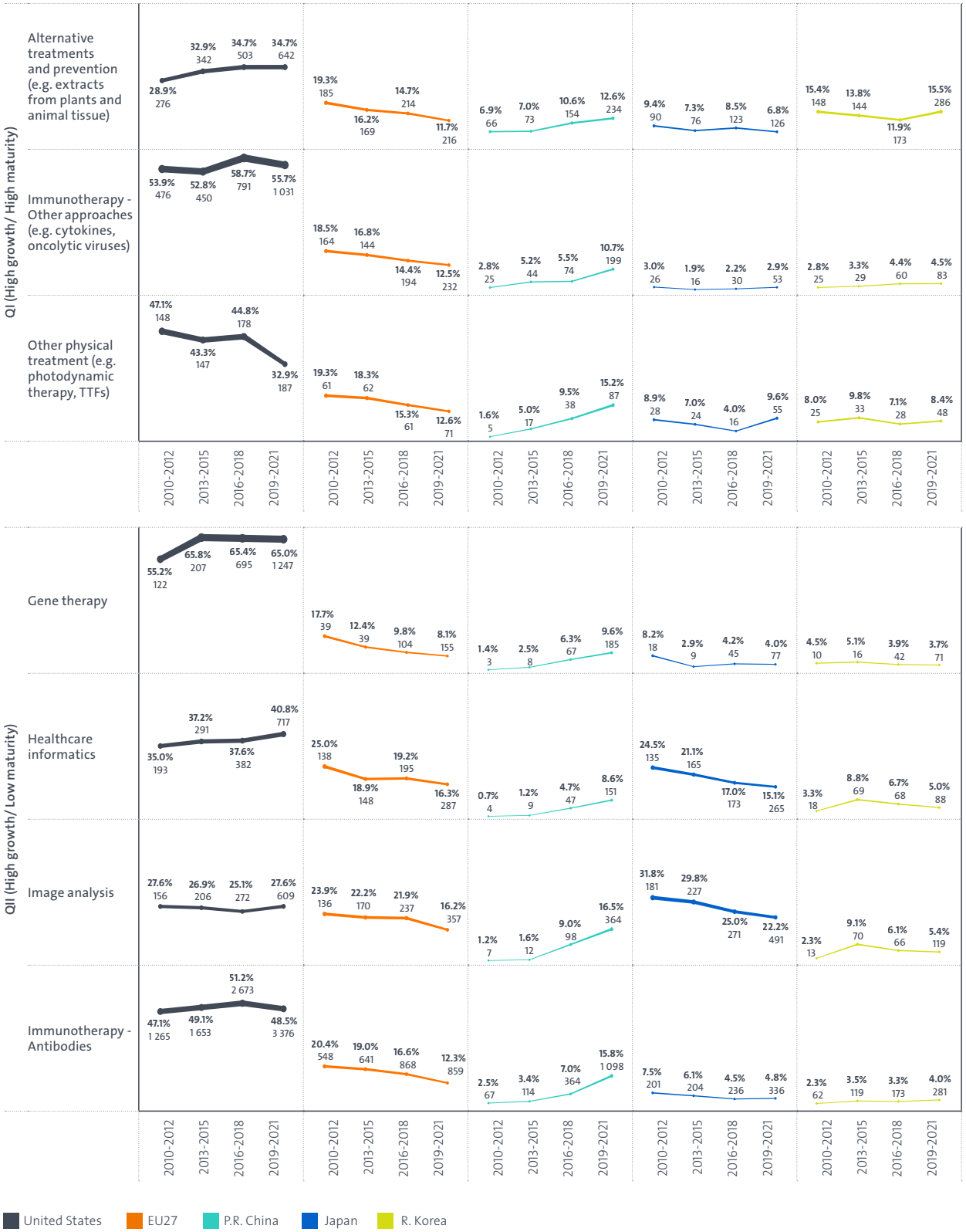
In the fourth quadrant, comprising more established low-growth technologies, US shares saw only minor decreases. For chemotherapy with antimetabolites, shares remained relatively stable at just above 50%. In other chemotherapeutic fields such as DNA-damaging agents and anti-tubulin agents, shares declined from 51.1% to 47.0% and from 54.5% to 48.8%, respectively, over the same period. In hormonal therapy, US shares stayed above 50%, reflecting continued dominance in this mature technology. Similarly, US applicants maintained shares near 50% in targeted therapy fields like conjugates and small molecule targeting agents. However, sharper declines were observed in radiotherapy, surgery, cancer models and imaging agents. In mitigating side effects, US shares decreased only slightly, while they remained stable around 50% in tumour biopsies and above 30% in imaging apparatus.

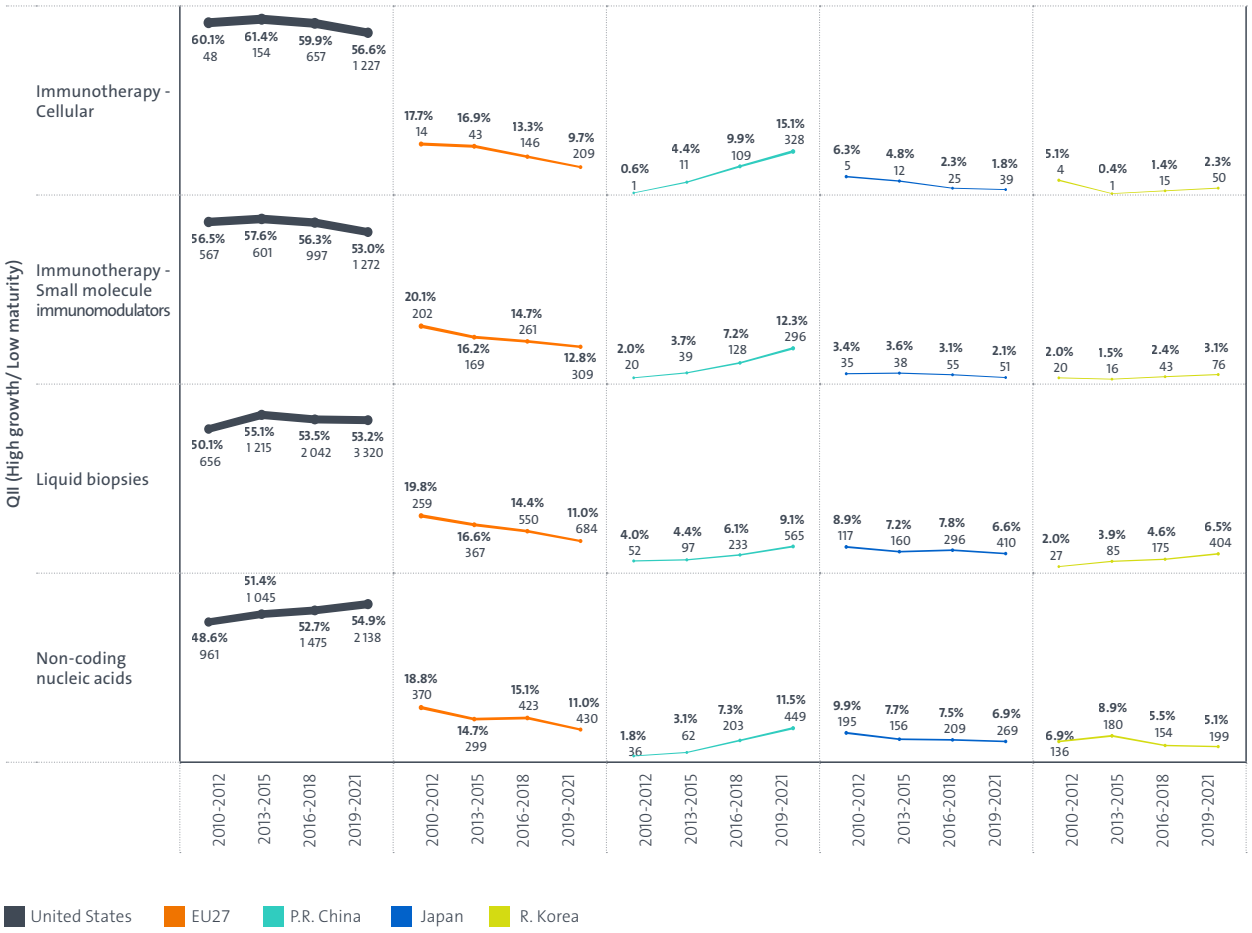
The EU's shares in all four quadrants have steadily declined over the four periods, with the most significant drop occurring in the high-growth, low-maturity quadrant 2. Among the more established high-growth technology fields, shares fell from nearly 20% in 2010-2012 to 11.7% in 2019-2021 in alternative treatments and prevention. Notable declines include also immunotherapeutic approaches with cytokines and oncolytic viruses, and other physical treatments like photodynamic therapy and tumour treating fields (TTF), where shares decreased from 18.5% to 12.5% and 19.3% to 12.6%, respectively.

Emerging high-growth technology fields also saw sharp declines in EU shares. Gene therapy experienced the steepest drop, more than halving from 17.7% in 2010-2012 to 8.1% in 2019-2021. Despite increasing absolute numbers of IPFs, shares in the three immunotherapeutic fields also decreased: from 20.4% to 12.3% in antibodies, from 17.7% to 9.7% in cellular immunotherapy, and from 20.1% to 12.8% in small molecule immunomodulators. Non-coding nucleic acids saw a similar decline, with shares falling from around 19% to just over 11%. Interestingly, healthcare informatics and image analysis stand out as fields where EU shares remain comparatively strong, with EU applicants retaining a share above 16% in 2019-2021, despite drops from approximately 25% in 2010-2012.

Figure 8

Trends in shares and absolute numbers of IPFs across the high-growth technology fields of cancer-related technologies, 2010-2021, by major innovation centre





Source: EPO

In the less dynamically growing fields, the performance of EU applicants presents a mixed picture. In several diagnostic-related fields, such as personalised medicine and the more mature technologies of imaging agents and imaging apparatus, EU applicants largely maintained relatively high shares, close to 20% in 2019-2021. However, other established fields such as tumour biopsies and cancer models as well as the younger field of bioinformatics experienced significant declines. Shares dropped from 20.4% in 2010-2012 to 15.4% in tumour biopsies, from 18.8% to 11.6% in cancer models, and from 17.5% to 10.8% in bioinformatics over the same period. EU shares also declined across nearly all cancer treatment fields. In targeted therapy and chemotherapy technologies, shares fell from around 18% in 2010–2012 to approximately 12% in 2019-2021. In surgery, the decline was even sharper, from 20.1% to 12.5%. Notably, EU applicants largely managed to maintain their shares in radiotherapy and immunotherapeutic vaccines, both remaining steady at around 20% in 2019-2021.

The shares of Chinese applicants have increased significantly across all four quadrants over all successive 3-year periods. For instance, in the field of other physical treatments (e.g. photodynamic therapy and TTFs) their share surpassed 15% in the most recent 3-year period 2019-2021. A similar upward trend is evident in most emerging high-growth fields. Notable gains include image analysis, where their share rose to 16.5% in 2019-2021, and immunotherapy with antibodies and cellular immunotherapy, with shares reaching 15.8% and 15.1%, respectively. Despite dynamic growth, Chinese applicants' shares remained below 10% in key fields such as healthcare informatics, gene therapy and liquid biopsies.

In the low-growth quadrants 3 and 4, Chinese applicants made notable gains in targeted therapy fields, particularly with protein kinase inhibitors, reaching a share of 17.7% in 2019-2021, and other small molecule targeting agents, with a share of 15.8%. In chemotherapeutic fields such as anti-tubulin agents and DNA-damaging agents their shares grew to 15.5% and 14.7%, respectively. The highest

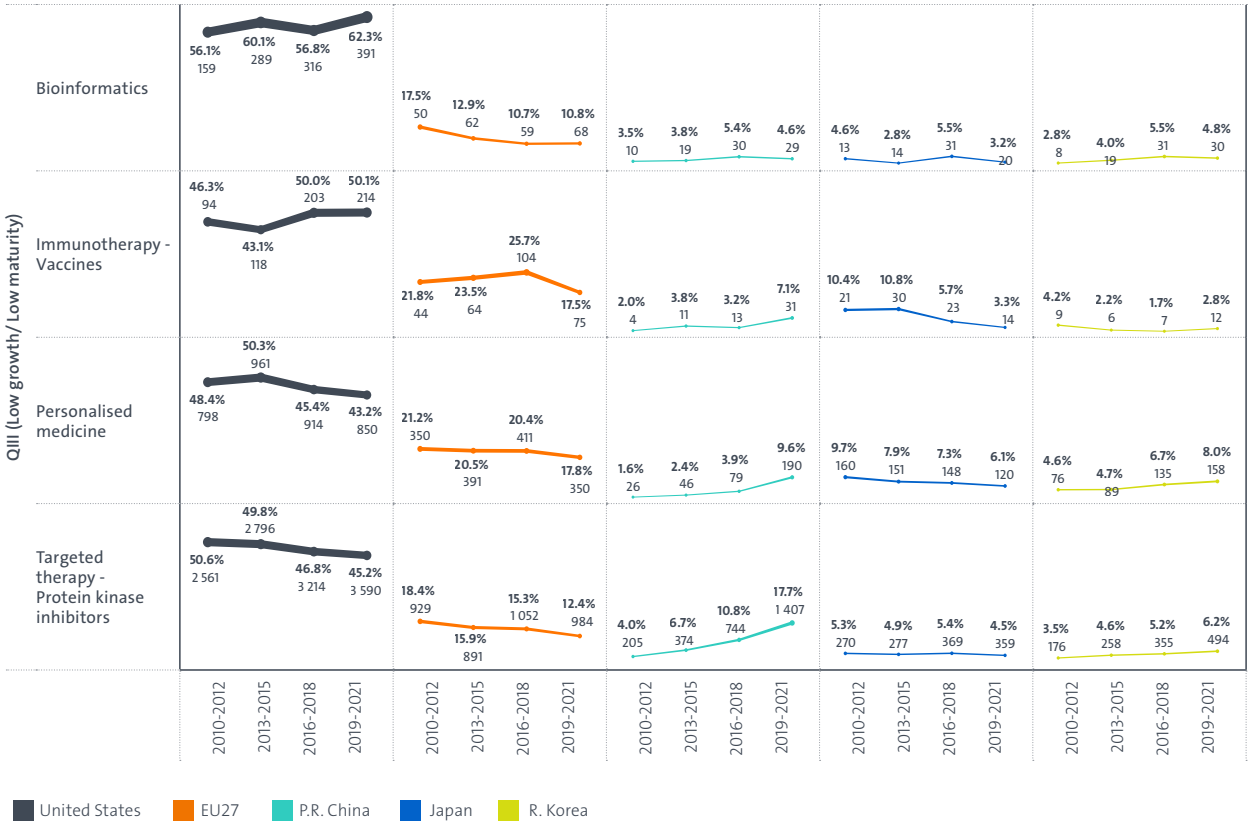
share for Chinese applicants in 2019-2021 was in cancer models, where they achieved 18.1%. While contributions in immunotherapies with vaccines (7.1%), tumour biopsies (8.0%) and personalised medicine (9.6%) have grown significantly, these shares have yet to surpass 10%. In bioinformatics, however, Chinese applicants still lag behind, with their share remaining below 5% in 2019-2021.

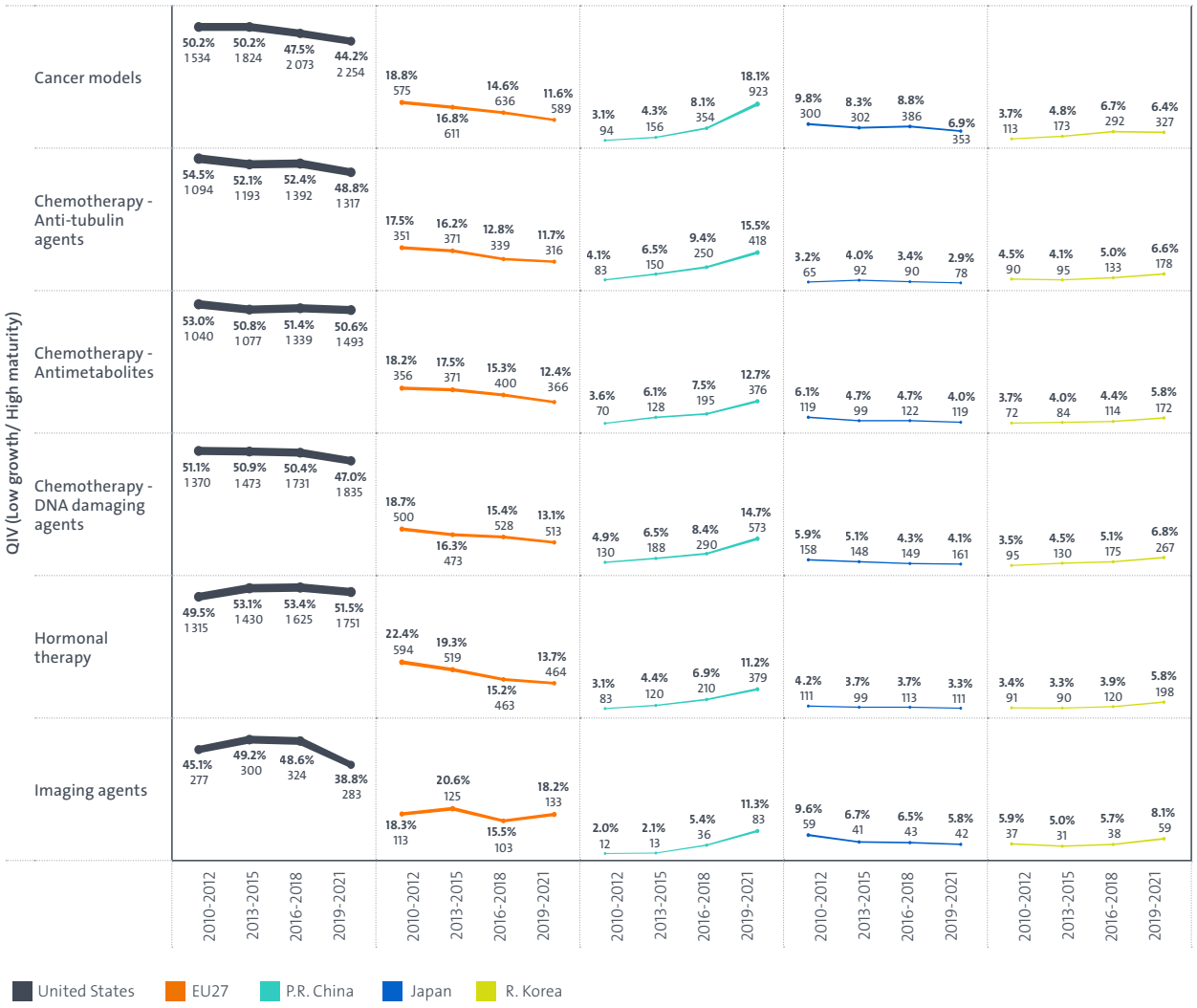
Japanese applicants' biggest strengths in high-growth cancer-related technologies during 2019-2021 were in ICT-related fields, specifically healthcare informatics (15.1%) and image analysis (22.2%). However, their shares in both fields have declined significantly over time. In other emerging high-growth fields Japan maintained modest shares, including 6.6% in liquid biopsies and 6.9% in non-coding nucleic acids. One notable exception is the more established but smaller field of other physical treatments (e.g. photodynamic therapy and TTFs), where Japan increased its share to 9.6% in 2019-2021.

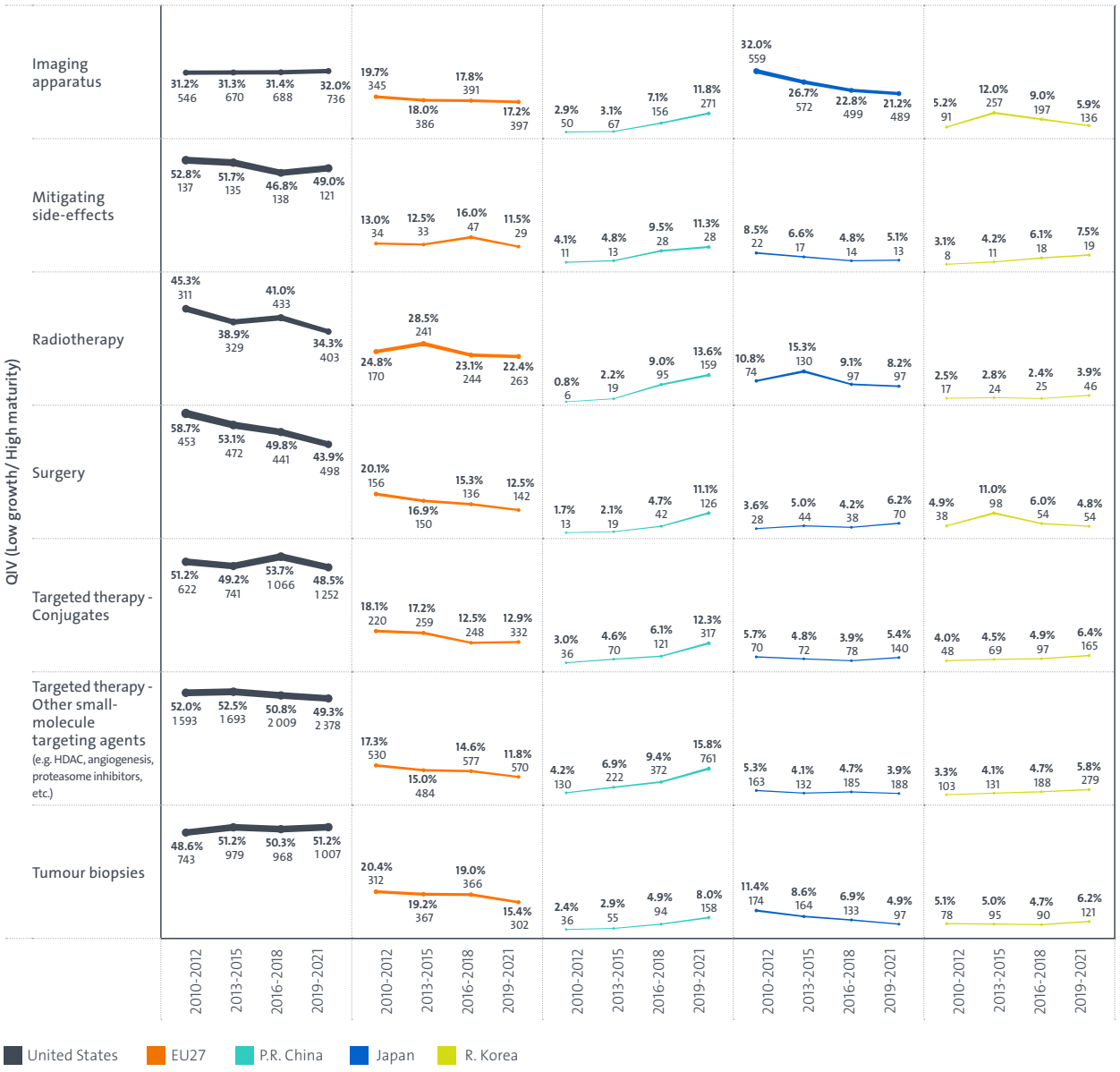
Among low-growth fields, imaging apparatus remained Japan's strongest area with a 21.2% share in 2019-2021 despite a decline of over 10 percentage points since 2010-2012. Radiotherapy was the only other field where Japanese applicants maintained a strong presence, with a share close to 10% in 2019-2021. In contrast, tumour therapies and immunotherapeutic vaccines saw the steepest declines, with shares dropping from 11.4% to 4.9% and 10.4% to 3.3%, respectively, over the four 3-year periods.

