What works for innovation: supporting R&D and innovation in deep tech chemistry SMEs

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Executive Summary

Whether it is tackling climate change, helping to create sustainable processes, or improving and saving lives, chemistry SMEs have a crucial role to play in developing new technologies which can transform our world. Despite the crucial role of chemistry SMEs, they are not well understood or supported in the UK. This report aims to shed some light on the challenges, barriers and unique contributions of a specific subgroup of chemistry SMEs; deep tech chemistry SMEs. We explore the characteristics of these deep tech chemistry SMEs, their potential contribution to the UK's mission-driven

Current support for deep tech SMEs in the UK and elsewhere

The UK has a well-developed national R&D and innovation support system which offers a wide range of public support for innovating firms across the country. However, in the UK and internationally, we identified no specific measures targeted at either chemistry SMEs or more specifically deep tech SMEs.

Indeed, few countries have consistent and different policy approaches for innovative SMEs. South Korea and Italy have both implemented policy approaches with a more specific focus on innovative SMEs. In both cases there is some positive impact evidence, consistent with wider evidence of stronger policy additionality effects in smaller firms.

In our interviews with SMEs and industry experts we explored their current engagement with government institutions and policy and noted a range of challenges many of which reflected the issues highlighted earlier. Most of these issues were generic to deep tech SMEs, a number were chemistry-specific or at least impacted more intensively on deep tech chemistry SMEs.

Two challenges stand out in particular. First, within the context of the national system supporting R&D and innovation there is considerable geographical variation for chemistry SMEs seeking support from their local university and associated networks. Second, the effectiveness of the UK innovation system in supporting commercialisation has been questioned, an issue of critical importance to the success of deep tech firms in chemistry and other sciences. Limitations in the support available for commercialisation often overlap with the regional disparities.

Why support deep tech chemistry SMEs?

The case for intervention to support chemistry deep tech SMEs has two key elements: first, the potential of chemistry deep tech SMEs to introduce innovations which may have very substantial social returns and contribute to innovation missions; and second a range of market failures which are currently constraining their innovation activities.

Innovation in chemistry is fundamental to achieving potentially transformational breakthroughs in a range of areas from climate change, to developing new treatments for a number of diseases including cancer and to addressing plastic pollution. The implication is that innovation in these firms has the potential to generate very significant social, economic and environmental benefits which far exceed the direct benefits to the businesses concerned. In more technical terms, innovation in deep tech chemistry SMEs can drive very significant and positive externalities suggesting a *prima facie* case for policy intervention.

Market failures may constrain innovation and the available literature and the empirical evidence from this study suggest a number of key issues in the UK. Some of these market failures are relevant to all deep tech companies, others are more specific to distinctive aspects of deep tech chemistry SMEs. The market failures most relevant to chemistry deep tech SMEs include: failures in capital markets; failures in the market for grant funding; failures in the availability of premises and specialist equipment; information failures and perceptions of risk; failures in technical and managerial skills development.

Better supporting deep tech chemistry through Access to Capital

The recent Innovation Strategy highlighted the challenges deep tech SMEs face in accessing finance. Indeed, a majority of the deep tech chemistry-based SMEs that participated in this research reported being constrained by struggles to secure appropriate finance. Addressing these constraints is crucial to securing better outcomes for these businesses in chemistry deep tech but also other science areas:

- ***Increased proof of concept funding*** – Several respondents to this study highlighted the importance to their businesses of being able to undertake proof of concept research which is often crucial to securing further funding.
- ***Angel investment*** – Several of the respondents to this study suggested that angel investment remains difficult to access outside of the so called 'Golden Triangle'. Consideration might well be given to whether online based platforms could help to overcome these issues by reducing the information barriers to investment and allowing investors access to business profiles nationally.
- ***Equity gap*** – Both the academic literature and the responses to this study confirm the existence and significance of an equity gap which means that deep tech chemistry SMEs often struggle to secure intermediate levels of funding to enable scale up and the commercialisation of new technologies. Our research suggests there is a quantitative shortage of available equity investment, and interviewees perceived a lack of scientific understanding and expertise among potential investors.
- ***Grant application processes*** – there is a strong case for evaluating whether current processes are fit for purpose in supporting deep tech innovation, and to revise these processes as appropriate. Our research identified a number of specific issues on both the supply and demand side which are constraining deep tech chemistry SMEs' access to public funding.

Better supporting deep tech chemistry through access to flexible and affordable chemistry facilities

Given the very widespread perception that the lack of availability of suitably equipped premises is a key constraint on business development and scaling up for deep tech chemistry SMEs, this is clearly an area where intervention would be both practical and useful. Existing sources of information do not appear to be well known or used by deep tech SMEs and better signposting to existing information sources may be useful. Developing new public/private partnerships for provision may also be useful here. Other policy options under this general heading are:

- ***Consider gaps in the provision of bespoke incubators/accelerators*** – The facilities provided by incubators and accelerators are clearly helpful in providing appropriate, suitably equipped, premises. Given the particular challenges our interviewees identified which are faced by chemistry deep tech SMEs in accessing suitable premises for scaling, an audit to establish what premises are available (for example in established Catapults) would be sensible. Improving the information available to firms about the facilities which are available would also be potentially beneficial.
- ***Improving access to equipment to allow scale-up*** – our interviewees stressed the difficulty of funding specialist equipment purchases particularly during the scale-up phase. Consideration could be given to whether public-private partnership investment could help with the acquisition of specialist facilities/equipment for leasing to SMEs working in chemistry deep tech.

Better supporting deep tech chemistry through better developed Innovation Management and Leadership

Perhaps surprisingly our interviews did not suggest any consistent issues around accessing technical skills. Instead, they emphasised the critical impacts on business performance associated with underdeveloped entrepreneurial and innovation

Better supporting deep tech chemistry through ecosystem and resources/ networking

The businesses interviewed in this study highlighted several areas where new policy measures could contribute to the development of an enabling ecosystem more conducive to business success.

- ***Reducing spatial inequalities*** – There is no doubt that it is easier for deep tech chemistry-based SMEs to operate successfully in the Golden Triangle and London than it is for them to do so in other areas of the country. Accordingly, there would appear to be clear merit in looking to develop existing regional incubators into more substantial entities capable of comprehensively supporting businesses throughout their journeys from establishment to maturity.
- ***Establish and support networking*** – it is generally accepted that networking with peers expands the ambition,

Section 1: Chemistry and chemistry SMEs

1.1 Introduction

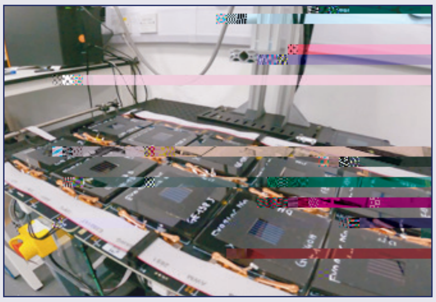
Small and medium enterprises (SMEs) are the bedrock of economies and in the UK they account for 99 percent of all firms. SMEs also provide three fifths of the employment and around half of the turnover of the UK private sector[1]. In addition to their contribution to job creation and prosperity, some SMEs such as chemistry SMEs have another important role to play. Whether it is tackling climate change, helping to creatn

Box 1.2 Examples of deep tech chemistry SMEs and their potential impact

Carbon capture – creating value from carbon dioxide

ViridiCO$_2$ Ltd [illegible]

