THE MUSCATELLI REPORT

Driving Innovation in Scotland – A National Mission

Contents

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Foreword by Professor Sir Anton Muscatelli

Scotland's universities are among the best in the world, with a social impact that is felt right across the globe – at the vanguard of work that is leading the way in helping to meet some of the major social, economic and environmental challenges of the 21st century. To take my own institution, the University of Glasgow, ground-breaking and life-changing work is taking place in areas as diverse as Precision Medicine which is revolutionising how we view healthcare, quantum technology, nanofabrication and photonics in which Scotland is a world leader, as well as major contributions to international development. Similar success stories are apparent at institutions right across Scotland.

Our universities are already a major driver of Scotland's economy – referred to by the Cabinet Secretary for Finance, Economy and Fair Work, Derek Mackay, as "engines of knowledge and growth". And while our economic impact is already very clear – I firmly believe that we are only seeing the tip of the iceberg.

Our potential as a sector and as a nation is so great that I think there is so much more we can achieve if we work together to create the right environment to allow that great potential to be fulfilled.

That's why I was delighted to be asked to undertake this report focused on how Scotland's universities can improve our engagement with industry and boost our contribution to economic growth.

The fact that the report has been commissioned at all is deeply heartening – showing the level of emphasis the Scottish Government is placing on the role of universities in delivering inclusive economic growth. This is a role our sector must be willing to embrace.

We can and should be the driving force of Scotland's economy – the quality of our institutions and our research is a competitive economic advantage we simply must capitalise on in the coming years. We should not forget that we have an obligation to the communities we serve to ensure that they see the economic benefits of the often world-changing work we undertake.

This report considers how the immense strengths of Scotland's universities can be channelled to the maximum economic benefit for our country by enhancing industrial partnerships and promoting greater collaboration across the sector.

This report makes a small number of headline recommendations for all actors in this space – government, universities, industry and economic development agencies. This is in recognition that this is not a task for Government alone – for Scotland to meet our full economic potential, we must all play our part in a great, shared national mission.

We are starting from a strong position: across the country, exciting partnerships with major industry, SMEs, spin-outs and social enterprises are already under way, with many success stories to be celebrated, and I have highlighted just a few of these examples throughout this report.

A number of our universities have developed close relationships with businesses focused on innovation. City Deals in Scotland, such as the Edinburgh City Deal where the University of Edinburgh played a key role, together with other HE institutions in the City, have increasingly focused on the important role of innovation and skills.

Many of these innovation successes are based on the foundations of research successes which were fuelled by earlier public investment and the ingenuity and entrepreneurial spirit of our Universities.

Of course, we know that there must be room for improvement. It would be surprising if we did not have major lessons to learn. We know that Scotland suffers from very low levels of business R&D (Research and Development) compared to its levels of R&D in Higher Education.

Equally, we know that there are opportunities to leverage more funding into Scotland, from international business, from the UK industrial strategy, from UKRI (UK Research and Innovation) and from international agencies. The funding landscape for innovation is changing, so it is to be expected that we might be able to do better, to respond to external incentives, and to play an even greater role in driving economic prosperity for Scotland.

This is the great economic prize that Scotland needs to grasp – and which our universities and industry have a duty to play their part in winning.

Our universities only succeed when Scotland succeeds – and Scotland will only meet its full economic and social potential with a thriving university sector, working with industry and other partners and translating its world-leading work into tangible economic benefits for our country.

Our collective national mission must be to make Scotland the most innovative small economy in the world, where industry can partner with universities in the common good – linking social impact with tangible economic growth and job creation.

I have every confidence that the fundamentals are there to make this a reality for Scotland. I hope this report will be a useful first step in making this a reality.

1. Executive Summary

Scotland's strengths

As a nation, we are blessed with extraordinary resources and potential, and perhaps no sector is more emblematic of this than our universities: a field in which Scotland continues to punch well above our weight.

With four of our universities in the world top 200, many of our institutions lead the way in vital areas of research with truly global impacts and Scotland continues to be seen as a desirable location to study and work for talented undergraduates and researchers. Our Higher Education sector is a national success story of which we are all justifiably proud.

Our contribution is felt at home as well as internationally – for as we undertake the research which saves lives across the globe and come up with solutions to improve the climate on the planet we all share, we are also creating opportunities, contributing to growth and inspiring ambition in the communities we serve.

However, just as the research we undertake must continue to evolve to meet new challenges, so must our ambitions – both for our universities and for Scotland. There is so much potential to contribute even more to our economy and our society – a potential that I hope this report will go some way towards realising.

Scotland's opportunity

Here in Glasgow, I have often spoken of the potential for the innovation agenda, the interplay between industry and academia and the hi-tech jobs which could result as offering us the opportunity to reimagine the entrepreneurial spirit for which we are famed internationally.

We are known throughout the world for our proud history of shipbuilding and heavy industry – we can no longer afford to look backwards to past glories but must instead take the industrial legacy of which we are all proud and use this as the springboard to create our own legacy of innovation and invention for the 21st century.

The opportunities are there right across our country. We have seen the River Clyde go from launching the world's greatest ships to becoming a world-leader in nanofabrication, making devices measured in a millionth of a millimetre, to the North-East of Scotland making the most of its extraordinary renewables potential, building on its expertise in oil and gas.

These great opportunities exist – it is up to us to find ways to meet them.

Can the nation which helped drive the industrial revolution, with all its positive and negative consequences, also stand at the forefront of the coming green industrial revolution? Can innovative solutions from our universities and pioneering companies, supported by government, help repair some of the damage to our planet unleashed in centuries past – while bringing environmentally friendly jobs and investment to Scotland?

Can the country which gave the world the "father of modern surgery" in Joseph Lister, marshal its intellectual, clinical and industrial resources to reimagine medicine and provide a genuine revolution in healthcare by leading the world in the emerging field of Precision Medicine, while we hold the competitive advantage – improving outcomes for patients while saving billions for our NHS and putting Scotland at the cutting edge of a multi-billion pound industry?

Can we find ways of ensuring that the economic benefits of these activities are shared fairly amongst our communities in a genuinely inclusive growth – giving opportunities to people across Scotland, regardless of their economic background?

These will be some of the defining questions of our age – and, if the answer to these questions is yes, we will all reap the rewards, socially and economically.

This will all depend on many factors – investment, collaborative working, clarity of purpose, sound planning and many more. The will is there, and the potential is there – and this report sets out some of the actions we must take as a nation, to see Scotland retake its place at the forefront of international industry and innovation.

Scotland's next steps

These recommendations have been grouped within three overarching themes; that of ensuring that the innovation agenda becomes **a truly national mission** for universities, industry, government and agencies working together in the national interest, that we ensure our efforts in this space are built on **the strongest foundations** with all actors equipped with the necessary information and tools, and that our collective efforts as a nation are joined up with a **clarity of purpose** that has often been lacking while efforts are duplicated and colleagues across organisations and sectors occasionally work at cross purposes.

A truly national mission

The Scottish Government has already set the ambition for Scotland to be a world-leading entrepreneurial and innovative nation and is steering collective action accordingly through its CAN DO Innovation Action Plan.

It is imperative that this becomes more than a government target but becomes a **shared national mission** for institutions across all sectors in Scotland. Universities and the public funding agencies must ensure that they play an active role towards achieving this ambition, if they are in receipt of public funding for research and innovation.

- The Scottish Government objective of turning Scotland into a world-leading innovative nation should be adopted as a shared national mission, with universities pledging to work more closely together in the national interest and government doing all it can to facilitate this.