Figure 9

Trends in shares and absolute numbers of IPFs across the low-growth technology fields of cancer-related technologies, 2010-2021, by major innovation centre




QIV (Low growth/ High maturity)
Cancer models
50.2% 1 534
50.2% 1 824
47.5% 2 073
44.2% 2 254
18.8% 575
16.8% 611
14.6% 636
11.6% 589
3.1% 94
4.3% 156
8.1% 354
18.1% 923
9.8% 300
8.3% 302
8.8% 386
6.9% 353
3.7% 113
4.8% 173
6.7% 292
6.4% 327
Chemotherapy - Anti-tubulin agents
54.5% 1 094
52.1% 1 193
52.4% 1 392
48.8% 1 317
17.5% 351
16.2% 371
12.8% 339
11.7% 316
4.1% 83
6.5% 150
9.4% 250
15.5% 418
3.2% 65
4.0% 92
3.4% 90
2.9% 78
4.5% 90
4.1% 95
5.0% 133
6.6% 178
Chemotherapy - Antimetabolites
53.0% 1 040
50.8% 1 077
51.4% 1 339
50.6% 1 493
18.2% 356
17.5% 371
15.3% 400
12.4% 366
3.6% 70
6.1% 128
7.5% 195
12.7% 376
6.1% 119
4.7% 99
4.7% 122
4.0% 119
3.7% 72
4.0% 84
4.4% 114
5.8% 172
Chemotherapy - DNA damaging agents
51.1% 1 370
50.9% 1 473
50.4% 1 731
47.0% 1 835
18.7% 500
16.3% 473
15.4% 528
13.1% 513
4.9% 130
6.5% 188
8.4% 290
14.7% 573
5.9% 158
5.1% 148
4.3% 149
4.1% 161
3.5% 95
4.5% 130
5.1% 175
6.8% 267
Hormonal therapy
49.5% 1 315
53.1% 1 430
53.4% 1 625
51.5% 1 751
22.4% 594
19.3% 519
15.2% 463
13.7% 464
3.1% 83
4.4% 120
6.9% 210
11.2% 379
4.2% 111
3.7% 99
3.7% 113
3.3% 111
3.4% 91
3.3% 90
3.9% 120
5.8% 198
Imaging agents
45.1% 277
49.2% 300
48.6% 324
38.8% 283
18.3% 113
20.6% 125
15.5% 103
18.2% 133
2.0% 12
2.1% 13
5.4% 36
11.3% 83
9.6% 59
6.7% 41
6.5% 43
5.8% 42
5.9% 37
5.0% 31
5.7% 38
8.1% 59
2010-2012
2013-2015
2016-2018
2019-2021
United States
EU27
P.R. China
Japan
R. Korea



Source: EPO

Overall, Korean applicants' shares remained relatively stable in the high-growth quadrants 1 and 2 but showed notable increases in the low-growth quadrants 3 and 4. At the technology field level, their highest shares in 2019-2021 were in alternative treatments and prevention (15.5%) and in other physical treatments (8.4%). However, significant declines occurred in digital fields such as healthcare informatics, where shares fell from 8.8% in 2013-2015 to 5.0% in 2019-2021, and image analysis, which dropped from 9.1% to 5.4% over the same period. Conversely, the largest percentage-point increase was observed in liquid biopsies, rising from 2.0% in 2010-2012 to 6.5% in 2019-2021.

Among the less dynamic but emerging fields, Korean applicants saw growth in personalised medicine with shares increasing from 4.6% in 2010-2012 to 8.0% in 2019-2021, and in targeted therapies with protein kinase inhibitors, rising from 3.5% to 6.2%. In more established technologies, Korean shares grew across most fields, particularly in mitigating side-effects, where shares rose from 3.1% to 7.5%. However, exceptions to this trend included imaging apparatus, where shares declined from 12.0% in 2013-2015 to 5.9% in 2019-2021, and surgery, which dropped from 11.0% to 4.8% over the same period.

4.3. Cancer-related innovation performance across European countries

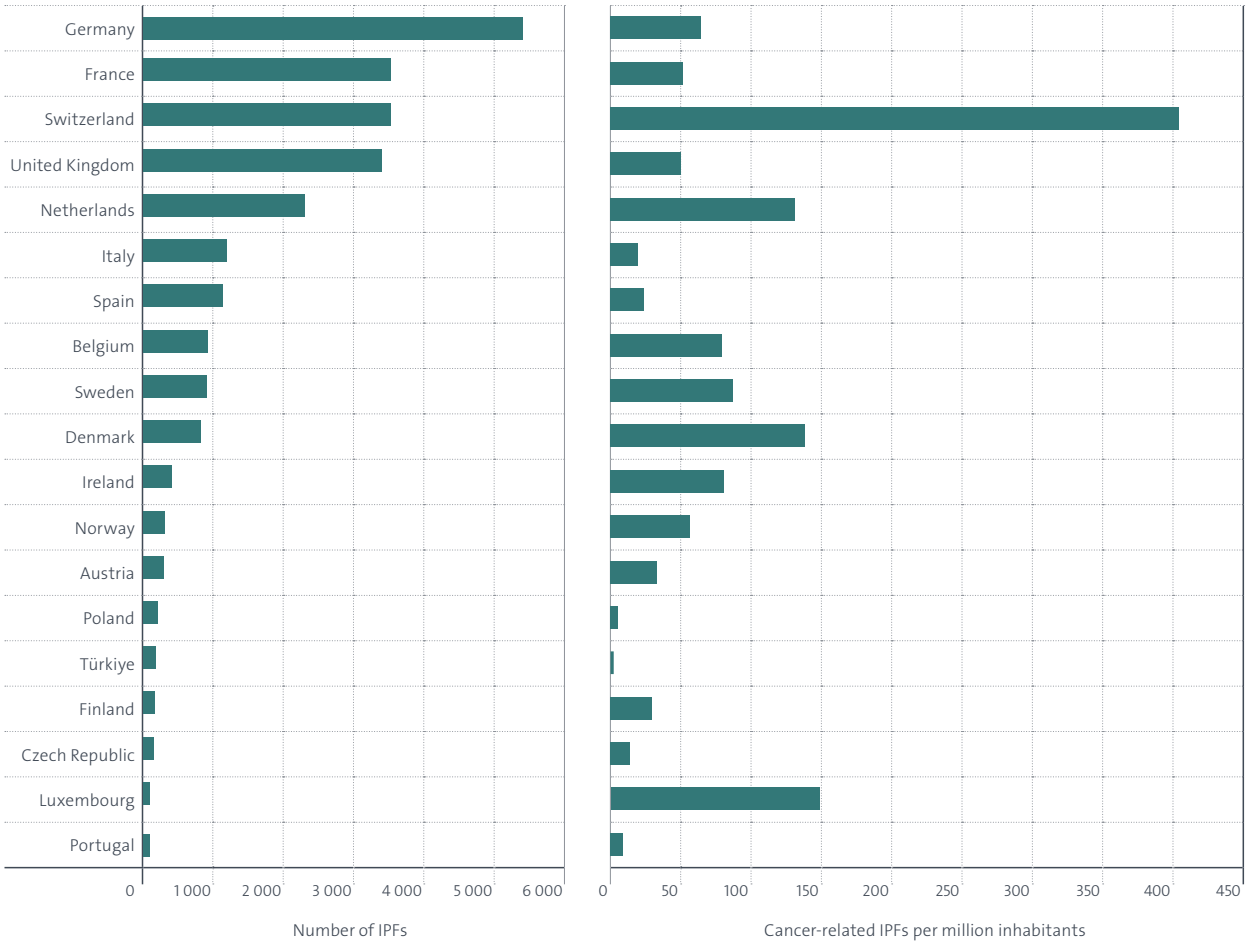
Among European countries, Germany leads with nearly 5 400 cancer-related IPFs published between 2010 and 2021, accounting for 5.1% of the global total (Figure 10). France and Switzerland follow closely, each contributing just over 3 500 IPFs and a 3.3% share, placing them second and third, respectively. Switzerland stands out as the country with the highest number of cancer-related IPFs per million inhabitants, exceeding 400. The UK ranks fourth with 3 384 IPFs and a similar 3.3% share. The Netherlands holds the fifth position in Europe and third within the EU, with over 2 300 IPFs and a 2.2% share. Italy and Spain rank sixth and seventh in Europe, each contributing over 1 100 IPFs and securing shares above 1%. Luxembourg and Denmark rank among the top three European countries with the highest number of cancer-related IPFs per million inhabitants.

As shown in Figure 11, while the total number of cancer-related IPFs has grown in absolute terms for most European countries over the four periods, some countries experienced stagnation or even a decline in relative contributions. In Germany, the number of IPFs remained stable at around 1 300 per 3-year period. In France, contributions have shown a slow but steady increase, whereas Swiss applicants saw a notable rise only during the most recent 3-year period. The UK exhibited significant growth after 2015, nearly doubling its cancer-related IPF output. Among smaller countries, particularly positive developments were observed in Ireland, where IPFs increased from under 90 in 2016-2018 to 181 in 2019-2021, and in Türkiye, which saw a jump from 40 to over 100 IPFs over the same timeframe. Other smaller countries, such as the Czech Republic and Portugal, also demonstrated growth, though on a smaller scale.

Figure 12 illustrates the development of shares in IPFs for the five largest European countries across the four quadrants across the four 3-year periods. Figures 13 and 14 provide a more detailed view, showing changes at the individual technology field level between the two aggregated 6-year periods (2010-2015 and 2016-2021). This aggregation accounts for smaller IPF volumes in individual European countries while enabling a meaningful analysis of share changes during the growth phase in cancer-related technologies post-2015.

Figure 10

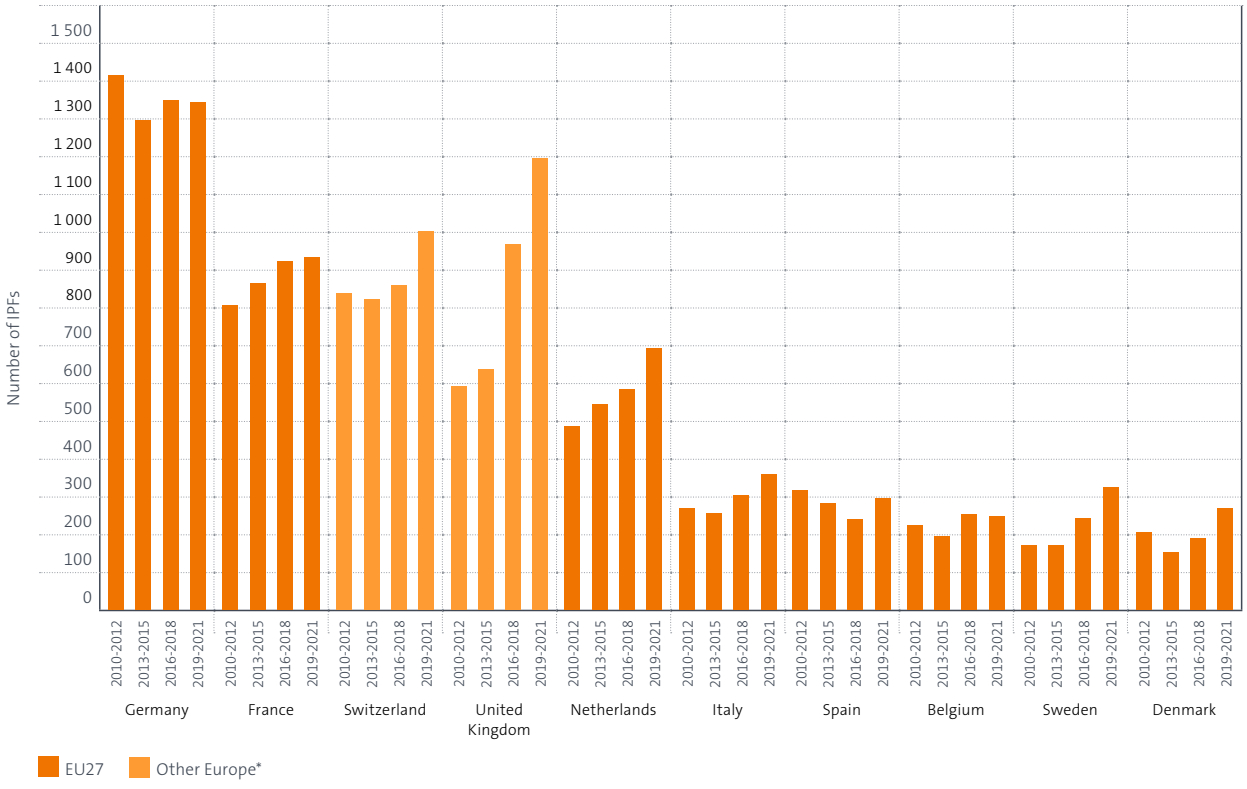
IPFs in all cancer-related technologies by European country between 2010 and 2021 (number of IPFs and global share) and per million inhabitants



Source: EPO

Figure 11

Trend in all cancer-related IPFs by European country across four consecutive 3-year periods, 2010-2021



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

Figure 12

Trends in shares and absolute numbers of IPFs across the four quadrants of cancer-related technologies, 2010-2021, by top European country

Germany's shares have declined across all four quadrants, dropping from 6% or more in 2010-2012 to below 4% in 2019-2021. At the individual technology level, significant share losses in high-growth fields between the two periods 2010-2015 and 2016-2021 were observed in other physical treatments (from 6.5% to 2.1%) and liquid biopsies (from 6.2% to 3.6%), despite an increase in absolute IPF numbers. Smaller declines were recorded in fields such as immunotherapy, gene therapy and non-coding nucleic acids. However, German applicants retained leading shares in image analysis (7.9%) and healthcare informatics (6.8%) in 2016-2021.

In the low-growth fields, Germany's shares also dropped across most cancer treatment technologies. Notable declines occurred in hormonal therapy (from 7.8% to 3.3%) and radiotherapy (from 9.7% to 6.1%), along with various fields related to chemotherapy. However, shares in diagnostic-related technologies, such as tumour biopsies and imaging apparatus, showed only slight decreases, while shares in personalised medicine (around 5%) and mitigating side effects (around 4%) remained largely unchanged. German applicants achieved their highest share in 2016-2021 in immunotherapeutic vaccines, with 9.1%.

French applicants also experienced a decline in their shares across all quadrants, from around 4% in the early 2010s to below 3% in 2019-2021. Despite an increase in the absolute number of IPFs in high-growth technology fields, French applicants struggled to maintain their relative position. The largest drop occurred in cellular immunotherapy, where shares fell from 7.0% in 2010-2015 to 3.0% in 2016-2021. Declines in other high-growth fields were more modest. In low-growth fields, French shares remained stable in most areas, with exceptions such as an increase in immunotherapeutic vaccines (4.0% to 4.7%) and decreases in cancer models (4.8% to 3.3%) and anti-tubulin agents (4.0% to 2.6%). Personalised medicine emerged as the leading field for French applicants, holding a share of 5.6% in 2016-2021.

Swiss applicants showed more varied trends. Strong gains were recorded in high-growth fields such as gene therapy (1.6% to 3.2%) and other physical treatments (1.2% to 5.4%). However, significant declines were observed in their historically strongest field, immunotherapy with antibodies, where shares fell from 8.4% to 4.7%. Among less dynamic fields, Swiss shares dropped notably in targeted therapies, including protein kinase inhibitors (6.6% to 3.7%), conjugates (4.8% to 3.1%) and other small-molecule targeting agents (5.1% to 3.4%). In fields related to chemotherapy, the declines were more moderate. Conversely, shares increased in smaller fields like radiotherapy (3.0% to 4.3%) and immunotherapy with vaccines (1.4% to 3.1%). Stability was achieved in areas such as hormonal therapy (around 4%) and bioinformatics (around 3%).

The shares of UK applicants remained relatively stable at or above 3% across the periods, despite oscillations. In high-growth technology fields, UK applicants managed to maintain or improve their contributions except in gene therapy where the share fell from 3.3% in 2010-2015 to 2.2% in 2016-2021. Noteworthy increases were observed in cellular immunotherapy, which rose from 4.5% to 5.8%, and liquid biopsies, from 2.7% to 3.9%. In the less dynamic fields of quadrants 3 and 4, UK applicants saw declines in imaging agents (4.8% to 3.3%) and immunotherapeutic vaccines (4.7% to 3.2%) but maintained or increased their shares in all other areas. Significant gains were recorded in surgery (1.4% to 5.1%), personalised medicine (2.8% to 3.9%), targeted therapy with conjugates (3.3% to 4.6%) and tumour biopsies (2.3% to 3.6%).

Dutch applicants demonstrate a distinctive profile, with a substantial concentration of IPFs in high-growth fields like healthcare informatics and image analysis. However, their shares in these fields declined from over 7% to around 5.5%. In less dynamic technology fields, Dutch IPFs are predominantly focused on certain diagnostic and treatment fields (but, as the Agendia case study shows, it may even be that the whole configuration of such fields is critically tributary to breakthroughs originally derived from such a science-intensive innovation system). Shares in imaging apparatus remained stable at 7.9%, while radiotherapy and surgery experienced significant declines, falling from 7.7% to 6.0% and 7.5% to 3.8%, respectively.