Advanced solar cells – converting more energy from the sun



Oxford PV [illegible]

[illegible]

[illegible]

[illegible]

Superfast charging – next generation battery technology

Echion Technologies [illegible]

[illegible]

[illegible]

Graphene sensors – portable analysis tools for cheaper, faster drug development

HexagonFab, a fa [illegible]

[illegible] $1.3 b [illegible] 1 2 [illegible] 10,000 d [illegible] 75% [illegible] SME [illegible] SME [illegible]

[illegible]

Novel diagnostics and therapeutics – next generation testing and treatments for pandemic preparedness and combatting disease

T e C [illegible] d-19 [illegible] **Iceni Glycoscience's** [illegible]

[illegible] 2014, [illegible]

[illegible]

Underlying our analysis is the view that government policy and other support organisations can make a critical contribution to the success or failure of scientific research and innovation, through a range of interventions, from the funding of research at UK universities to taxation policies which favour R&D investment to wider policy on international trade and domestic employment and skills. The current government's approach to supporting UK innovation was laid out in July 2021 in the Innovation Strategy. This sets out the government's vision for making the UK a global hub for innovation by 2035 and the actions to bring this about, categorised under four pillars:

- Unleashing Business
- People
- Institutions & Places
- Missions & Technologies

The Innovation Strategy presents polices and initiatives which both seek to address existing barriers in the innovation landscape and to galvanise resources to proactively address critical challenges such as the need to achieve environmental goals and, building on the success of the Covid-19 Vaccination Taskforce, to address other immediate problems as they arise. Chemistry innovation has a critical role to play in supporting the delivery of the vision articulated in the Innovation

1.2 Our approach

Evidence gathering was divided into three Phases with a view to establishing a rationale for policy support for chemistry SMEs, identifying the objectives of such support measures and conducting an initial appraisal of policy options in partnership with a group of chemistry SMEs and industry experts. In Phase 1 we examined existing data sources to describe and understand chemistry SMEs and conducted a literature review to describe the wider context of innovation in SMEs and current UK and international policy. In Phase 2 we conducted new primary research with deep tech chemistry SMEs and other ecosystem players, allowing a testing and deeper exploration of the issues identified in Phase 1 and the identification of policy options. Phase 3 of the project involved testing the policy options developed with a wider group of industry and policy stakeholders.

Phase 1 of the study was conducted in Spring 2021 and focused on defining, profiling and understanding the policy and operational context of chemistry SMEs and deep tech chemistry SMEs in the UK. Defining the population of firms of interest proved complex given that there is little consistency in definitions across studies (e.g. 'R&D active', 'deep tech') and the associated difficulties in translation of definitions into a coding which would allow analysis of existing data sources. A key challenge was the extent to which it is possible to identify 'R&D active' or 'deep tech' chemistry SMEs and their R&D and innovation characteristics in existing publicly available and proprietary databases.

In particular, information on individual small firms' investment in R&D is not readily identifiable from any publicly available data source. For larger firms this data is often observable from company accounts but the restrictions of the Companies Acts mean that smaller firms are only required to publish very limited accounting data. However, while investment data on R&D may not be available for these firms, either the business description of activities available on databases such as FAME or business websites can provide a qualitative indication of firms' engagement with R&D activity. Additionally, other sources provide some data on the input measures (such as the conduct of R&D), but there are other limitations. For example, the UK Innovation Survey, the key data source on innovation activity in UK firms, excludes micro-businesses with fewer than 10 employees from the survey. This survey does however provide size and sector data and can be used for profiling the group of chemistry SMEs and addressing questions as to whether such firms are more or less innovative than other companies. The UK Innovation Survey also provides some information on whether R&D active firms are faster or slower growing or have higher productivity. We report this data analysis in Section 3, shedding some light on chemistry SMEs.

To identify the population of deep tech chemistry SMEs, it is necessary to consider the nature, development journey and potential impact of their technologies. National datasets do not provide the technology specific data required to identify these deep tech businesses and, in many cases, do not capture businesses in the micro stage of development. The definition, and how we arrived at it, is set out in Section 2. Once agreed, the definition allowed us to Identify firms and variables of interest in data sources and to develop search terms for the literature review.

The Phase 1 literature review supplemented the quantitative analysis by exploring:

- Patterns and trends in R&D activity generally, R&D activity in SMEs and in chemical sciences sectors
- Current government science and innovation policy as it relates to SMEs and the chemical sciences sector.

Finally, in Phase 1, interviews were conducted with 6 'key informants' from a variety of sector representative bodies. Phase 1 resulted in a profile of chemistry SMEs (Section 4) and an initial assessment of the adequacy of existing policy support (Section 5).

In Phase 2, we conducted new primary research based on 29 interviews with SMEs and sector experts covering climatetech, platform chemtech, medtech, and biotech. Interviews were undertaken during July and August 2021 spanning the publication of the UK Innovation Strategy which was an item of discussion in some later interviews. This gives a total of 35 interviews across phases 1 and 2. The SMEs interviewed were selected to provide a mix of establishing and established SMEs – i.e. pre or post revenue (see definitions in Section 3). All the firms interviewed were operational, with some success in either attracting private and/or public investment and a number had progressed to have products on the market. The intention was to learn from successful SMEs to identify challenges and enablers on their development journeys. While most had spun out of universities there were some non-university start-ups and whilst there was a variety of routes to commercialisation, few had sold or licensed IP outright to a larger entity.

To capture a wider range of perspectives, we also interviewed nine other stakeholders representing other elements of the support and policy eco-system for deep tech firms. These individuals included investors, advisors, larger companies and academics engaged in providing facilities for developing chemistry firms. Together, these individuals provided a broader perspective than the SMEs but also all represented their particular organisations and expertise.

Phase 3 of the project comprised a policy workshop (October 2021), hosted by the Royal Society of Chemistry, and attended by a number of interviewees from Phase 2 research (including SMEs and sector experts) and additional policy experts. This allowed us to share insights and explore the most effective policy options. Policy options emerging from our own research were also compared to those of other recent reports to identify interventions which may have benefits beyond chemistry SMEs.

1.3 Report Structure

The findings of this study are set out in this report. Section 2 defines deep tech chemistry SMEs and their potential role in meeting the objectives set out in the Innovation Strategy. Section 3 profiles SMEs which engage in research and development (R&D) – R&D-active SMEs - and identifies characteristics of chemistry R&D as far as is possible through existing quantitative data sources. Section 4 sets out the findings of our new primary research, including the development journeys of deep tech chemistry SMEs and factors which have helped or hindered their development. We then consider the UK policy environment, particularly in the light of the Innovation Strategy, and we draw in learning from international policy to assess how policy might best enable deep tech chemistry SMEs to contribute (Section 5). Section 6 presents our conclusions and recommendations for policy development.

Section 2: Defining deep tech chemistry SMEs

2.1 Introduction

As described above, a unique challenge for this study was to define and identify deep tech chemistry SMEs. There are several definitions of all the concepts involved, and where there are standard international definitions, they do not ideally or simply correspond to the firms of interest to this study. This poses significant challenges in recognising and understanding these firms, how they operate, what they need to enable them to reach their full potential as they may fall below the radar of existing data sources (e.g., the UK Innovation Survey).

In this section we first describe standard definitions of 'SME', 'R&D active', 'innovation active' and 'deep tech' and then set out how they have been utilised and interpreted in this study.