1. Executive Summary

- The Scottish Funding Council (SFC) and the Enterprise Agencies should set a target for Scotland to attract investment for innovation activity from external sources such as Innovate UK, in which we are currently underperforming.
- Government and its agencies should introduce a mechanism to ensure greater collaboration and coordination in bidding for UK funding streams, preventing actors in Scotland from pursuing conflicting objectives or duplicating efforts.
- Higher Education Institutions (HEIs), through Universities Scotland, should work closely with Scottish Development International (SDI) and Directorate for International Trade and Investment officials to ensure that we are maximising our impact on trade, including identifying ways to effectively use their existing international networks.
- Universities should encourage some of their most influential alumni to join a network of people able to help connect Scotland with potential inward investors, akin to the Globalscot Network.

The strongest foundations

As we strive to meet Scotland's full potential as an innovative economy, it is important that we are equipped with the right tools – to take both positive action, and to help understand where there are currently areas for improvement.

We should not be afraid to reflect openly and honestly on the areas in which we are currently struggling. We must also recognise the ways in which we are currently constrained in our actions. Neither of these actions will change anything in and of themselves but will ensure our efforts to see Scotland at the forefront of innovative economies around the world are built on the strongest possible foundations.

- Many of the basic policy tools utilised by comparable countries to promote innovation and to drive productivity growth are not currently devolved to Scotland. The Scottish Government, supported by the HE sector, should continue to call for powers over skilled immigration to be devolved to the Scottish Parliament and should explore the possibility of introducing some flexibility in R&D tax incentives between the devolved nations.
- Scottish Government should investigate Scotland's relative competitiveness in the area of early-stage capital in innovative firms to allow greater insight into how we turn Scotland's world-class research base into innovation.

Clarity of purpose

Learning lessons from other small, innovative economies, the report stresses the importance of setting clear priorities for innovation in Scotland that are congruent with strategic areas, i.e. where we have major strengths in basic research which can act as a pole of attraction of innovative companies wishing to invest; or where we have highly-innovative and productive companies which can help to drive the economy in the 21st century and where we should encourage more applied research by the HE sector.

Scotland should concentrate innovation efforts more clearly in those areas where there is real critical mass, where we have a competitive advantage, and where we could add significantly to major innovation efforts or missions at UK or EU level.

SFC and the Enterprise Agencies should work with the HEIs to gradually sharpen the focus of Scotland's innovation strategy. This might involve setting some over-arching mission-led themes and linking these to the range of publicly-funded and university-funded knowledge exchange assets – whether sector or technology-based.

- Scottish Government should encourage SFC and the Enterprise Agencies, in consultation with the HE sector, to advise it on a clear focus for a national innovation strategy which is congruent with the Government's priorities in key areas of policy which would naturally fit into a mission-oriented approach to innovation policy.
- The Enterprise and Skills agencies should seek to align their investment streams more closely to help drive innovation from the research base. The agencies have already begun to do this. Government should also consider aligning other relevant streams of funding in this area.
- Scottish Enterprise should help Scotland's major City Regions and their component local authorities to develop city-based place-making strategies with the universities and colleges in each City/City Region.
- The Scottish National Investment Bank (SNIB) should consider, with the Enterprise and Skills Agencies, what role it could play in respect of encouraging and incentivising place-based innovation activity which will drive the economy.
- The Scottish Government should ask the analytical unit of the Enterprise and Skills Strategic Board, SFC and the Enterprise Agencies to assess the rate of return from current spending, and the potential rate of return from future investments on publicly-funded R&D, in terms of Scotland's inclusive economic growth.
- As Scotland's industrial and business sector has a lower demand for innovation activities than other UK regional and national economies, SFC and the Enterprise Agencies should consider the implications of this for the balance of their innovation investments e.g. in UIF and Innovation Centres.
- The analytical unit of the Enterprise and Skills Strategic Board should work with SFC and the Enterprise Agencies to benchmark our current levels of public R&D spending, and its outputs, in Scotland's research base with some of the most dynamic small EU economies with similarly sized HE sectors.
- Universities should encourage greater collaboration between their Knowledge Exchange and innovation activities, possibly involving regional hub-and-spoke models, which would involve the larger HEIs with greater capacity to engage and co-ordinate innovation activities taking the lead.
- SFC should consider focusing its Research Excellence Grant (REG) and University Innovation Fund (UIF) funding in a way which maximises the impact for Scotland both in terms of UKRI leverage and more generally the excellence of Scotland's research and innovation landscape.

1. Executive Summary

- SFC should consider the long-run sustainability of Scotland's universities' research and innovation activities and provide advice to Government during the next spending reviews. The HE sector should be open about its ambitions for expanding its research activities and leveraging more income into Scotland from UK and other sources.
- SFC, working closely with universities, Universities Scotland and the Enterprise Agencies, should ensure that UKRI and major research funders (e.g. Wellcome Trust, Cancer Research UK [CRUK]) understand Scotland's competitive advantage in areas of research-driven innovation. Scotland has the opportunity to attract greater investment if it brings together consortia across disciplines, universities, research institutes and business to make larger bids. SFC should work with universities, research pools, innovation centres and its partner agencies to increase Industrial Strategy Challenge Fund (ISCF) investment through collaborative bids of scale.

2. Introduction

Background and remit

Professor Sir Anton Muscatelli was commissioned by Derek Mackay, Cabinet Secretary for Finance, Economy and Fair Work, to undertake an independent report on the economic impact of Higher Education Institutions (HEIs) in Scotland and how this could be maximised through, for example, improving links between the Higher Education sector and industry.

Scottish HEIs are internationally renowned and this report seeks to identify what steps might be taken to maximise the impact HEIs have on the Scottish economy through their research and innovation activities and their collaboration with businesses.

The review considered what is working well in the current interface between universities and business and where there are areas for improvement. There are numerous examples of success in Scotland and some are featured as case studies throughout this report.

There are wider economic impacts of HEIs in Scotland beyond research and innovation activities, and many other actors and factors which drive the innovation activity described in this report. The most significant economic impact of HEIs is equipping Scotland's graduates with the skills needed for success in the modern economy. For instance, much of the knowledge transferred from universities to industry occurs through knowledge embedded in graduates who take up employment in business and industry. These spill-over effects from human capital formation to the productivity of business and industry are not easy to measure, but many SMEs in high-technology sectors emphasised that, to them, having the supply of high-level skills is key to their own innovation activities in Scotland.

This report does not focus on the provision of skills by Higher Education institutions. The main reason is that the Enterprise and Skills agencies and the Strategic Board for Enterprise and Skills have already given considerable focus to the issue of how best to match Scotland's skills provision to the needs of industry and business. Nevertheless, when considering the channels whereby research and innovation activities in universities are translated to productivity growth in the business sector, it is important to understand that an important channel of this translation is through the human capital from Scottish Universities which augments the capabilities in the business sector.

Understanding channels of interaction between universities and business beyond research and innovation activities and the wider actors and drivers of innovation will be important to driving improved innovation performance in Scotland – but this is beyond the scope of this report and the recommendations put forward.

Recently a similar report to this one was commissioned by Cabinet Secretary for Finance, Economy and Fair Work on the impact of Further Education in Scotland on the economy and will be prepared by Audrey Cumberford, Principal of Edinburgh College, and Paul Little of City of Glasgow College. There has been dialogue between the team preparing this Higher Education report and the one for Further Education.

Approach

Professor Sir Anton Muscatelli invited written responses from key stakeholders and met with a number of individuals and groups (Annex A) to inform the report's recommendations. Professor Muscatelli has also benefited from numerous conversations with individuals from industry and business who did not submit formal written evidence but provided helpful insights of their own experience of interactions with Higher Education Institutions in Scotland.