Figure 13

Trends in shares and absolute numbers of IPFs across the high-growth technology fields of cancer-related technologies, 2010-2021, by top European country

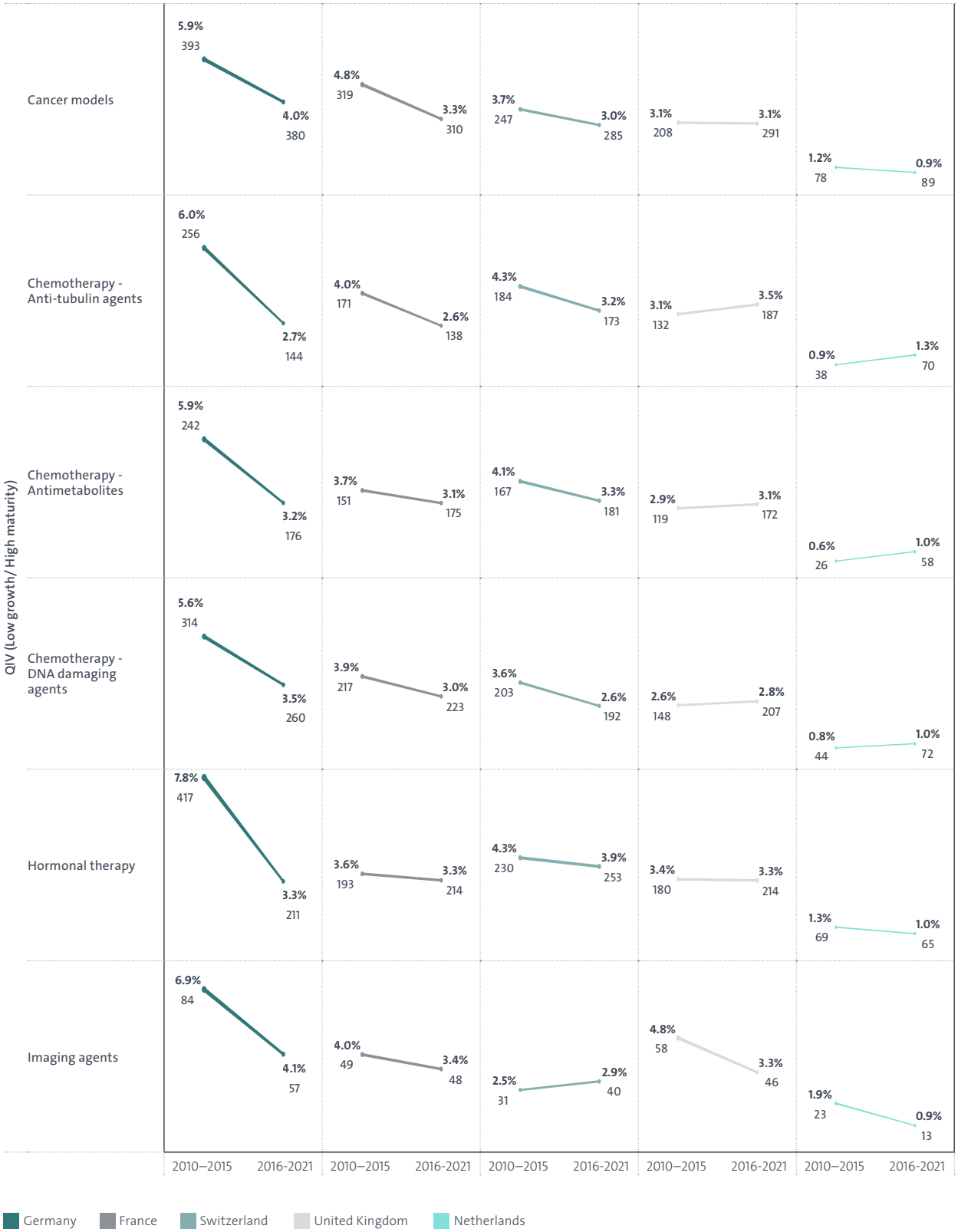

QII (High growth/ Low maturity)
Gene therapy
4.0% 22
2.7% 81
3.0% 16
1.9% 58
1.6% 9
3.2% 96
3.3% 18
2.2% 65
1.8% 10
0.7% 22
Healthcare informatics
8.7% 116
6.8% 189
2.4% 32
1.6% 46
2.3% 31
2.6% 72
2.9% 38
2.2% 61
7.0% 94
5.7% 157
Image analysis
9.2% 122
7.9% 260
2.6% 35
1.7% 57
0.9% 12
1.4% 47
2.4% 32
2.2% 71
7.5% 100
5.5% 181
Immunotherapy - Antibodies
6.2% 375
4.3% 526
5.0% 305
3.5% 427
8.4% 507
4.7% 573
3.8% 232
3.9% 475
1.2% 75
1.1% 133
2010–2015
2016-2021
Germany
France
Switzerland
United Kingdom
Netherlands

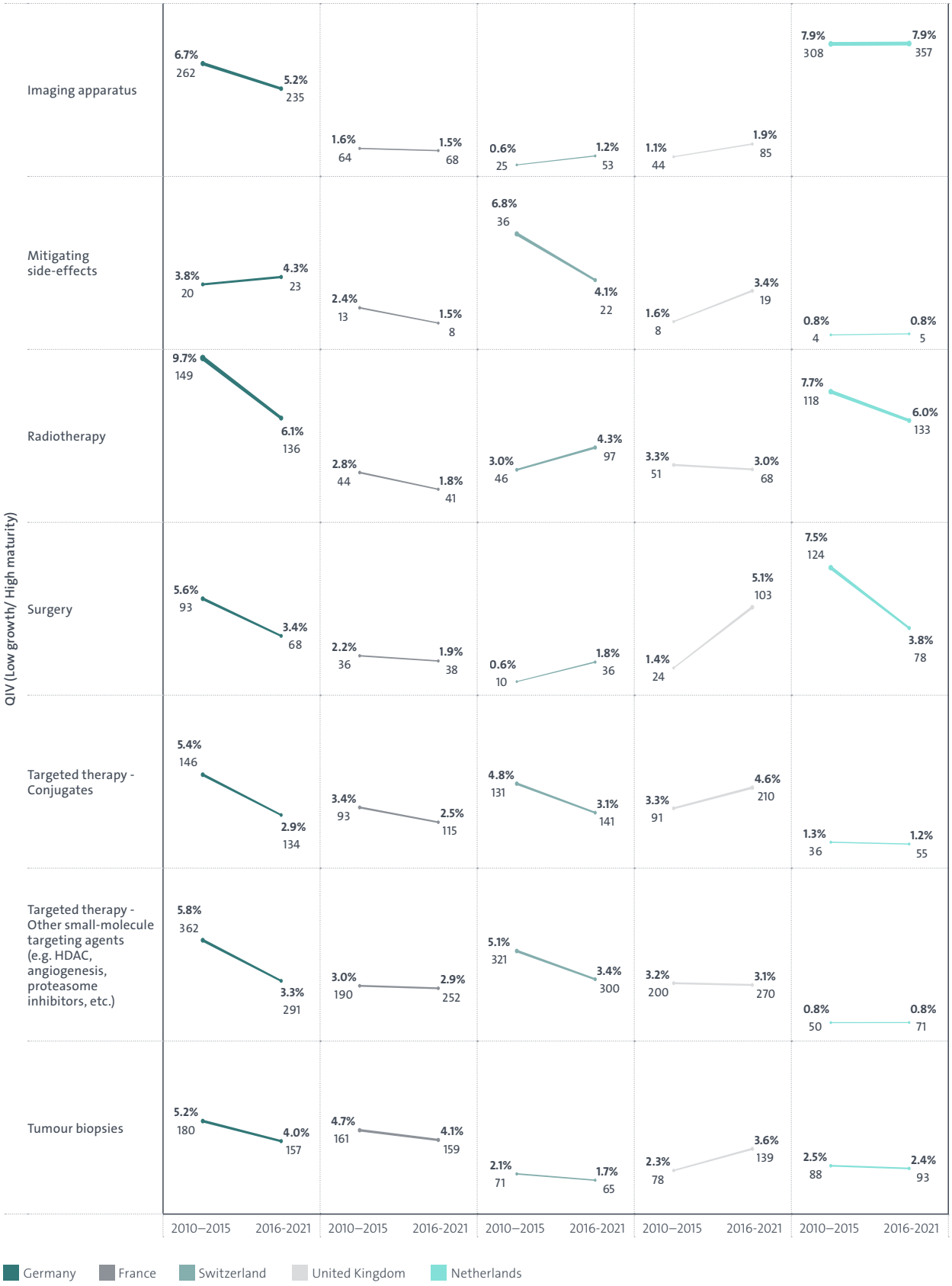

QII (High growth/ Low maturity)
Immunotherapy - Cellular
5.2% 17
4.2% 139
7.0% 23
3.0% 100
1.4% 5
2.6% 84
4.5% 15
5.8% 188
1.5% 5
0.7% 22
Immunotherapy - Small molecule immunomodulators
5.4% 112
4.2% 175
3.7% 75
2.7% 115
3.5% 73
3.3% 138
3.7% 76
3.2% 132
0.7% 14
0.8% 34
Liquid biopsies
6.2% 217
3.6% 361
3.5% 122
2.3% 228
2.9% 103
3.0% 300
2.7% 94
3.9% 397
1.6% 56
0.8% 78
Non-coding nucleic acids
4.9% 198
4.3% 287
4.2% 167
2.7% 183
3.5% 142
2.4% 160
2.8% 110
2.3% 156
1.3% 54
1.0% 69
2010–2015
2016-2021
Germany
France
Switzerland
United Kingdom
Netherlands

Source: EPO

Figure 14

Trends in shares and absolute numbers of IPFs across the low-growth technology fields of cancer-related technologies, 2010-2021, by top European country


QIV (Low growth/ High maturity)
Cancer models
5.9% 393
4.0% 380
4.8% 319
3.3% 310
3.7% 247
3.0% 285
3.1% 208
3.1% 291
1.2% 78
0.9% 89
Chemotherapy - Anti-tubulin agents
6.0% 256
2.7% 144
4.0% 171
2.6% 138
4.3% 184
3.2% 173
3.1% 132
3.5% 187
0.9% 38
1.3% 70
Chemotherapy - Antimetabolites
5.9% 242
3.2% 176
3.7% 151
3.1% 175
4.1% 167
3.3% 181
2.9% 119
3.1% 172
0.6% 26
1.0% 58
Chemotherapy - DNA damaging agents
5.6% 314
3.5% 260
3.9% 217
3.0% 223
3.6% 203
2.6% 192
2.6% 148
2.8% 207
0.8% 44
1.0% 72
Hormonal therapy
7.8% 417
3.3% 211
3.6% 193
3.3% 214
4.3% 230
3.9% 253
3.4% 180
3.3% 214
1.3% 69
1.0% 65
Imaging agents
6.9% 84
4.1% 57
4.0% 49
3.4% 48
2.5% 31
2.9% 40
4.8% 58
3.3% 46
1.9% 23
0.9% 13
2010–2015
2016-2021
Germany
France
Switzerland
United Kingdom
Netherlands


QIV (Low growth/ High maturity)
Imaging apparatus
6.7% 262
5.2% 235
1.6% 64
1.5% 68
0.6% 25
1.2% 53
1.1% 44
1.9% 85
7.9% 308
7.9% 357
Mitigating side-effects
3.8% 20
4.3% 23
2.4% 13
1.5% 8
6.8% 36
4.1% 22
1.6% 8
3.4% 19
0.8% 4
0.8% 5
Radiotherapy
9.7% 149
6.1% 136
2.8% 44
1.8% 41
3.0% 46
4.3% 97
3.3% 51
3.0% 68
7.7% 118
6.0% 133
Surgery
5.6% 93
3.4% 68
2.2% 36
1.9% 38
0.6% 10
1.8% 36
1.4% 24
5.1% 103
7.5% 124
3.8% 78
Targeted therapy - Conjugates
5.4% 146
2.9% 134
3.4% 93
2.5% 115
4.8% 131
3.1% 141
3.3% 91
4.6% 210
1.3% 36
1.2% 55
Targeted therapy - Other small-molecule targeting agents (e.g. HDAC, angiogenesis, proteasome inhibitors, etc.)
5.8% 362
3.3% 291
3.0% 190
2.9% 252
5.1% 321
3.4% 300
3.2% 200
3.1% 270
0.8% 50
0.8% 71
Tumour biopsies
5.2% 180
4.0% 157
4.7% 161
4.1% 159
2.1% 71
1.7% 65
2.3% 78
3.6% 139
2.5% 88
2.4% 93
2010–2015
2016-2021
Germany
France
Switzerland
United Kingdom
Netherlands

Source: EPO

Case study: Agendia

Headquarters/Offices: Irvine, California / Amsterdam
Products: Gene-based breast cancer test

Genome prognosis for better-informed breast cancer management

Gene-based testing plays a crucial role in shaping the prospects for those living with breast cancer over the long-term. Women diagnosed with breast cancer, armed with reliable information, can approach the risk of a 10-year cancer recurrence with increased confidence. Patient care can now better distinguish between those patients with a higher predisposition who require chemotherapy and those who can avoid the potentially harmful side effects of toxic treatments without compromising their chances of survival.

Triangulating science, PRO management and business innovation

Laura Johanna van't Veer built her academic path in the Netherlands, initiating her studies on molecular oncology at the University of Amsterdam and continuing at the University of Leiden where she arrived at the frontier of oncogene activation and tumorigenesis. She later stepped into the Netherlands Cancer Institute and became Head of Diagnostic Oncology. Her contributions include over 100 research papers in various renowned scientific journals.

At the turn of the millennium, Laura was beginning a process that used a DNA signature of 70 genes to assess whether a breast cancer patient is at risk of recurrence. This proved to be a breakthrough that would make her globally known in the field, with many awards followed suit: the ESMO Lifetime Achievement Award for Translational Research in Breast Cancer in 2007, the European Inventor Award in 2015 and the Giants of Cancer Care Award in 2020 are just a few examples.

van't Veer decided to bring her discoveries to the clinical frontlines. Her solutions obtained the first FDA 510K "In Vitro Diagnostic Multigene Index Assay" (IVDMIA) clearance in 2007, and now they figure in several international and national guidelines. She eventually switched continents to take up an academic position at the University of California, San Francisco. As principal investigator there, van't Veer has received multiple research grants from the National Institutes of Health (NIH).

Computational approaches: Bringing about the era of individualised medicine

Through a series of new methodologies around the turn of the millennium, van't Veer's inventions created an early combination of microchips and biological materials to advance medical practice. Her answer was turning large-scale biomedical data into usable and actionable information.

van't Veer partnered with René Bernards, professor of molecular carcinogenesis at Utrecht University, who would become a winner of the Spinoza Prize and an elected international member of the National Academy of Sciences of the United States. Together they founded a company called Agendia, currently based in Amsterdam and California, that launched the genetic test onto the market back in 2004 under the name MammaPrint.

Genetic testing: Empowering choices along the patient journey

Anticipating the risk of recurrence of cancer gave early information for deciding on the best recovery treatment, with or without chemotherapy. Based on knowledge of the genetic makeup of the tumour as well as the genetic makeup of the patient, the test made it possible for patients and doctors to choose the right treatment ahead of time.

Measuring the activity of cancer-specific genes with just a small tissue sample from the breast cancer would prove to have a great impact. It was not just about information: it brought into sharp focus the importance of personalised medicine in advancing patient management. Agendia is now a leading company worldwide in the field of molecular diagnostics.

5. Benchmarking European public research institutions

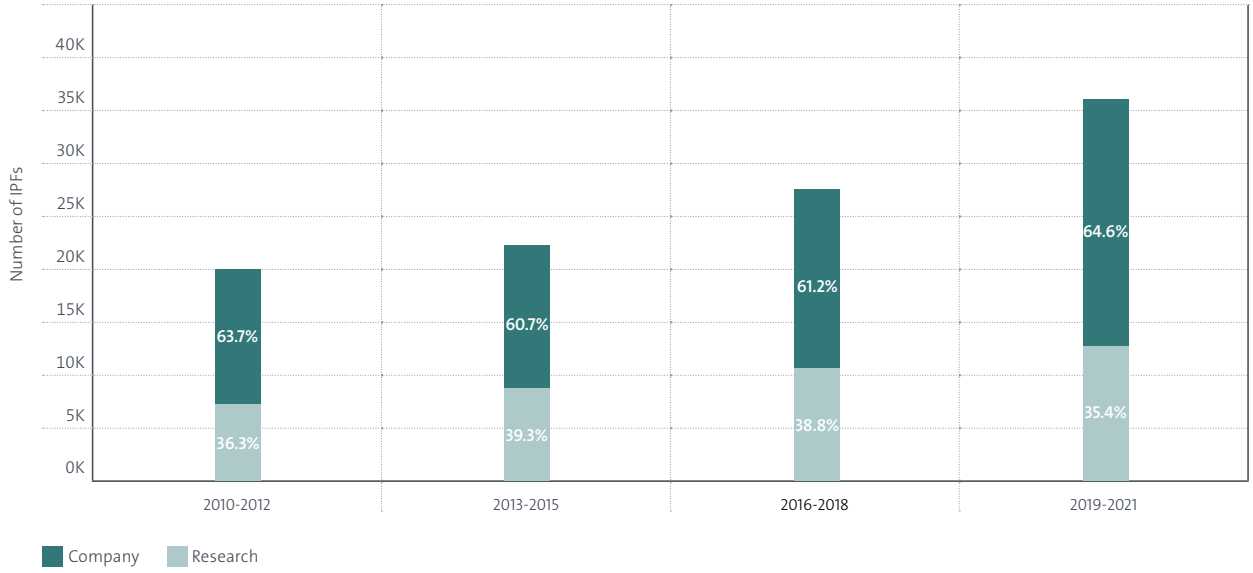
This section examines the critical role of research institutions, including universities, hospitals and public research organisations (PROs), in driving innovation in cancer-related technologies. The first EPO cancer study (EPO, 2024a) highlighted their substantial contribution to patenting activity, with several research institutions ranking among the top applicants. Building on these findings, this section further investigates their performance in cancer-related IPFs and explores patenting dynamics across various technology fields, focusing on major global innovation centres and selected European countries.

5.1. Contributions to global cancer-related patenting

Between 2010 and 2021, research institutions were co-applicants for nearly 40 000 IPFs, representing 37.3% of all cancer-related IPFs. Their share grew from 36.3% in 2010-2012 to a peak of 39.3% in the following three-year period, but began to decline during the following growth phase, dropping to 38.8% in 2016-2018 and 35.4% in 2019-2021 (Figure 15). However, this global figure masks significant regional variations.

Figure 15

Trend in IPFs and shares of research institutions in cancer-related patenting



Source: EPO

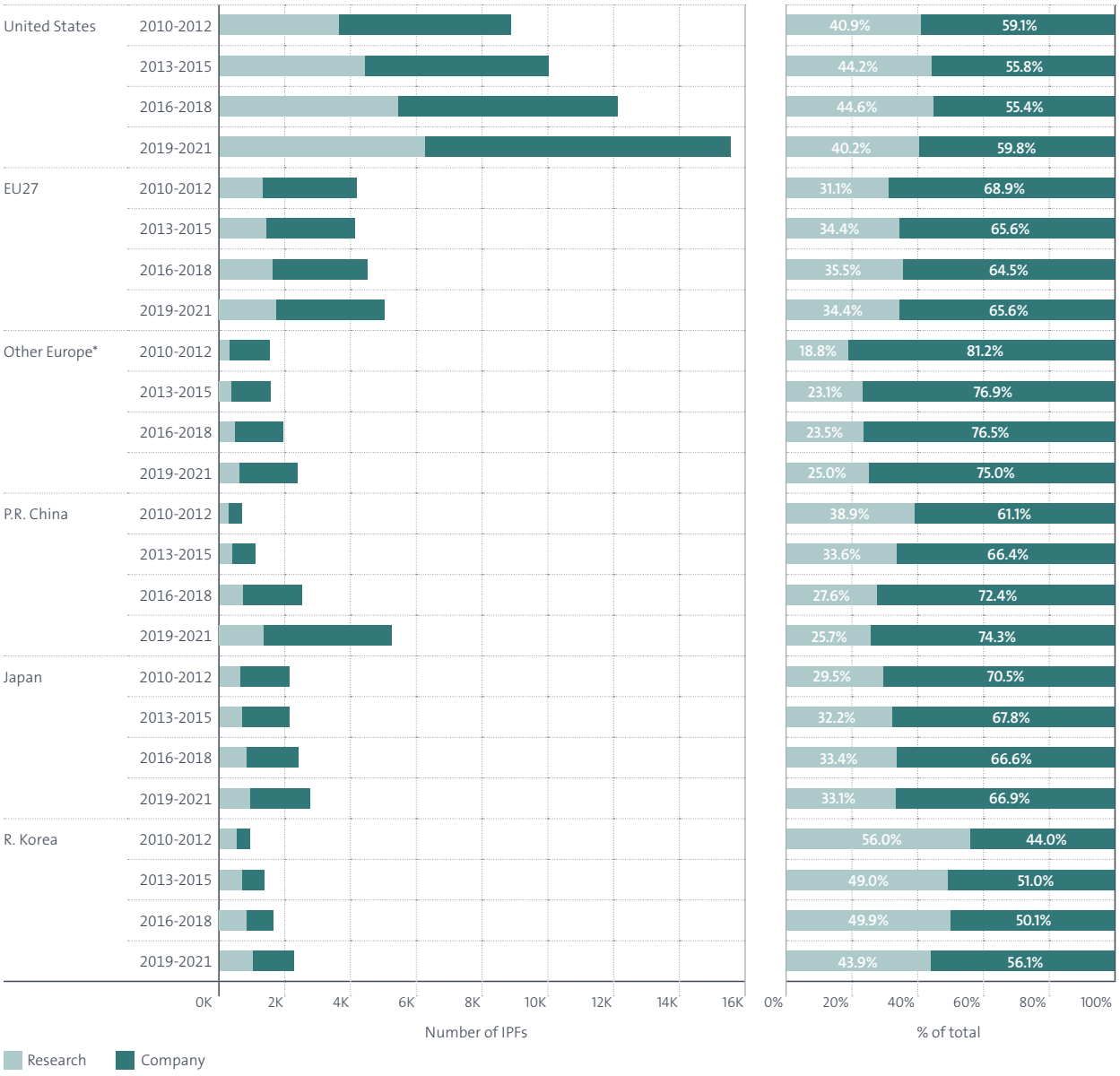
While the absolute number of IPFs co-applied for by research institutions increased in all major innovation centres over this period (Figure 16), their relative shares followed different trajectories. US research institutions consistently held one of the highest shares, rising from 40.9% in 2010-2012 to 44.7% in 2016-2018 before a pronounced decline to 40.2% in 2019-2021. The R. Korea had the highest share of IPFs co-applied for by research institutions globally, but their contribution fell significantly over the periods, from 56.1% in 2010-2012 to 43.8% in 2019-2021.

In contrast, the shares of Japanese research institutions grew steadily, from 29.5% in 2010-2012 to 33.3% in 2016-2018, and 33.2% thereafter. EU research institutions displayed a similar trend, with their share increasing from 31% in 2010-2012 to 35.5% in 2016-2018, before a slight decline to 34.5% in 2019-2021. Other European countries also saw a rise, with shares growing from 18.8% to 25.1% over the same period, though still below EU levels.

In the P.R. China, however, the share of IPFs co-applied for by research institutions declined sharply, from 38.9% in 2010-2012 to 25.6% in 2019-2021. This indicates that the recent surge in cancer-related patenting activity from China was predominantly driven by companies, with a diminished role for the research sector.

Figure 16

Contribution of research institutions to cancer-related IPFs in major innovation centres, 2010-2021



*AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

The impact of research institutions on cancer-related patenting extends well beyond the IPFs they file directly, as highlighted in the recent EPO study on patenting by European universities (EPO, 2024b). Using the dataset developed in that study, we identified IPFs originating from European research institutions but filed by companies.[6] Notably, 12.5% of cancer-related IPFs from EU applicants and 6.4% from applicants in other EPO member states originated from such institutions (Figure 17).