2.2 What is an SME and a chemistry SME?

In the UK, SMEs are normally defined simply by the size of their workforce. Businesses with zero to 249 employees are normally categorised as SMEs. Businesses with no employees – sole traders – are the most common category. Those with one to nine employees are categorised as 'micro' businesses, those with 10 to 49 employees as 'small' businesses and

2.4 What is a deep tech SME?

Deep tech firms are a sub-group of the R&D-active firms in which the R&D activity itself is central to the strategic approach of the firms and success is dependent on underlying IP, novel technological advances and requires concerted R&D investment to move to market. International definitions capture R&D active businesses within which deep tech businesses are a (small) sub-set. Deep tech businesses are recognised by three attributes:

- their technologies can have a disruptive impact on markets and technologies;
- developments take a long time to reach market-ready maturity; and,
- they require a substantial amount of capital.

These businesses develop technologies which:

- are novel and significant technological advances;
- may have the power to create their own markets or disrupt existing industries;
- require concerted R&D to develop practical business or consumer applications and bring them from the lab to the market;
- may help to address big societal and environmental challenges;
-

Section 3: Profiling R&D-active chemistry SMEs

3.1 Introduction

Reflecting the definitions developed in Section 2, and the limitations of the secondary datasets, this section applies the definition of chemistry SMEs based on sector and size band criteria to the UK Innovation Survey. Specifically, we use data from the UK Innovation Survey 2019 to profile SMEs (those firms with 10-249 employees) in 87 4-digit SIC codes identified by the RSC as including chemistry SMEs. It is important to note, however, that as the UK Innovation Survey only covers firms with 10 or more employees, this analysis may exclude many spin-out businesses and newer chemistry SMEs below the employee size cut-off. Despite this limitation, the UK Innovation Survey still provides the most useful source to understand the characteristics of chemistry SMEs compared to other SMEs.

In this section (3.4), we also review evidence from other phases of the research which helps us to understand the nature of chemistry SMEs and if and how they differ to other R&D active SMEs.

3.2 Investing in R&D and innovation – survey evidence

The main source of innovation data in the UK is the biennial UK Innovation Survey which is undertaken by BEIS. The survey uses definitions of innovation based on the OECD Oslo Manual and focuses on firms' innovation activities during the previous three years. The UK Innovation Survey is a sample survey, and in 2019 – the most recent data currently available - included 10,700 SMEs of which around 2,100 are in the chemistry-intensive sectors identified by the RSC and 8,600 in other sectors.

Using data from the UK Innovation Survey 2019, Table 3.1 provides a profile of firms' investments in innovation contrasting SMEs in the chemistry-intensive sectors with SMEs in the remaining sectors. Table 3.1 sugk Imaining sectors. Table 3(tiossts)0.5 (with

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This need in science, perhaps especially chemistry, for more complex facilities and long-term funding is also associated with the longer time required for development, echoing RSC's earlier study, for example:

'Firstly, you've got to develop bench scale processes, and then pilot it, and then take it to commercial scale. And each of those requires technology transfer and optimisations and so on. And then generation of all the quality data that goes with the process, and its scale up. And three years is nothing in this. In contrast, in software, if you haven't got your idea to market in three years, it's dead in the water' (Chemistry industry expert).

Whilst most respondents were clear about the difference between the development requirements of establishing chemistry-based and software firms, the distinction between establishing chemistry-based and other science-based SMEs was sometimes less clear. There is a general perception that while other sciences shared many of the same challenges, there are perhaps three areas in which establishing chemistry-based SMEs differ from other science-based SMEs:

- The foundational nature of chemistry and the consequent diversity of the market for chemistry products often makes it difficult to identify the best target markets. One of our Phase 2 interviewees commented: *'chemistry covers a broad range. It's enabling technology, which spans everything from biopharma through to petro-chemicals and polymers, speciality chemicals' (Expert, Platform Technologies)*.
- There is less critical mass in chemistry with less specialised equipment, fewer specialist or 'sector savvy' investors and fewer exemplars of success than, for example, in biotech. One of our interviewees commented: '*the biotech industry in this country is incredibly strong and has some super role models and a well-established financing mechanism – lots of money, lots of great exemplars' (Expert, Platform Technologies)*.
- The particularly long development times from lab to market for chemistry technologies mean that financial, skills and other challenges during the development process are more acutely felt in chemistry than in other sectors.

"I think it is a general issue ...and not necessarily limited to the chemical sector, although I think within chemicals it is particularly challenging because of the scale of what's involved" (Sustainability SME).

"When things work well in the lab, great, but it's a very di erent story to manufacture things in large quantity, we again and again face something just not scaling up the way it was working in the lab or properties not matching what we felt we could achieve before running an industrial pilot" (Sustainability SME).

3.5 Summary

Data from the UK Innovation Survey suggests that chemistry SMEs are approximately twice as likely to be investing in R&D as other SMEs and also more likely to be investing in other innovation activities. They are more likely to be engaged in new to the market innovation, with 16 percent of SMEs in chemistry-intensive sectors involved in new to market product or service innovation compared to 9 percent of all SMEs and 8 percent of Chemistry SMEs involved in new to market process innovation compared to 4 percent of other SMEs.

Chemistry SMEs are more likely to collaborate in their innovation activities than the general SME population, particularly with universities, suggesting a different type of innovation behaviour in these firms.

Cost, underdeveloped skills and market barriers are all more likely to be reported in SMEs in chemistry-intensive sectors. Finance is also a key barrier. The financial barriers to innovation are often suggested to reflect market failures related to the difficulties for firms and their financiers in assessing *ex ante* the returns from innovation and the associated risks. This incomplete information suggests that firms will tend to under-invest in R&D and innovation activity and has long been a rationale for fiscal policy intervention. The barriers to accessing finance are likely to be greater where firms are engaging in new to the market innovation which has high up-front innovation costs and long project durations.

4. Understanding deep tech chemistry SMEs

4.1 Introduction

In this section we present evidence from our qualitative research with deep tech chemistry SMEs and sector experts to explore their experiences of the challenges to, and enablers of, innovation. The challenges faced by deep tech firms were often complex and multi-dimensional and had typically changed as the firm and its technology moved from the laboratory towards a market application.

The firms interviewed in this research were selected to represent four diverse technology application spaces: climatetech, platform chemtech, medtech, and biotech. The SMEs interviewed in the climatetech sub-sector are engaged in carbon capture, use of nano materials for the photonics industry, the supply of silicone materials for use in lithium-ion batteries and plastics technologies. Their role might be characterised as one of contributing a less visible component or process to a bigger product or broader activity. They are seeking to meet a demand derived from the net zero challenge, e.g.:

> ***'in terms of getting more performance from your batteries for longer driving range, faster charging, this is where materials like silicon can make a positive contribution' (Net Zero SME)***

In the medtech and biotech sectors respondents included several businesses developing improved treatments for various cancers.

Many respondents stressed the foundational nature of chemistry to many activities within this sector:

> ***'We have made advances with many invasive human diseases but there are still a lot of people dying from the big ones, cancer, heart disease. But chemistry is really the cornerstone of [addressing] all of that' (Health and Pharma SME)***

Finally, the SMEs involved in platform chemtech are engaged in the discovery of a new molecules; the production of super-black-absorbing materials; the development of a multi-purpose flow reactor and the design and manufacture of metal-organic frameworks, a class of super-absorbent nanomaterials with global impact. All of these products had multiple potential applications.