This report builds on a significant body of work undertaken in Scotland and the UK, including the Innovation Centres Review, Growing Value Scotland Task Force work, and the Dowling Review of Business-University Research Collaborations. Desk-based research and analysis was also undertaken to inform this work. A full list of the reports and policy documents reviewed to establish the existing evidence base is in Annex B. International best practice was also examined – while there is no one-size-fits-all approach to a successful knowledge exchange ecosystem, Scotland could learn lessons from similar small advanced economies who have successfully capitalised on their innovation outputs. The details of this are included in Annex F.

This report reflects the views of Professor Muscatelli as an expert stakeholder in higher education, and not those of his institution or the wider sector.

3. Context for the Report

In order to suggest how Scotland can enhance the economic impact of our universities, it is important to first set out some of our current key strengths which we could do more to capitalise on, as well as some of the areas in which we know we need to improve.

Universities already play an incredibly important role in Scotland's economy. As well as their obvious role in creating a skilled workforce, universities make a significant contribution to inclusive economic growth through Gross Value Added (GVA) and jobs, attracting Foreign Direct Investment (FDI), translating research into new products for the private sector, creating spin-out companies and generating export income through international research. A recent report estimated that this activity contributed £7.2bn to the Scottish economy in GVA impact in 2013/14[1].

In FDI, Scotland performs particularly well, ranking second behind London in the UK in 2017 for the number of FDI projects, and attracting the most Research and Development (R&D) FDI projects of any part of the UK, with 22 of the 89 (25 per cent) UK projects coming to Scotland in 2017. Scotland's world-class universities have been identified as a key driver of this success by Ernst and Young[2]. The two most-cited factors of attractiveness for locating R&D activities in a recent EU survey was the 'quality of researchers' and a 'high availability of researchers[3]' , highlighting the key role universities can play in attracting high-value inward investment.

HEIs also have a significant economic impact through knowledge exchange activities – essentially the process of applying university R&D to making a social impact, including spin-out companies, research collaborations, the sharing of resources etc. A study of the Russell Group of universities indicted that for every one pound invested in research activity at these institutions, a further £5.50 is generated across the UK economy, resulting in total productivity spillovers of £31.26bn[4].

In 2017/18, there were 1154 active spin-out companies in Scotland, generating an estimated turnover of £613m – 19 per cent of the UK total. Clearly, this is an area of real strength for Scotland and one in which we already punch significantly above our weight in terms of turnover. Yet we have slightly below our population share of active spin-offs (7 per cent of the UK total) and new spin-offs (215 in 2017/18 or 5 per cent of the UK total)[5]. The economic impact of bringing these figures at least into line with our population share is clear, in light of the success of currently active spin-outs in Scotland.

Another area in which Scotland and our universities perform well is in research collaboration with business with income from contract research of £183m in 2017/18 (9 per cent of UK total) and income from consultancy contracts at £77.7m (16 per cent of UK total). Indeed, Scotland's universities do more than a quarter of all contract research between universities and SMEs in the UK, at 29 per cent. Clearly, significant and fruitful relationships already exist in terms of research – a field in which Scotland's universities are genuinely world-leading[6].

However, Scotland's overall innovation performance is mixed – with areas of real strength but also some notable challenges. Gross Expenditure on Research and Development (GERD) was 1.63 per cent of GDP in 2017, placing Scotland 20th out of 37 in the OECD – below the UK, EU and OECD averages. A large proportion of Scotland's GERD is attributable to the Higher Education sector – indeed, the proportion attributable to HE was higher in Scotland than any other OECD country in 2017[7].

Scotland's Higher Education Expenditure on Research and Development (HERD) was 0.69 per cent of GDP in 2017, placing Scotland 7th in the OECD and in the top quartile, outperforming the UK, EU and OECD averages. However, our Business Expenditure on Research and Development (BERD) stands at 0.8 per cent of GDP, 23rd in the OECD and below the UK, EU and OECD averages.

Our BERD performance partly reflects Scotland's industrial structure but also a lower spend on R&D in innovative sectors. In 2016, the five most R&D intensive industry sectors in the EU accounted for 2.6 per cent of jobs in Scotland, compared with 3.3 per cent in the UK and 7.3 per cent in Germany. These sectors were also responsible for 35.3 per cent of Scotland's BERD significantly lower than countries like Croatia (78.2 per cent) and Germany (64.7 per cent). R&D expenditure in Scotland is also concentrated in a small number of large businesses in 2017, five companies accounted for more than a third of Scottish R&D expenditure.

R&D is funded through a variety of sources – including direct investment from public, private and charitable sources, R&D tax credits and investment from EU framework programmes, research councils and Innovate UK.

Gaining access to Innovate UK funding is an area in which Scotland seems to underperform compared with other parts of the UK. Average grants are generally lower in Scotland on average, with only 5.4 per cent of the value of UK grants awarded in Scotland between 2003/4 and 2018/19[8]. While Scotland's universities perform well and indeed better than their counterparts in the UK in accessing Innovate UK funding, it is clear that Scotland as a whole has lessons to learn.

Our research and innovation activities are important for a variety of reasons, but specifically as key drivers of productivity growth, an area of real challenge for Scotland, which has seen slow productivity growth since the financial crisis, albeit higher than the UK rate and only slightly behind the EU and OECD averages[9].

There has been extensive research on 'productivity puzzles', which look for potential causes of this sustained slowdown in productivity growth across developed economies. Evidence suggests that there has been a slowing in rates of technological diffusion to firms in Scotland – that is, there is a long and lengthening tail of companies failing to keep pace with the technologies used in frontier companies[10]. OECD analysis suggests that well-designed policies can support technological diffusion and increase productivity[11]. There is also evidence to suggest that the long tail of less productive firms is not responsible for all of the UK's lagging productivity, with the slowdown in productivity isolated in the top tail of the distribution of productivity across workers[12].

Further understanding the drivers of productivity and the causes of the slowdown will be important to developing

3. Context for the Report

successful interventions and targeting support. Further work is required to evidence the links between research, innovation and productivity growth in Scotland, but there is no evidence to suggest that the mechanism whereby public R&D spending has a positive impact on the domestic economy has somehow changed. The international evidence from Annex F also suggests that many small and large European economies are investing heavily in public R&D, aiming to boost private R&D spending, private investment and productivity growth.

This report will attempt to examine this further as an important element of understanding how, given the policy levers Scotland currently has at its disposal, expenditure on HERD can stimulate additional BERD.

This is one of the challenges and opportunities facing Scotland currently as we seek to ensure maximum economic impact from our universities and their collaborations with industry.

However, it is clearly not the only challenge and opportunity in front of us – the many strengths and some weaknesses identified in the context of Scotland's current position will each inform the recommendations made in this report.

This report builds on significant work undertaken in this space in Scotland and the UK. While it does not seek to replicate work, it is important to set out the current understanding on areas where further progress is required, and actions are already under way.

Although not within the remit of this report, the most significant economic impact that HEIs have is through the human capital channel. Skills are of central importance to businesses and to entrepreneurial ambition in Scotland. A number of respondents emphasised the need for universities to equip both graduates and academics with the skills necessary to meet industry needs. While this report has not investigated skills needs within its remit, this is obviously a key area where HEIs drive positive business and economic impact and has been the subject of a number of recommendations in reviews, including the work of the Growing Value Scotland taskforce and the Royal Society of Edinburgh[13].

The complexity of the innovation system, particularly for businesses who are not currently engaged or engage infrequently, is well-documented in the literature[14] and the Reid Review of the Innovation Centres, the Enterprise and Skills Review, and Growing Value Scotland taskforce outlined a number of recommendations for simplifying the landscape and making the offer of universities clearer to businesses.