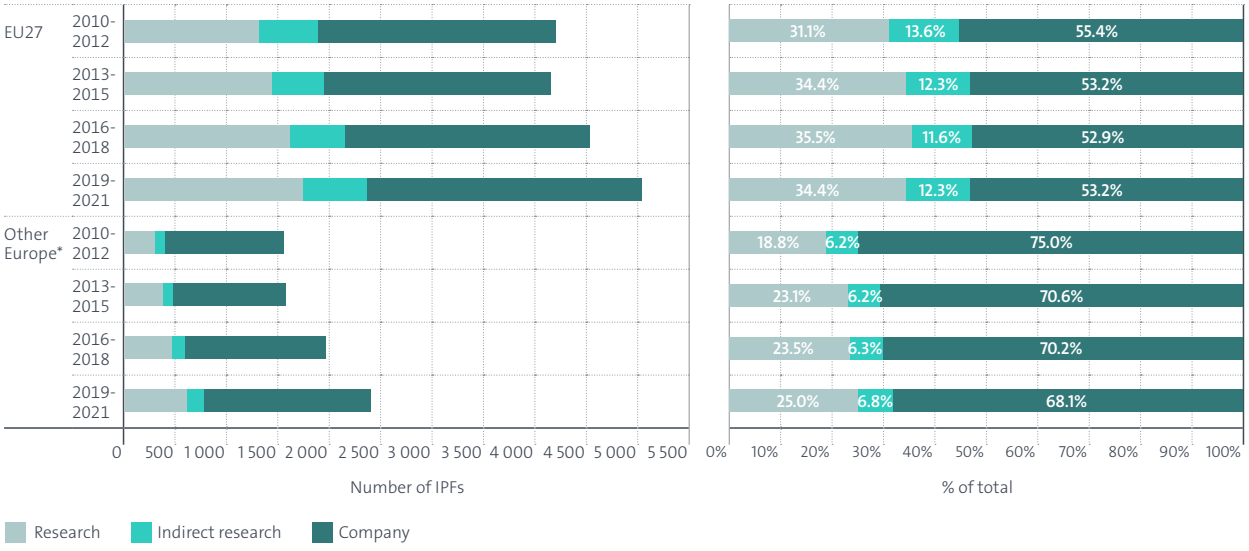
[6] See Annex 3 in EPO (2024b).

These shares remained relatively stable across the four three-year periods analysed, underscoring the significant indirect contribution of European research institutions. When both direct and indirect contributions are considered, European public research institutions are linked to nearly half of all cancer-related IPFs from EU applicants and over 30% from other EPO member states.

Interestingly, their influence extends beyond Europe: 212 IPFs with US companies as applicants between 2010 and 2021 originated from European research institutions, accounting for 0.5% of all US cancer-related IPFs. Of these, 82 were published in the most recent three-year period (2019-2021). This highlights the broader international impact of European research institutions on cancer innovation.

Figure 17

Direct and indirect contribution of European research institutions to cancer-related IPFs, 2010-2021



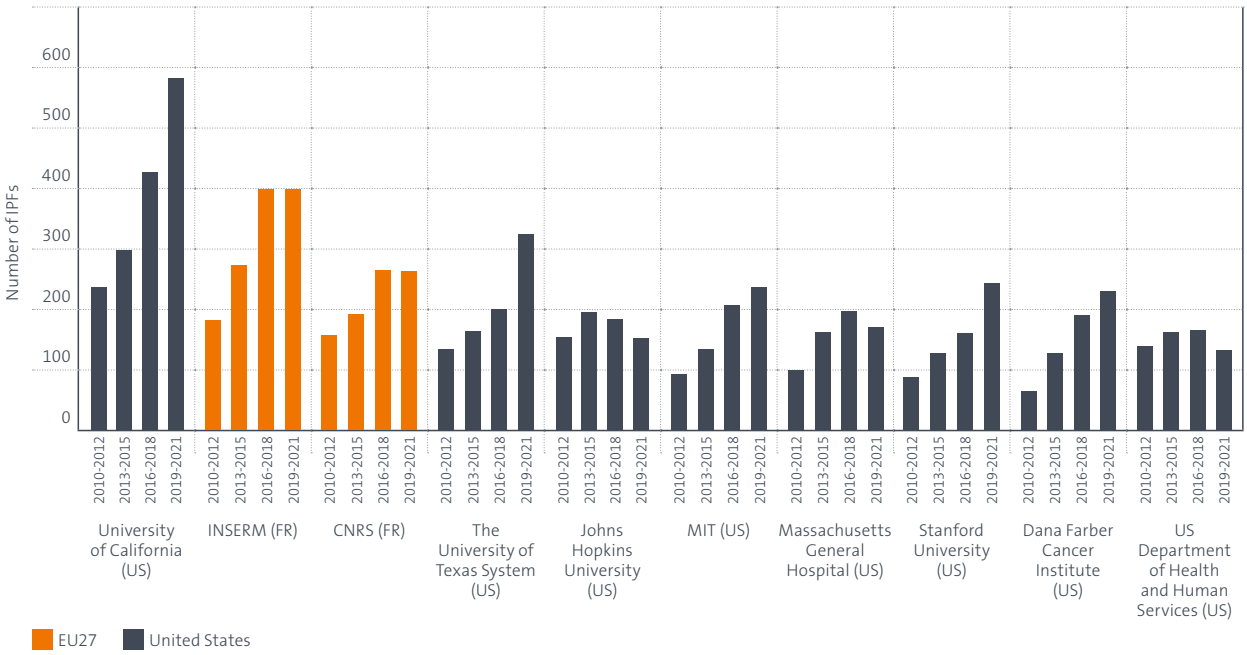
*AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

Given the substantial contribution of US public research institutions to overall cancer-related innovation, it is unsurprising that a US university leads the ranking of top research contributors in cancer-related technologies between 2010 and 2021, with over 1 500 IPFs (Figure 18). Seven additional US institutions rank among the top ten, and 18 feature in the top 20.

Figure 18

Top ten research institutions, 2010-2021



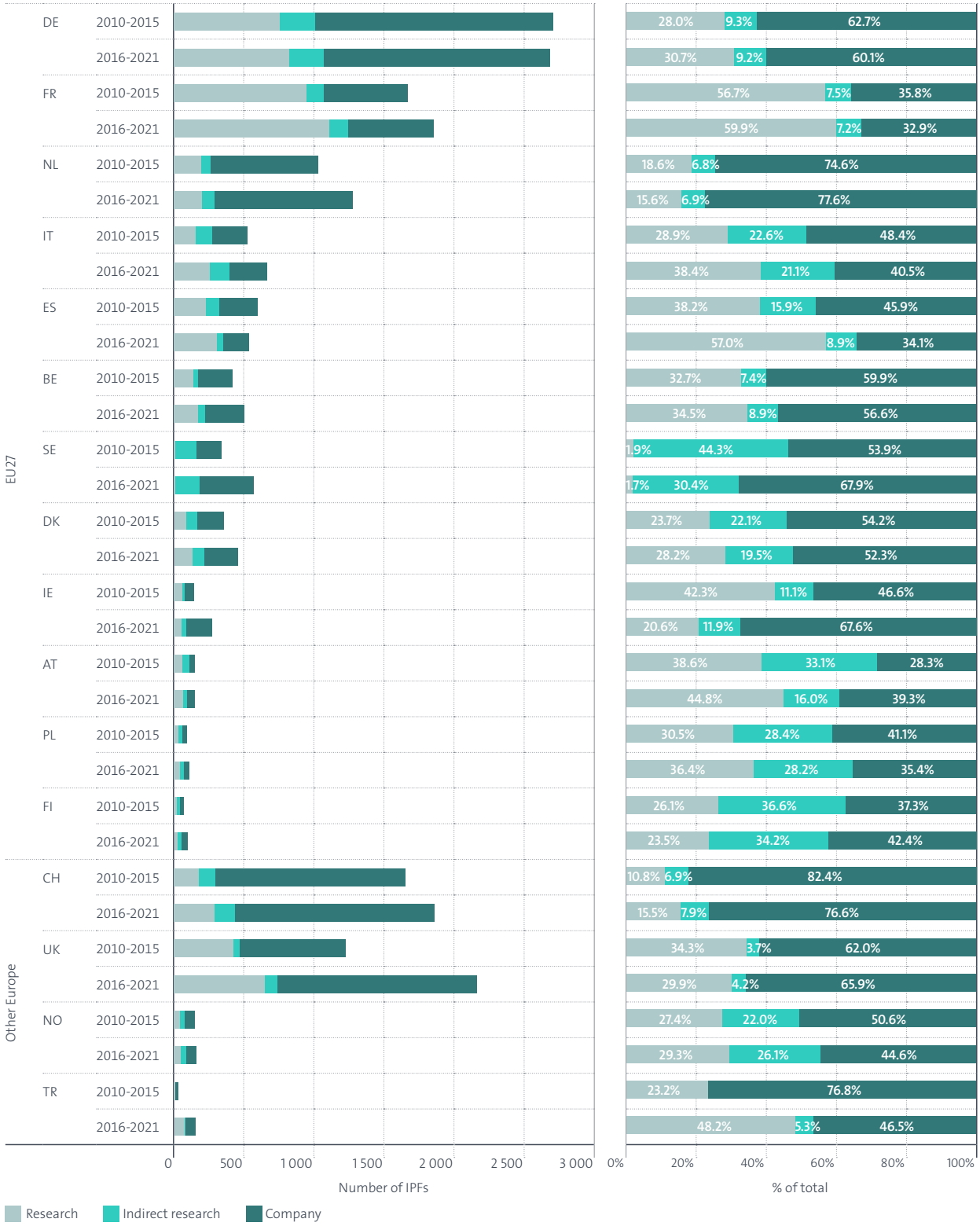
Source: EPO

The French National Institute of Health and Medical Research (INSERM) and French National Centre for Scientific Research (CNRS) rank second and third globally, with 1 251 and 876 IPFs, respectively. Their contributions grew steadily across the first three periods but plateaued during the most recent period (2019-2021). In contrast, the two leading US universities significantly expanded their IPF portfolios, particularly during the latest period, such that the University of Texas System became the third largest research institution in 2019-2021.

A closer look at European countries reveals notable differences in the contribution of research institutions to cancer-related patenting (Figure 19). Among the top contributors, France leads with the highest direct impact: the share of cancer-related IPFs filed by French research institutions increased from 56.6% in 2010-2015 to 59.9% in 2016-2021. When indirect contributions are included – IPFs originating from a research institution but filed by companies – this figure rises significantly to 67.1%.

Figure 19

Direct and indirect contribution of European research institutions to cancer-related IPFs by European country and six-year periods, 2010-2021



Source: EPO

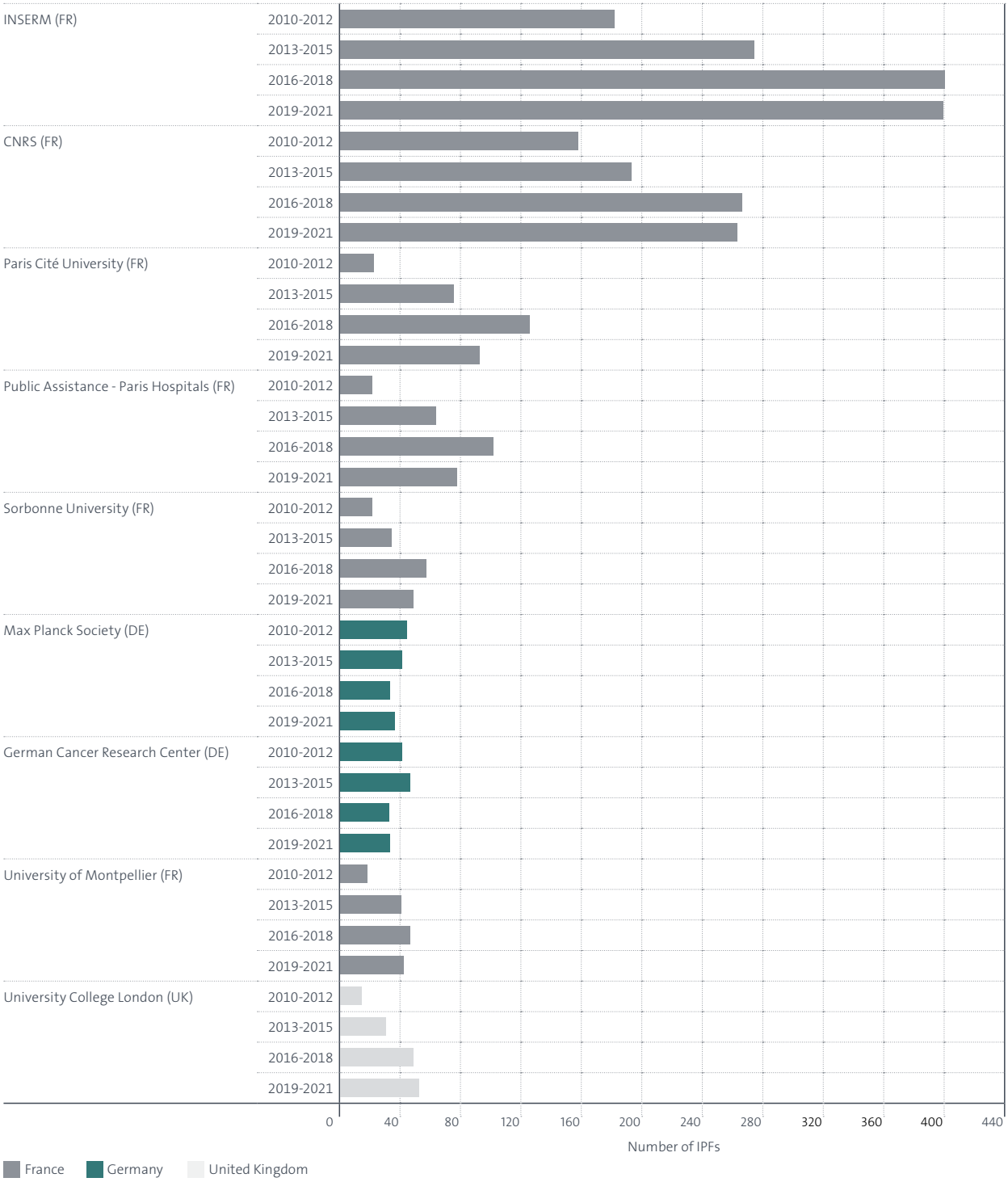
In contrast, the Netherlands and Switzerland have the lowest shares, with less than 16.0% of direct contributions from research institutions and around 23% when indirect IPFs are included. Germany and the UK occupy a middle ground, with direct contributions of approximately 30% in 2016-2021, and 39.9% and 34.2%, respectively, when indirect contributions are also considered.

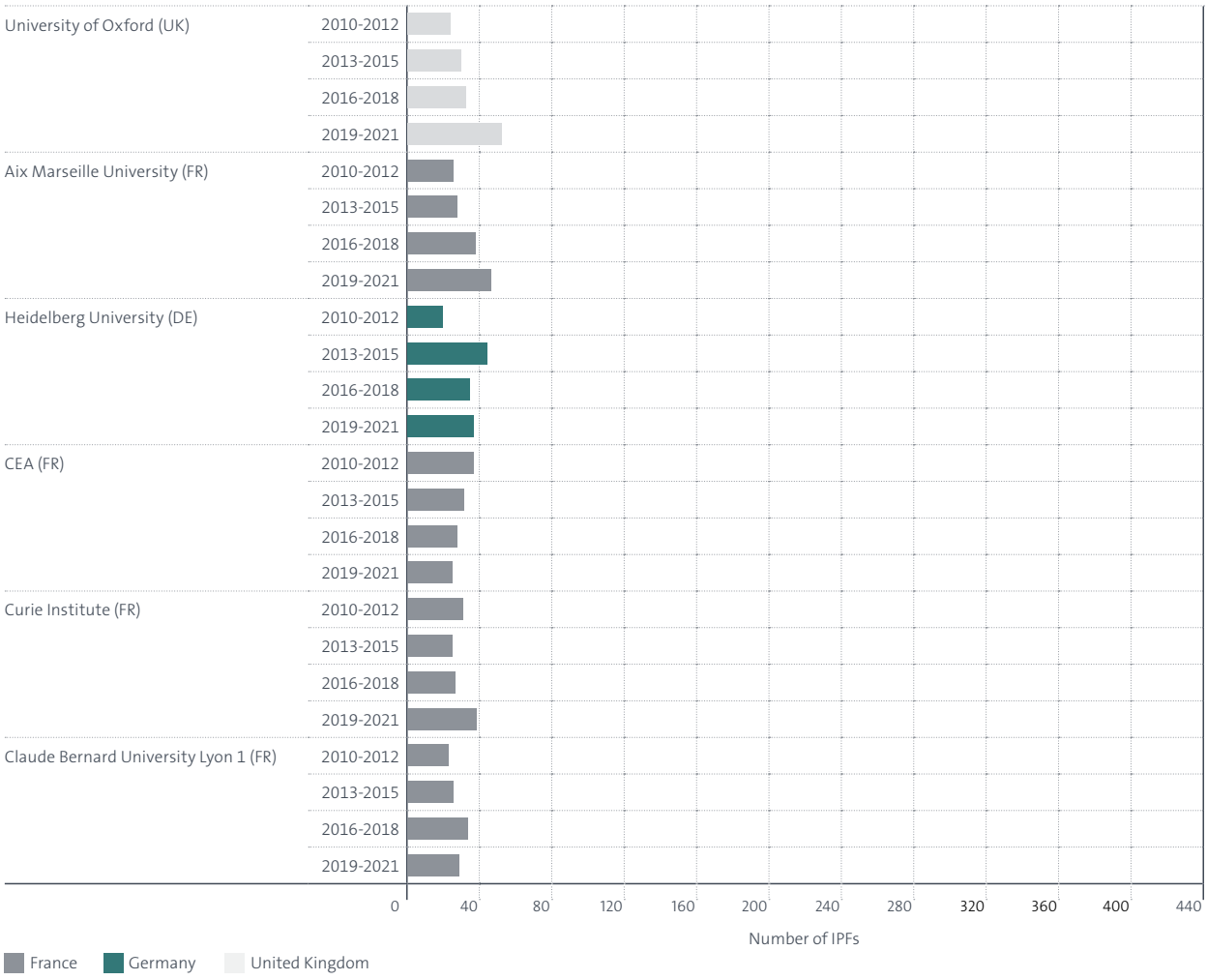
Sweden, due to the professor's privilege model by which inventors retain ownership of patent rights rather than research institutions, has the lowest share of direct contributions. However, it boasts one of the highest shares of indirect contributions. These indirect research shares, however, decreased from 44.3% in 2010-2015 to just over 30% in 2016-2021, suggesting that the growth in Swedish IPFs after 2015 was predominantly driven by companies rather than research institutions. Similarly, in Ireland, patenting growth was largely company-driven. In most other European countries, however, the relative contributions of public research institutions increased during the period 2016-2021.

Figure 20 highlights the top research institutions in Europe for cancer-related IPFs between 2010 and 2021. Among the top 15, France dominates with ten institutions, led by INSERM and CNRS, followed by the Université Paris Cité (fourth with 314 IPFs), the Greater Paris University Hospitals (AP-HP; fifth with 262 IPFs) and Sorbonne University (eighth with 160 IPFs). Germany is represented by three institutions: the Max Planck Society (sixth with 154 IPFs), the German Cancer Research Centre (DKFZ; seventh with 152 IPFs) and the University of Heidelberg (12th with 137 IPFs). The UK contributes with two institutions: University College London (ninth with 144 IPFs) and the University of Oxford (tenth with 140 IPFs). This distribution underscores the regionally dominant role of French institutions in European cancer innovation.