4.2 Challenges and enablers in deep tech development

The deep tech firms we interviewed highlighted a wide range of challengers and enablers of development. We group discussion of these factors under the following headings:

- Innovation leadership skills
- Finance and Funding
- Equipment and running costs
- Technical skills and recruitment
- Accessing advice and networks
- Location
- Collaboration and Intellectual Property

We treat these themes separately here but recognise that many of these are interconnected, e.g. access to existing equipment might reduce the need for finance, access to skills and equipment might be made easier by location.

4.2.1 Innovation leadership skills

Within this broad heading, we identified many different skills and abilities needed by the business leader and the challenges in combining these skill sets. One of our experts identified the need for a team of three at the top of the deep tech enterprise:

> ***'your top team is usually a CEO, a chief technology or scientific o cer, and possibly a business development o cer. That triad usually forms the core of a spin-out' (Chemistry Industry Expert)***

This reflects the diverse skills needed by firms' leadership teams, which go beyond 'management and leadership' or 'entrepreneurial' or other common descriptions of the skills of business leaders. A lack of any one of these skills amongst the leader or team can, we were told, impact on the success of the enterprise:

- Ability to identify markets and to commercialise innovation
-

The leaders of some platform tech SMEs had to adapt their original intended markets and applications and were flexible in that approach. One of the SMEs interviewed reported this is an important challenge, as it enabled them to become more realistic in their target product and market (Box 4.2):

'I think some di culties are good di culties to have for a start-up to kick-o with'. (Net Zero SME)

These SMEs were so far succeeding, though they may still pivot at some future point and are still in the process of developing a commercially viable and successful product.

Another problem identified by some of the experts we spoke to is a lack of knowledge amongst business leaders on where and how to access the right finance (this is aside from the issues of access to finance described below) and the ability to speak to investors in a language they understand. For example:

'Sometimes they don't even know where the finance can come from, where the investors are and how do they leverage those connections and get the money? Do they know how to make a good pitch to get the money?' (Health and Pharma expert)

Many innovators recognise these problems and seek to recruit business leaders, however, high quality commercial leaders might be too expensive for them to recruit unless they have the investment to attract top talent (which becomes a vicious circle). Additionally, more 'non-innovation' management skills were identified by some respondents as being absent with one respondent citing:

'Generally speaking, teams are pretty ignorant in terms of HR and the law associated with that. You're basically finding out as you're going along. And, hopefully, touch wood, they don't get into trouble. I think general, legal, and ops management. And another area which is pretty badly covered is IT support, particularly cyber security'. (Chemistry Industry Expert).

Box 4.2: The market as an enabler

[illegible]

'… the good news for us is the market [for batteries] story is a constant positive, continually being refreshed to be a bigger opportunity'. (Net Zero SME)

[illegible]

'..manufacturing and the manufacturing space as a whole has not been attractive for people, and so hasn't tended to attract the high-flying entrepreneurial innovators in quite the same way as, maybe, biotech or some of the other areas. That is changing with the whole sustainability agenda'. (Sustainability expert)

4.2.2 Private funding for innovation

The Innovation Strategy identified the challenges in accessing finance in deep tech SMEs. Access to private finance is both a challenge and enabler in the SMEs interviewed for this research. The firms interviewed had generally been able to access start-up funding. But, amongst the SMEs and sector experts, there is a perception that obtaining funding which could support subsequent growth and scaling is a bigger challenge. This may relate specifically to 'Series B' funding which applies when firms have progressed beyond the start-up stage and are preparing to scale:

'the big gap is at Series B, where companies need a lot of capital'. (Platform Industry Expert)

This may be a common challenge to innovators, particularly in natural sciences, however, some respondents connected this to be the unique aspects of innovation in chemistry, in particular the length of time needed to develop and test a product before revenue:

'You have to have deep pockets and you have to have a longer-term perspective and people who really understand that sort of investment climate'. (Platform tech Industry Expert)

The long duration of chemistry innovation projects also leads to risks which while not unique to chemistry SMEs may be more impactful due to the development time needed, namely the risk of a change of ownership or management of investors or investors withdrawing support. Some respondents have experienced this and the need to find financing elsewhere:

'Some investors lose patience. Some funds are consolidated to be different. And so, generally, the longer you take, the more uncertainty you're adding, apart from the obvious one of burning up your cash'. (Net Zero SME)

One SME, which was set up in 2006 noted that they were able to access VC funding, but argued that it had become harder over time:

'Back then, there was a lot of investment in materials science companies, so we were lucky. Today, I think it would be very different because they're more interested in software-type applications because they get much better exits and multiples'. (Net Zero SME)

The research suggests that investors are also less likely to invest in innovation which they do not understand or cannot see. This can pose a challenge for the innovator but also represents a potential risk to investors in missing opportunities if they are not able to fully understand and appreciate the market potential of a chemistry innovation. 'Sector savvy' investors are reported to be a positive enabler by some of our respondents, investors who understand the science and the markets.

4.2.3 Public funding for deep tech chemistry SMEs

Respondent businesses tended to see real merit in grant funding for early-stage SMEs. For example, small, voucher grants have helped them develop the technology along the way by buying time or access to equipment to answer proof of concept questions:

'We've had Innovate UK grants and that's been very helpful - in fact that's what we formed the company around'.

However, for others, it is not their ability to write applications, but that these were often rejected on the basis of criteria which had not been clear in the application guidance, or on grounds which seemed irrelevant to the purpose of the grant. This was demoralising for people who worked on such bids.

There were also concerns about the ability of the people reviewing applications to understand the applications (akin to the need for 'sector savvy' investors):

> ***'on government panels, the people that they select either have no clue about the technology because they're just consultants that are experts in everything'. (Platform SME)***

As we have seen, chemistry innovation is also expensive and takes longer than many other types of innovation. Public funding of 3 years or so duration was seen as insufficient for chemistry development.

> ***'I would say that the use of government grants, and so on - is an essential part of the funding mix to help translate technologies to the market. But the problem with this sort of funding is it's only three years. It's an extremely short period of time to be building up capacity. You're just about getting to the point when everything***

4.2.4 Equipment and running costs

One of the main challenges identified by almost all the deep tech chemistry SMEs we interviewed is the availability of suitable chemistry lab space and associated facilities. This applies at all stages of development: initial availability of lab space; testing the production process for larger quantities; and scaling to larger manufacture. University spin-outs typically have some initial access to labs, though for one firm, this is expensive (at £15,000 per annum per chemist) and is restricting recruitment of key staff. For a non-university spin-out, access seemed more problematic until they found a space on a science park. However, to test and demonstrate effectiveness, larger scale testing becomes necessary. A common problem across the deep tech chemistry SMEs we interviewed was the need to be able to provide samples on a scale sufficient to convince large manufacturers to adopt the new technology, e.g.:

> ***'You also need to have a set of equipment that can make the material at scale even during the material development phase to be able to test it and, ideally, sample it to customers. So, it's not a question of making a few milligrams. We need to be able to make hundreds of grams, and then kilos, and then hundreds of kilos. So, the process development and scale-up need to be linked into that as well'. (Net Zero SME)***

Firms may consider collaborating with a manufacturer at this stage, to share the costs and expertise required for testing at a greater scale (Box 4.3). However, access to larger chemical manufacturers (with a capacity of tons) in the UK was said to be problematic:

> ***'You don't have a huge pool of good ton manufacturers to begin with for chemistry and then you have even fewer that are game enough to try brand new ways of doing things' (Platform SME)***

One expert noted that while the plant is needed, so too are the skilled people to operate it:

> ***'It's about assets, but it's about people as well. So, somebody who knows how to run a pilot plant is a highly skilled individual'. (Platform tech Expert)***

Access to specialised equipment is a recurring theme in our research and one which is seemingly an important differentiation between chemistry from other natural sciences.

