Innovation Caucus

UNDERSTANDING AND ARTICULATING THE NATURE OF INNOVATION AND COMMERCIALISATION IN BIOSCIENCE

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In partnership with:

UKRI Biotechnology and Biological Sciences Research Council

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Acknowledgements

The core members of the research team for this project were as follows:

- Dr Syahirah Abdul Rahman, Innovation Caucus and Oxford Brookes University
- Professor Tim Vorley, Innovation Caucus and Oxford Brookes University
- Phil Wallace, Innovation Caucus and University of Sheffield

We are very grateful to all those individuals who generously gave their time to participate in the interviews.

About the Innovation Caucus

The Innovation Caucus supports sustainable innovation-led growth by promoting engagement between the social sciences and the innovation ecosystem. Our members are leading academics from across the social science community, who are engaged in different aspects of innovation research. We connect the social sciences, Innovate UK and the ESRC, by providing research insights to inform innovation policy and practice. We champion the role of social science in innovation and enhance its impact. Professor Tim Vorley is the Academic Lead. The initiative is funded and co-developed by the ESRC and Innovate U..

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EXECUTIVE SUMMARY

The Biotechnology and Biological Sciences Research Council (BBSRC) is part of UK Research and Innovation, and has the mission to fund world-class 21st century bioscience, promoting bioscience innovation and delivering societal benefit within and beyond the UK. New technologies and approaches are revolutionising biology and advancing our knowledge and understanding of the complex and dynamic processes that underpin life. This provides unprecedented opportunities for the power of biology to contribute to transforming our lives, redefining markets and addressing the complex and longer-term socioeconomic challenges faced by humanity. Biology can help deliver a net zero world; provide safe, nutritious and resilient agriculture and food systems; decarbonise manufacturing; and unleash the capabilities to develop new materials and high value products, including therapeutics.

The bioscience innovation and commercialisation ecosystem (BICE) in the UK is critical to curating and capturing the economic and societal value of research and innovation, the impacts of which are seen across the UK economy and wider society. The role of BBSRC is wide-ranging, from advancing the knowledge base through fundamental research to the commercialisation of new technologies and public engagement.

The purpose of this project was to explore and better understand the opportunities for the BBSRC as a catalyst for research and innovation as part of BICE in the UK, and for increasing the impact of the bioscience as part of the UK economy. As part of the overarching project there are two reports, and the aim of this first report is threefold:

1. Understand the profile and perception bioscience and the BICE among key stakeholder and public communities
2. Identify potential bioscience innovation pathways focusing on academic commercialisation
3. Identify internationally leading BICEs and summarise points of good practice.

The report seeks to identify and inform how the BBSRC can strengthen BICE in the UK, by understanding the barriers, challenges, opportunities and support needed to maintain the UK's position as a leader in bioscience research and innovation. The aim is to provide insights to the BBSRC to help inform future investments and interventions that can enhance the value and visibility of bioscience.

This report employed a multi-method approach and was conducted between June 2021 and September 2021. The research comprised two phases: 1) a review of the literature on challenges and opportunities in commercialisation and innovation in the UK's bioscience industry; 2) in-depth interviews to gather qualitative data and build a nuanced understanding of the profile of innovation in the UK bioscience industry.

The findings demonstrate:

1. Using the ecosystem framework, the profiles of the BBSRC and bioscience are not consistently understood among different stakeholders and, at times, could be negatively perceived by public communities. There is an opportunity to consider the proactive role that the BBSRC could play in facilitating more open and diverse communication with different stakeholders in promoting bioscience in the UK.
2. Higher education institutions (HEIs) are important stakeholders in BICE with very limited resources. There is an opportunity to think about the role that regional centres composed of consortia of HEIs could play to enable bioscience innovation and commercialisation.
3. Examples from different countries encourage us to think about factors such as regulatory barriers and opportunities in bioscience innovation and commercialisation, public perception of the value of bioscience, the importance of the right infrastructures to support bioscience innovation specifically, and the narratives behind the profile of bioscience.

1. INTRODUCTION

The Biotechnology and Biological Sciences Research Council (BBSRC) is part of UK Research and Innovation (UKRI), a body which works in partnership with universities, research organisations, businesses, charities, and government to create the best possible environment for research and innovation to flourish. BBSRC's mission is to lead world-class 21st century bioscience, promoting innovation in the bioscience industry and realising benefits for society within and beyond the UK.

Bioscience innovation and commercialisation offers huge potential to support a more productive, prosperous and sustainable UK, through the projected creation of four million jobs and £153 billion gross value added (GVA) (BBSRC, 2015, 2018).[1] It is therefore central to BBSRC's mission to ensure that there is a flourishing BICE in the UK. BBSRC aims to enable the optimal and successful application of the outcomes from the research and capabilities it funds.

This project aimed to build the evidence base and rationale for BBSRC's future work on enhancing the profile of innovation and commercialisation in the UK bioscience industry. At present, there is limited understanding of what enables or constrains the interdependence between the actors and factors in BICE. In particular, this research project sought to develop new and alternative insights about BICE, in the UK and internationally, to inform the BBSRC's work.

This first report draws on entrepreneurial ecosystem literature, which is itself inspired by ecological studies. The metaphor of ecosystems has grown in popularity in academia, policy, and industry. From a biological perspective, ecosystems refer to the interactions between living organisms and the physical environment in which they exist. The biological analogy is useful in the context of innovation, commercialisation and entrepreneurship as it emphasises the different aspects of the 'system' that collectively provide the overarching environment. The operation of an ecosystem is also not just about the presence of specific characteristics, factors or conditions, but rather the importance of their interdependence and their balance.

Entrepreneurial ecosystems help us to think about a systemic view of innovation and commercialisation like that of biological ecosystems. Using this view, we can consider what injects life into, or withdraws life from, the living system; its community of independent actors in conjunction with the non-living components of the observed environment (Smith & Smith, 2015). To understand the health of BICE in the UK, we observe the social, cultural and economic forces to gain a more nuanced understanding of what enables, or creates barriers to, its health.[2]

The remainder of this report is structured in four further sections: Section 2 presents the research design and methods used in the study; Section 3 depicts the profile and perception of bioscience and the BICE among key stakeholder and public communities; Section 4 discusses bioscience innovation pathways with a focus on commercialisation activities and higher education institutions (HEIs); and Section 5 presents a selection of good practice from analysis of internationally leading BICEs.

This report is intended to inform and stimulate further discussion about the commercialisation of bioscience research and is not intended to be either representative or definitive in nature. The findings provide insights for the BBSRC on how to better understand and engage with the BICE in promoting a stronger culture of innovation and commercialisation in bioscience.

[1] The British Bioeconomy. Available online: https://bbsrc.ukri.org/documents/capital-economics-british-bioeconomy-report-11-june-2015/.

[2] World Economic Forum. Available online: https://www3.weforum.org/docs/WEF_EntrepreneurialEcosystems_Report_2013.pdf.

2. METHODS AND RESEARCH DESIGN

There were two parts to the research design. This Section outlines each part in turn before summarising the analysis.

Part 1

The first part of the project involved a desk review of relevant academic and grey literature, looking into the bioscience innovation and commercialisation in the UK and internationally. At the time of research, the term 'bioeconomy' had been widely used in policy documents worldwide, in reference to bioscience innovation and commercialisation. As such, the focus of the desk review is on reviewing activities surrounding the term "bioeconomy" and as part of the overarching aim of the project.

The BBSRC defines the bioeconomy as "All economic activity derived from bio-based products and processes which contributes to sustainable and resource-efficient solutions to the challenges we face in food, chemicals, materials, energy production, health and environmental protection". However, the term 'bioeconomy' can be problematic, vagueness on how it is formally defined, and is only used in this report where it reflects usage by third parties.

Part 1 was also useful in identifying stakeholder groups crucial to innovation and commercialisation in the bioeconomies of other countries. In consultation with the BBSRC, the stakeholder groups have been categorised as:

- **Bioscience businesses:** Businesses involved in the commercialisation of bioscience products, processes, or services. These businesses are further sub-categorised as businesses with innovation funds and start-ups.
- **Bioscience intermediaries:** Non-governmental organisations integral to the innovation and commercialisation of bioscience, including research institutes, industry organisations and universities (specifically, technology transfer offices).
- **Financial community:** Public or private actors providing the finance that supports innovation and commercialisation of bioscience.
- **Regulatory, standards, and policy bodies:** Organisations core to the regulatory framework of the UK bioscience industry.
- **Critical Friends:** Actors who are integral to our understanding of the value of the bioscience industry, including communications groups, public relations bodies, and campaign groups.

The desk review was also used to inform the exemplars of internationally leading BICEs and highlight points of good practice. This involved the analysis of documents primarily, although not exclusively, in English, and should not be taken as definitive.