Reviews in the UK and Scotland have also focused on the need to ensure that incentives are appropriate to encourage long-term collaboration between universities and businesses – including recognising the value of knowledge exchange activities in academic promotion and tenure. Engagement throughout this review has highlighted that people and individual relationships are fundamental to the success and longevity of university-business collaborations, so it is important to ensure that any incentive frameworks encourage the sharing of ideas and people between academia and industry. Work has been undertaken or is under way in many institutions in Scotland to recognise the value of these activities to an academic career path.

[1] BiGGAR Economics, Report to Universities Scotland - Contribution of Universities to the Scottish Economy.
[2] EY's Attractiveness Survey, Scotland, June 2018.
[3] The 2017 EU Survey on Industrial R&D Investment Trends. Figure based on 141 responses from major R&D investing companies. The surveyed firms had a total global R&D investment of €54bn in 2016/17, accounting for over one quarter of the total R&D investment from the top 1,000 R&D companies worldwide.
[4] London Economics (2017), The economic impact of Russell Group universities, Final Report for the Russell Group..
[5] HESA, Higher Education – Business and Community Interaction Survey
[6] Ibid.
[7] Scottish Government, Gross Expenditure on Research and Development 2017.
[8] UKRI, Innovate UK Funded Projects since 2004.
[9] Scottish Government, Labour Productivity Statistics.
[10] ONS Research Database and Bank of England calculations: https://www.bankofengland.co.uk/-/media/boe/files/speech/2018/the-uks-productivity-problem-hub-no-spokes-speech-by-andy-haldane. Growth in firm productivity between 2004 and 2014 was 13% on average a year for the top 0.1% of firms in Scotland, 7% for the top 1% of firms, and 0% for 99% of firms
[11] Andrews et al. (2015), 'Frontier firms, technology diffusion and public policy: micro evidence from OECD countries. OECD.
[12] Schneider (2018), 'Decomposing differences in productivity distributions.' Bank of England Staff Working Paper No. 740. https://www.bankofengland.co.uk/working-paper/2018/decomposing-differences-in-productivity-distributions
[13] The Growing Value Scotland Task Force (2016), "The Step Change – Business-University Collaboration powering Scottish Innovation". The Royal Society of Edinburgh, (2015), Discussion paper, "Entrepreneurial Education in Scotland".
[14] See: Scottish Government, Enterprise and Skills Review report on Phase 2: Innovation for a summary of evidence.

4. Scotland's Innovation and Research Landscape

The innovation system in Scotland, as elsewhere, is complex and any attempts to raise the performance of the system must pay attention to the operation of the system as a whole.

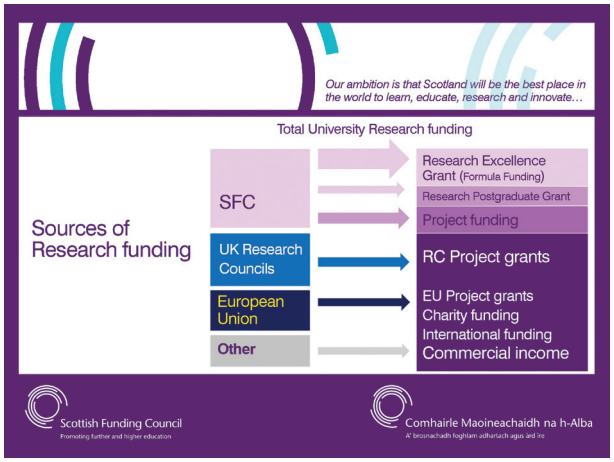
This complexity arises because there are many interdependent and non-linear components and few single chains of cause and effect. There are many actors, both individual and institutional, that are involved in producing research and innovation outputs, including government, public services, higher and further education, business and industry, financial markets, customers and the public, as well as charities.

This report focuses on the interface between Higher Education and businesses but, as outlined above, there are a number of other actors and factors that will be important to understand in order to drive that improved innovation performance in Scotland.

Higher education institutions

The four UK higher education funding bodies or equivalents[15] (in Scotland, the Scottish Funding Council (SFC)) provide universities with an annual block grant to support their strategies for research excellence. This stable and predictable core of infrastructure funding also supports universities to co-fund project funding from the UK Research Councils and wider, such as the European Commission's Horizon 2020 programme[16]. This is commonly referred to as the UK dual support system. In Scotland this funding is provided by SFC's Research Excellence Grant (REG).

Figure 1: Sources of University Research Funding in Scotland



The research excellence of the UK's universities is measured approximately every 6-8 years by the Research Excellence Framework (REF) the last exercise concluded in 2014 and the next exercise will conclude in 2021. The REF outcomes inform the main component of the REG formula[17].

The research pooling initiative[18] was created by SFC in 2004 to encourage researchers across Scottish higher education to pool their resources into research collaborations of scale and thereby respond to increasing international competition through contributing to research excellence in Scotland. An independent review of the research pooling initiative was published in September 2019.

The underpinning research excellence supported by this system is the main asset from which universities work with businesses and create impact. It should be noted that impact is also captured by the REF exercise through 'impact case studies' and the criteria for Research Council proposals include 'pathways to impact' statements. Therefore, while the dual support system is focused on research excellence, it also seeks to sustain a culture where the potential impact from research forms part of any research endeavour from the outset – and impact therefore drives funding.

Knowledge exchange

The four UK funding bodies also invest in the university knowledge exchange infrastructure. In Scotland this is the University Innovation Fund (UIF). The UIF has helped universities to build capacity for effective knowledge exchange which in turn drives greater innovation in the economy.

The UIF aims to deliver seven outcomes which are aligned with Scottish Government strategy[19]. This includes: "**working with Scotland's Enterprise Agencies (EAs), Scottish Government, business networks, Interface and others, Scottish HEIs will have helped to increase the demand and quality of engagement from businesses and the public sector for university services.**"

Interface with business

UIF funding is primarily used by universities to support university research and commercialisation offices which act as critical interfaces for university/business engagement[20].

The university interface is improving continuously. This is being driven in a collaborative way by the university sector and the UIF is helping to incentivise further this shared improvement. Universities Scotland's Research and Commercialisation Directors' Group (USRCDG) has a role to help the sector identify and apply good practice. For example, in 2015 universities adopted a shared contract and guidance for the SFC Standard Innovation Vouchers scheme to ensure businesses have the same experience with every university. Scotland's enterprise agencies are partners in this approach to continuous improvement.

4. Scotland's Innovation and Research Landscape

SFC, in partnership with Scottish Enterprise and Highlands and Islands Enterprise (HIE), funds Interface, the knowledge connection for business, which is detailed further below.

Interface

Interface complements the university interface by providing an impartial single point of access for businesses wishing to partner with a university. This is particularly useful to businesses that have not worked with a university before.

The Interface service is unique in joining up all universities and research institutions across a region/ place to provide one central point of access for businesses and organisations seeking to access knowledge, expertise, facilities or technologies. The Interface business model offers economies of scale for universities and research institutions to stimulate demand and reach companies and businesses effectively, signposting away non-relevant enquiries.

Interface has introduced more than 2,928 businesses to academic partners and its success story is reflected in the following (as of 30th April 2019):

- 1,972 company and university collaborative projects initiated
- 97% of businesses said their project would either have not happened or taken longer without Interface
- 83% of businesses recorded reduced operating costs, increased productivity, profits, export, turnover and new or safeguarded employment

Companies supported by Interface add an estimated £64.2 million GVA into the economy each year through new services, processes or products, or efficiencies leading to cost savings.

SFC, in partnership with Scottish Enterprise, HIE, and the Scottish Government, funds the Innovation Centre (IC) programme[21]. There are currently eight ICs in operation. The ICs act as sector or technology interfaces between business, universities and colleges. The IC programme is in its second phase – the ICs now have modest project budgets and an increased focus on working with universities and businesses to win competitive funding such as UK Industrial Strategy funding.