The decision to manufacture or not is a critical point in the journey of deep tech chemistry SMEs, and there are a number of choices to be made at different stages of the development process. To some extent the route taken depends on the preferences of the founder/management team, but there are constraints in these choices, such as the availability of facilities at the required scale.

At the earliest stage, a technology developed in a university can be developed through a spin-out or through selling the IP or licensing the technology to an existing chemistry manufacturer.

These choices apply as the technology is tested on a bigger scale moving on to manufacturing. Most of the SMEs

4.2.6 Accessing advice and networking

Leaders of deep tech chemistry SMEs need to be able to access the right support to help deal with the array of issues they face, sometimes perhaps for the first time. Throughout our research, questions were raised about the quality of advice available to firms. One respondent noted that university spin-outs can access university business support, which they felt was better than the support on offer through general business support mechanisms. Even so, university Technology Transfer Offices were reported to be widely variable in their ability to support chemistry start-ups, and the individuals themselves tend to be generalists, without an understanding of the specific technology, markets, or regulatory regimes (particularly important in chemistry innovation) and do not necessarily have a business background:

> ***'The universities will say, well, we have schemes to help people. But you have to argue, universities are not the right people to be supporting new entrepreneurs because that's not their business. That's not what they're good at'. (Health and pharma SME)***

Peer to peer learning through business and social networks can be an important additional resource for SMEs. There is good evidence that networking can increase motivations, confidence and dynamism in SMEs generally[5]. Access to these networks may well be more difficult in the UK than elsewhere because there is less strength in depth in chemical companies than in other parts of Europe (except for pharmaceuticals and oil and gas). Again a possible side-effect of the lack of critical mass in chemistry in the UK. However, not all expertise comes from other chemical companies. Many SMEs need to tap into their potential markets or work with other start-up companies, accessing a range of knowledge and connections. The science park location of one of our SMEs facilitated informal networking and collaborations with other diverse businesses and casual access to academics which has provided opportunities for them.

4.2.7 Location

Respondents tended to see the spatial clustering of chemistry SMEs as being important to their success. The agglomeration effects of clusters of firms operating in a similar environment enables employment mobility between firms and more relevant support and collaboration opportunities which are so vital to establishing SMEs.

Generally, it is reported that both government funding and private sector investors favour businesses located in the so called 'Golden Triangle' of Oxford, Cambridge and London. Some respondents argued that the advantages for an SME in being located in the 'Golden Triangle' extend well beyond finance however and, conversely, that being located elsewhere tends to create disadvantage:

> ***'Cambridge is part of the Golden Triangle - Oxford, Cambridge and London. It is well known and established, in legend and in truth, that the venture capital community of London is very London centric. We have our own ecosystem here in Cambridge. But we also have the benefit of being close enough that in non-pandemic times, at least, we can attract people up out of London. We also have the cachet of an internationally prestigious university to mean that we can also interest international investors, particularly those from the US'. (Health and Pharma SME).***

Outside of the 'Golden Triangle', access to venture capital is reported to be particularly problematic as there are fewer investors willing to invest in time-consuming, expensive innovation in other parts of the country, fuelling a vicious cycle of fewer such innovations:

> ***'I think there are projects in the regional universities but they're just not visible, [and] VCs will not leave the M25 unless they're going to Oxford or Cambridge. But that doesn't mean there aren't great projects outside Oxford London and Cambridge'. (Health and Pharma SME).***

One respondent did report that there are traditional areas of chemical strength in the UK which have the potential to be built upon (e.g. the North East), but arguably, they do not have the advantages of critical mass, financing or reputation that occur South East, thus presenting a different locational challenge for SMEs, even in these days of virtual networking and conferencing. Depending on where you are, location is either a challenge or an enabler.

[5] See [illegible].

4.2.8 Collaboration and IP management

The high level of collaboration among chemistry SMEs for innovation was evident from our analysis of the UK Innovation Survey although the survey also suggests that significant barriers to collaboration remain. The need for collaboration was also recognised by almost all interview respondents in order to access expertise, finance, equipment or regulatory requirements which the SME will not have themselves:

> ***'[Collaboration is] absolutely critical. In all aspects. From scaling the business, to bringing in expertise and skills, to bringing in the networks of competency and expertise, to partnering, to getting global reach in your customer engagement processes. It should be all-pervasive through the company'. (Sustainability expert).***
>
> ***'Collaboration is absolutely critical. Drug development doesn't happen on its own. We can't run our own clinical trials. We can't run our own animal experiments. We don't formulate the drug ourselves; we outsource that. We don't manufacture our drug. So, a lot of the time, everything we do is in collaboration with other people'. (Heath and Pharma SME)***

Many deep tech SMEs are collaborating with universities as they continue to develop their technology and bid for

Section 5: The UK policy environment for deep tech SMEs

5.1 Introduction

In this section, we explore aspects of R&D and innovation policy in the UK and a selection of comparator countries with a particular focus on how this influences R&D active and deep tech SMEs in chemistry and other sectors. This sets the context for the policy options that could provide better support to deep tech chemistry SMEs in Section 6.

5.2 Innovation Strategy

The policy context in the UK and the shape of future policy development is set by the current policy infrastructure and new directions signalled in the Innovation Strategy (July 2021). This reaffirmed government's ambition to put R&D and innovation at the centre of future policymaking while at the same time recognising many of the challenges and enablers of innovation success identified in our research. Of particular interest is the case for evidence-based intervention to support deep tech SMEs outlined in the Innovation Strategy:

> ***'The case for government to promote innovation in deep and transformative technology is strong. Prospective investors and customers of deep tech may be unwilling to take chances on new and unproven technology or may not fully understand its potential. The journey of tech- based innovation to market can be long, complex, and often non-linear. The UK excels at certain stages of this process but is weaker at others. We should pursue these signals of weakness and address the underlying issues. ... The UK government can build on that model, identifying barriers to innovation that are felt acutely in deep and transformative tech, and articulating how government can empower industry to overcome them'.***

This applies to all deep tech firms and is not specific to deep tech chemistry firms. But the case made for intervention here resonates with our own research into deep tech chemistry SMEs, with a long, complex and non-linear journey from discovery to innovation and wary investors and customers. The case may be slightly more pronounced or slightly different for chemistry, but addressing the weaknesses identified by the Innovation Strategy would represent a significant step forward.

The Innovation Strategy recognises the need to focus support on a group of Missions and key Technologies, which are defined as:

> ***'Innovation Missions and technologies are separate but complementary. Missions are about a clear and measurable outcome, such as vaccinating the UK against COVID-19, for which we need to draw on multiple technologies and research disciplines, work with di erent industries and supply chains and tackle innovation, manufacturing, and logistical challenges. Technologies, such as AI or genomics, will be vital for tackling these challenges but we may not know from the outset precisely how they will help'.***

To support this objective, the Innovation Strategy lays out plans to:

- Establish a new Innovation Missions programme to tackle some of the most significant issues confronting the UK and the world in the coming years.
- Identify the key seven technology families that will transform our economy in the future.
- Launch new Prosperity Partnerships to establish business-led research projects to develop transformational new technologies, with £59m of industry, university and public investment.