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For an international perspective, four countries were chosen based on three criteria: 1) the extent of their research base, measured by publications and citation impact, through which research into bioscience will have an incidental impact (BEIS, 2019); 2) the amount of investment in and public funding commitment to the development of the life sciences industry, which bioscience falls under (Deloitte Insights, 2021; World Intellectual Property Organisation, 2020); and 3) their long-term commitment and strategy. The documents reviewed included grey literature, policy documents, academic journals, government reports and consultancy reports, among others.

Part 2

Qualitative semi-structured interviews were undertaken with 30 individuals identified as experts possessing in-depth knowledge of bioscience innovation and commercialisation in the UK. Given the exploratory nature of the research, and that it does not aim to arrive at a generalisable conclusion, the smaller sample size is justified based on academic literature. Baker et al. (2012) argued that in cases of hard-to-access populations such as experts, smaller sample sizes with a minimum of six interviewees are justified given the interviewees' wealth of knowledge and insights into the area and/or phenomenon observed.

Purposive and snowball sampling techniques were used to identify interviewees. In collaboration with BBSRC, emails were sent to potential participants, identified via the stakeholder mapping exercise in Phase 1. The 28 interviewees (12 females; 16 males) participated in the interviews through video meeting software such as Zoom, Google Meet and/or Microsoft Teams during the period June to October 2021.

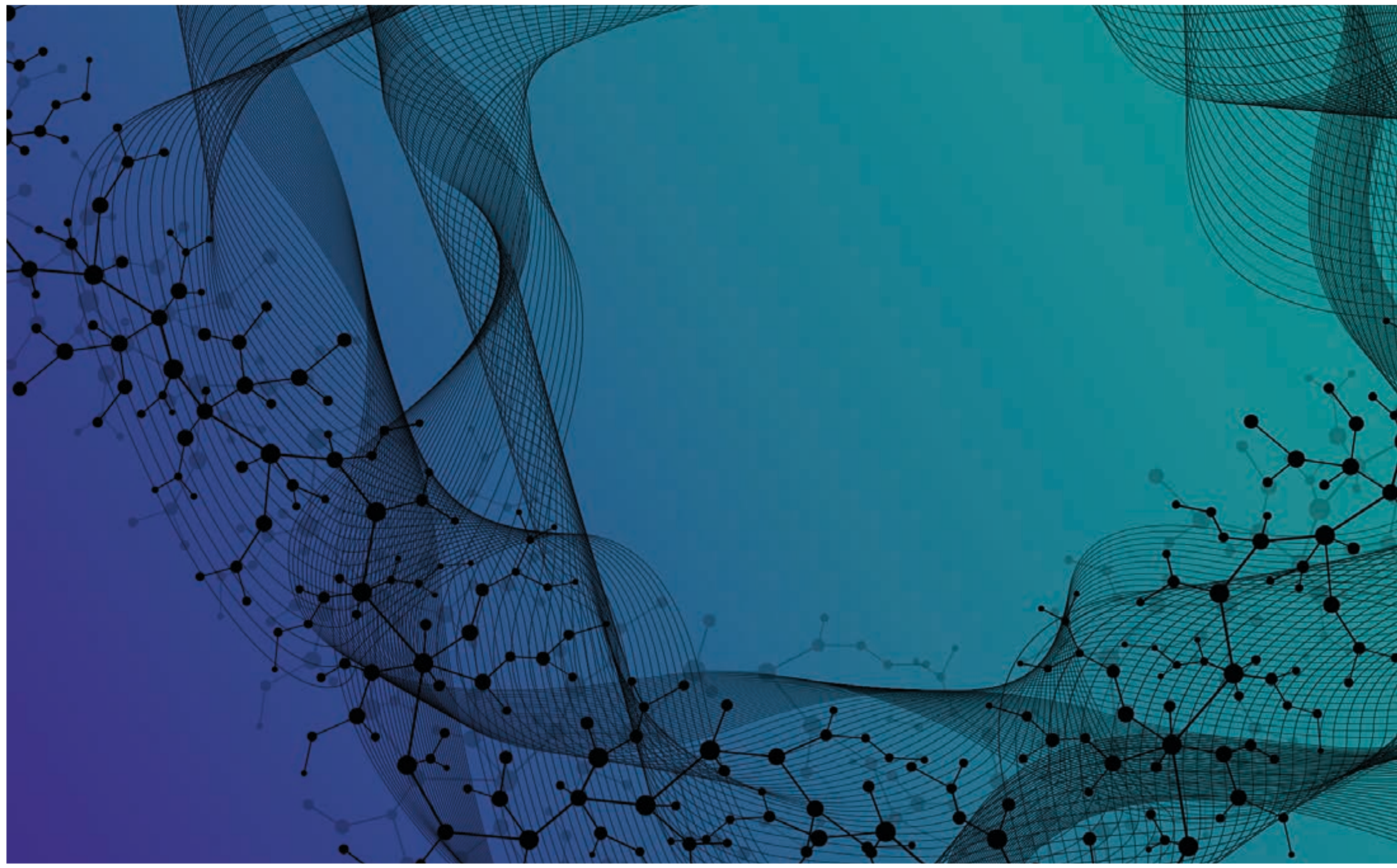

Table 1. Interviewees by organisation type and role type

No.	Interviewee Code	Organisation Type	Role Type
1	Business 1	Biotech Start-up	Director / Academic
2	Business 2	Industrial Biotech Start-up	Director of Technology & Operations / Academic
3	Business 3	Biotech Start-up	CEO / Academic
4	Business 4	Agri-tech Start-up	Former CEO / Academic
5	Business 5	Biotech Start-up	CEO / Academic
6	Business 6	Biotech Start-up	Former CEO / Academic
7	Business 7	Biotech Start-up	CEO / Academic
8	Business 8	Large Agriculture Firm	Senior Professional
9	Intermediary 1	Research Institution	Business Developer
10	Intermediary 2	Russell Group University	Project Manager in a Technology Transfer Office
11	Intermediary 3	Russell Group University	Business Engagement Manager in a Technology Transfer Office
12	Intermediary 4	Consultancy Company	Managing Director
13	Intermediary 5	Russell Group University	Licensing Manager in a Technology Transfer Office
14	Intermediary 6	Public Research University	Knowledge Exchange & Policy Professional
15	Intermediary 7	Russell Group University	Research Commercialisation Manager in a Technology Transfer Office
16	Intermediary 8	Russell Group University	Research Commercialisation Manager in a Technology Transfer Office
17	Intermediary 9	Professional Association	Head of Technical Programmes
18	Intermediary 10	Innovator Network	Senior Official in Agri-tech
19	Intermediary 11	Professional Association	Head of Advisory Committee
20	Intermediary 12	Professional Association	Head of Policy and Public Affairs
21	Intermediary 13	Post-1992 University	Senior Officer in Technology Transfer Office
22	Critical Friends 1	Non-Profit Organisation for Science and Engineering	Director
23	Critical Friends 2	Independent Consultancy Group	Senior Official in Agri-tech
24	Critical Friends 3	GM Freeze (Campaign Group focusing on GM food, crops and patents)	Director
25	Critical Friends 4	Russell Group University	Activist
26	Policy & Regulatory 1	Policy Organisation	Policy Advisor
27	Policy & Regulatory 2	Regulator	Scientific Officer
28	Finance 1	Enterprise Incubator	Senior Official in Investment
29	Finance 2	Enterprise Incubator	Senior Official in Investment
30	Finance 3	Enterprise Incubator	Director

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Data Analysis

The interviews were audio-recorded and transcribed to facilitate data analysis. Interview participants were assured of confidentiality and anonymity to encourage candid responses, although in one instance, an interviewee has specifically requested not to be anonymised (Liz Moore, Director of GM Freeze). The data analysis was conducted using NVivo coding software. The final codes have been grouped into wider themes adapted from the theoretical framework of Stam's (2015) integrative model of entrepreneurial ecosystems. The final discussion combines findings from both primary and secondary data analyses.

3. BIOSCIENCE INNOVATION AND COMMERCIALISATION ECOSYSTEM

In analysing the findings, we adapted Erik Stam's integrative model of the entrepreneurial ecosystem. Stam's model was chosen as it is one of the earlier entrepreneurship models which actively encourage researchers to think critically about the role that social relationships and connections play in the system of innovation and entrepreneurship. The concepts of innovation and commercialisation resonate with entrepreneurial ecosystems. Based on the Department for Business, Energy & Industrial Strategy's (BEIS) UK Innovation Strategy report, innovation refers to "the creation and application of new knowledge to improve the world," (BEIS, 2021, p. 11). The application of innovation can be managed through commercialisation which enables "new innovations to have real impact on people's lives" (BEIS, 2021, p. 45). Innovation, thus, is the process of researching and developing new ideas and technologies, while commercialisation is the process that brings their application as products or services to market. This either leads to, or happens simultaneously with entrepreneurship, the process of extracting value from bringing product or services to market through business activities.

The ecosystem view also highlights the broader social context of what enables, or creates barriers to, innovation and commercialisation. Our findings are illustrated through an adaptation of Erik Stam's model to the UK bioscience innovation and commercialisation context (Figure 1). It should be noted that the adaptation of this model is purely for analytical and discussion purposes.