Figure 20

Top European research institutions, 2010-2021





Source: EPO

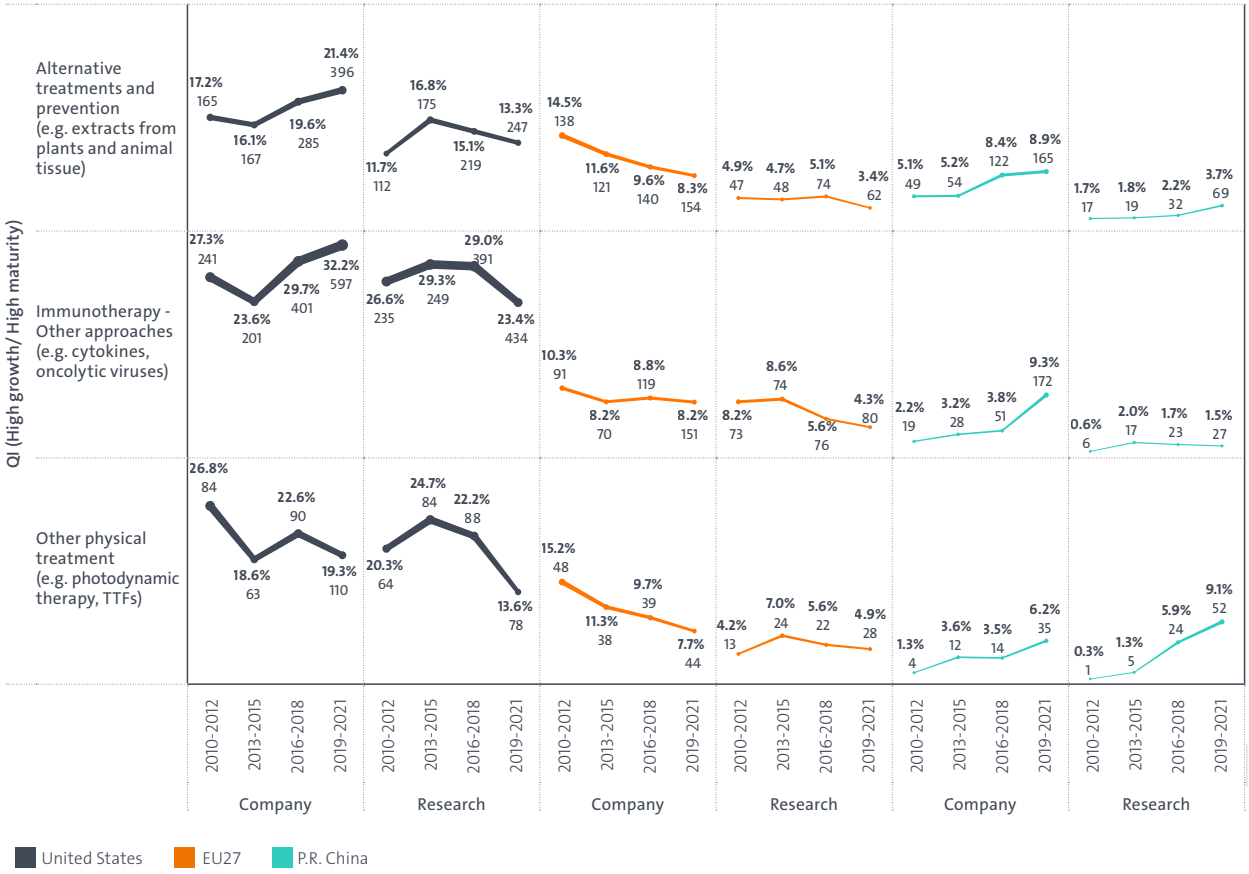
5.2. Performance of European research institutions across technology fields

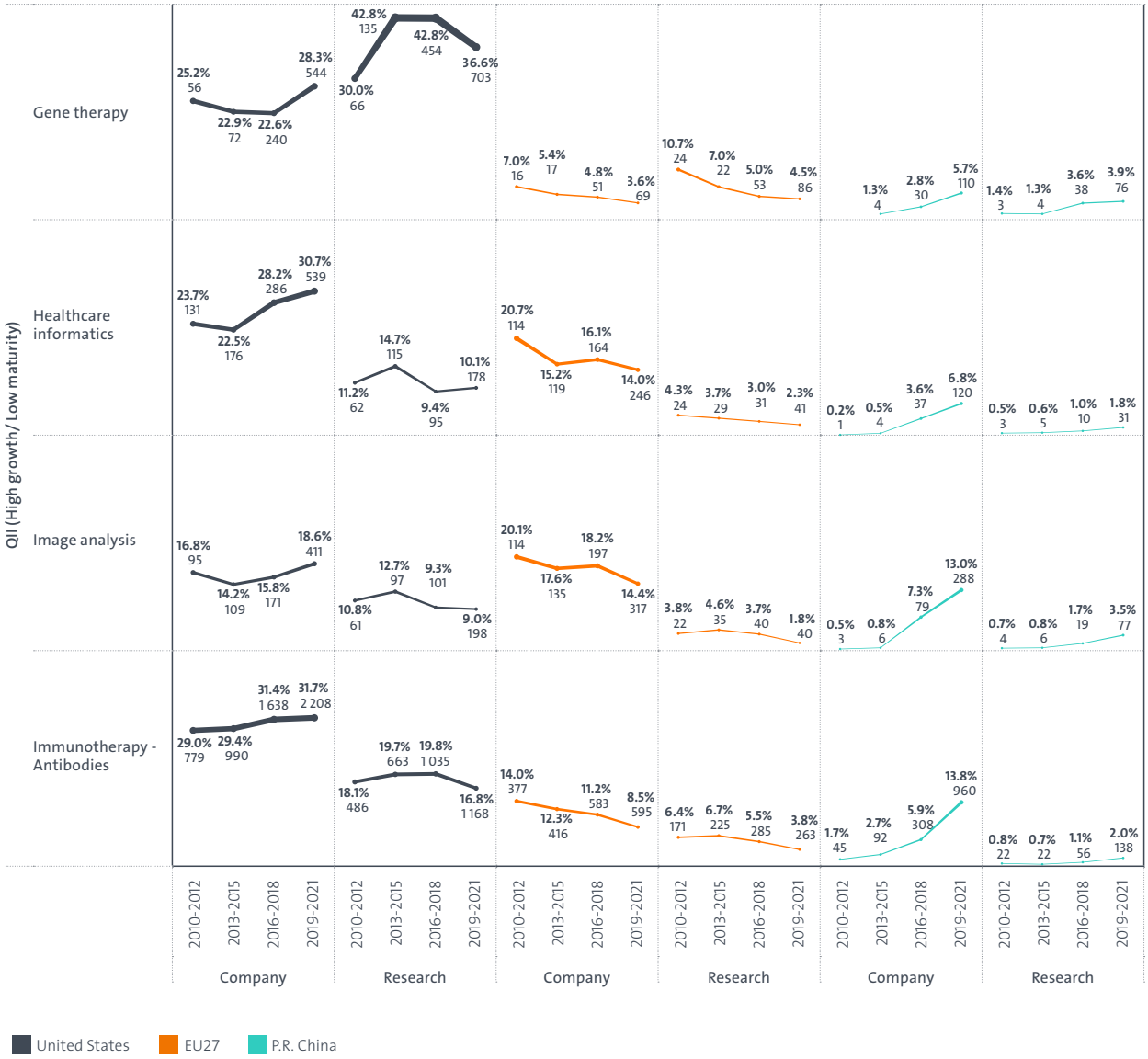
This section examines the evolving role of research institutions in cancer-related patenting activity across the US, the EU and the P.R. China, focusing on contributions to high-growth and low-growth technology fields. Figures 21 and 22 illustrate these dynamics, disregarding the indirect contributions of public institutions.

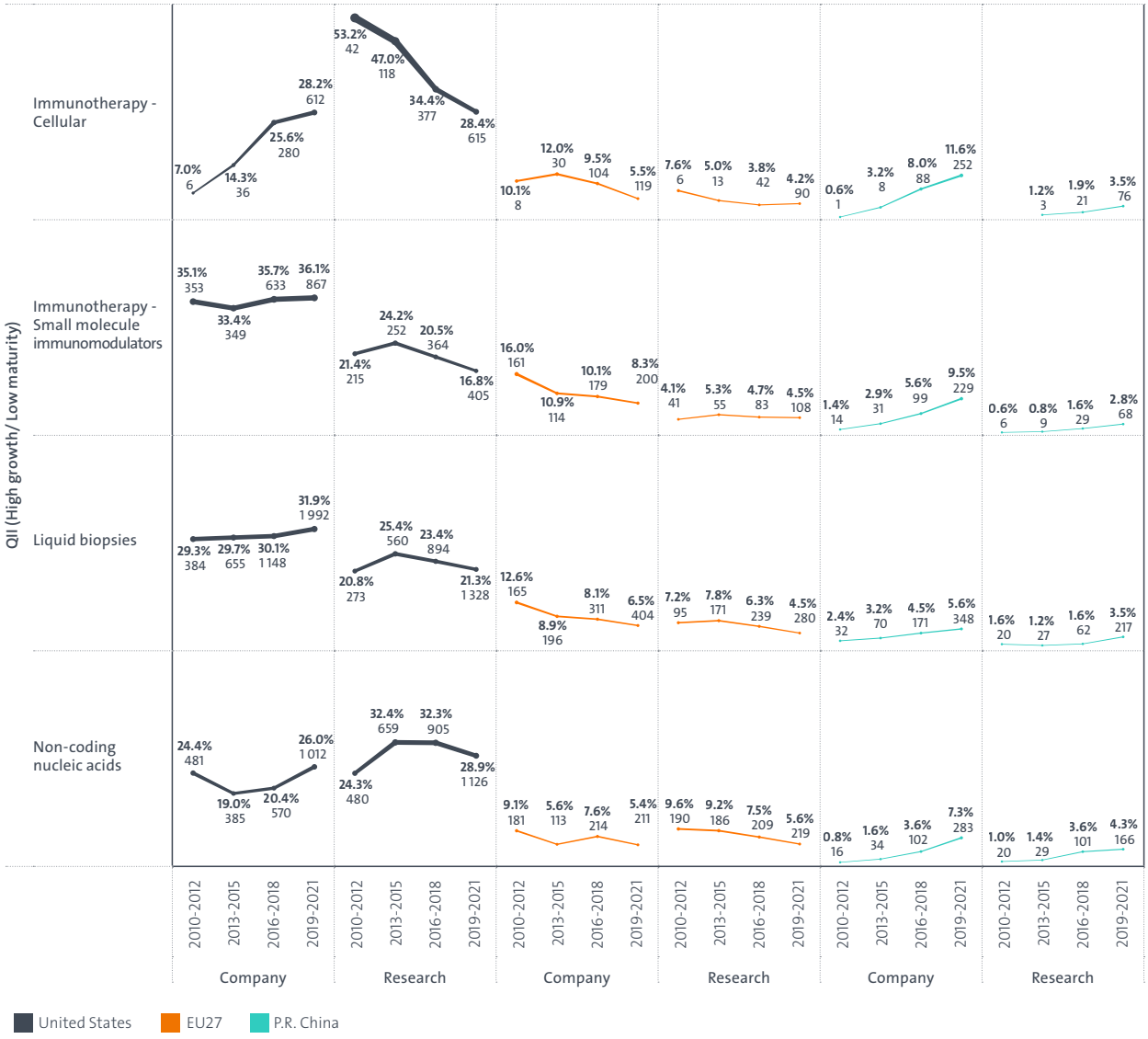
In high-growth fields, a key trend among US applicants is the shifting balance between research institutions and companies. Initially, contributions from research institutions grew substantially. For instance, in gene therapy, their share rose from 30.0% to 42.8% between the first two 3-year periods, nearly double that of US companies in 2016-2018. However, this trend reversed in the subsequent period, with research institutions' share falling to 36.6% in 2019-2021 as US companies increased their share to 28.3%. In cellular immunotherapy, that change started even earlier: between 2010 and 2021, US research institutions dominated with 53.2% of all IPFs, while US companies accounted for just 7%. By 2019-2021, US companies had nearly caught up, holding 28.2% of IPFs compared to 28.4% for research institutions. This shift highlights the increasing role of US companies in driving cancer-related innovation in high-growth technology fields in the most recent period.

Figure 21

Trends in shares and absolute numbers of IPFs across the high-growth technology fields of cancer-related technologies, 2010-2021, by major innovation centre and applicant type



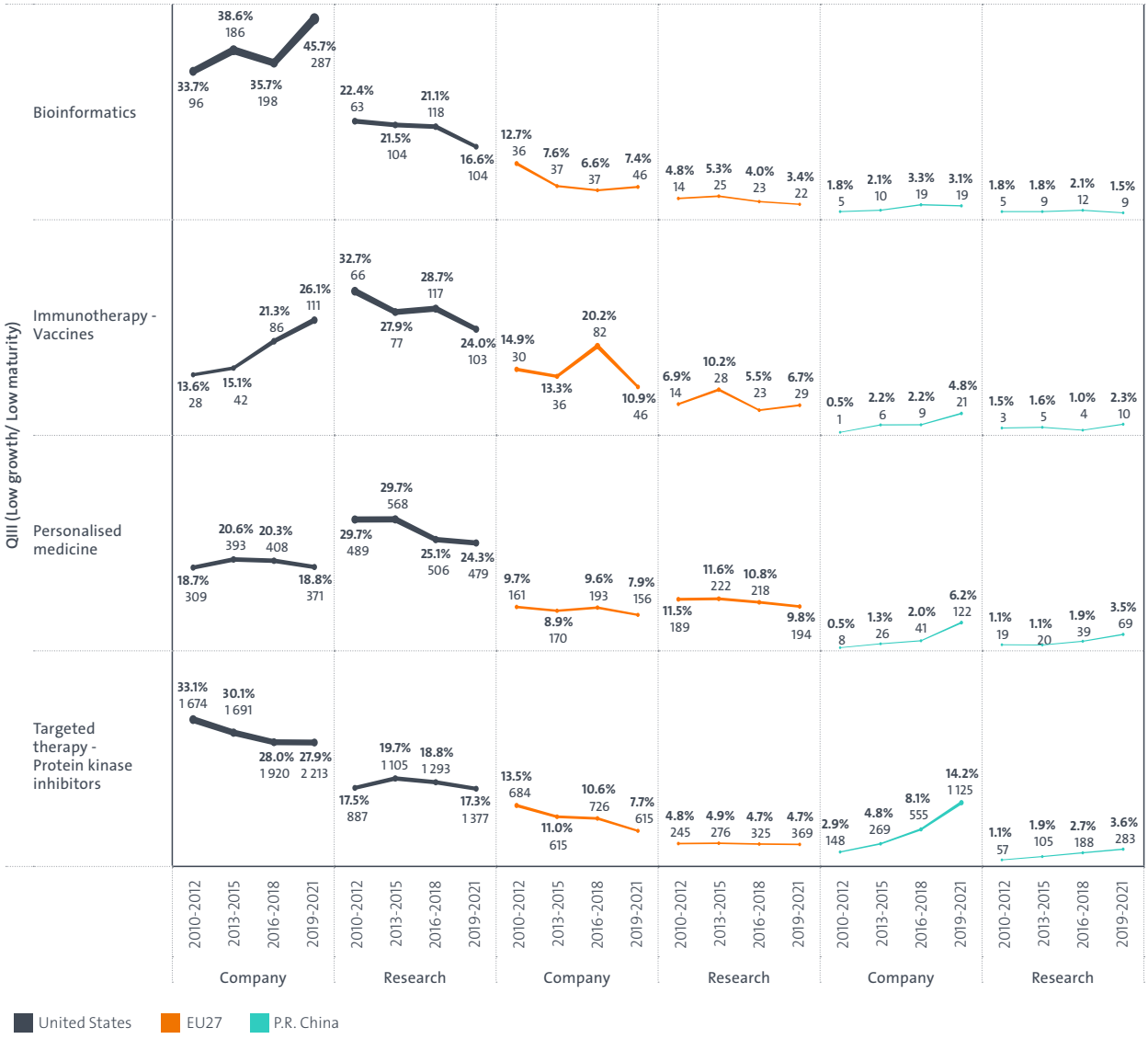

QII (High growth/Low maturity)
Gene therapy
Healthcare informatics
Image analysis
Immunotherapy - Antibodies
25.2% 56
22.9% 72
22.6% 240
28.3% 544
42.8% 135
30.0% 66
42.8% 454
36.6% 703
7.0% 16
5.4% 17
4.8% 51
3.6% 69
10.7% 24
7.0% 22
5.0% 53
4.5% 86
1.3% 4
2.8% 30
5.7% 110
1.4% 3
1.3% 4
3.6% 38
3.9% 76
23.7% 131
22.5% 176
28.2% 286
30.7% 539
11.2% 62
14.7% 115
9.4% 95
10.1% 178
20.7% 114
15.2% 119
16.1% 164
14.0% 246
4.3% 24
3.7% 29
3.0% 31
2.3% 41
0.2% 1
0.5% 4
3.6% 37
6.8% 120
0.5% 3
0.6% 5
1.0% 10
1.8% 31
16.8% 95
14.2% 109
15.8% 171
18.6% 411
10.8% 61
12.7% 97
9.3% 101
9.0% 198
20.1% 114
17.6% 135
18.2% 197
14.4% 317
3.8% 22
4.6% 35
3.7% 40
1.8% 40
0.5% 3
0.8% 6
7.3% 79
13.0% 288
0.7% 4
0.8% 6
1.7% 19
3.5% 77
29.0% 779
29.4% 990
31.4% 1 638
31.7% 2 208
18.1% 486
19.7% 663
19.8% 1 035
16.8% 1 168
14.0% 377
12.3% 416
11.2% 583
8.5% 595
6.4% 171
6.7% 225
5.5% 285
3.8% 263
1.7% 45
2.7% 92
5.9% 308
13.8% 960
0.8% 22
0.7% 22
1.1% 56
2.0% 138
2010-2012
2013-2015
2016-2018
2019-2021
Company
Research
United States
EU27
P.R. China

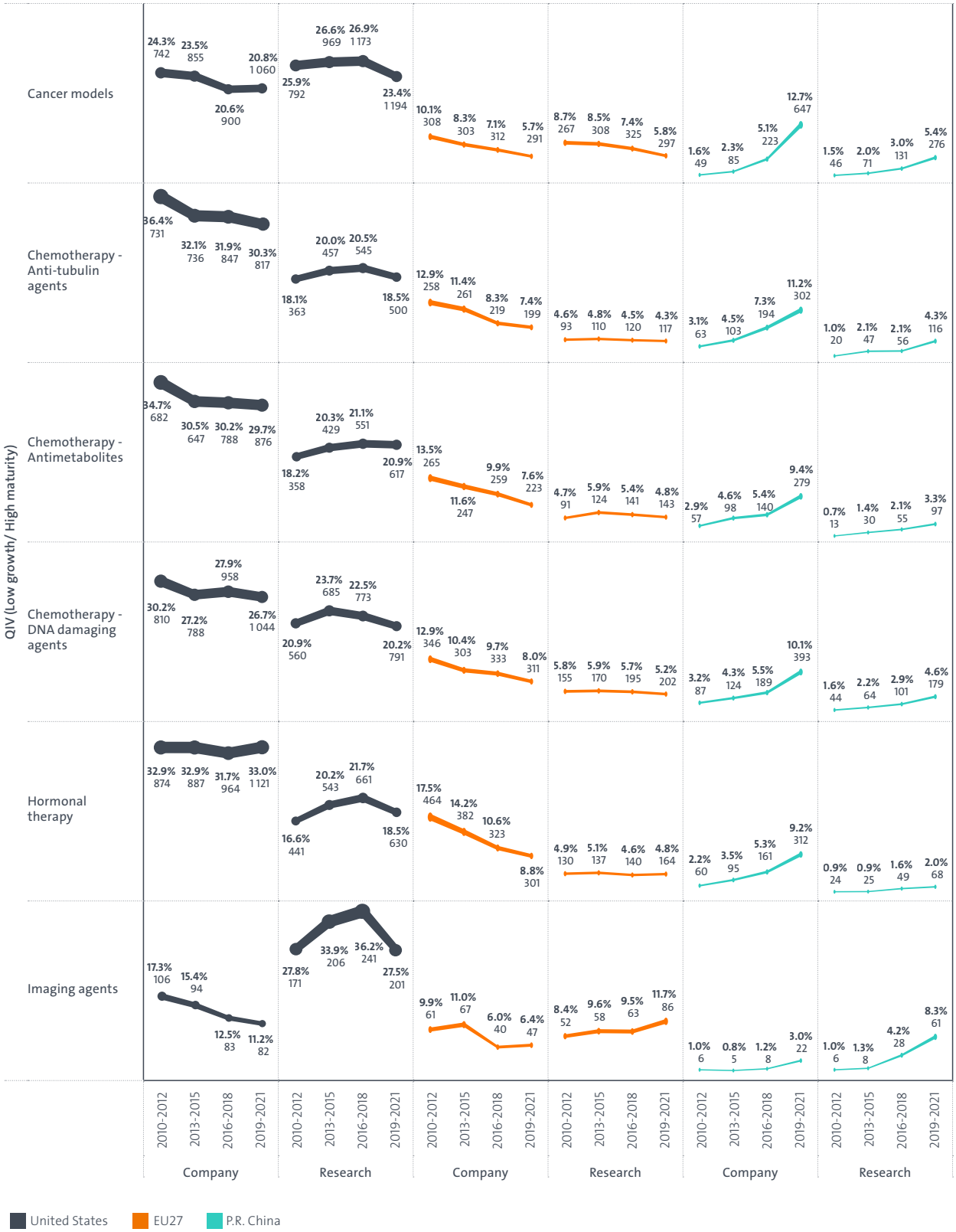

QII (High growth/Low maturity)
Immunotherapy - Cellular
Immunotherapy - Small molecule immunomodulators
Liquid biopsies
Non-coding nucleic acids
2010-2012
2013-2015
2016-2018
2019-2021
Company
Research
United States
EU27
P.R. China

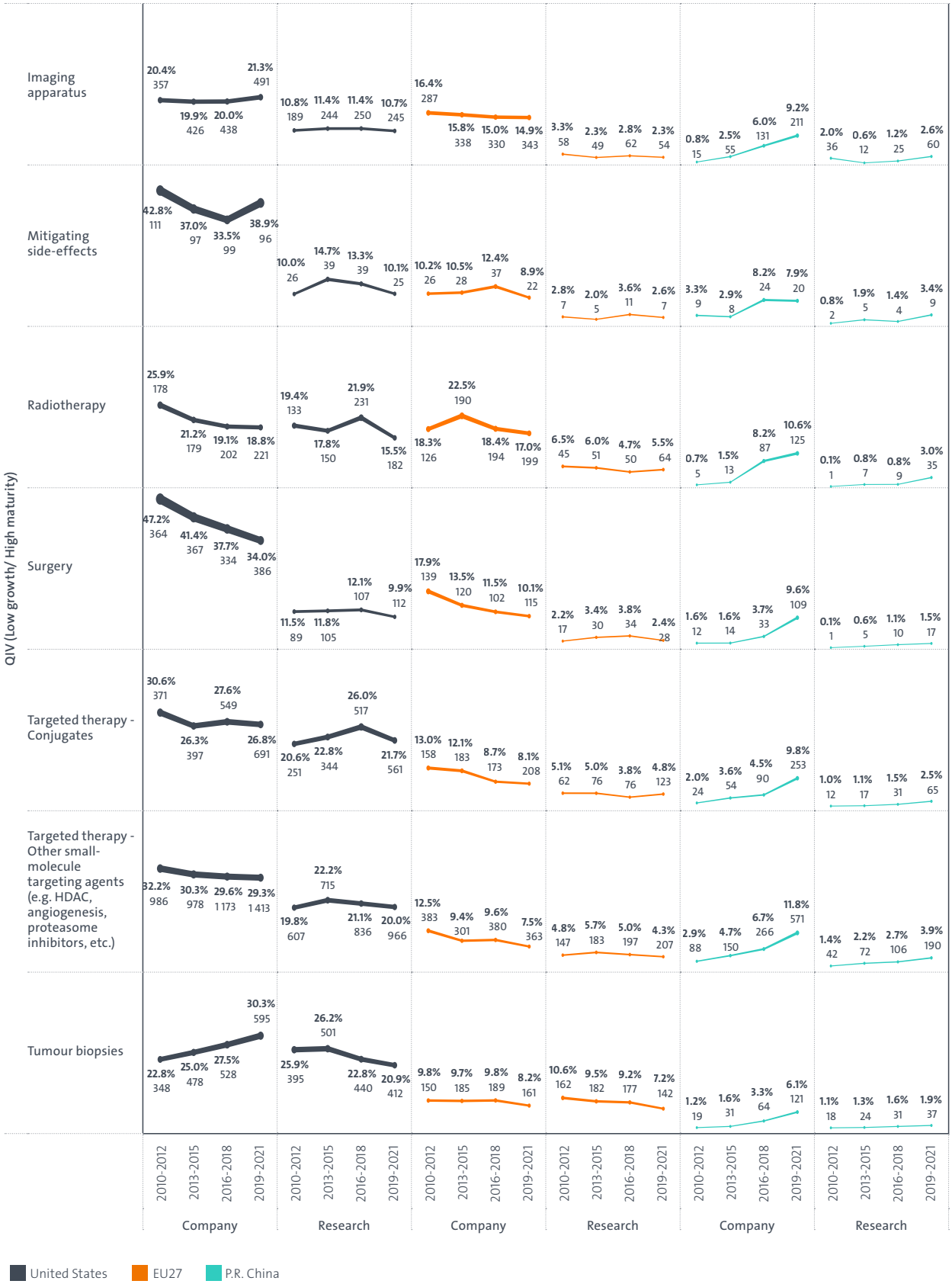
Source: EPO

Figure 22

Trends in shares and absolute numbers of IPFs across the low-growth technology fields of cancer-related technologies, 2010-2021, by major innovation centre and applicant type




QIV (Low growth/ High maturity)
Cancer models
Chemotherapy - Anti-tubulin agents
Chemotherapy - Antimetabolites
Chemotherapy - DNA damaging agents
Hormonal therapy
Imaging agents
2010-2012
2013-2015
2016-2018
2019-2021
Company
Research
United States
EU27
P.R. China


QIV (Low growth/ High maturity)
Imaging apparatus
Mitigating side-effects
Radiotherapy
Surgery
Targeted therapy - Conjugates
Targeted therapy - Other small-molecule targeting agents (e.g. HDAC, angiogenesis, proteasome inhibitors, etc.)
Tumour biopsies
2010-2012
2013-2015
2016-2018
2019-2021
Company
Research
United States
EU27
P.R. China

Source: EPO

Among the slower-growing fields, the trends are more varied. In surgery, the decline in US shares can largely be attributed to US companies, whose share dropped from 47.2% in 2010-2012 to 34.0% in 2019-2021, while the share of IPFs involving US research institutions remained stable at around 10% throughout the periods. In contrast, fields such as tumour biopsies, bioinformatics and immunotherapy with vaccines saw increasing shares from US companies over time, accompanied by declining contributions from US research institutions, particularly during the most recent period (2019-2021). For larger, more established fields like chemotherapy-related technologies, the shares of US companies and research institutions developed in parallel, remaining largely synchronised between 2013 and 2021.