Another part of the university interface with business is University Technology[22] which was formed in 2004 by Scotland's universities. This is an easy-to-access IP platform in the form of a website providing a single location to enable companies and investors from business and industry to find new technologies and technology transfer opportunities in Scotland.

At the UK level the Knowledge Transfer Network (KTN) "… helps businesses get the best out of creativity, ideas and the latest discoveries, to strengthen the UK economy and improve people's lives.[23]"

Funding collaboration with businesses

SFC's REG and UIF both contribute to the ability of universities to engage with businesses, create businesses, and win collaborative innovation funding.

HEI research and innovation is, on average, not conducted at Full Economic Cost and therefore must be cross-subsidised by other sources. The recovery of FEC for Scottish HEIs in 2016/17 was 80.1%. The comparable figure for the UK is 71.7%[24]. Some additional funding streams from Scottish and UK public bodies can assist with the direct or marginal costs of the initiatives which they fund.

The funding of university-business collaborations happens across different routes, designed to facilitate and overcome barriers at different point in the research and innovation pipeline.

A detailed outline of the funding ecosystem is included in Annex G.

Universities and the balance of research and innovation activity

The economics of research and innovation in universities is often poorly understood outside Higher Education. As noted above, most research conducted in Scottish and UK Universities, including PhD training, is done at an economic loss. Universities usually cover the direct costs of research and PhD training, but will not recover the cost of infrastructure or buildings used as part of this work. Often this infrastructure is expensive and specialised and needs to be in place to conduct the research. This means, for example, that attracting funding from an external source (e.g. UKRI) would not meet FEC of research and innovation work, implying that additional funding would be required from another source.

Carrying out UK-funded, publicly-funded research at a loss is a strategic decision by universities and one that is a dynamic balance if done properly. Very roughly, more research drives reputation and league table performance and thus profitable international student income to subsidise research. To some extent, decisions on the level of FEC which UK public funders choose to fund at is also a strategic one vis-à-vis the UK Government's desire to balance volume of research funded and price.

Even industry-funded innovation work is run at a loss: industry-funded innovation work in universities is often carried out at marginal cost plus a margin which does not cover full economic costs. This is because in some countries research infrastructure is provided through public funding and research institutes so universities can therefore afford to price research for industry below full economic costs, unlike Scottish and UK universities which have to fund their own capital base.

Universities' investments in translational facilities (see Annex D), which seek to bring industry closer to University research, may similarly not cover the life-time costs of this activity.

The 2016 McMillan review of good practice in technology transfer indicates that universities undertake this activity as

part of their mission to deliver impact for society. The review notes that universities have always had missions that reflect societal contribution but that this is now further driven by the continuing high priority for the Scottish Government to create economic impact as reflected in national policies, most notably the inclusion of 'impact' in the Research Excellence Framework (REF). The review also points out that activities related to licensing and spin-out creation are expensive and are almost always a cost base to universities rather than an income stream[25].

These losses in research and innovation work by universities will usually be cross-subsidised by non-publicly funded teaching and training, where universities make a margin above total costs. The implication is that it may be difficult for Scottish and UK Universities which do not have sufficient numbers of international and postgraduate fee-paying students to have the resources to engage in an unconstrained way with research and innovation. This means that the HE sector's capacity to engage in knowledge exchange activities will be determined only in part by the availability of research and innovation funding, or Scotland's ability to attract such funding from external sources. A more binding constraint is the sector's ability to grow its non-public/unregulated teaching income so that institutions can co-fund research and innovation activity. This may require the sector to specialise more, so that research and innovation is focused on those institutions that are able to fund it in a sustainable way.

As we highlight in our recommendations in Section 6, the fact that research and innovation activity is done at a loss means that careful thought should be given to how SFC should distribute REG and UIF funding, if it wishes to maximise the impact of a given quantum of public funding through these streams. It is also wrong to simply suggest to universities that a solution to financial pressures lies in gaining more research funding from outwith Scotland (e.g. from UKRI, EU, or other sources). If an institution is running at a loss in terms of cash generation, taking on additional loss-making activities will simply make things worse. It is only by increasing those sources of funding which generate an FEC surplus (e.g. non-publicly funded surplus), that Universities can build more financial muscle to improve Scotland's ability to expand its research and innovation activities with industry.

Wider innovation system

The overall innovation and commercialisation ecosystem of the country or region is fundamental to the performance capability of a university. For example, availability of proof of concept funding, venture finance and management capability are key to the creation of successful spin-outs, and the presence of larger R&D companies are essential for the absorptive capacity for research collaborations, contracts and licences with indigenous companies.

Exploration of all aspects of this wider system is beyond the scope of this review but building up the evidence base on the workings of the whole ecosystem will be important for maximising the economic impact of Scotland's research and innovation activities.

[15] Scottish Funding Council, Research England, Department for the economy Northern Ireland, Higher Education Funding Council for Wales
[16] The UK's eligibility to Horizon Europe, the successor programme to H2020, was not known at time of writing.
[17] http://www.sfc.ac.uk/funding/university-funding/university-funding-research/university-research-funding.aspx
[18] http://www.sfc.ac.uk/research/research-pooling/research-pooling.aspx
[19] http://www.sfc.ac.uk/innovation/innovation-funding.aspx
[20] They are not the only interface at the university level. For example, business can and do interface with universities at faculty level.
[21] http://www.sfc.ac.uk/innovation/innovation-centres/innovation-centres.aspx
[22] http://www.university-technology.com/home.aspx
[23] https://ktn-uk.co.uk/about
[24] SFC, Annual Transparent Approach to Costing 2016-17. The Transparent Approach to Costing (TRAC), introduced in 2000, is the standard methodology used by higher education institutions (HEIs) in the UK for costing their activities. It was established as an approach to identifying the Full Economic Costing (FEC) of all activities to improve the accountability for the use of public funds and inform institutional decision making. These figures include income receipts which may not be matched by the related expenditure and so result in volatility in the surplus/ deficit results.
[25] 'University Knowledge Exchange (KE) Framework: good practice in technology transfer,' Report to the UK higher education sector and HEFCE by the McMillan group. September 2016.

5. The Case for Investment in R&D in Scotland

Scotland's Economic Strategy places inclusive growth at its heart – recognising that growth should be made to benefit all of our communities, creating better jobs and hopefully stimulating additional growth which will in turn help to further reduce inequality with a fair allocation of resources.

In modern economic theory, it is well established that two key drivers of economic growth are skills development and R&D. Higher Education sits at the heart of both these processes, which is why universities are key drivers of the economy.

Economists estimate the private rate of return from a company's own R&D spending is about 27% and the social rate of return from spillovers is higher[26]. Companies also experience significant returns when they collaborate with universities on innovation activities – recent studies at the UK level show that collaborating with HEIs is associated with increases in firm-level total factor productivity[27, 28] with one estimate suggesting this is 12% higher for businesses collaborating with HEIs in the UK[29]. The evidence also suggests that the impacts are significantly larger for businesses that are technologically closer to universities[30]. At a more local level, this is seen in the case studies throughout this report and numerous examples of successful HEI-business collaboration in Scotland, for example the Medicines Manufacturing Innovation Centre, the Informatics cluster in Edinburgh, the Clinical Innovation Zone around the Queen Elizabeth University Hospital, and many others, such as those outlined in Annex I.

In spite of these significant benefits, the private sector is often unable to meet the full costs of R&D, due to the associated uncertainties around outputs and timescales and the fact that social returns from R&D can significantly exceed private returns. As already established, universities very rarely meet their Full Economic Cost from their ventures in this area. For some businesses, there may be an information market failure around awareness of the benefits of innovation activities.