The elements of BICE can be distinguished as framework conditions and systemic conditions. At the bottom of the model are framework conditions - formal institutions, culture, physical infrastructure and demand; conditions that enable or constrain important social interactions needed for successful innovation and commercialisation. At the top of the model are systemic conditions - networks, intermediaries, talent, knowledge and leadership; fundamental causes which are driven by framework conditions to create a successful innovation and commercialisation ecosystem.

The data analysis process demonstrated a stark difference between systemic and framework conditions. Interviewees' answers to the question "What are the challenges of innovation and commercialisation of bioscience in the UK?," fit within the categories of systemic conditions in the ecosystem. Interviewees discussed issues of networking, the importance of intermediaries, the need for talent, issues of funding, and the importance of role models in successful innovation and commercialisation.

However, the characteristics of framework conditions (i.e., formal institutions, culture, demand, and infrastructure), were not immediately identified by interviewees as challenges for innovation and commercialisation. Instead, these themes come up when interviewees were probed on the broader themes of value and profile of bioscience. Findings under these themes resonate with the framework conditions of the ecosystem. They relate to:

- The importance of formal (regulation) and informal (culture) institutions in the ecosystem
- The lack of understanding of bioscience's value, which may impede demand for bioscience innovation and commercialisation; and,
- How this affects the overall infrastructure of the ecosystem.

As the ecosystem framework is based on both economic and social factors, its process is rarely linear. Instead, when the value of bioscience is not well recognised, its effects on the innovation and commercialisation ecosystem permeate all conditions, affecting them in various ways in a multidimensional manner. Through this finding, we are able to visualise systemic and framework conditions in the ecosystem using an iceberg analogy (Figure 2).

Systemic conditions are elements above the surface of the ocean. They form visible conditions that interviewees were able to point out when discussing challenges and opportunities in innovation and commercialisation. The presence of systemic conditions and the interactions between them are identifiable and predominantly determine the health of the innovation and commercialisation ecosystem. Framework conditions are less visible, below the surface of the ocean. They are often taken-for-granted aspects of innovation and commercialisation, affected by the social system in which the ecosystem operates. Its strength, therefore, can hold the weight of systemic conditions, thereby affecting the entire ecosystem.

Figure 1: Bioscience Innovation and Commercialisation Ecosystem (BICE) (Adapted from Stam, 2015)

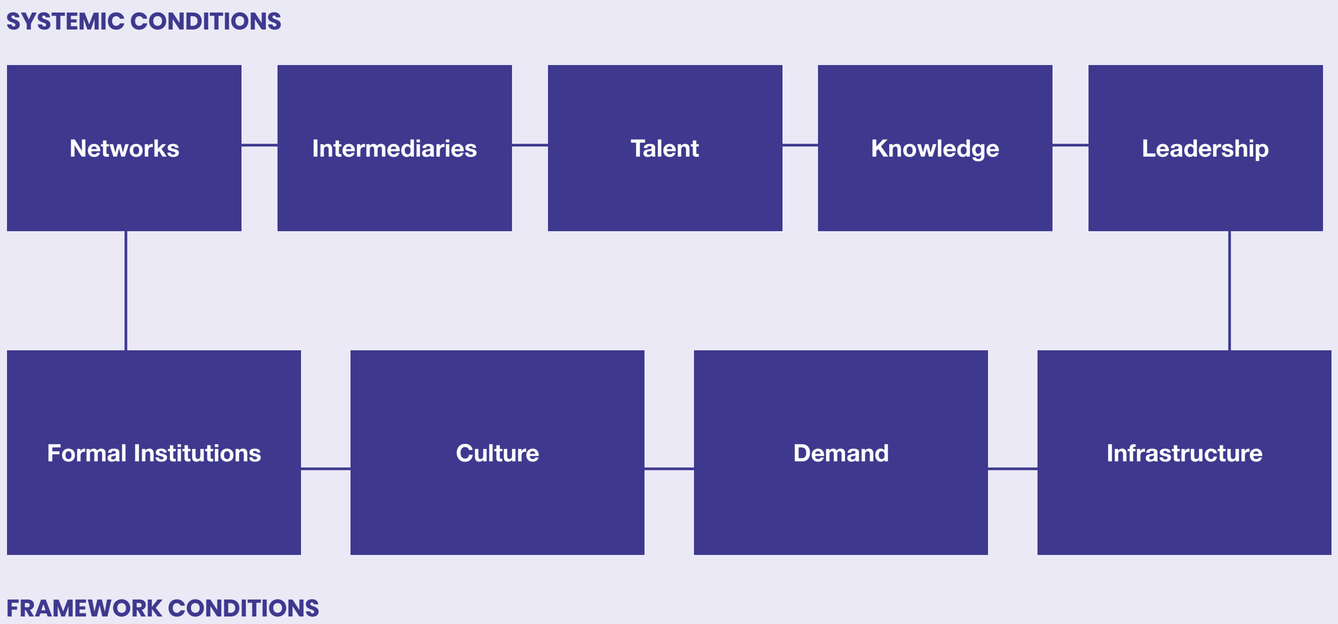


Figure 1:
The Bioscience Innovation Ecosystem

SYSTEMIC CONDITIONS

Networks: Meetups, collaboration spaces, skill training programmes, incubators, networks of mentors and angel investors

Intermediaries: Inclusivity, diversity and transparency of regulatory and policy making aspects need to be explored

Talent: Diversity in education and research background, training and education capacity

Knowledge: Actors with knowledge of bioscience potential to provide appropriate funding and investment

Leadership: Diversity of businesses and sectors, availability of knowledge and translation for R&D in universities

FRAMEWORK CONDITIONS

Formal Institution: Anticipatory and conducted in collaboration with multiple stakeholders

Culture: Having a coherent understanding of the value of bioscience and bioeconomy, tolerance for risk and failure of bioscience innovation

Physical Infrastructure: Access to basic entrepreneurial infrastructures

Demand: Private & public institutions' investment commitment; public perception on value of bioscience and its influences on formal institutions

3.1 Systemic Conditions

3.1.1 Networks

The first systemic condition is **networks**, which enable the effective distribution of ideas, capital and labour. A healthy ecosystem would have a variety of activities to support these networks, such as meetups, collaboration spaces, workshops, incubators, and facilitation of mentors (actors who can also provide direction and mentorship for others wanting to pursue innovation and commercialisation in bioscience) and angel investors.

Findings for networks are best observed under the interview question **"What are some of the advantages of the UK innovation landscape for bioscience?"** Nearly all interviewees agreed that the UK has an advantage over many countries in the strength of its innovation networks.

Nonetheless, in BICE in the UK, networks exist predominantly at sub-sector and/or technological application level. Some sub-sectors (pharmaceutical and medical biotechnology) have greater availability of networks of innovators than others, according to the group of Business and Intermediary Interviewees.

A variety of networks also exists based on the sectors to which bioscience technologies are providing support services. **This demonstrates the lack of identification that innovators have in relation to the wider profile of bioscience.**

3.1.2 Intermediaries

The second systemic condition is the **intermediaries** who are responsible for supplying support services which can lower barriers and reduce the time to market for innovation and commercialisation. This not only includes support by research councils and public funders, but also highlights the importance of knowledge transfer activities conducted by technology transfer offices.

Findings suggest that the UK's current policy efforts might be perceived as prioritising some bioscience-related sub-sectors over others. This is experienced through the allocation of public funding, for example, as described by the two interviewees below:

> *We sit on a massive dataset essentially that we haven't really ever analysed. […] There are opportunities, I think, from that perspective in terms of sharing data and sharing ideas. […] But I think there's still a need for more, what I would think of as fundamental science, but you know real scientists would think of it as very, very applied. […] We don't have the money or funding to do the sort of experiments you really want to do.* – ***Interviewee Critical Friends 2 [emphasis added]***.

> *What we've ended up with is essentially a big imbalance in funding.* – ***Interviewee Intermediary 9.***

The first interviewee above spoke about their experience in the agriculture sector over the past decade. They described how innovation in farming practices could be achieved using existing datasets if there were interest and funding in this area. An interviewee with **Interviewee Policy & Regulator** 1 shed light on policy interest on bioscience changing depending on the incumbent administration's "areas of interest". This sentiment is shared by several other interviewees who have experience in bioscience sub-sectors other than pharmaceutical and medical biotechnology **(for example, Interviewees Business 2, Business 4, Intermediary 9, Intermediary 10).**

The second interviewee's quote came from a longer discussion of the development of the bioscience sector in the UK. Over the years, reduced attention has been given to other bioscience sub-sectors, specifically agriculture, which used to have more policy focus. The interviewee explained that there has been a change of appetite in policy in regard to funding agriculture-based research, innovation and commercialisation, especially after a period of controversy in the 1990s surrounding genetic modification (GM) technologies. Interviewee **Intermediary 9** added, "This has far-reaching consequences, particularly for the research capacity. Because if you turn the money off you can't just turn the expertise back on again."