The Innovation Missions Programme will be developed, and the specific missions determined by the new National Science and Technology Council. The Innovation Strategy says these missions will be in the priorities covered in 'Build Back Better: our plan for growth' and 'The Integrated Review of Security, Defence, Development and Foreign Policy', they will build on existing or potential competitive advantage and generate a wealth of societal and economic benefits. Our analysis suggests there is a potential contribution for deep tech chemistry SMEs across a number of these Missions. Examples of where chemistry innovation is making an impact are:

- Clean, affordable energy; for example, battery technologies; solar technologies; materials science; thermal energy storage.
- Better health and medicine; for example, drug discovery and development; drug delivery systems; diagnostics; improved treatments and therapeutics.
- Circular economy; for example, novel recycling and reuse technologies or processes across a wide range of applications (including food waste, textiles, packaging, or industrial waste).
- Combatting climate change and its impacts; for example, carbon capture; conversion of CO_2 into energy and/or materials; development of renewable energy sources.

There is a general recognition in the Innovation Strategy that in the past commercialisation processes in the UK have not worked as effectively as those in other countries, particularly the US. The Innovation Strategy points to the need to better facilitate the transfer of science into industry and support scale up to full scale manufacture to deliver the long-term value from innovation to the UK.

The weaknesses of commercialisation processes in the UK apply particularly in the case of smaller companies – such asup to full sca

In 2015 the What Works Centre for Local Economic Growth published the findings from a systematic review of evaluations

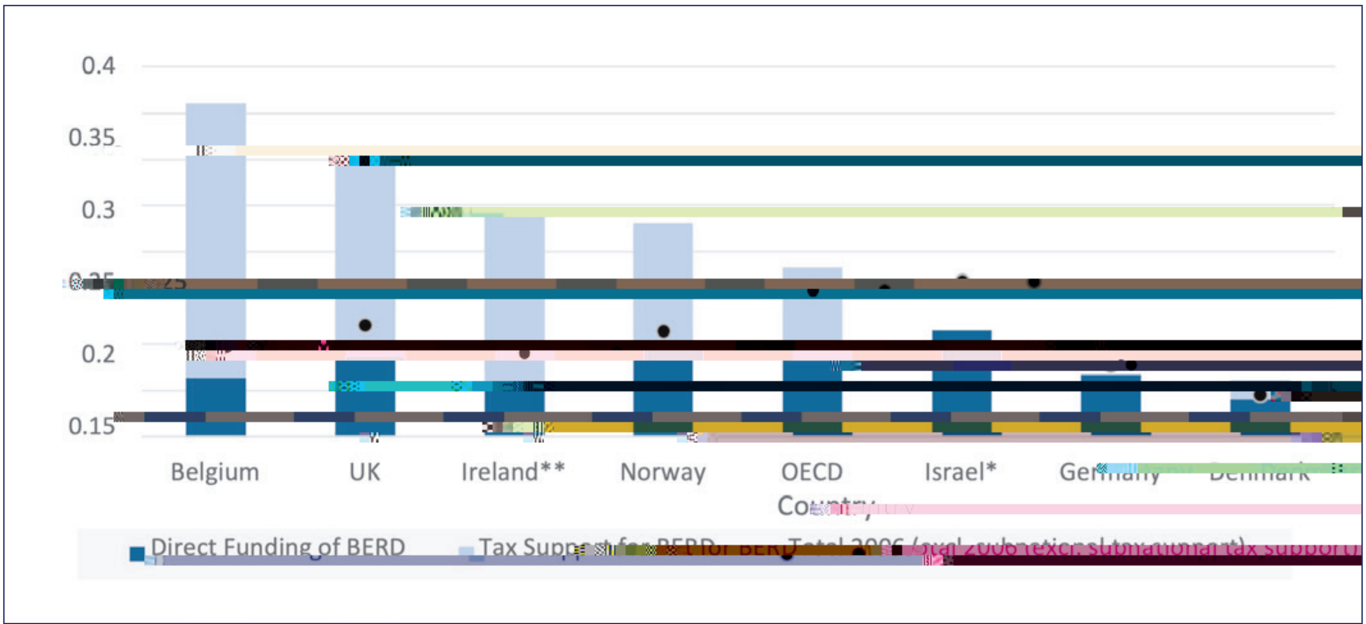
5.5 International policy - differences and commonalities

For this study we undertook a review of innovation policy in a small number of countries, to explore how the UK differs in key respects of importance to deep tech chemistry SMEs.

A 2020 review of innovation policy in eight countries (including the UK) concluded that there are similarities in the broad descriptions of innovation policies across countries, but also differences in the detailed application and in the mix of policy instruments available to firms (Mulligan et al, 2020). The report shows how government support for business R&D (BERD) has increased in most of the countries reviewed between 2006 and 2017 and how this breaks down between direct government support (e.g. R&D grants) and indirect government support (e.g. R&D tax credits). Figure 5.1 shows there were particular increases in the percentage of GDP allocated to BERD in Belgium, the UK and Ireland. Also, the majority of the countries were shown to have a higher percentage of indirect support than direct support (the data precedes the introduction of a Federal R&D tax credit programme in Germany in January 2020). Denmark has the lowest overall level of support for firm level R&D, relative to GDP.

However, Denmark's R&D Tax Credit are only applied to loss making firms – focussing support on early stage, pre-revenue spin-outs.

Figure 5.1: Government Support for BERD, 2006 and 2017



Source: Mulligan et al (2020)

5.6 Summary

Our review of R&D and innovation support in the UK and internationally suggested that the UK has a well-developed national R&D and innovation support system which offers a wide range of public support for innovating firms across the country. Alongside the support offered by the Research Councils and Innovate UK, measures such as the Research and Development Tax Credit, Patent Box and support offered to risk capital by the British Business Bank all help shape the environment for deep tech firms. Internationally, we identified no specific measures targeted at either chemistry SMEs or more specifically deep tech SMEs. Many countries operate a similar grant/tax credit policy mix as in the UK although the relative weights on grants and fiscal supports for innovation varies considerably. Few countries have consistent and different approaches for innovative SMEs. South Korea and Italy have both implemented such SME-specific policy approaches with a more specific focus on innovative SMEs in Italy. In both cases there is some positive impact evidence, consistent with wider evidence of stronger policy additionality effects in smaller firms.

In our interviews with SMEs and industry experts we explored their current engagement with government institutions and policy and noted a range of challenges many of which reflected the issues highlighted earlier (Section 4). Most of these issues were generic to deep tech SMEs, however a number were chemistry-specific or at least impacted more intensively on deep tech chemistry SMEs.