This is why the public sector has a key role, both in providing direct support for R&D activities and increasing the visibility and awareness of such activities. As Mariana Mazzucato notes: "From the Internet to biotech and even shale gas, the [public sector] has been the key driver of innovation led growth – willing to invest in the most uncertain phase of the innovation cycle and let business hop on for the easier ride down the way."[31]

Equally importantly, R&D spending has a significant social rate of return[32]. Evidence from the OECD shows the benefits from R&D spend are not only from producing innovation but also from improving the adoption of existing ideas[33]. Research carried out by universities drives knowledge exchange but is also hugely important in developing the absorptive capacity of businesses and researchers to exploit the benefits of research carried out internationally, attracting a research and talent base, and increasing attractiveness to inward investors.

In essence R&D helps drive productivity and this lies at the heart of why many countries subsidise R&D, both through tax incentives for private R&D spending and through public R&D investment through the research base (including universities).

Research can also drive vital social returns, such as through improving public health, better governance and policy-making. For example, the development of a vaccine for an infectious disease provides monetary returns to the vaccine developer and social returns through improved public health.

The vast social returns are what underpin the rationale for public investment in research. Without public support for university-based research, wide-ranging and important business and societal challenges would go unaddressed due to the social returns significantly exceeding market returns.

Interestingly, evidence from the EU, UK and the USA at regional level also shows that R&D spending, the stock and investment in skills and fixed capital investment are major determinants of differences in growth[34] and that increased R&D spending's impact on growth in the EU countries often comes through export growth[35].

Productivity spillovers from public R&D in the UK have been evidenced in a number of reports[36]. As mentioned above, a recent report on the economic impact of Russell Group universities estimated that for every £1 invested in research activities at Russell Group universities, an additional annual economic output of £5.50 is generated across the UK economy. This results in total productivity spillovers of approximately £31.26 billion[37]. Another study found that for every £1 the Research Councils spend on research, an additional annual output of £12.70 is generated by UK companies[38].

Public investment in research and development can drive virtuous cycles of private investment and innovation, as quality research attracts international talent which in turn attracts global companies – all of which results in further advances in both knowledge creation and exploitation. There is evidence of a positive correlation between public and private investment in R&D and empirical studies tend to suggest that public funding 'crowds-in' private funding. A recent UK study estimated that an extra £1 of public funding of research will give rise to an increase in private funding between £1.13 and £1.16, and that an extra £1 of public expenditure on HEI research leads to £0.29 of private funding of HEI research and £1.07 of research conducted elsewhere[39].

It is important to recognise that Scotland does not currently have the full range of economic levers at its disposal which other comparator OECD economies, listed in Figure 6 in Annex F, use to stimulate innovation and R&D spending.

Economists highlight a number of policies which nation states can take forward to promote innovation and to drive productivity growth, and the potential effects on the inclusive nature of that growth: Direct R&D grants; R&D tax credits; Patent box policies; Skilled immigration; Incentives for Universities; STEM/skills supply; Trade and competition; Intellectual property reform; and Mission-oriented policies[40].

Of these only a very few are currently devolved to Scotland. This is important: when we compare the policies which a number of innovative small OECD economies (see Annex F) have undertaken on the fiscal incentivisation of R&D, these

tools are not available to the Scottish Government. In broad terms, none of the tax-incentive schemes to boost business investment in R&D are available, nor the immigration policies to boost human capital and skills to drive innovation[41].

This only leaves the spending channels. If the social return from R&D is very high – and private R&D subsidies through tax incentives are not possible because the fiscal levers are not available – then direct public R&D spending can help to crowd-in private investment and drive significant economic and social returns, providing that the public investment is targeted appropriately.

As has been widely recognised, Scotland's challenge is how one can ensure that, given a certain level of HERD spending, more could be generated in terms of BERD.

Of course not all of the spillover effects from public spending on R&D will happen through the BERD channel. The transfer of knowledge to business and industry could happen through the adoption of new production methods and investment spending, or through intangible or knowledge investments – not all of which are R&D spend by companies[42]. Nevertheless, one would expect some of the spillover effects to occur through the BERD channel, given the evidence that public investment in R&D crowds in private investment.

One question to be addressed at the outset is whether redistributing any funding spent on research and innovation (e.g. SFC's UIF, or even elements of REG) from HE to industry might be able to support an increase in BERD. The answer is no, for three reasons.

First: the current funding system provides support across the whole innovation spectrum, and in my judgement offers a balanced support of basic/discovery, applied and translational research (see Annex D for definitions). A shift in the balance of support would be a very risky strategy. When Ireland tried such a shift in approach away from basic and towards applied research in its universities this had to be reversed subsequently. Such evidence as currently exists suggests that a healthy level of HERD while not a sufficient condition, is a necessary condition for increased BERD.

Second: as has been highlighted, the Scottish research ecosystem is highly integrated in the European research ecosystem: a shift in balance will probably lead to a loss in HE research capacity (people and talent) which would then shift to neighbouring countries (both within the UK and neighbouring European countries). It would also hamper efforts by the Scottish Government to attract highly-skilled talent to Scotland. The focus on university-based research in the EU is likely to be cemented through the next Horizon Europe Programme. Jean-Pierre Bourguignon the outgoing President of the European Research Council (ERC) noted[43] that the university research funded by the ERC, notwithstanding its sole focus on academic excellence, resulted in a much bigger direct impact on innovation than might have been expected given its share of funding in Horizon 2020.

Third: given the fragmented nature of the business base in Scotland dominated by SMEs, rather than large R&D-intensive industrial players, it's not obvious which actors in the private sector would play the complex co-ordinating role which would be required in the innovation space. As noted above, innovation has a public good element because of its spillover/external effects which means some elements of R&D activity are under-supplied in a market economy.

This implies that if Scotland wants to increase BERD, there are four routes which could be followed. These four approaches are not mutually exclusive.

1. We could strive to make the Scottish research and innovation system even more effective. Ensuring that public investment through existing funding streams through HE (e.g. REG, UIF) or directly funding Scotland-specific innovation activities (e.g. ICs) can have more impact and leverage on BERD. Although much progress has been made in enhancing collaboration between HEIs and industry in Scotland, and across the HE sector, arguably more could be done. Some of the machinery (e.g. the creation of the Enterprise and Skills Strategic Board) has been put in place to encourage greater co-ordination of action between public agencies. Universities are collaborating actively around particular projects. However, there are examples of areas where naturally complementary activity in translational areas in different HEIs does not lead to collaboration.

2. One could seek greater co-investment by the private sector. Other innovation economies (e.g. Germany) have been very successful in leveraging industrial investment into interface institutes such as Fraunhofer. Other smaller economies have sought to encourage their industrial base to co-invest in R&D and innovation activity. In the recommendations section I explore whether ways could be found to ensure greater R&D activity linked to inward investment in Scotland.

3. Ensuring that the University system properly incentivises innovation activity within its research base and focuses sufficient support towards the innovation end of the research and innovation spectrum. This would need to be done with care – without weakening Scotland's competitive advantage in discovery-based research.

4. There is scope for the public agencies to gain more of an evidence base on the innovation spillover effects for the Scottish economy, to understand the effectiveness of public R&D spend on stimulating productivity and economic growth, some of which will happen through boosting private R&D spending and some through other channels[44]. The public agencies can also help to ensure that Scottish HEIs can maximise access to sources outside Scotland (e.g. leveraging more UK-wide funding through the UK industrial strategy and Innovate UK funding) to boost innovation spend. This may lead to greater specialisation in Scotland's HE sector over time.