Interviews with intermediaries that are focused on technology transfer have also shown that there is a greater volume of commercialisation activities among bioscience research linked to pharmaceutical and medical biotechnology. There is a perception that these sub-sectors are more lucrative in the UK than other bioscience sub-sectors (BBSRC, 2019). While this could be true in terms of financial returns, the government's Growing the Bioeconomy report identified that there is much to be gained from other bioscience sub-sectors (HM Government, 2018). This shows a lack of understanding of the overall value that bioscience has to offer beyond pharmaceutical and medical biotechnology.

3.1.3 Talent

Talent forms the third systemic condition. The presence of a diverse and skilled group of workers is integral to a successful innovation and commercialisation ecosystem. They provide the pool of creativity, ideas and skills needed to inspire innovation which can lead to commercialisation.

The UK is home to a world-class talent pool. There is no shortage of creativity, skills and research in the country, although there are challenges in bringing those ideas to market through commercialisation. Interviews shed light on the barriers found in the career development of academics, whereby commercialisation is still treated as a new and highly risky option. Due to their lack of experience in commercialisation, academics face barriers from having limited entrepreneurial skills **(Interviewees Intermediary 1-8).**

A discussion with these interviewees on the commercialisation culture among academics reveals that the support academics get from their HEIs is not consistent. For example, Interviewee Business 1 compared their experiences of commercialising in England and in Scotland, and said there is a discrepancy in how English and Scottish HEIs approach commercialisation:

> *"I was exposed to a lot of Scottish universities and the systems that they have, the enterprise support that they have in Scotland, it was so impressive. You have universities like Dundee, Strathclyde, Edinburgh and they support innovative research. The systems that they put in place were very helpful.* – ***Interviewee Business 1***

Interviewees Business 1-7 and **Intermediaries 1-8** mentioned that support also differed between HEIs based on the central and/or department level's management and how they accept and promote the culture of commercialisation. This, in turn, influences the resources they dedicate to it. While there is a change of culture in accepting commercialisation among UK HEIs, many academics still face the challenge of not receiving support from their department heads, whereby academic outputs are perceived as more valuable than commercial outputs.

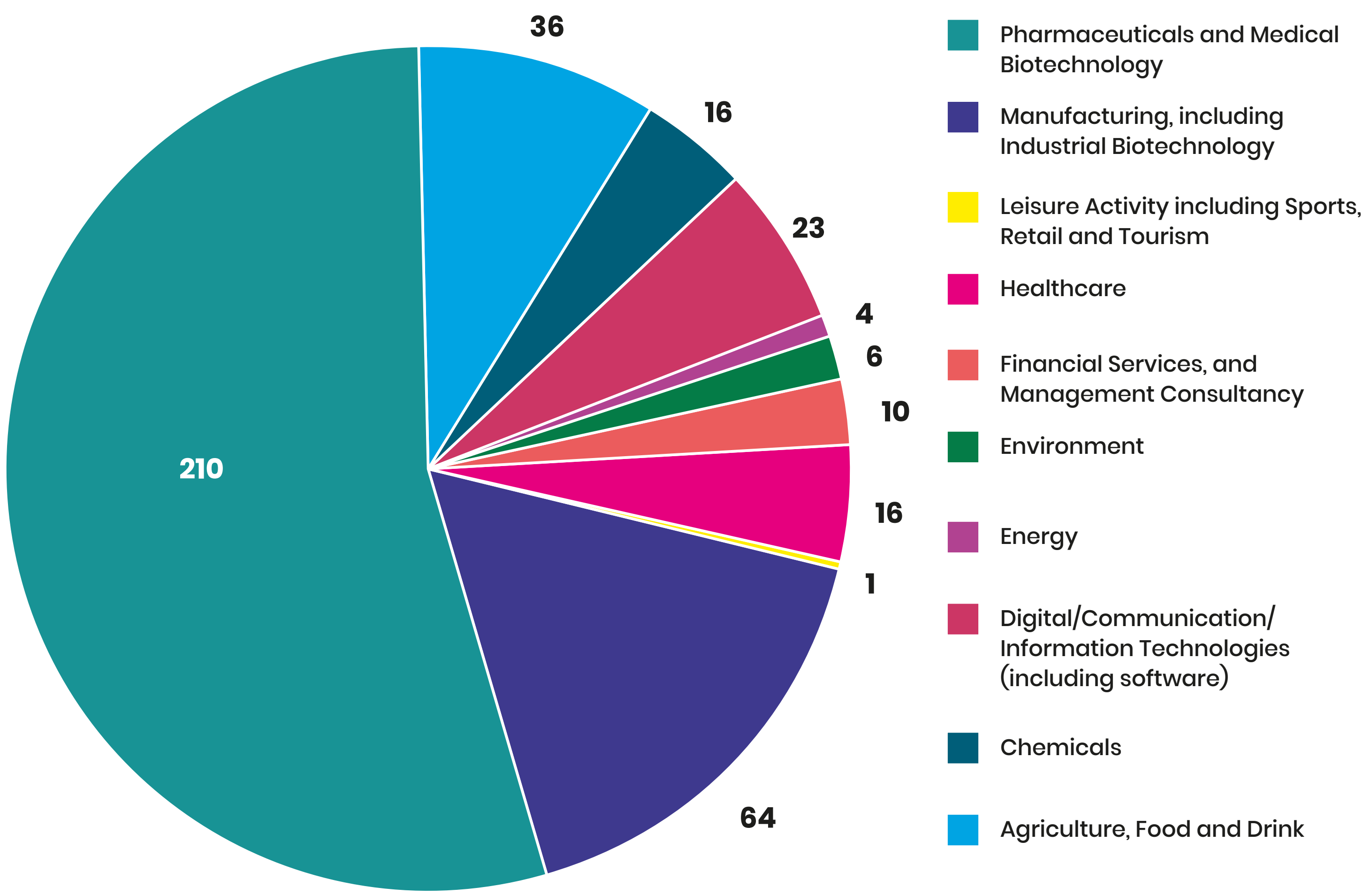
3.1.4 Knowledge

Knowledge refers to access to financing. In spaces of uncertainty such as innovation and commercialisation, and more so in bioscience where the route from research to market can take much longer than in other disciplines, there is a greater need for public and private actors who possess the right innovation and commercialisation knowledge. They need to know about the opportunities and risks involved in successful innovation and commercialisation, and should also be willing to take risks in providing access to financing.

Interview findings show that the UK is at an advantage in terms of knowledge of, and access to financing. Start-up interviewees, for example, said that there is a great amount of funding to be secured from research councils. Outside the US, the UK is considered to be world-class in its investment infrastructure for bioscience start-ups.

Nonetheless, this perception is not equally shared among all sub-sectors in bioscience. This can be seen in the lack of diversity among bioscience start-ups and spinouts. A BBSRC study in 2019 has shown that, of 387 spinout companies linked to BBSRC investments, 210 (54.3%) were from pharmaceutical and medical biotechnology (BBSRC, 2019). Figure 3 demonstrates that the other bioscience sub-sectors share a small percentage of commercialisation in comparison. Furthermore, there is a perception that funders of bioscience research and investors in bioscience-related R&D do not know the full breadth of its potential.

Figure 3: Distribution of spinout companies underpinned by BBSRC investments, per industry sectors (BBSRC, 2019)



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3.1.5 Leadership

The fifth systemic condition is **leadership**, which refers to the presence of role models, actors who have successfully innovated and commercialised. They can be organisations or individuals who are not just economically successful, but who can also provide direction and mentorship for others wanting to pursue innovation and commercialisation in bioscience. Leadership in this sense is critical in building and maintaining a healthy ecosystem. A good ecosystem would have visible leaders who are committed to the ecosystem, whether via informal or formal mechanisms.

Due to the concentration of bioscience companies in two sub-sectors (pharmaceutical and medical biotechnology), it is currently challenging to find a diverse pool of role models that could inspire innovation and commercialisation in other sub-sectors. Interviews with **Intermediaries, Critical Friends** and **Finance** interviewees tend to gravitate towards discussing best practices and case studies in the two sub-sectors. When these interviewees were probed to discuss other bioscience sub-sectors, there was a sense that the landscape of innovation and commercialisation in those sectors is less well understood. This demonstrates an opportunity to encourage and give visibility to role models in other bioscience sub-sectors to inspire and provide mentorship for others who want to pursue innovation and commercialisation in those sub-sectors.

3.2 Framework Conditions

While systemic conditions form the visible, 'above the surface of the ocean' elements of the innovation and commercialisation ecosystem, framework conditions form the hidden driving forces. Framework conditions are taken-for-granted social and physical elements that enable or constrain human interactions integral to a healthy ecosystem.