Two challenges stand out in particular. First, within the context of this national system supporting R&D and innovation there is a highly localised dimension to the commercialisation landscape with different universities having different priorities in terms of commercialisation, incubation and business acceleration activity. Technology transfer capabilities and links to potential sources of investment also differ markedly between institutions as does success in accessing national schemes such as Knowledge Transfer Partnerships. Combined with the variability of quality related research funding between institutions, and in keeping with some of the views of key informants set out earlier, it is evident that there is considerable geographical variation for chemistry SMEs seeking support from their local university and associated nunding bhm cap(t)15 (eo5apabilities(onential sots and fisca8D5apabilitititititind vi(y (ersite25 (abl-10 (t)15 (em supporting

Section 6: Conclusions and Recommendations

6.1 Introduction

It is generally accepted that R&D and innovation are fundamental drivers of productivity gains and growth throughout the economy. However, the available evidence, reflected in the Innovation Strategy, suggest that the UK lags key competitor countries in terms of investment in R&D and innovation performance particularly our ability to effectively commercialise new discoveries. This is reflected in our own interviews. Interviewees recognised the potential contribution of deep tech chemistry firms to national innovation missions (e.g. net zero, drug discovery) and also identified a range of challenges during the commercialisation process.

In this section we draw together conclusions from the study, set out the case for more effective support for deep tech chemistry SMEs, and outline out a range of policy options for achieving this.

6.2 The case for intervention

The findings from this research provide a substantive, evidence-based, rationale for the development of policy to better support innovation in chemistry deep tech SMEs. The case for intervention to support chemistry deep tech SMEs has two key elements. First, the potential of chemistry deep tech SMEs to introduce innovations which may have very substantial social returns and contribute to innovation missions; and, second a range of market failures which are currently constraining their innovation activities.

Our interviews and the case studies reported in earlier sections suggest the potentially profound impacts that innovation by chemistry deep tech SMEs can have on issues of national and often global concern. Innovation in chemistry is fundamental to achieving potentially transformational breakthroughs in a range of areas from climate change, to developing new treatments for a number of diseases including cancer and to addressing plastic pollution. The implication is that innovation in these firms has the potential to generate very significant social, economic and environmental benefits which far exceed the direct benefits to the businesses concerned. In more technical terms, innovation in deep tech chemistry SMEs can drive very significant and positive externalities suggesting a *prima facie* case for policy intervention.

Market failures may constrain innovation and the available literature and the empirical evidence from this study suggest a number of such failures in the UK. Some of these market failures are relevant to all deep tech companies, others are more specific to distinctive aspects of deep tech chemistry SMEs. The market failures most relevant to chemistry deep tech SMEs include:

- ***Failures in capital markets*** – these failures occur throughout the R&D and commercialisation journey, but may be more impactful for chemistry deep tech SMEs than other SMEs due to the length of their innovation journey. SMEs may struggle with securing funds to establish proof of concept and with accessing the mid-level equity-based funding required to achieve scale and bring new technologies to the market. Research respondents also suggested that there is a particular structural issue with securing angel investment outside of the so called 'Golden triangle' of Cambridge, Oxford and London. Angel investors require a critical mass of investment opportunities in order to spread the risks of their investments. This critical mass does not exist outside of the Golden Triangle. and it remains to be seen whether the pandemic and moves to online working by investors will have, in any way, addressed this issue.
- ***Failures in the market for grant funding*** - It is generally accepted that R&D intensive start-up businesses typically require grant funding to help establish the validity of their technology. The majority of chemistry deep tech SMEs interviewed for this study are generally supportive of grant funding provided by government. However, the application process was also viewed as complex, with unclear success criteria, increasingly competitive and with a higher likelihood of bid failure. Reviewers were often thought to lack an understanding of the potential of deep tech chemistry, a sector-specific issue.
- ***Failures in the availability of premises and specialist equipment*** - There was a very clear view amongst the respondents interviewed for this study that the availability of suitable premises and specialist equipment presents an acute challenge for many chemistry deep tech SMEs, particularly those seeking to scale up. Respondents generally reported a spatial dimension to these market failures which were said to more of an issue outside the Golden Triangle where agglomeration benefits are weaker. This market failure was highlighted as applying specifically to chemistry deep tech SMEs because of the very specific requirements of chemicals production.

- ***Information failures and perceptions of risk*** - There are widespread information failures that result in poorly informed perceptions of risk related to the chemistry deep tech sector. Evidence from our interviews suggests that these information failures affect the decisions of businesses, business support professionals and policy makers. For example, it is widely accepted that collaboration with other businesses, and often with the university sector, is a key driver and enabler of R&D and innovation. Such collaboration may be constrained by exaggerated fears of IP leakage or a lack of advisory support with in-depth sector expertise and understanding. Policy makers, although often concerned to reduce the risks faced by deep tech SMEs, typically also seek to minimise the risks associated with policy initiatives.
- ***Failures in technical and managerial skills development*** – There is extensive evidence that under-developed management and leadership skills are a constraint to SME performance throughout the UK economy (see, for example, Hayton 2014)[21]. Evidence from this study suggest that underdeveloped management and leadership skills, particularly poorly developed entrepreneurial and innovation skills, are both widespread in deep tech SMEs in the chemicals sector and a major constraint on business performance and the commercialisation of their technologies. Indeed, this research has shown that these businesses tend to face challenges in innovation management and leadership that transcend those typically encountered in the general case. In particular, respondents emphasised the inter-disciplinary nature of much innovation and the weakness of multi-disciplinary training.

6.3 Supporting the whole deep tech journey

As the recent Innovation Strategy points out "The journey of tech-based innovation to market can be long, complex, and often non-linear". This is very clearly the case for chemistry deep tech SMEs which typically face an on-going, atypically consequential and long-lasting series of challenges in commercialising their technologies. The key point here is that whilst policy support can be developed to address individual market failures, if other subsequent market failures prove to be insurmountable, the supported businesses may well still not be successful despite the earlier support[22].

Addressing all the identified market failures in a comprehensive package of support is unlikely to be achievable in practice and would be a daunting ask of policy makers. From this perspective, policy makers are more likely to pursue a strategy of identifying and addressing the most widespread and impactful barriers to business success. In later sections we therefore identify a series of policy options which may be particularly impactful for deep tech chemistry SMEs.

A number of the market failures identified in our interviews, however, suggest the potential value of policy measures which have a general rather than a closely targeted impact. Specifically, they emphasise the appropriateness and merits