The recommendations section explores a variety of actions aimed at addressing these four areas. Again, these will be actions for all actors in the field – Government, universities and industry – recognising that while governmental action is crucial, a genuine team approach is needed to make Scotland meet its full economic potential as an innovative nation.

[26] See Griffith, R. (2000), 'How Important is Business R&D for Economic Growth and Should Government Subsidise it?" Institute for Fiscal Studies, Briefing note n.12, October, and Griliches (1992), 'The Search for R&D Spillovers', Scandinavian Journal of Economics, vol. 94, p. 29 – 47.
[27] Haskel, J., & Wallis, G. (2010). 'Public support for innovation, intangible investment and productivity growth in the UK market sector'. http://ftp.iza.org/dp4772.pdf. Their findings imply that every £1 spent on university research through the Research Councils results in an additional annual output of £12.70 in UK companies.
[28] Haskel et al. (2014) found the impact of general public research to be 0.2 (i.e. every £1 spend on public R&D results in an additional annual output of £0.20 within the UK private sector
[29] Harris et al. (2011), The impact of higher education institution-firm knowledge links on firm-level productivity in Britain. Applied Economic Letters: 18, p. 1243 – 1246.
[30] Kantor and Whalley (2009). 'Do Universities Generate Agglomeration Spillovers? Evidence from Endowment Value Shocks,' NBER Working Paper No. 15299.
[31] Mariana Mazzucato. 2010. "The Entrepreneurial State: Debunking Public vs. Private Sector Myths." Anthem Press.
[32] Griffith (2000), How Important is Business R&D for Economic Growth and Should the Government Subsidise it?, Institute for Fiscal Studies, Briefing Note No. 12.
[33] Griffith, Redding and Van Reenen, Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Countries, The Review of Economics and Statistics, vol. 86, p. 883 – 895.
[34] Frenz and Oughton (2007), Innovation in the UK Regions and Devolved Administrations: A Review of the Literature. Final Report for the Department of Trade and Industry and the Office of the Deputy Prime Minister; Buegelsdijk et al. (2018), Regional economic development in Europe: the role of total factor productivity, Regional Studies, 52:4, p. 461 – 476.
[35] Bayar et al. (2007), An Analysis of R&D Spillover, Productivity, and Growth Effects in the EU. Knowledge for Growth: Role and Dynamics of Corporate R&D, First European Conference, 8th – 9th October 2007.
[36] Haskel et al. (2014) found the impact of general public research to be 0.2 (i.e. every £1 spend on public R&D results in an additional annual output of £0.20 within the UK private sector.
[37] London Economics (2017), 'The economic impact of Russell Group universities', Final Report for the Russell Group. https://www.russellgroup.ac.uk/media/5608/the-economic-impact-of-russell-group-universities.pdf
[38] Haskel, J., & Wallis, G. (2010). 'Public support for innovation, intangible investment and productivity growth in the UK market sector'. http://ftp.iza.org/dp4772.pdf.
[39] Economic Insights Ltd., 'What is the relationship between public and private investment in science, research and innovation?', A report commissioned by the Department for Business, Innovation and Skills, April 2015.
[40] See N. Bloom, J. Van Reenen and H. Williams: ''A toolkit of policies to promote innovation", Journal of Economic Perspectives, Volume 33, Number 3—Summer 2019—Pages 163–184. The article is simply a useful summary of the 'toolkit' for innovation policy, although the authors recognise that their take on the relative effectiveness of different tools is highly subjective: for instance they are sceptical of mission-oriented policies.
[41] See also https://www.oecd.org/sti/rd-tax-stats.htm
[42] Indeed Haskel and Westlake (2017) illustrate the importance in the modern economy of investment by companies on intangible (or knowledge) assets, such as software, design, branding (and indeed R&D) not all of which is captured in official data.
[43] Jean-Pierre Bourguignon noted in his speech to the Royal Swedish Academy of Sciences on 23 May 2019 that: "The decision by the ERC Scientific Council to refuse to distinguish between pure and applied research retaining the expression "Frontier Research" for the programme has proved very successful; ERC grantees have given many examples of the production of totally unexpected applications, with very concrete and sometimes spectacular effects in society; a solid proof of the validity of this approach is the share of ERC projects among EU-funded projects in Intellectual Property Rights is far greater than the ERC budget, share when one would have expected the opposite (29% versus 17% in the 7th Framework Programme, and an even higher difference in Horizon 2020); this is very far away from the image of researchers living in their ivory tower; actually, a significant number of them went all the way to create spin-off companies;… One of the vehicles for this broader action is the Proof-of-Concept programme introduced by the ERC Scientific Council; it enables researchers, who, along the way of doing their research, see the possibility to get closer to markets or to respond to a societal need to be accompanied in their first steps; another positive way of encouraging researchers to explore new territories…"
[44] The OECD's Directorate for Science, Technology and Innovation has developed a project which examines a "distributed" approach to the empirical analysis of business R&D micro-data. The microBeRD project looks at the structure, distribution and concentration of business R&D and sources of R&D funding across countries and models the incidence and impact of public support for business R&D. See https://www.oecd.org/sti/microberd.htm

6. Conclusions and Recommendations

The central conclusion of this report is that there is much activity already taking place within the Scottish innovation system which will deliver for the Scottish economy and that there has been significant progress in collaboration between Universities, public agencies and industry over the past decade. However, there remains significant room for improvement.

Most of the consultees for this review recognised that more could be done to foster a greater degree of ambition. The Scottish Government has already made clear its determination that Scotland should become a world-leading entrepreneurial and innovative nation and is steering collective action accordingly through its CAN DO Innovation Action Plan. The Scottish Government has also already set a target for R&D investment for Scotland, aiming for business research and development (BERD) to reach £1.7bn by 2025.

Therefore, the recommendations below are about creating a clear sense of a shared national mission around the need to boost innovation and R&D activity (and BERD in particular). Most of the consultees recognised that greater collaboration is the key to achieving such a national goal and many of the recommendations focus on setting the right incentives to foster collaboration and monitoring that collaborative effort.

At a time of constrained public funding, the recommendations also recognise that public agencies, on behalf of government, may have to make choices to ensure that the investment made in publicly-funded R&D is good value for money, delivers maximum impact in terms of national R&D activity, and is appropriately focused, as well as ensuring that the Scottish HE research and innovation system,which is highly competitive internationally, remains sustainable.

A number of consultees also recognised the importance of setting clear priorities for innovation in Scotland that were congruent with strategic sectors, i.e. where Scotland has major strengths in basic research and this can act as a pole of attraction of innovative international or UK companies wishing to invest here; or where we have highly-innovative and productive companies which can help to drive the economy in the 21st century and where we should encourage more applied research by the HE sector. While there may always be a temptation to be comprehensive in the approach taken to innovation, it would perhaps be helpful to take a more selective approach.

It is clear what some of these sectors should be: sectors such as Precision Medicine, life sciences, engineering (including advanced manufacturing, quantum and nanotechnology); financial and business services; and creative, cultural and digital industries have immense potential and enjoy both high levels of public and private R&D spending, and so should be seen as clear priorities.

A truly national mission

Governments around the world have set ambitions for the level of R&D investment they want to see in their economies. The EU recognises that R&D spending is an important driver of economic growth, and has set a target for 3% of the EU's GDP to be invested in R&D, whereas countries such as Germany have been very successful in driving strategies to increase R&D spending. This has led the UK Government recently to set out a strategy to increase the UK's level of R&D spending to 2.4% of GDP by 2027 through its Industrial Strategy.

As mentioned above, the Scottish Government has set a target for business R&D (BERD) to reach £1.7bn by 2025. It is imperative that this becomes more than a government target, but becomes **a shared national mission** for institutions across all sectors in Scotland. Universities and the public funding agencies must ensure that they play an active role towards achieving this ambition if they are in receipt of public funding for research and innovation.