Examination of the shares of Chinese applicants reveals that the rapid growth in patenting activity across nearly all technology fields, particularly in high-growth quadrants, has been predominantly driven by Chinese companies, with a lesser contribution from Chinese research institutions. For instance, in the three technology fields related to immunotherapy, Chinese companies expanded their shares from very low levels to double digits by 2019-2021. Chinese research institutions also increased their shares, though they remained comparatively low. There are a few notable exceptions where Chinese research institutions were either the primary driver or contributed equally with Chinese companies. These include high-growth fields such as other physical treatments, alternative treatments and prevention, and gene therapy, as well as slow-growth fields like imaging agents and personalised medicine.

Among EU applicants, the trends in company shares and shares with research institution as applicants were generally aligned, though several notable exceptions stand out.[7] In high-growth fields like immunotherapy with small molecule immunomodulators and cellular immunotherapy, the share of IPFs filed by EU companies declined more steeply than those involving research institutions. This pattern is mirrored in several low-growth fields, including targeted therapy with conjugates, surgery, hormonal therapy and the three technology fields related to chemotherapy. The tumour biopsies field presents a unique case in which the decline in the share of IPFs filed by research institutions outpaced that of EU companies.

[7] The main trends remain largely unchanged if indirect contributions of EU research institutions are taken into account.

6. Benchmarking European cancer startups

Startups play a pivotal role in driving innovation in cancer-related technologies. Their agility enables them to translate scientific breakthroughs into practical applications faster than larger corporations. Patents are critical for protecting these innovations, attracting investment and fostering collaboration between startups, universities and industry players. Three examples of European startups that relied on European patents to commercialise cancer-related technologies can be found in Box 3. This section uses data from the Dealroom database, a leading provider of data on startups, growth companies and technology ecosystems, to analyse the number of startups patenting cancer-related technologies in Europe and compare them with their US counterparts. The startups were identified through a careful matching of startups listed and defined in Dealroom with patent applicants.

Box 3: EPO innovation case studies on patents and business success in oncology

In its EPO innovation case study series, the EPO created further detailed examples of how European startups and other small and medium-sized companies have benefitted from patent protection to commercialise new technologies and develop their business activiites. Three case studies have a particular focus on startups that are developing technologies to fight cancer, illustrating best practices in IP manangement and strategy.

OncoMark, an Irish cancer diagnostics startup, illustrates the successful journey from academic innovation to global market integration. Established in 2012 as a spin-out from University College Dublin, the company focused on developing OncoMasTR, a diagnostic assay designed to assess the risk of cancer recurrence in early-stage breast cancer patients. Through strategic collaborations, investment rounds and robust clinical validation, the company advanced its technology to market readiness. By 2017, it had raised EUR 4.8 million in funding and attracted the interest of Cepheid, a US-based molecular diagnostics firm. Cepheid's subsequent investment and collaboration enabled OncoMark to integrate its assay into an established diagnostic platform, culminating in its acquisition in 2021. This milestone shows how promising spin-outs often translate their research potential into global health outcomes through US-based corporate entities. Read the full case study here.

Damae Medical, a spin-out from the French Institut d'Optique Graduate School, exemplifies how a strong foundation in scientific research can lead to economic innovation. Founded in 2014, the French company developed and patented a non-invasive imaging device capable of diagnosing melanoma in real time, now employed in over 40 centres globally. Initially supported by academic institutions through licensing agreements, Damae secured outright ownership of its core patents, thus securing investor confidence while buying time for market launch. The company raised over EUR 20 million through venture capital, private investment and EU grants. Its IP strategy, combining patents, design rights and trade secrets, played a pivotal role in maintaining a competitive edge throughout the process of business afirmation. Read the full case study here.

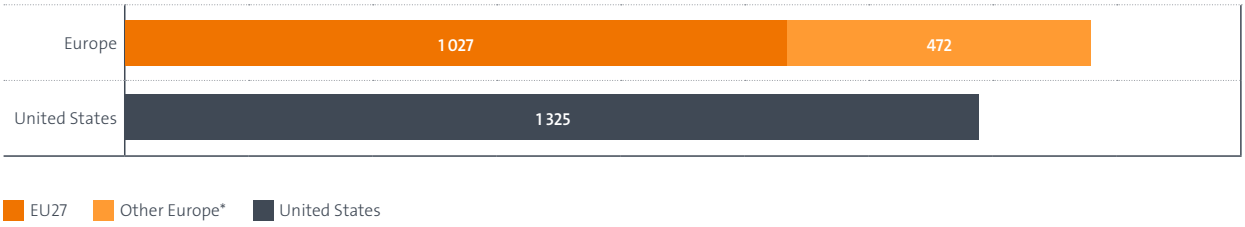
OncoQR, founded in 2013 in Vienna, develops targeted cancer vaccines based on the Specific Total Immune Remodulation (S-TIR) platform, a breakthrough immunotherapy. Initially spun out from F-star Therapeutics, the company was able to secure early-stage funding on the back of a robust patent portfolio. The strategic decision to focus on a single, versatile platform enabled OncoQR to reduce costs and expedite product development. With a three-pronged approach – focusing on in-house research, partial out-licensing and collaborations – the company successfully advanced its technology. OncoQR has generated revenue through out-licensing agreements and government grants, while also protecting proprietary production techniques with trade secrets. This strategy has allowed OncoQR to scale its operations and position itself for long-term growth in the biotechnology sector. Read the full case study here.

6.1. Cancer startups in Europe and the US

Europe is home to nearly 1 500 startups with cancer-related IPFs, including 1 027 headquartered in the EU and 472 in other EPO member states (Figure 23). The UK leads the ranking with 290 cancer-related startups, followed by France with 246, making France the top country within the EU (Figure 24). Germany ranks third in Europe with 208 startups, followed by Switzerland with 151 and Sweden with 112.

Figure 23

Startups with at least one cancer-related IPF published between 2010 and 2024

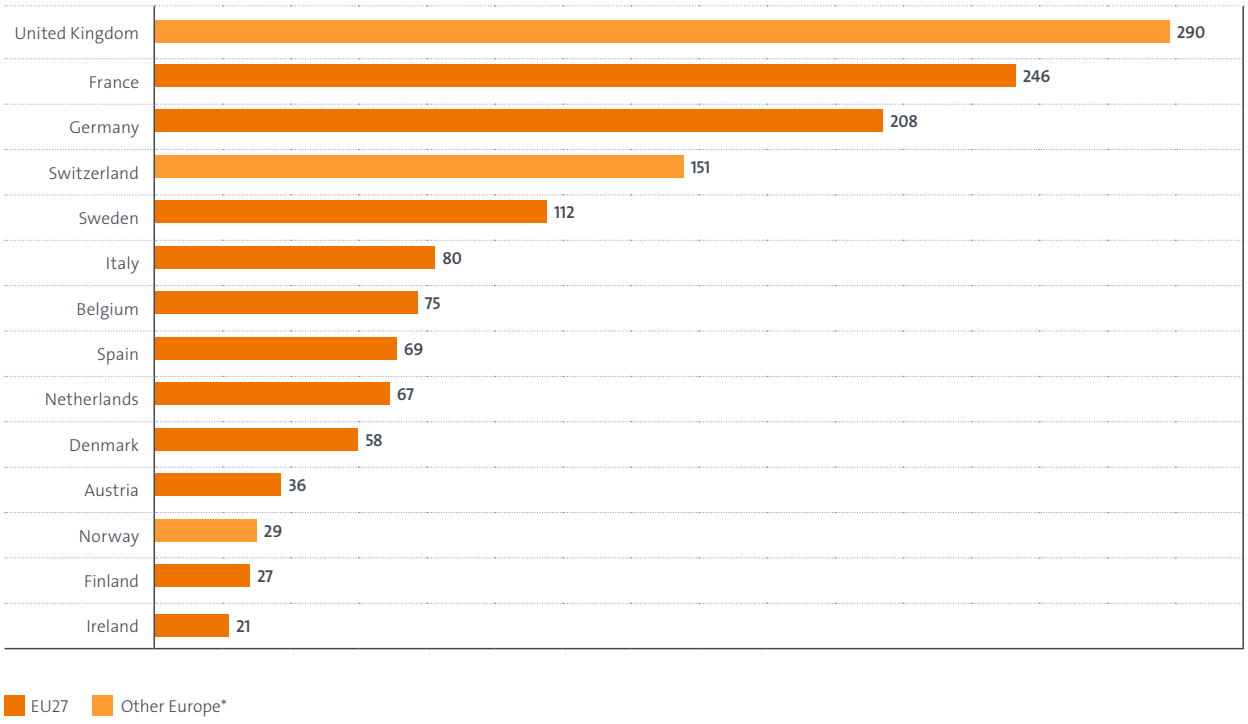


* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK
Note: Only operating startups with at least one cancer-related IPF published in 2010 or after are considered.

Source: EPO

Figure 24

European startups with at least one cancer-related IPF published between 2010 and 2024, by country



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK
Note: Only countries with 20 or more startups are displayed.

Source: EPO

In comparison, the US is home to 1 325 cancer-related startups, a figure higher than that of the EU alone but lower than the combined total for all EPO member states.[8] However, a closer look at the growth stages of these startups reveals significant differences as shown in Figures 26 and 27.[9] While the EU has nearly as many startups as the US in the seed and early growth stages, with 518 companies, the US has more than double the number of startups that have advanced to the late growth stage. Nearly 40% of US cancer-related startups have reached late growth stage, compared to only 24% in the EU and just under 27% in other EPO member states. In contrast, EU startups are predominantly in earlier stages, with 41.6% in the early growth stage and 34.7% still in the seed stage. This highlights the challenges European startups face in scaling compared to their US counterparts, a theme evidenced in past EPO studies for technologies such as cleantech (see EPO, 2024c). Box 4 provides a complementary analysis of acquisition patterns of US and European cancer-related startups.

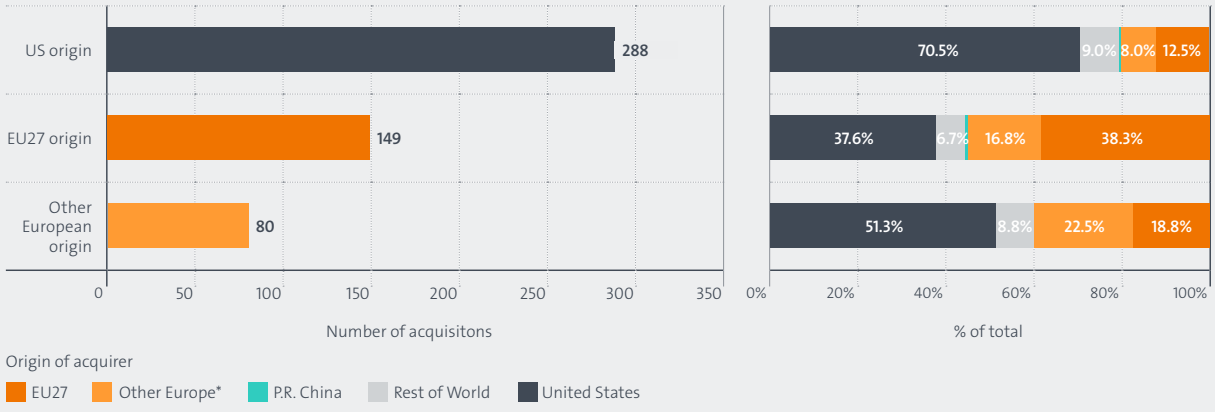
Box 4: Acquisitions of cancer-related European and US startups

This box provides an analysis of acquisitions of startup companies developing cancer-related technologies in the US and Europe. High transaction activity indicates robust funding, collaboration and commercialisation of innovative ideas, which are critical for advancing cancer-related technologies. Startups in regions with high transaction volumes often have better access to venture capital, enabling faster scaling and further R&D investments.

As shown in Figure 25, between 2010 and 2024 there were 288 acquisitions of US cancer-related startups, which is nearly double the 149 acquisitions of EU startups. An additional 80 acquisitions involved startups from other EPO member states. These transactions were predominantly driven by large pharmaceutical companies such as Merck, Johnson & Johnson, Sanofi and Pfizer, along with prominent biotech firms like Amgen and Illumina and medical technology companies such as Hologic, Bruker and Philips. Notably, over half of the startups from other EPO member states and nearly 38% of EU-based startups were acquired by US companies, with another 8.8% and 7.4%, respectively, acquired by companies from the rest of the world. In contrast, over 70% of US startups were acquired by US companies, while only 12.5% were acquired by EU-based companies and an additional 8.0% by companies from other EPO member states. This disparity highlights a potential imbalance in cross-border innovation acquisition dynamics between the US and Europe, with the risk for Europe of losing its innovative edge for cancer technologies.

Figure 25

Number of acquisitions of cancer-related European and US startups, by country of the acquiring company, 2010-2024



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

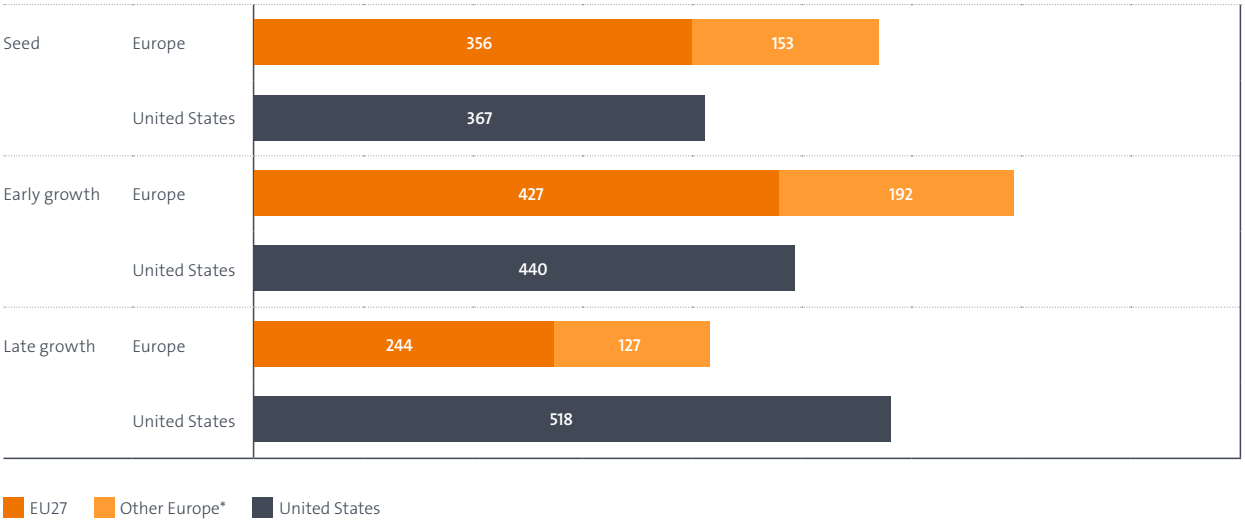
Source: EPO

[8] The results are similar if the Crunchbase database is used and an alternative to the Dealroom database.
[9] Information on growth stages is drawn from the original data from Dealroom. It is defined based on the following mutually exclusive criteria (in this order): number of employees, total funding received and age of company.
The table below summarises the possible categories:

Growth stage rules	"Founding"	"Early"	"Late"
By employees	< 10 people	11-50 people	50+ people
If no employees, total funding	< 2M funding	2-10M funding	10M+ funding
If no employees and no funding data, age	< 1.5-2 years ago	2-5 years ago	5+ years ago

Figure 26

Cancer-related startups in Europe and the US by growth stage of the company

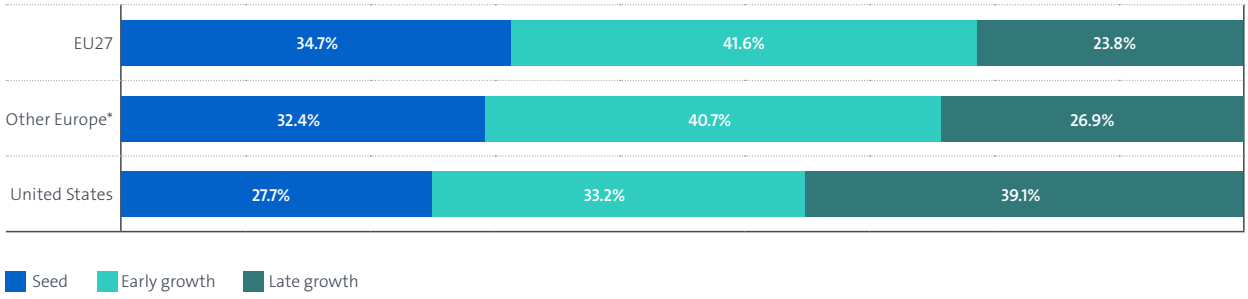


* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

Figure 27

Distribution of cancer-related startups in Europe and US by growth stage of the company



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

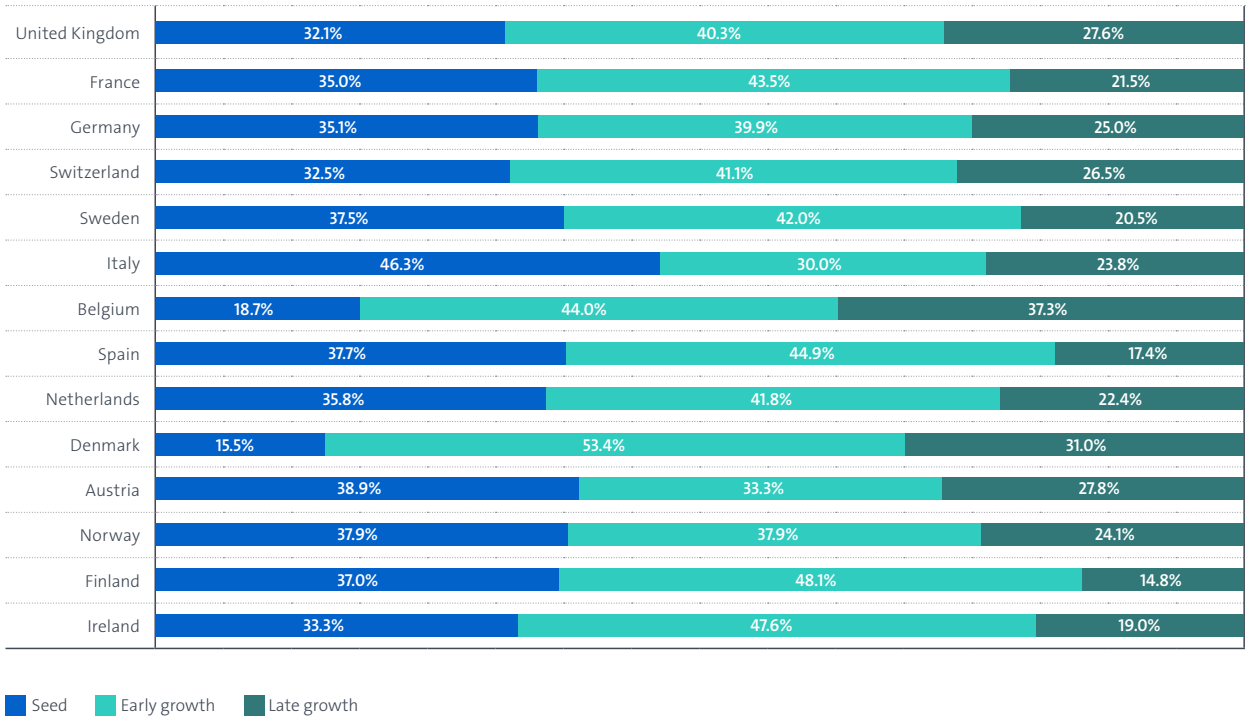
Source: EPO

Among European countries (Figure 28), Belgium leads with the highest share of late growth startups, at 37.3%, followed by Denmark at 31% and Austria at 27.8%. Conversely, Finland and Spain have the lowest proportions of late growth startups, with shares of 14.8% and 17.4%, respectively. Italy stands out for having the largest share of seed-stage startups, with over 46%.