Although conditions are treated separately in the conceptualisation of ecosystems, it should be recognised that all conditions affect one another simultaneously. This is especially true for framework conditions, as the taken-for-granted feature of these elements means that these conditions are constantly influencing one another. In this sense, it is perhaps useful to bear in mind their continuous effect on one another, rather than think of them in isolation.

3.2.1 Formal Institutions

Formal institutions (regulations and standards) provide the formal rules of the ecosystem. In combination with informal institutions (**culture**), the quality and efficiency of these institutions and the interaction between them are integral in influencing the other conditions in the ecosystem. Anticipatory and enabling regulations and standards are needed to lower barriers to market. Enabling formal institutions can be measured by, for example, how common and easy it is to start up a bioscience business.

Findings demonstrate that interviewees perceived the UK's regulatory framework as possibly discouraging to innovation in bioscience:

> *"[…] the level of regulation to approve pesticides, for example, is very, very stringent. […] It takes 10 years and millions of pounds to get a product on the market." – **Interviewee Intermediary 9***

*"Regulation essentially became kind of impossible to navigate and in this country, and, actually, in the EU, registering chemistry for agriculture is becoming extremely challenging. […] The US pursues a more scientific, risk-based analysis [for regulation]. It is less impacted by political interest. Whereas the EU is much less scientific, much less risk-based, much more politicised." - **Interviewee Business 8***

The above interviewees explored the notion of a stringent regulatory framework in UK bioscience, part of a discussion with many interviewees on the notion that the regulatory framework in the UK is heavily influenced by public opinion. Similarly, public opinion can shape the way policy agenda is framed, thereby affecting public funding for research areas with little or no public support.

This is especially prominent in relation to agricultural biotechnology, as the sector has a history of controversies surrounding GM (genetic modification) technologies. In dealing with biological materials, academic research in bioscience which could affect people's daily lives raises very sensitive issues.

To further explore whether the journey that shapes formal institutions begin with public opinion or other paths, we tried capturing alternative views on this issue. We did so by exploring the themes of regulation, public opinion and GM with experts in this area. Starting from wider research, there is evidence that public perception is the main driver of politicians voting for stricter regulation of GM outputs at the European Council (Mühlböck & Tosun, 2018). Policy narratives also play an important role in how supporters and opponents of GM develop and convey their views, which could determine policy and regulatory outcomes (Shanahan et al., 2011; Legge and Durant, 2010; Radaelli, 1999).

Our primary data agree with the notion that there is sensitivity in approaching regulation of GM activities, and wider biotechnology and/or bioscience innovation, based on public opinion **(Interviewees Policy & Regulator 1 & 2).** Due to this sensitivity, our findings demonstrate that there is a lack of facilitated communication between stakeholders on these issues. This results in poor understanding of the reasons for public sentiments which might be negative towards new discovery and/or research areas related to bioscience.

Interviews with activists shed some light in this area. **Liz Moore** from **GM Freeze** said the problem occurs when the topic is avoided out of fear that public sentiment could deter the commercialisation of research. Parties who may be against the development of a certain technology (in this case, GM) are dismissed as being "ignorant, biased, wrong and stupid" **(Interviewee Liz Moore).**

The lack of facilitated communication prevents understanding of why these parties were critical of GM in the first place. In many cases, the main aim of their activism is related to the system of commercialising science rather than the science itself. **Interviewee Critical Friends 4** who is also an activist, agreed with **Liz Moore's** perception that the main issue they are campaigning for is transparency concerning who benefits from the regulatory framework and government policies; the public or big businesses (rather than business in general). This elicited an interesting discussion among various interviewees about the lack of diversity in the industry.

This resonates with our findings on the systemic conditions of the ecosystem, whereby the dominant bioscience sub-sectors, such as pharmaceutical and medical, are characterised by oligopolies of large firms. Innovation in bioscience, however, tends to occur at the small –and medium enterprise (SME) level, with many coming from HEIs' spinouts and start-ups. Discussions with start-up/spinout interviewees further suggest that stringent regulation imposes a heavy financial burden. This leads to a formula of innovative start-ups/spinouts who have an average life of 5-10 years before they are sold to larger firms.

The breadth of discussions concerning the nuances of formal institutions in their effect on innovation and commercialisation could only be captured by including alternative views. Doezema (2019) found that there is still a lack of a public forum that permits deliberation of controversial research and technologies, thus skewing views on the reasons behind public opinion against innovation and commercialisation. The lack of facilitated communication among a diverse set of stakeholders could sustain and deepen negative public opinion, further impeding innovation and commercialisation. **Interviewee Critical Friends 1** reflected on the case of GM:

*"The debate was toxic early on, with 'Frankenstein food' headlines in the newspapers, and that label stuck for a long time to the point that there has not been a desire to even raise the topic in fear that you might immediately get dragged back into angry debates with people who felt very, very certain of what their views are." – **Interviewee Critical Friends 1***

The interviewee above added that there is a need to proactively approach uncomfortable topics with a range of stakeholders to best understand whether the value of research, innovation and commercialisation is well understood. Five interviewees **(Interviewees Intermediary 9, Intermediary 11, Policy & Regulatory 1, and Finance 1)** mentioned that there is much to be learned from the COVID-19 vaccination programmes, through which the combination of continuous and proactive communication with the public and the right regulatory framework could enable innovation and commercialisation more effectively.

3.2.2 Culture

Culture forms the informal institutions of an ecosystem; that is, informal rules and norms. Just as important as formal institutions, they reflect the degree to which bioscience, as well as research and development (R&D) as a whole, is valued in society.

Our findings here are twofold. First, there is limited understanding of the value of bioscience to innovation and commercialisation. This raises barriers to creating a profile of bioscience in innovation and commercialisation in the UK overall.

Having a common understanding of the value of a scientific discipline is instrumental to the success of its innovation and commercialisation. The basic tenet of commercialising scientific research is different from the concept of commercialisation as starting and running a company. In principle, commercialising scientific research is more complex as it is about turning basic and fundamental research into something that is usable and practical and, in most cases, it is about starting a new market rather than fitting into existing ones (Fletcher & Bourne, 2012). In this instance, attracting long-term stakeholders who create demand for innovation and commercialisation (policymakers, politicians, public and private funders, and consumers) by taking a risk in funding and committing to the R&D process of a scientific discovery is critical. It is therefore crucial in any innovation and commercialisation efforts of a scientific discovery that the value of its scientific discipline is first understood.

Findings demonstrate that the profile of bioscience is obscure in the UK, based on the extent to which stakeholders rarely identify with the term ‘bioscience’. Instead, there is a fragmented profile of bio-related areas, which are dominated by ‘life sciences.’ As evidence of this, all interviewees who were asked the question of “Is there a difference between how bioscience is understood in academia, policy, and industry?” had replied “Yes” **(16 out of 28 interviewees).** Interviewees discussed the issue that, while bioscience and its strands may be well understood in academia, the breadth of its potential value is rarely captured by policy focus or in industry.

Secondly, there is limited understanding of the value of commercialisation among bioscience academics. This raises barriers to extracting value from scientific discovery by bringing the application of these scientific discoveries to market. Academics who have successfully commercialised made comparisons to the academic culture in the US. An interviewee said:

> *“There is an expectation that you will found a company or two or three and it’s not even questioned, it’s just something that everybody does.” –* ***Interviewee Business 6***

The interviewee recalled the time when commercialisation was perceived as “a bit dirty” and that one would only get involved in industry “if you’re not quite good enough as an academic.” Although this perception has since changed, according to several interviewees (Interviewees Intermediary 2, 3, 5, 6, 7 and 8) there is still a need to advance and normalise commercialisation as a viable career option for academics.

Interviewees also claim that the lack of HEI support (or lack of suitable support) can impede success in commercialisation. Interviewee Intermediary 6, for example, had experiences as a technology transfer officer both in a larger HEI which valued commercialisation, and a smaller HEI which prioritised fundamental research. The commitments made in the two HEIs were so different that the former HEI regularly produced a number of spinouts annually, while the latter would produce one or two spinouts every several years.

3.2.3 Demand

Demand can be understood in three ways: i) demand from consumers (Do they understand how bioscience research can create value to their daily lives by altering end products in a better way? Do they want those products to begin with?); ii) demand from private investors (Do they see the value in investing in bioscience innovation?); and iii) demand from public funders (Do they see the value of bioscience to the economy and society?).

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The first finding for this condition is that the demand for bioscience innovation and commercialisation must be observed through its sub-sectors. There is a perception that demand for bioscience-related innovation and commercialisation exists primarily within pharmaceutical and medical biotechnology research. First, while policy stakeholders may understand the value of bioscience, it appears that there is a prioritisation of pharmaceutical and medical biotechnology, based on funding commitments. Second, financial communities are much more attracted to the term ‘life sciences’ rather than ‘bioscience.’ While ‘life sciences’ as a term seems to hold more value among various stakeholders, this is not to say that the term has replaced and represents ‘bioscience’. Based on **Intermediaries** and **Finance interviewees**, ‘life sciences’ is exclusively understood as being linked to pharmaceutical and medical biotechnology.