6

- ***Angel investment*** – Several of the respondents to this study suggested that angel investment remains difficult to access outside of the so called 'Golden Triangle' despite initiatives such as the British Business Bank Regional Angels Programme[26]. The key issue here is argued to be structural – the lack of a critical mass of the businesses in the regions which means that potential investors cannot ensure that the risks they face are reduced by their ability to fund a sufficiently large number of businesses. Consideration might well be given to whether IT based platforms could help to overcome these issues by brokering links between angel investors and potential investment opportunities. This involves reducing the information barriers to investment and allowing investors access to business profiles nationally.
- ***Equity gap*** – Both the academic literature and the responses to this study confirm the existence and significance of an equity gap which means that deep tech chemistry SMEs often struggle to secure intermediate levels of funding to enable scale up and the commercialisation of new technologies[27]. Given the foundational importance of deep tech chemistry SMEs to national and international missions, there is a case for targeted chemistry-specific public support. This would need to reflect the long-term and high risk (uncertainty across multiplicity of markets) nature of investing in chemistry. Our research suggests there is a quantitative shortage of available equity investment, and interviewees perceived chemistry's share to be falling.
- Some of these issues are not unique to deep tech chemistry SMEs but do suggest the value of further policy intervention to create a more enabling financing environment along the lines of the ENABLE[28] programme or National Security Strategic Investment Fund[29]. Measures which might be considered include:
  - The Innovation Strategy refers to work by UK Finance to develop the next generation of lenders (BEIS 2021, p. 25). Our interviews highlighted issues with a lack of understanding of deep tech innovation among both public and private funders. Future developments in this area should therefore consider building understanding of the specific requirements of deep tech businesses in chemistry and elsewhere as well as addressing issues such as IP and intangible assets and ensuring the widespread dissemination of any research in this area.
  - Access to the appropriate public and private funding opportunities should be facilitated through online portals, clearly signposted, and supported as a public good. The need for improved signposting of public support for R&D and innovation has also been emphasised recently by the RaEng[30] and relates strongly to aspirations around 'levelling up'.
  - In terms of private funding, the cost of undertaking due diligence is a key factor limiting the involvement of Venture Capital (VC) in this sector. Accordingly, consideration might well be given to interventions that would underwrite these costs and thereby make the provision of medium sized funding more attractive to VC investors.
  - Public funding – perhaps offered through BEIS, BBB or Innovate UK - could be developed to specifically target deep tech firms across the science sectors to leverage additional private funding.
- ***Grant application processes*** – Given the widely expressed concerns about the appropriateness and effectiveness of the established grant application processes used by Innovate UK and other bodies, there is a strong case for considering whether current processes are fit for purpose in supporting deep tech innovation, and to revise these processes as appropriate. Our research identified a number of specific issues on both the supply and demand side which are constraining deep tech chemistry SMEs' access to public funding. On the supply side, funding timescales - the usual three-year funding opportunities do not allow for the innovation to be fully tested or developed. A lack of flexibility in milestones, and a perceived lack of appreciation by review panels of the challenges involved in deep tech innovation also emerged as issues in our study[31]. These issues could usefully be considered as part of the development of the new UKRI Commercialisation Funding Framework highlighted in the Innovation Strategy (BEIS 2021, p. 45). On the demand side, there is a lack of understanding of what makes a convincing proposal by businesses. Accordingly, there is also a case for training to improve businesses' competences in this area perhaps working through the KTN or Enterprise Europe Network.

[26] See

6.6 Access to bespoke, affordable facilities

Given the very widespread perception that the lack of availability of suitably equipped premises is a key constraint on business development and scaling up for deep tech chemistry SMEs, this is clearly an area where intervention would be both practical and useful. Existing sources of information do not appear to be well known or used by deep tech SMEs and better signposting to existing information sources may also be useful. Developing new public/private partnerships for provision may also be useful here[32].

Other policy options under this general heading are:

- Consider gaps in the provision of bespoke incubators/accelerators - The facilities provided by incubators and accelerators are clearly helpful in providing appropriate, suitably equipped, premises (e.g. Unit DX in Bristol, Biocity). Given the particular challenges our interviewees identified for chemistry deep tech SMEs in accessing suitable premises for scaling, an audit to establish what premises are available (for example in established Catapults) would be sensible[33]. This may help to build a case for establishing new facilities specifically designed to meet the needs of chemistry deep tech SMEs. Improving the information available to firms about the facilities which are available would also be potentially beneficial.
- Improving access to flexible equipment - our interviewees stressed the difficulty of funding specialist equipment purchases particularly during the scale-up phase. This is an issue beyond deep tech chemistry firms, and the need for innovative firms to have better access to specialist equipment is recognised in the Innovate UK Delivery Plan 2021-25 in terms of strengthening innovation eco-systems[34]. Consideration could be given to whether public-private partnership investment could help firms obtain access to equipment perhaps through leasing to SMEs working in chemistry deep tech. This would benefit businesses by increasing the availability of suitable equipment while reducing the financial burdens they face.

6.7 Innovation Management and Leadership

If, as argued above, the overall programme of support for chemistry deep tech SMEs must move beyond measures that target specific constraints on performance, the policy programme must include initiatives related to innovation management and leadership.

Perhaps surprisingly our interviews did not suggest any consistent issues around accessing technical skills. Instead, they emphasised the critical impacts on business performance associated with underdeveloped entrepreneurial and innovation management and leadership skills which were widely reported to be a common and significant constraint to business performance. Indeed, there is good reason to believe that deep tech chemistry-based SMEs require particular innovation management competencies beyond those needed in the more general case. Not the least of which are the particular skills needed to successfully manage a business through a protracted period of establishment and commercialisation that will inevitably span a number of years. This strongly reflects the focus in the Innovate UK Delivery Plan 2021-25 on 'enhancing the leadership and commercialisation skills needed by companies to grow their businesses' (p. 51). Among the measures of most importance for deep tech chemistry SMEs are:

- ***Promoting engagement with management and leadership training***. There was a widespread acceptance amongst the SMEs involved in this research that initiatives that aim to develop entrepreneurial, innovation management and leadership skills are necessary and would be useful. However, there is some reluctance to engage with existing training opportunities. Two issues are important here. First, skills development is best achieved through experiential learning rather than being taught per se. Second, the majority of respondents favoured peer-based learning over more formal approaches. The BEIS Peer-networking programme and Help-2-Grow initiative adopt this peer learning approach within each programme, although both are general programmes rather than having a specific focus

- ***Incentivising engagement with formal training*** – given respondents' concerns about the value of formal training programmes, it may be useful to consider incentives that encourage training take-up. One obvious driver that could be employed would be to modify grant application scoring so that applicants who had completed suitable training received a small premium to the scoring of their application. However, it is not clear that this would be well received by either policy makers or businesses.
- ***Encourage the provision of business modules in post graduate training programmes*** – Respondents to this study were also concerned that post-doctoral candidates looking to work in this sector almost invariably lack any real understanding of the non-technical issues faced by these businesses. Accordingly. it would be sensible to review and evaluate the opportunities currently available for post-graduates to develop their entrepreneurial skills while at their university. Several respondents to this study suggested that the Royal Academy of Engineering Enterprise Hub provides an exemplar of effective practice in this area. The Innovation Strategy also highlights the potential value of cross-sectoral training (BEIS 2021, pp57-58). Consideration might also be given to a funded internship scheme through which chemistry post-graduates and subsequently their employers would benefit from the experience and enhanced understanding of the issues involved in working in deep tech-based SMEs. The scope for this type of internship for doctoral students is also recognised in the Doctoral Training Partnership funding provided by EPSRC[36].
- ***Provide better IP and regulatory advice and support*** – Although, as this research confirms, concerns about IP

- ***Establish and support networking*** – In this report, we have emphasised the need to complement tightly focussed interventions with overarching policies that can support chemistry deep tech SMEs throughout their journeys to commercialising their technologies. We have also noted the scepticism that many of these businesses have in relation to formal knowledge sources and for management and leadership training. Given this context, we see considerable merit in the provision of networking opportunities for chemistry deep tech SMEs. It is generally accepted that networking with their peers expands the ambition, skills, confidence and dynamism of SME owners and managers. Most respondents interviewed for this study agreed with this and were open to participating in such initiatives. Industry representative bodies, local organisations and organisations such as the RSC are closer to these businesses than government and may well be more trusted and better placed to organise and run initiatives of this kind. The value of peer-to-peer networks has also been recently recognised by the Scale Up Institute[38] and in the establishment of the BEIS peer networking programme[39]. While promoting networking may appear to be a 'soft' option not directly linked the challenges concerned, the evidence suggests that it would be relatively inexpensive to deliver and may well be amongst the most effective policy options available to promote growth and innovation in deep tech chemistry SMEs.

[38] See [illegible].

[39] See [illegible].

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