Notably, the four European countries with the highest number of cancer-related startups – the UK, France, Germany and Switzerland – exhibit similar profiles. Approximately one-third of their startups are in the seed stage, around one-quarter have reached the late growth stage and roughly 40% are in the early growth stage.

Figure 28

Distribution of cancer-related startups by growth stage of the company across European countries



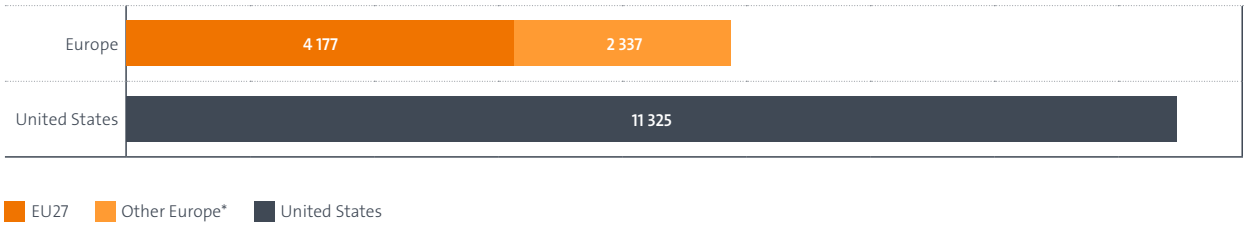
Source: EPO

6.2. Patent portfolios of European and US startups

While the previous section examined the number of startups that protect their innovations through patents, this section analyses the size and composition of their patent portfolios. US startups, with 11 325 cancer-related IPFs published since 2010, have portfolios 2.7 times larger than those of EU startups and 1.7 times larger than all European startups combined (Figure 29). On a per-company basis, a US startup holds an average of 8.55 IPFs – 110% more than the average EU startup with 4.07 IPFs and 73% more than startups in other EPO member states, which average 4.95 IPFs. This highlights the stronger patenting capacity of US startups in the cancer innovation space.

Figure 29

Cancer related IPFs of European and US startups, 2010-2024



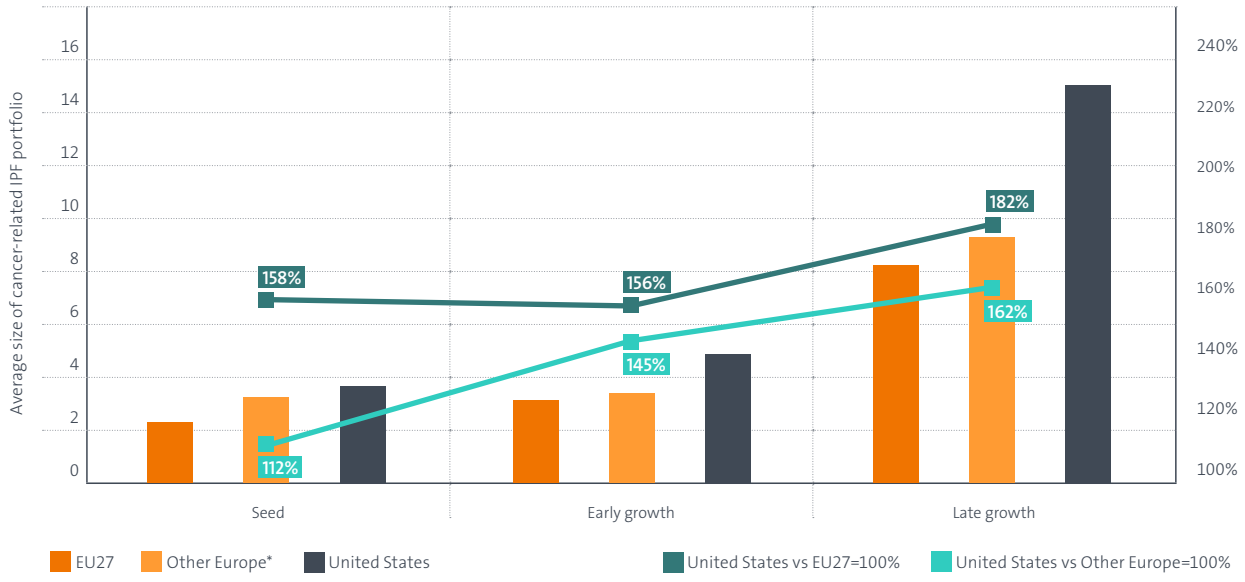
* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

These findings hold true across all startup growth stages. As illustrated in Figure 30, differences in IPF portfolio sizes persist at every stage of development. Late growth companies on both continents maintain higher IPF portfolios, but US late growth startups outpace their EU counterparts by 82%. While the gap narrows in earlier stages, it remains significant: US seed-stage companies have IPF portfolios 58% larger than those of EU startups, and 56% larger at the early growth stage. Startups from other EPO member states generally hold larger IPF portfolios than EU companies, but their portfolios are still considerably smaller than those of US startups.

Figure 30

Average size of cancer-related IPFs per startup by growth stage, 2010-2024



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

ANNEX 1: Europe at a crossroads

Timed to offer a roadmap at the beginning of a new cycle in the EU executive bodies, two complementary reports were published in 2024 highlighting that the European productive system suffers from an increasing performance gap compared to its global counterparts just when the international environment is becoming less favourable. A common explanation for the situation is the existence of internal fragmentation and administrative hurdles that hamper productivity, and the emergence of new players at scale. It is understood that simultaneously achieving decarbonisation and economic security will require not only governance reforms but more impactful R&D commitments.

In the context of the health sector, Enrico Letta (2024) specifically refers to the reliance on external suppliers for critical chemically synthesised active ingredients, the excessive and cumbersome authorisation procedures for medicines and the promise of common data spaces (the European Health Data Space, EHDS). He underscores a sense of urgency to mobilise research resources in the global context:

"A decisive factor to guarantee the sustainability of the health sector is technology. Leveraging technology and healthcare innovation accelerating the digitisation of the health systems, use of AI, robotics, telemedicine and biotechnologies investing in advanced genomics can improve dramatically efficiency and effectiveness in healthcare delivery. The EU and national budget should prioritise investment, and deployment of advanced health technologies must be a priority. Innovation procurement through public tendering plays an important role together with an innovation-friendly regulatory environment that facilitates the roll-out of new health technologies." (Letta 2024, p. 79)

Ahead of its much-awaited official presentation, key-points of the report by Mario Draghi (2024a, 2024b) were anticipated in several speeches. Messages were expressed on the need to "re-think the innovation environment in Europe", to foster "a greater capacity to support startups and help them grow", and to overcome structural barriers in favour of "technological opportunity". Notably, a discourse on European dynamic capabilities is also emerging with a call for a "fundamentally different approach to its industrial capacity in strategic sectors like defence, space, critical minerals and parts of pharmaceuticals."

In his section on the pharmaceuticals sector, Draghi (2024b) notes that while the EU's pharma sector still leads globally in trade measured by value, it is missing out on new opportunities in the key segments of the field (orphan drugs). He warns that Europe's pharma sector "is falling behind in the most dynamic market segments and losing market share to US-based companies" (Draghi 2024a, p. 27). Draghi's report subsequently sets out the policy goal of maintaining and expanding "the capacity of the EU to conduct R&D", while adding a specific focus on nascent markets like ATMPs, biologicals and orphan products (Draghi 2024b, p. 199). He states that cutting-edge AI capabilities will underpin the performance in adjacent fields like pharma through so-called "combination products" – diagnostic and therapeutic offerings combining drugs, devices and biological components – which integrate real-time big data and medicine delivery systems. Regarding explanations, the decline of the EU's position in innovative stronghold sectors like pharma is linked to hurdles such as low investment in R&D and regulatory fragmentation. Furthermore, he points out that "hubs uniting industry, academia and investors fail to reach critical mass in the EU." (Draghi 2024b, p. 192). The reports were acknowledged as providing a foundation for the *Budapest Declaration on the New European Competitiveness Deal* in the context of the Bulgarian presidency of the EU in 2024. Here, the European Council concludes that the EU must "develop a European industrial policy to ensure the growth of tomorrow's key technologies."

ANNEX 2: The EPO's engagement with health challenges

The EPO's statistics usually monitor the latest high-level developments. The health sector at large displays a vibrant demand for patents as a governance tool for technology-based breakthroughs. Leading industries such as pharmaceuticals, biotechnology or medical technology are major drivers of innovation. In 2023, two health-related areas made it to the top 10 most filed patenting fields: medical technologies (at No. 2) and pharmaceuticals (No. 7). For a number of healthcare fields, the EPO has dedicated statistics portals, including medical technology, pharmaceuticals and biotechnology.

Realising the potential of patents as an informational public good is a commitment of the EPO, namely, it is a key strategy for addressing urgent global societal challenges. The EPO was the first patent office to collaborate with the Medicines Patent Pool (MPP) and sign an agreement to support MedsPaL by facilitating the automatic update of some of the information contained in MedsPal through use of the Open Patent Service (OPS). These efforts are significant from the point of view of open innovation (Chesbrough et al., 2024).

The EPO has also developed research tools that are free to use by the healthcare communities of practice. Thus, the EPO supports innovation in health both by gathering big data and facilitating access to relevant information in the field. A flagship example is the EPO's health platform "Fighting Coronavirus", which draws from a unique cartography of technical information developed by a team of EPO expert examiners. It was created to be the first port of call when assessing the technical solutions tracking COVID-19. This effort is important, as it elicits emergent real-time management under radical uncertainty (Cunha et al., 2010).

The EPO has also actively initiated a more targeted approach by building reports covering a range of relevant areas in order to probe and anticipate the dynamics of key technologies. For instance, a number of "patent insight reports" have been published covering health issues, like the particularly dynamic sub-area of mRNA technologies. This type of EPO initiatives is relevant, as it underscores the public value of mission-oriented interventions (OECD, 2021).

Under the Strategic Plan 2028, the EPO is reinforcing its contribution as a technology intelligence hub that brings dynamic, diversified and high-quality information to all users and stakeholders in various forms. In this context, the Observatory of Patents and Technology was established with the mandate to explore the latest innovation trends, thereby empowering decisions for a better future for all. The formal public consultations held to gather viewpoints on the Observatory's inaugural Biennial Work Plan (2023-2025) reaped a large amount of feedback: a total of 63 contributions from a variety of sources extending from the research sector to industry, and from IPR specialists to sectoral practitioners, etc. Once inputs were consolidated, it is significant to note that the health topic made it to the top three priorities highlighted by stakeholders.

In the domain of health, the Observatory was set up with the goal of contributing to the critical dimensions of the modern innovation system, including technological, economic and governance-related aspects. With a holistic approach, the EPO implemented its 2024 cancer-fighting project along three main deliverables that were produced in collaboration with 10 national patent offices in Europe:

- Economic study: "Patents and innovation against cancer" revealed the patenting patterns of 140 000 cancer-fighting technologies worldwide since the early 1970s.
- Espacenet technology platform: a free online Espacenet facility on "Technologies combatting cancer" developed by EPO experts to integrate over 130 datasets.
- Deep Tech Finder: a free DTF filter covering oncology, launched to map thousands of emerging actors from all over Europe to help investors and potential partners to find new ventures with valuable new cancer technology patent assets in a variety of cancer-fighting fields.

ANNEX 3: Breakdown of the 28 cancer-related technologies

Table A1

Descriptions of all cancer technology fields

Area	Technology field	Description
Cancer diagnostics	Imaging apparatus	Imaging apparatuses are the machines or devices used to capture images, such as X-ray machines, CT scanners and MRI machines. To accurately screen, stage and provide 3D images of tumours, it is essential to have an apparatus that has an excellent tumour-tissue-to-background ratio.
Cancer diagnostics	Image analysis	Image analysis technologies are the tools and techniques used to interpret the images captured by the imaging apparatuses. This can include software for image reconstruction, as well as artificial intelligence algorithms that can help identify abnormalities and make diagnoses.
Cancer diagnostics	Imaging agents	Imaging agents are the substances used to enhance the images captured by the imaging apparatuses. These can include contrast agents used in CT scans and radiotracers used in PET scans. They help to visualise cellular activity and can provide additional information about the function and metabolism of tissues and organs.
Cancer diagnostics	Liquid biopsies	Liquid biopsies involve isolating tumour-derived entities such as circulating tumour cells, circulating tumour DNA and tumour extracellular vesicles from body fluids, followed by an analysis of the genomic and proteomic data contained within them. They are best used for screening, identifying mutations in primary and metastatic cancer and tracking changes in mutations for treatment.
Cancer diagnostics	Tumour biopsies	Tumour biopsies, also known as tissue biopsies, are fully utilised when a known tumour's location is confirmed and available for extraction. It is conducted by obtaining a sample of the tumour tissue for analysis through a needle, endoscopy or surgery.
Cancer diagnostics	Personalised medicine	Also known as precision medicine, this medical approach tailors cancer treatment to the individual characteristics of each patient, taking into account their genetic, environmental and lifestyle factors. It focuses on understanding the unique molecular and genetic characteristics of each patient's cancer, which can help in determining the most effective treatment strategies and may have fewer side effects. Personalised medicine relies on both cancer diagnostics and treatment technologies. However, it is highly dependent on diagnostic technologies because of their focus on identifying genetic variations, predicting risk and guiding treatment selection based on diagnostic information.
Cancer treatment	Chemotherapy – DNA damaging agents	Alkylating and alkylating-like agents work by directly damaging the DNA of cancer cells, preventing them from dividing and proliferating. Effective across all cell cycle phases and used to treat various types of cancer, they are particularly effective for slow-growing cancers.
Cancer treatment	Chemotherapy – Antimetabolites	Antimetabolites are false substrates for nucleic acids synthesis. Cancer cells die from using these drugs instead of the natural components
Cancer treatment	Chemotherapy – Anti-tubulin agents	These agents disrupt the function of microtubules, which are essential components of the cytoskeleton in eukaryotic cells. Microtubules play a critical role in maintaining cell shape, intracellular transport and, most importantly, mitosis (cell division). By interfering with microtubule dynamics, anti-tubulin agents effectively halt cancer cell proliferation and induce cell death.
Cancer treatment	Targeted therapy – Protein kinase inhibitors	Protein kinases are involved in various cellular functions, including metabolism, cell cycle regulation, survival and differentiation. Dysregulation of protein kinases is implicated in various processes of carcinogenesis. Protein kinase inhibitors interfere with these proteins, disrupting the processes that allow cancer cells to grow and divide.

Area	Technology field	Description
Cancer treatment	Targeted therapy – Conjugates	Conjugates cover drugs that are linked to a carrier molecule which can help deliver the drug to the cancer cells. The carrier molecule can help increase the drug's effectiveness, reduce side effects or allow the drug to bypass resistance mechanisms.
Cancer treatment	Targeted therapy – Other small-molecule targeting agents (e.g. HDAC inhibitors, angiogenesis inhibitors, proteasome inhibitors, etc.)	This group of small molecules includes a variety of targeted therapies that are not protein kinase inhibitors These drugs target specific molecular pathways that are crucial for cancer cell growth and survival. For instance, angiogenesis inhibitors block the growth of new blood vessels that tumours need to grow.
Cancer treatment	Immunotherapy – Small molecule immunomodulators	Small molecule immunomodulators are compounds that can modulate the immune response. They can either enhance the immune response against cancer cells or suppress elements of the immune system that may aid cancer growth.
Cancer treatment	Immunotherapy – Cellular	Cellular immunotherapy involves the use of immune cells to fight cancer. One example is T-cell transfer therapy, where immune cells found in and around tumours, known as tumour-infiltrating lymphocytes (TILs), are isolated, expanded, purified and used as an autologous anti-cancer treatment. It also involves the use of modified T-cells that recognise and kill cancer cells expressing specific molecules at their surface (CAR T-cell therapy).
Cancer treatment	Immunotherapy – Vaccines	Cancer vaccines are a form of active immunotherapy that aim to stimulate the immune system to attack cancer cells. These vaccines can be made from a variety of materials, including proteins or carbohydrates, that are exclusively or overly expressed in tumour cells. By introducing these antigens into the body, the immune system can be trained to recognise and attack tumour cells that express these antigens.
Cancer treatment	Immunotherapy – Antibodies	Therapeutic antibodies are immune system proteins produced in laboratories that are designed to bind to specific targets on cancer cells. Some antibodies specifically mark cancer cells so that they will be better seen and destroyed by the immune system. Others, known as immune checkpoint inhibitors, work by masking specific proteins on cancer cells preventing immune cells from killing them (e.g. PD-L1) , thereby allowing the immune system to destroy the cancer cells.
Cancer treatment	Immunotherapy – Other approaches (e.g. cytokines, oncolytic viruses)	Other immunotherapeutic approaches comprise techniques such as oncolytic viruses, soluble TCR or immunotherapy that uses cytokines, which are molecular messengers of the immune system.
Cancer treatment	Gene therapy	Gene therapy involves the introduction of exogenous nucleic acids into a cancerous cell or the surrounding tissue to cause cell death or slow the growth of the cancer. Gene therapy can involve several strategies. It can (i) replace missing or non-functioning genes with the native gene,(ii) insert genes into cancer cells that then trigger the patient's immune system to attack the cancer cells as foreign invaders,(iii) insert genes into cancer cells so that chemotherapy, radiotherapy, or hormone therapies are more effective, , (iv) introduce „suicide genes" into cancer cells, causing them to self-destruct, or (v) prevent the formation of the blood vessels that tumours need to grow and survive. Gene therapy was originally based on the direct delivery of the therapeutic gene to the patient, but now includes new genome editing technologies (e.g. CRISPR-Cas9) that allow the precise editing of the genome of the patient's cancer or immune cells, inside or outside the body.

Area	Technology field	Description
Cancer treatment	Hormonal therapy	This type of cancer treatment slows or stops the growth of cancer that uses hormones to grow. It works by removing, blocking or adding specific hormones to the body. Hormone therapy can be used to treat certain types of cancer, such as breast and prostate cancers, that require sex hormones to grow. It can be used alone or in conjunction with other treatments such as surgery, chemotherapy or radiotherapy.
Cancer treatment	Mitigating side effects	Cancer therapy can cause various side effects that vary by cancer type and treatment. While most are temporary and subside after treatment, these agents help to manage them and are crucial for improving the patient's quality of life. Common side effects include: - anaemia: low red blood cell count, leading to fatigue and shortness of breath - mucositis: inflammation of the mucous membranes in the digestive tract, mouth, nose and throat - nausea: a sensation of feeling you are about to vomit - neutropenia: a low neutrophil count, reducing the body's ability to fight infections. - thrombocytopenia: low platelet count, impairing blood clotting.
Cancer treatment	Non-coding nucleic acids	Non-coding nucleic acids are natural or engineered small RNA molecules that do not code for proteins. Specifically, naturally occurring non-coding RNAs (ncRNAs or miRNAs) play crucial roles in regulating gene expression and cellular functions in cancer cells. They are emerging as potential targets in cancer treatment. Artificial nucleic acids are designed to interfere with cellular gene expressions, protein function or sequence-specific gene editing, thereby interfering with cancer cell proliferation and/or survival. They cover interfering RNAs, antisense, aptamers and guide RNAs.
Cancer treatment	Other physical treatment (e.g. photodynamic therapy, TTFs)	Other physical treatments include photodynamic therapy (PDT) and tumour treating fields (TTF). PDT uses a light-activated drug known as a photosensitiser to destroy cancer cells, and is typically applied locally. TTFs, on the other hand, uses low intensity alternating electric fields to disrupt cancer cell division, slowing tumour growth and potentially leading to cancer cell death.
Cancer treatment	Alternative treatments and prevention (e.g. extracts from plants and animal tissue)	There is an interest in plant and animal extracts in cancer treatment, both as standalone treatments and in combination with other therapies. Some plant-derived compounds have been shown to have properties that inhibit cancer cell activity, such as proliferation and survival. Probiotics, such as live bacteria and yeast supplements, minerals, fibres or vitamins, have also been studied for their potential role in cancer treatment and prevention.
Cancer treatment	Radiotherapy	Radiotherapy uses high-energy particles or waves such as X-rays, gamma rays, electron beams or protons to destroy or damage cancer cells. The therapy is generally used for localised cancers and can be delivered (i) externally, where a machine aims beams of radiation at the tumour, or (ii) internally, where radioactive material is placed into or near the tumour . The therapy is designed to target rapidly dividing cells, which is why it is effective against cancer cells, but it can also affect some healthy cells, leading to side effects such as fatigue, sore skin and nausea. Despite these side effects, radiotherapy remains a crucial tool in cancer treatment, often used in combination with other treatments such as surgery or chemotherapy.
Cancer treatment	Surgery	Surgical technology in cancer treatment involves various techniques to remove cancerous tumours from the body. This includes traditional open surgery, minimally invasive procedures such as cryosurgery, and advanced methods such as robotic surgery and laser surgery that are used to remove a patient's cancer with more precision than conventional techniques.

Area	Technology field	Description
Cancer models	Cancer models	Cancer models are essential for reproducing and understanding the mechanisms underlying cancer, such as tumour growth and spread, and for developing new diagnostic, treatment and prevention strategies. , These models can be genetically altered to study the genetic causes of cancer and reproduce tumour types that occur naturally in humans. Cancer models have been successful in developing treatments for various cancer types, thus benefiting many patients, and enabling the study of human cancer within a whole-organism context.
ICT in cancer	Bioinformatics	Bioinformatics focuses on the analysis and interpretation of biological data such as genomic and proteomic information to better understand cancer biology and develop targeted treatments. These technologies enable more precise and personalised approaches to cancer treatment and provide an improved understanding of the genetic and molecular basis of cancer, which can help identify biomarkers for early detection of the disease as well as for personalised treatments.
ICT in cancer	Healthcare informatics	Healthcare informatics deals with the management and analysis of health-related data, including electronic health records and medical imaging, to improve cancer diagnosis, treatment, and prevention. The integration of AI technologies is transforming cancer diagnostics and treatment. AI enables rapid and precise identification of cancer types, stages and genetic features, improving outcomes through personalised treatment plans and disease monitoring. In treatment, AI helps understand drug resistance in cancer cells, aiding drug development. It also enhances radiotherapy by optimising imaging, treatment planning, simulation, quality assurance and dose delivery. In surgery, AI-powered navigation systems and robotic tools improve safety and efficacy.