Beyond the remit of ‘life sciences,’ the **Finance** interviewees claim that the financial community is not very aware of the potential of bio-related technologies and research in finding solutions for industry. Investors are more concerned about the solutions that end products and technologies could offer industry, without knowing or having any interest in their having stemmed from bioscience.

The second finding for the condition of demand relates to HEIs’ approach in commercialising bioscience research. Specifically, **Interviewees Business 1-7** and **Finance 1-3** described how demand from investors could vary based on the arrangement of ownership of HEI spinouts. From the entrepreneurs’ perspective, when HEIs take a large percentage of ownership, this places limits on their ability to secure sufficient external funding, as private investors base their investment on the equity available. This also places a lot of pressure on entrepreneurs as founders, as it reduces the appeal of commercialisation:

> *One worry is the university. They have too much equity at the expense of the founder so that as you go through funding rounds, the founders get diluted too much. –* ***Interviewee Business 4***

> *I know I’m going to be held on a short leash. If our stuff doesn’t pass the trials early next year, they’ll find some way to work around it and take even more equity. […] All VC (venture capitalist) investors want to do is close […] while the universities are giving us trouble.* ***– Interviewee Business 7***

3.2.4 Infrastructure

The last framework condition is infrastructure. This refers not only to wider access to good accommodation and transportation to facilitate commercialisation activities, but also to the overall supporting infrastructure that can minimise the risks of investment for private investors and entrepreneurs, and thereby encourage demand for bioscience innovation and commercialisation.

Finance Interviewees claim that investment in bio-based research is highly risky, given that its route to market is characterised by a much lengthier R&D process than is the case for other disciplines. Having the right infrastructure available could significantly lower the risks of investment. For example, having plug-and-play research facilities can encourage private investment:

"[Facilities] that can be plugged into […] and obviously that encourages investment. Without [companies] having to build the labs from scratch themselves. […] Companies can plug into and actually save themselves quite a lot of cash as they are not starting back from square one." – ***Interviewee Finance 1***

"What [investors] are looking at is 'how do I deploy capital?' You're asking questions that give us the confidence that there is going to be a business. So yes, plug and play labs [could lower the risks of investment]." – ***Interviewee Finance 2***

The above quotes suggest there are nuances specific to bioscience in understanding the infrastructure condition of the ecosystem.

Having observed the three framework conditions above, findings suggest that the combination of challenges in formal institutions, culture, and demand could lead to a lack of the infrastructures needed to enable innovation and commercialisation of bioscience in the UK. While the UK has world-leading innovation and commercialisation as a whole, bioscience requires different sets of infrastructures that could lower the risks of investing in innovation and commercialisation activities.

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4. COMMERCIALISATION PATHWAYS

Commercialisation pathways for academic research are the different routes to market that a researcher may take to sustain research and make enhanced impact.[3] There are various commercialisation pathway vehicles. Looking at the commercialisation policies of different institutions, the most common are:[4]

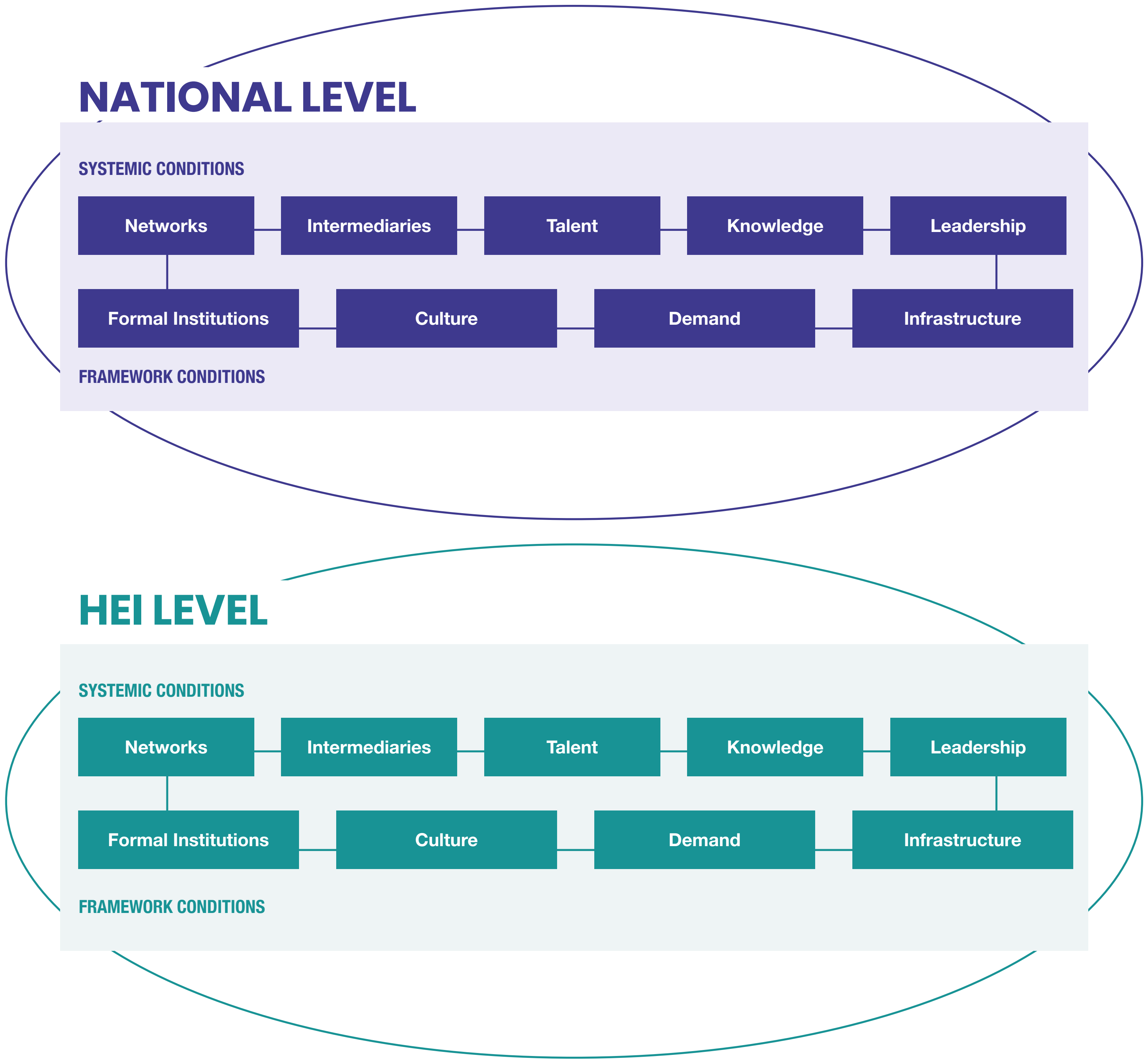
- Direct sale of products and services
- IP licensing
- IP assignment / sale
- Start-ups and spinouts
- Joint ventures
- Direct commercial use of IP developed in-house.

The analysis of commercialisation pathways in bioscience will focus on the role that HEIs play as 'anchor institutions' in the BICE. As described previously, HEIs are central to the success or failure of many bioscience innovation and commercialisation activities. At the HEI level, where much bioscience research begins, bioscientists often identify commercial opportunities and assess the commercial viability of their research. It might not be surprising, therefore, to learn that all the bioscientists we interviewed mentioned that the start of their commercialisation journey began at the HEI level.

To begin our discussion, it is useful to imagine the innovation and commercialisation ecosystem at HEI level as a microcosm of the wider innovation and commercialisation ecosystem (Figure 2). Microcosms here refer to a specific subset of the social system, such as the innovation and commercialisation ecosystem, which is a part of a larger social system but also operates with a degree of autonomy. From the early ideation stage during the formulation of research, to the realisation of revenue by applying innovation at the commercialisation stage, HEIs' innovation and commercialisation systems tend to parallel the innovation and commercialisation ecosystem more broadly (Shamsir & Abd Jamil, 2019). That is to say, commercialisation activity that might otherwise be supported and delivered as a product of the ecosystem occurs within the microcosm of the HEI.

[3] City-REDI's Commercialisation: Bridging the University-Industry Gap report. Available online: https://www.birmingham.ac.uk/documents/college-social-sciences/business/research/city-redi/projects-docs/commercialisation-policy-briefing-oct-2019.pdf.
[4] See for example: University of Edinburgh's commercialisation policy (https://www.ed.ac.uk/edinburgh-innovations/for-staff/commercialisation-routes/commercial-process), University of Bristol's Key Routes to Commercialisation presentation (https://www.bristol.ac.uk/media-library/sites/business/documents/commercialisation/Choosing%20a%20route%20to%20commercialisation.pdf.