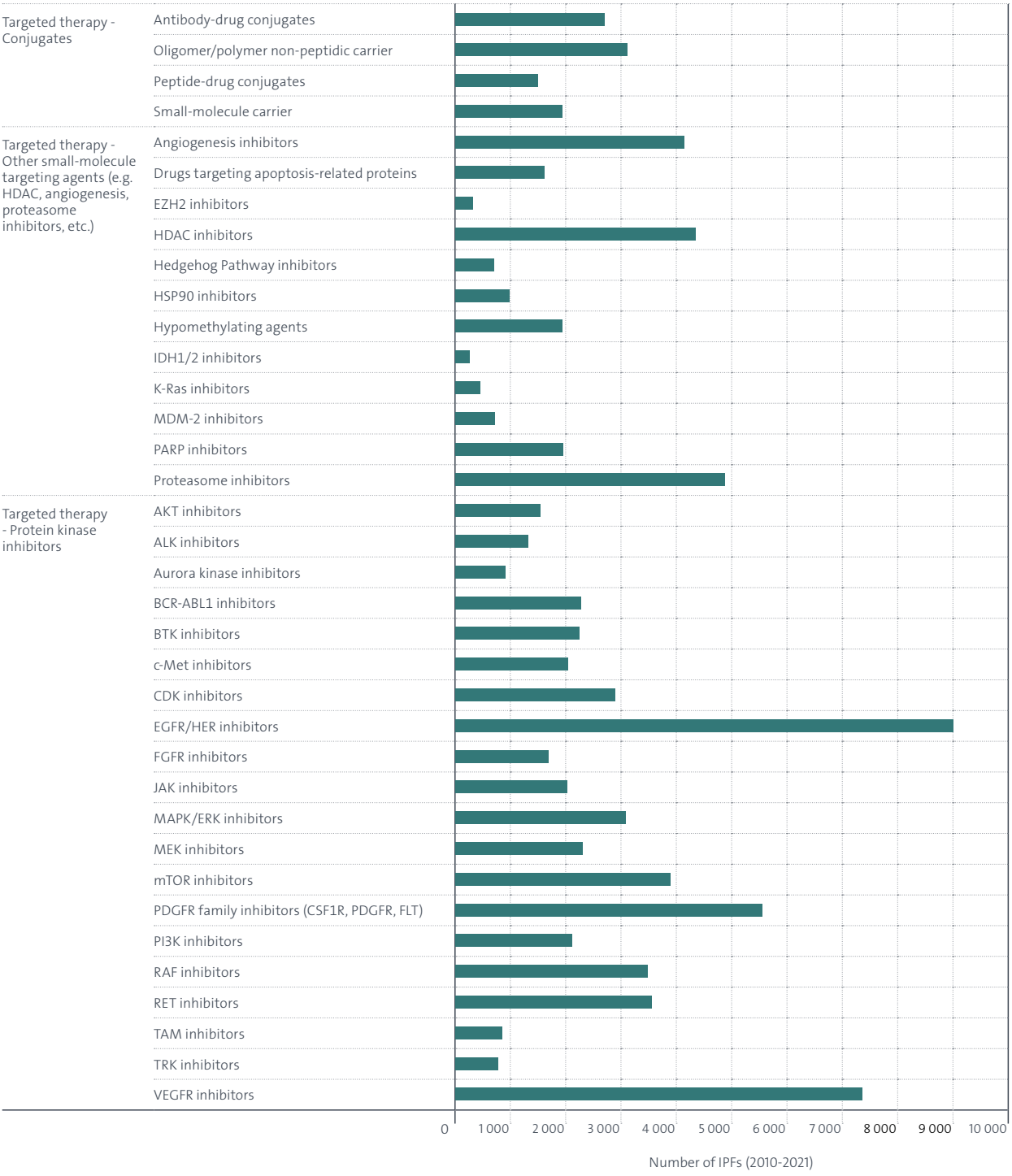
Figure A1

Breakdown of cancer technology fields and number of IPFs between 2010 and 2021


Image analysis
CNN cancer image
GAN cancer image
General image analysis
SVM cancer image
Tumor detection in images
Imaging agents
Antibody
Carriers for radionuclides
For fluorescent and near-infrared imaging
For MRI
For ultrasound & photo/optoacoustic
For X-ray
Oligomer, polymer
Peptide
Small molecule
Imaging apparatus
Endoscopy
Fluorescent and near-infrared imaging
Magnetic resonance imaging (MRI)
Nuclear medical imaging (PET/SPECT/Scintigraphy)
Photoacoustic, optoacoustic imaging
Ultrasound
X-ray
Immunotherapy - Antibodies
Angiogenesis inhibitors
Antibody-mimetics (according to type)
Costimulatory receptors
Cytokines/cytokine-receptors
Hormones and hormone-receptors
Human (according to type)
Humanised and chimeric (according to type)
Immune checkpoints
Inhibitors of CD20 or CD38
Multispecific (according to type)
Immunotherapy - Cellular
Chimeric antigen receptor (CART, CAR NK, CAR, NKT...)
Dendritic cells, monocytes, macrophages
TCRT cells
TILs (tumor infiltrating lymphocytes
Immunotherapy - Other approaches (e.g. cytokines, oncolytic viruses)
Cytokines
Immunoadhesinse/decoy receptors
Oncolytic viruses
Soluble TCR
0K
1K
2K
3K
4K
5K
6K
7K
8K
9K
10K
11K
12K
13K
14K
15K
16K
Number of IPFs (2010-2021)


Immunotherapy - Small molecule immunomodulators
Adenosine receptor antagonists
Cannabinoids
Cereblon inhibitors
Ido inhibitors
TLR agonists
Immunotherapy - Vaccines
Nucleic acid vaccines (RNA/DNA)
Protein vaccines
Vectored vaccines
Liquid biopsies
Circulating cancer DNA
Circulating proteins
Circulating tumour cells
Mitigating side-effects
Anemia
Diet during and post-therapy
Minerals during and post-therapy
Mucositis
Nausea
Neutropenia
Thrombocytopenia
Vitamins during and post-therapy
Non-coding nucleic acids
Antisense nucleic acids
Aptamers
DNA-based therapy
RNAi and MictroRNAs
Other physical treatment (e.g. photodynamic therapy, TTFs)
Electroporation, electrochemotherapy
High frequency signals
Hyperthermia (apparatus)
Hyperthermia (chemical)
Photodynamic therapy (apparatus)
Photodynamic therapy (chemical)
Tumor Treating Fields (TTFs)
0K
1K
2K
3K
4K
5K
6K
7K
8K
9K
10K
11K
12K
13K
14K
15K
16K
Number of IPFs (2010-2021)


Personalised medicine
Prognosis, predicting, or monitoring of response to treatment
Radiotherapy
Adaptive radiotherapy
AI in radiotherapy planning
Brachytherapy-General
Carriers for radionuclides used in therapy
FLASH radiotherapy
Image-guided therapy-Other
IMRT-General
Intensity modulated arc therapy (IMAT)
Interstitial radiation therapy
Intracavitary radiation therapy
Intraluminal radiation therapy
Neutron capture (apparatus)
Neutron capture (chemical)
Particle beam generation using lasers
Radiolabelled antibodies or antibody conjugates
Radiolabelled oligomers and polymers
Radiolabelled peptides or peptide conjugates
Radiolabelled small molecules or small molecule conjugates
Radiosensitization (chemical)
Radiotherapy planningGeneral
Radiotherapy using charged particles-General
Using magnetic resonance imaging (MRI)
Using portal imaging
Using x-ray imaging
Surgery
Coagulating and cutting
Computer-aided surgery (CAS) and robotics
Countercooling healthy tissue
Counterheating healthy tissue
Direct contact with tissue
Electromagnetic radiation or optical heating (microwave - lasers)
Electroporation
Image correlation
Indirect contact (e.g. balloon)
Magnetic/Induction heating
Markers
Resistance heating
Thermoelectric heating
Tissue impedance heating (RF)
Ultrasonic heating (N7/12)
Ultrasound cell poration
0
1 000
2 000
3 000
4 000
5 000
6 000
7 000
8 000
9 000
10 000
Number of IPFs (2010-2021)

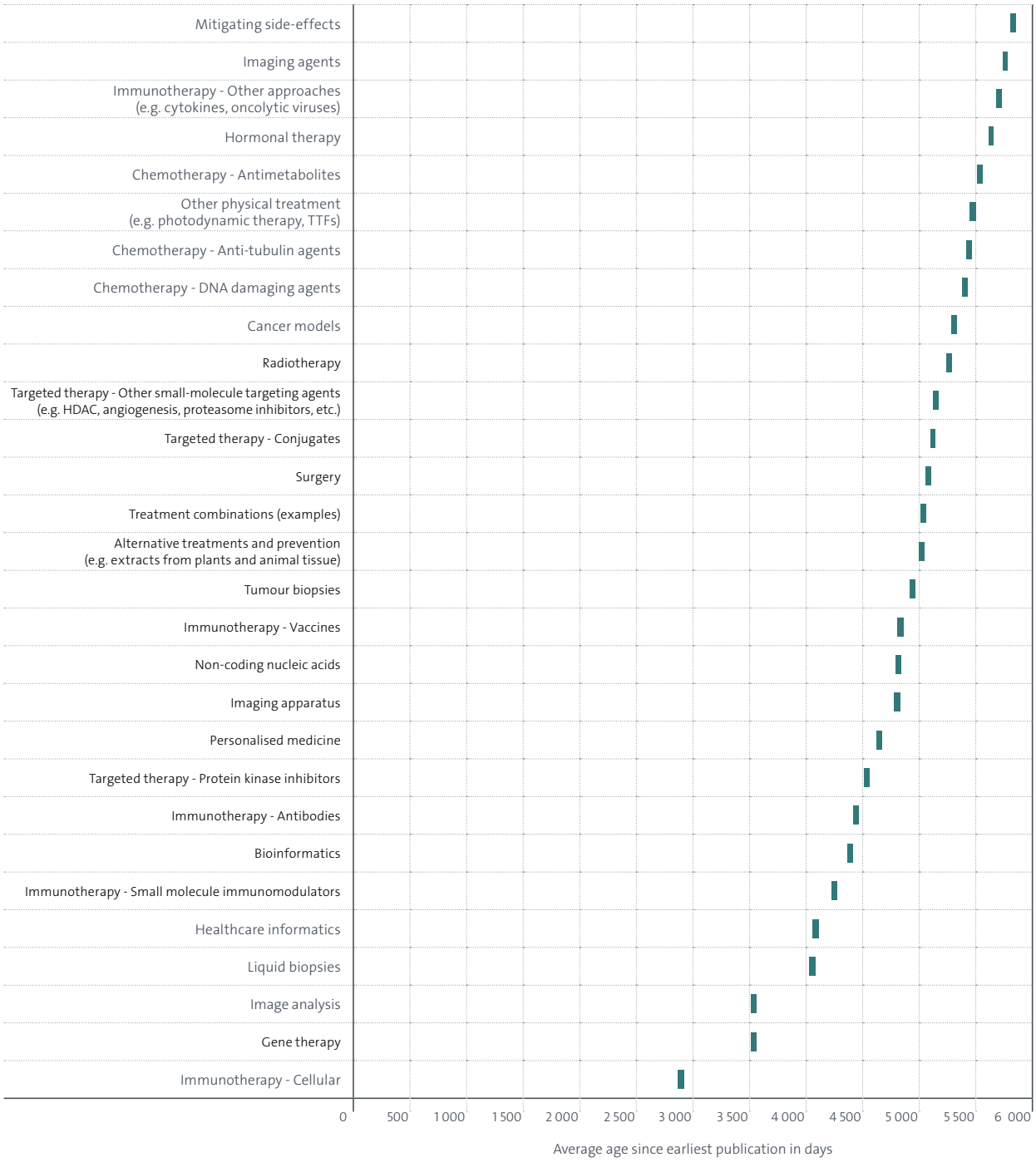

Targeted therapy - Conjugates
Antibody-drug conjugates
Oligomer/polymer non-peptidic carrier
Peptide-drug conjugates
Small-molecule carrier
Targeted therapy - Other small-molecule targeting agents (e.g. HDAC, angiogenesis, proteasome inhibitors, etc.)
Angiogenesis inhibitors
Drugs targeting apoptosis-related proteins
EZH2 inhibitors
HDAC inhibitors
Hedgehog Pathway inhibitors
HSP90 inhibitors
Hypomethylating agents
IDH1/2 inhibitors
K-Ras inhibitors
MDM-2 inhibitors
PARP inhibitors
Proteasome inhibitors
Targeted therapy - Protein kinase inhibitors
AKT inhibitors
ALK inhibitors
Aurora kinase inhibitors
BCR-ABL1 inhibitors
BTK inhibitors
c-Met inhibitors
CDK inhibitors
EGFR/HER inhibitors
FGFR inhibitors
JAK inhibitors
MAPK/ERK inhibitors
MEK inhibitors
mTOR inhibitors
PDGFR family inhibitors (CSF1R, PDGFR, FLT)
PI3K inhibitors
RAF inhibitors
RET inhibitors
TAM inhibitors
TRK inhibitors
VEGFR inhibitors
0
1 000
2 000
3 000
4 000
5 000
6 000
7 000
8 000
9 000
10 000
Number of IPFs (2010-2021)


Treatment combinations (examples)
Anti-cytidine in combination therapy
Anti-pyrimidines in combination therapy
Antiestrogens/Aromatase inhibitors/Progestogens in combination therapy
Bcr-Abl1 inhibitors in combination therapy
CDK inhibitors in combination therapy
Cereblon inhibitors in combination therapy
Combinations of immune checkpoint inhibitors with a TKI
Combinations of RAFi and MEKi
Drugs targeting apoptosis-related proteins in combination therapy
EGFR/HER inhibitors in combination therapy
HDAC inhibitors in combination therapy
PARPi in combination therapy
PDGFR family inhibitors in combination therapy
PI3K/AKT/mTOR inhibitors in combination therapy
Platinum agents in combination therapy
Proteasome inhibitors in combination therapy
Taxanes in combination therapy
Topoisomerase I inhibitors in combination therapy
Topoisomerase II inhibitors in combination therapy
Tumour biopsies
Biopsy with a needle
Biopsy with endoscopy
Biopsy with surgery
DNA/mRNA/mutations/transcriptome
OMIC analysis of single cell
Proteins
0
1 000
2 000
3 000
4 000
5 000
6 000
7 000
8 000
9 000
10 000
Number of IPFs (2010-2021)

Source: EPO

Figure A2

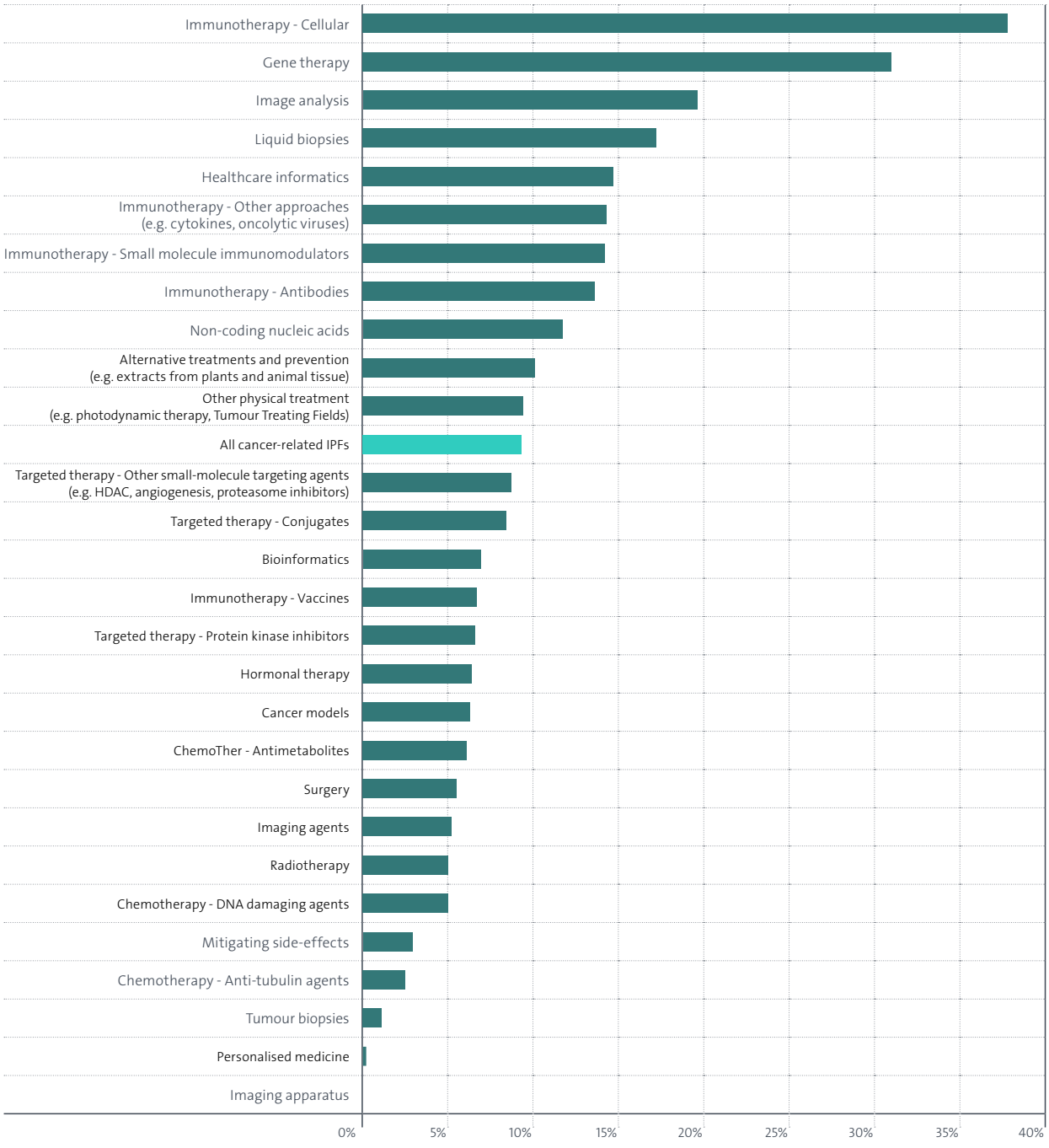
Distribution of average age of all IPFs by cancer technology field from earliest publication date, in days



Source: EPO

Figure A3

Distribution of CAGR of IPFs between 2015 and 2021, by cancer technology field

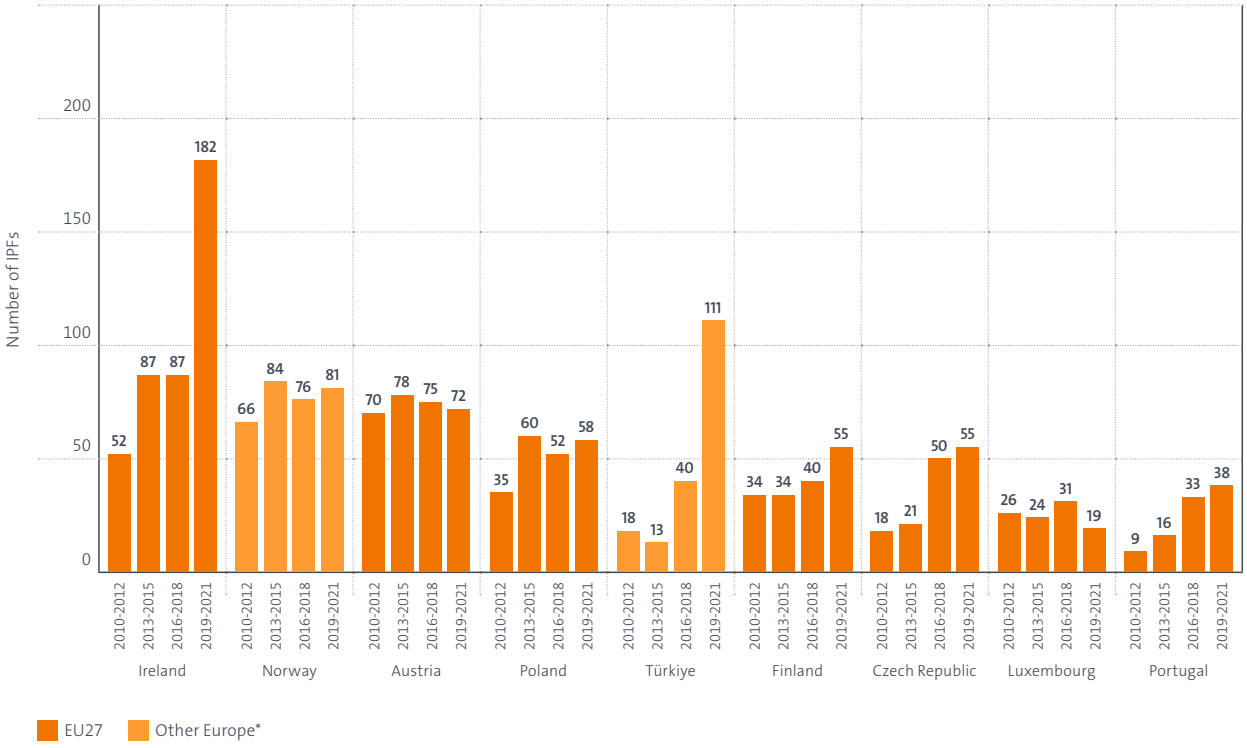


Source: EPO

ANNEX 4: Cancer technology profiles of selected European countries

Figure A4

Trend in cancer-related IPFs for selected European countries across four consecutive three-year periods, 2010-2021



* AL, CH, IS, LI, MC, ME, MK, NO, RS, SM, TR, UK

Source: EPO

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