Figure 2: HEI Innovation and Commercialisation Ecosystem as a Microcosm of the National Innovation and Commercialisation Ecosystem



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To extend the ecosystem analogy, microcosms can only support and sustain the life of a much smaller group of social actors and activities than the wider ecosystem. At the HEI level, the resources available for innovation and commercialisation are often limited compared to the wider ecosystem. When looking across the HEI landscape this is broadly true of commercialisation teams which can have limited in-house resources and expertise, although there are some exceptions, such as Oxford Innovation. This causes several results, which we refer to as the microcosm effect of innovation and commercialisation:

- HEIs tend to have different preferences for pathways to commercialisation. Universities with fewer resources would prioritise licensing, as the risks and costs of spinouts can be too high. Many HEIs prefer to license rather than sell research IP rights to external buyers. This is a method of ensuring that the control of the IP remains in the hands of the HEI should the spinouts be unsuccessful.
- The skills of TTO officers are crucial in identifying commercialisation opportunities for academic research. TTO officers need to be able to identify the application of research in solutions for industry activities, and provide access to the right networks to bring research to market successfully (for example, to connect academics with private investors). In addition, TTO officers need to be skilled in starting up enterprises and having the right know-how in the legal and contractual aspects of entrepreneurship. Commercialisation skills often come with years of experience in industry. However, recruiting highly skilled TTO officers with industry experience is costly, and many HEIs are unable to afford it.
- Bioscience academics, who typically could only commercialise through the HEI microcosm, might be deterred from doing so by the microcosm effect of innovation and commercialisation.

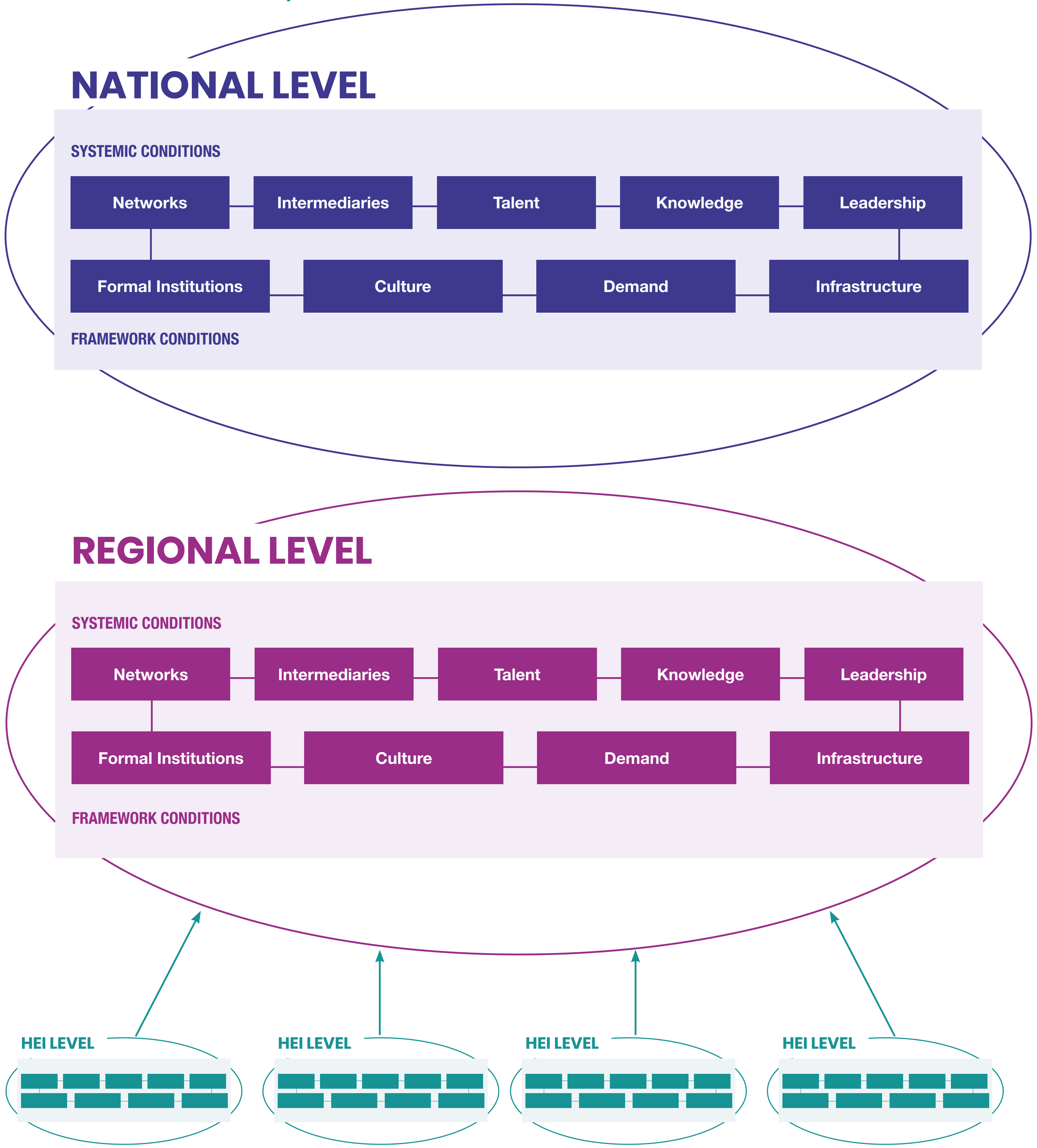
One possible solution is to enlarge the microcosm beyond individual HEIs and centralise the resources of several HEIs. IP Group is an example of a centralised solution for commercialisation of academic research.[5] IP Group's aim is to centralise resources using HEI partnerships and to benefit from economies of scale. During its earlier years, IP Group only had 5 HEI partnerships. Currently, IP Group has partnerships in the UK, the US and Australasia. They support their portfolio companies with financial capital and external investors' funding, strategic and commercial expertise, executive search and development, and corporate financing and capital raising.

The example of IP Group demonstrates the advantages of centralising capability and resources for commercialisation beyond that of an individual HEI. A potential area for gain lies in the development of regional levels of microcosm that follow the same logic (see Figure 3). This might be done through regional bioscience centres that are, in effect, collaborations between HEIs and private providers, to centralise resources for innovation and commercialisation by:

1. Providing initial investment
2. Taking spinouts through the proof-of-concept stage
3. Sustaining research by commercialising it; and,
4. Providing additional support to help spinouts gain momentum for growth and maturity after going to market.

[5] See for example: https://www.ipgroupplc.com/about-us/business-model

Figure 3: Regional Microcosm of Innovation and Commercialisation Ecosystem



The arrow represents resources going from individual HEIs into the regional microcosm of innovation and commercialisation ecosystem

5. LESSONS TO BE LEARNED INTERNATIONALLY

Four countries have been identified as offering useful insights from management of their national BICE and its contribution to wider bioeconomy strategy. First, we look at the **United States** and its formal institutions in bioscience. Second, we look at **France** and its management of public opinion surrounding bioscience. Third, we look at **Germany's** creation of demand for innovation and commercialisation in bioscience. Finally, we look at **China** and creation of the right infrastructures to encourage bioscience innovation and commercialisation.

5.1 United States

The US has shown a great commitment to the bioeconomy, with formal institutions recognising the value of bioscience to the bioeconomy as early as the 1990s. Currently, the US bioeconomy is worth almost $1 trillion and contributes 5% of GDP (The National Academy of Sciences, 2020).

The US bioeconomy strategy was first articulated in the National Bioeconomy Blueprint in 2012. The Blueprint is integral to understanding the development of the US bioeconomy strategy, which highlights biotechnology as a main driver. The Blueprint promotes a multi-departmental/agency approach to develop the bioeconomy and has led to:

- The Department of Agriculture (USDA)'s expanding effort to procure bio-based products using the Biomass Crop Assistance Program; the BioRefinery, Renewable Chemical and Biobased Product Manufacturing Assistance Program; and the BioPreferred Program
- The White House's Precision Medicine Initiative, which aims for the use of biological data and new analytics tools in understanding diseases and developing diagnostics and treatments
- The Department of Energy and USDA joint effort in producing and promoting the use of renewable biomass through the Billion Ton Biomass Report in 2016
- The Department of Energy's establishment of The Agile BioFoundry, a consortium of national laboratories dedicated to accelerating biomanufacturing, building the bioeconomy and addressing precompetitive research challenges identified by industry.
(Frisvold et al., 2021)

While various initiatives followed suit, the White House only renewed their interest in the bioeconomy in 2019 when the Administration's Research and Development Priorities budget memorandum identified the bioeconomy as a key area of interest for FY2021 and FY2022.[6] Since then, several acts have been passed, including H.R. 4373 Engineering Biology Research and Development Act of 2019 and S.3734 The Bioeconomy Research and Development Act of 2020, to assist in the development of the national bioeconomy. These Acts allowed for the implementation of a National Engineering Biology Research and Development Initiative, which represents an interagency commitment on recommending the ethical, legal, environmental and other societal issues that need to be taken into account in relation to engineering biology R&D.[7]

[6] US Office of Management and Budget. Fiscal Year 2021 Administration Research and Development Budget Priorities. Available online: https://www.whitehouse.gov/wp-content/uploads/2019/08/FY-21-RD-Budget-Priorities.pdf
[7] Engineering Biology Research and Development Act of 2019. Available online: https://www.congress.gov/bill/116th-congress/house-bill/4373/text

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The value of the bioeconomy to the national economy is well understood by wider stakeholders, considering that it has been a focus of, or plays a significant part in several Congressional hearings.[8] As described in the 2012 Bioeconomy Blueprint, 25 Federal departments and agencies initially supported biological R&D in direct promotion of the US bioeconomy (the number has since grown). Key industries include biomedicine, chemicals, agriculture, agri-tech, and biofuels.

5.2 France

In 2018, France presented its national bioeconomy strategy, the Bioeconomy Action Plan. The focus is on framing the bioeconomy as a "range of activities linked to bioresource production, use and processing," with central aims linked to sustainability and developing the circular economy (Ministère de l'agriculture, de l'agroalimentaire et de la forêt, 2018).

What makes the French approach to bioeconomy strategy interesting is its intention to put public opinion at the centre of the programme. The Action Plan aims to spread awareness of the knowledge and value of the bioeconomy and bioresource production, mobilisation and processing.[9] Consideration for public opinion and awareness is focused on, therefore creating demand.

One area of the *Action Plan*, focuses on disseminating the bioeconomy concept and its value through training courses and school programmes, in partnership with the Ministry of Education and regional governments. This forms part of the government's intention to include the bioeconomy in school curricula and university courses, both in standard school education and specialist vocational courses. Another area focuses on spreading knowledge of the bioeconomy through collaboration with multidisciplinary research organisations, which must respond to societal and economic issues.

Furthermore, the Action Plan has a nine-point action programme for promoting the bioeconomy and its value to the general public. This includes communication campaigns with consumers and citizens, standardisation of bio-based products, promotion of bio-based product databases, design of mobile exhibitions to showcase the positive impact of the bioeconomy in day-to-day life, and setting up regional discussion forums with citizens to foster stakeholder convergence and foster public ownership of the bioeconomy.

France's approach highlights the importance of public perception in the promotion and development of the bioeconomy. It appears that public consultation and stakeholder convergence play a more important role in France before the embedding of strategy in law, to guarantee recognition of the value of the bioeconomy to the national economy.

[8] Congressional Research Service. Available online: https://crsreports.congress.gov/product/pdf/R/R46881

[9] A bioeconomy strategy for France: 2018-2020 Action Plan. Available online: https://agriculture.gouv.fr/bioeconomy-strategy-france-2018-2020-action-plan

5.3 Germany

In 2009, Germany's Federal Ministry of Education and Research and the Federal Ministry of Food, Agriculture and Consumer Protection established the Bioeconomy Council (Bioökonomierat), an independent advisory board to the Federal Government on the development of the national bioeconomy. The Council also supports R&D to expand the knowledge base within the country's bioeconomy, set up framework conditions, improve training and professional development in the bioeconomy and conduct an open dialogue with societal stakeholder groups. Currently, the Council is made up of 20 members from academia and industry, all of whom have expertise in the various scientific and/or technological disciplines of the bioeconomy.

Germany has had a dedicated bioeconomy research strategy since 2010, when it published its *National Research Strategy: Bioeconomy 2030.* The strategy committed Federal funding of €2.4 billion over six years (Müller, 2014), focused on uplifting R&D in the bioeconomy through a collaboration of the Federal Ministry of Education and Research and six other ministries.

Like France, Germany's recent bioeconomy development is centred on sustainability and climate change. Having a strong, clearly defined narrative encourages demand for bioscience innovation and commercialisation. The Federal Government defines bioeconomy as *"the production, exploitation and use of biological resources, processes and systems to provide products, processes and services across all economic sectors within the framework of a future-oriented economy*." The Federal Government has also made a commitment to the bioeconomy with the publication of the National Bioeconomy Strategy (2020),[10] aligned to the UN Sustainable Development Goals. By doing so, the objective is to position Germany as leader in the bioeconomy.

Two overarching guidelines support the objectives and actions set out in the National Bioeconomy Strategy. As the Ministry of Education and Research notes, "[t]he first guideline highlights how biological knowledge and advanced technology are the pillars of a future-oriented, sustainable and climate-neutral economy... Bioeconomy is integrative and combines interdisciplinary research and systemic solutions... The second guideline relates to the raw materials used by industry and the need for a sustainable economy based on biogenic resources." The focus here is on biomass as a renewable raw material to achieve "[s]ustainable production and an efficient, cycle-oriented use of biogenic raw materials." [11]

[10] Germany's National Bioeconomy Strategy. Available online: https://www.bmel.de/SharedDocs/Downloads/EN/Publications/national-bioeconomy-strategy-summary.pdf;jsessionid=02808473C915D33A47856057CBC477D7.live832?__blob=publicationFile&v=6

[11] https://www.fona.de/en/topics/biooekonomie-biobased-economy.php

5.4 China

Political interest in the bio-based economy has grown in China with a strong linkage to biotechnology development. These efforts started as early as 1986 through the High-Tech R&D Program, which is one of the most complex, diversified, and multi-agency R&D programmes in the world. As of 31 December 2020, China has ended 13 five-year plans for science and technology, with the 14th currently in development. Today, bioeconomy development is promoted in multiple policy documents including:

- The Medium and Long-Term Plan for the Development of Science and Technology
- The 12th Five-Year Development for National Strategic Emerging Industries
- The Plan for Development of Bioindustry
- The 12th Five-Year Plan for National Agriculture and Rural Economic Development
- The forthcoming national strategy for circular bioeconomy.[12]

Although the term 'bioeconomy' has been used in policy documents, in recent years, 'bioindustry' has been used more frequently. The Central Committee (China's highest authority for policy development) has oversight of China's bioeconomy strategy, with a focus on making the country a leading global biotechnology player. Through the Central Committee, multiple ministries such as the Ministries for Science and Technology, Agriculture, for Industry and Information Technology, for Education, Land Use and Resources, and the Chinese Academy of Sciences have their own budget for bioeconomy/bioindustry R&D programmes. Key industries include biomedicine, agriculture, bioenergy and biobased industries.[13]

China is also growing its bioeconomy by building a strong domestic investment infrastructure. China's private investors have poured greater amounts than their counterparts in the US into the bioeconomy; up to $14.4 billion, compared to $10.4 billion in the US, in 2019 (Cumbers, 2020). Due to data scarcity, it is not known how much the Chinese government has invested in the bioeconomy. Nonetheless, the Chinese government committed in its bioeconomy strategy to exploit advanced technology in agriculture by providing authority to national and regional governments to contribute to the national bioeconomy agenda.

[12] Information on China's circular economy in bioeconomy strategy. Available online: https://wcbef.com/bioeconomy-news/china-plans-to-launch-a-national-strategy-for-circular-bioeconomy-in-the-second-quarter-of-2021%E2%80%8B/; Bai, Lin & Ding (2020)

[13] China Science & Technology report. Available online: http://www.chinaembassy.org.nz/eng/zxgx/kjhz/P020130422602766738926.doc

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6. WHAT NEXT?

This project provides both in-depth analysis and an indication of the nuances in the challenges and opportunities faced by the UK bioscience sector. Through it, we were able to gain a preliminary understanding of the health of the UK's bioscience innovation and commercialisation ecosystem.

Using the iceberg analogy helps us understand that systematic conditions are much more identifiable and visible to stakeholders than framework conditions, although it is the latter that exert significant influence on systemic conditions and on the overall ecosystem. More ambitious, cross-governmental policy initiatives, aimed at transforming the system, are necessary to tackle structural and systemic challenges in bioscience innovation and commercialisation.

Based on the findings, we pose a series of questions to inspire the BBSRC's thinking in response to the above potential research areas:

- Should we rethink what success and value in commercialisation mean?
- Should there be a clearer narrative for the bioeconomy and bioscience's contribution to it?
- How can the BBSRC encourage and support HEIs and TTOs to think of bioscience commercialisation more widely, beyond pharmaceutical and medical biotechnology?
- Should the BBSRC take a more proactive role in spreading awareness of the value of bioscience?
- Should the BBSRC take a more proactive role in starting up regional centres for innovation and commercialisation?

Following these questions, we identify four areas for further research:

- Regulatory barriers and opportunities to innovation and commercialisation specific to bioscience with a focus on its diverse sub-sectors (i.e., beyond pharmaceutical and medical biotechnology)
- The role of TTOs in supporting innovation and commercialisation among bioscientists
- The role that consortia of HEIs can play, through regional innovation and commercialisation centres, in enabling or disabling innovation and commercialisation among bioscientists
- The proactive role that the BBSRC could play in facilitating more open and diverse communication with stakeholders in promoting bioscience in the UK.

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Innovation Caucus

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The Innovation Caucus is funded by:

UKRI Innovate UK
UKRI Economic and Social Research Council