A number of consultees also highlighted the view that a national ambition for increasing the level of innovation in the Scottish economy could galvanise the activity of actors involved towards turning what is a current government target into a collective ambition for Scotland.

1) The first overarching recommendation is that all actors in the field – agencies, universities and industry – should adopt the Scottish Government objective of turning Scotland into a world-leading innovative nation as a shared national mission.

- The HE sector for its part should articulate and signal a number of commitments set out in this report to work more closely together for Scotland's benefit, while the Scottish Government and its agencies should commit to doing everything possible to facilitate this. A number of recommendations below highlight some of the actions which could be taken by universities.
- SFC and the other Enterprise and Skills Agencies should, in turn, with the HE sector, lead on this mission, endorsed by the Scottish Government, to turn Scotland into a world-leading innovative nation.

2) As previously set out, Scotland seems to underperform other parts of the UK in terms of accessing Innovate UK funding (though our HEIs perform relatively well). In order to maximise how Scotland benefits from major external funding streams through, for example, the UK Industrial Strategy, SFC and the Enterprise Agencies should set a target for Scotland to attract investment for innovation activity from external sources.

Maximising collaboration between HEIs is also key to fulfilling a national innovation mission. Arguably universities already collaborate strongly in Scotland. Research data demonstrates the strong collaborative links, with around 10% of academic publications from 2007-2016 having national collaboration between Scottish HEIs, and 4.7% having corporate collaboration[45]. Similarly, there is evidence from some industry-focused initiatives (e.g. The Edinburgh City Deal, the Creative Industry Clusters bids led by Abertay and Edinburgh (Napier/Edinburgh), and the iCAIRD initiative (based at the QEUH/University of Glasgow but also involving Universities of Aberdeen, Edinburgh and St Andrews)) that Scotland is able to collaborate successfully.

However, more could be done to encourage closer collaboration, both between HEIs and with industry.

6. Conclusions and Recommendations

3) To ensure Scotland is equipped to succeed in this aim, a mechanism to ensure greater collaboration and coordination in bidding for UK funding streams is needed, preventing actors in Scotland from pursuing conflicting objectives or duplicating efforts.

- The Scottish Government, its agencies, universities and industry should come together to consider the most appropriate mechanism for doing so.
- This may depend on the particular funding streams in question. For instance, a major bid around one element of the UK industrial strategy which should be led by industry might best be co-ordinated at Scottish Government level, with expert input from the Enterprise Agencies and SFC. UKRI competitions, which are expected to be university-led, might best be co-ordinated by SFC.

4) Each HEI has strong networks and should help Scotland in its ambitious export strategy. HEIs, through Universities Scotland, should work closely with Scottish Development International (SDI) and Directorate for International Trade and Investment officials in Scottish Government to ensure that we are maximising our impact on trade, including identifying ways to effectively use existing international networks.

- In particular, HEIs should consider how they work in a Team Scotland way in priority export markets set out in *A Trading Nation* and public agencies should be willing to offer all the support necessary.

Richard Lochhead, Minister for Further Education, Higher Education and Science, recently set out the importance of Scottish universities' alumni to Scotland's global ambitions in terms of inspiring current and future students, helping businesses export and build connections, and promoting Scotland internationally[46].

5) HEIs might encourage some of their most influential alumni to join a network of people able to help connect Scotland with potential inward investors.

- Scottish Government, SFC, SDI and HEIs could work closely together around how, in a manner akin to the Globalscot Network, this might operate.

The strongest foundations

As we strive to make Scotland meet its full potential as an innovative economy, it is important that we are equipped with the right tools – to take both positive action and to help understand where there are currently areas for improvement.

First, we should not be afraid to reflect openly and honestly on the areas in which we are currently struggling – as has already been set out, one such area is in attracting Innovate UK funding to Scotland. Another area where we need to improve, which we turn to below, is trying to increase industry funding into both commercialisation activities and into joint innovation activities in Scotland. A further area is: how we can improve the flow of early-stage capital into university spin-outs and high-growth potential innovative Scottish-based companies.

We must also recognise the ways in which we are currently constrained in our actions. As pointed out in Section 5, Scotland does not currently have many of the policy levers available which comparable economies are able to utilise around R&D tax incentives and R&D policy.

While the precise nature of the devolution of powers will continue to be a matter for politicians, it seems clear that, if we are indeed to see us meet our full potential as an innovative economy, we require the same tools of which our competitor economies have made such effective use. I would urge all actors in the field – government, industry and the HE sector – to think about how additional powers might be devolved around innovation policy, or at least shared between the UK and the devolved nations, to allow policies tailored towards Scotland's specific challenges.

Neither of these actions will change anything in and of themselves but will ensure our efforts to see Scotland at the forefront of innovative economies around the world are built on the strongest possible foundations.

6) As already set out, many of the basic policy tools utilised by comparable countries to promote innovation and to drive productivity growth are not currently devolved to Scotland. The Scottish Government, supported by the HE sector, should continue to call for powers over skilled immigration to be devolved to the Scottish Parliament. It should also explore the possibility with the UK Government of introducing some flexibility in R&D tax incentives between the UK devolved nations. This would allow policies tailored to the needs of the HE sector and industry in Scotland and to allow us to unlock our full potential as an innovative nation.

Securing the strongest foundations also requires us to maximise the resources from the private sector. Below I look at ways in which universities might be able to attract more investors to drive Scotland's innovation ecosystem through additional investment into joint innovation activities and infrastructure in Scotland. This could help to leverage more resource at a time when public spending is constrained.

Turning to financing of early-stage innovation: as is well-documented, the UK and Europe more generally, are not as well served for patient capital, which might invest in the opportunities which Scotland's research and landscape offers, although this is not a Scottish-specific problem per se (c.f. The Treasury's Patient Capital Review[47], and Mike Rees' Review for Research England[48]). Indeed, through the funding provided by Scottish Enterprise, Scotland has fared relatively well, with Scottish Enterprise accounting for the second largest number of deals in the UK[49].

A number of UK universities and consortia have tried to mitigate this problem by developing pooled investment funds for early proof-of-concept funding and early-stage funding. Addressing this issue is beyond the scope of this review and would require a detailed review of these issues.

Nevertheless, ensuring a pipeline of funding ranging from early proof-of-concept funding to seed-capital and longer-term patient investment is a key issue to ensure that Scotland can take advantage of its active research base. The formation of the Scottish National Investment Bank (SNIB) could also

be helpful in this regard, especially if it focuses on some of the missions which are a key part of Scotland's innovation strategy.

7) The Scottish Government should investigate Scotland's relative competitiveness in the area of early-stage capital in innovative firms (both university spin-outs and Scottish companies which develop through access to the University research base) in order to allow greater insight into how we turn Scotland's world-class research base into innovation.

- This undertaking should seek to benchmark how Scotland fares relative to other parts of the UK and some of the most innovative small EU economies and identify any lessons for Scotland.
- As the SNIB begins to operate, it should also be asked to see how it can maximise Scotland's competitiveness in this area, particularly as it takes over a number of areas of funding previously provided by Scottish Enterprise.

Clarity of purpose

Internationally-successful small economies, including Finland and Denmark, have consistently prioritised innovation through public investment and national policy. Countries such as South Korea also placed innovation at the heart of their economic development strategy over the past 40 years and as a result continue to excel on measures of technology and innovation.

Finland has transformed itself into one of the most innovative and productive countries in the world by consistently placing innovation at the heart of government policy. Finland has faced recent economic difficulties but its innovation assets remain strong and there is evidence of universities being at the heart of the recovery. Innovation is actively coordinated at the highest level – the Research and Innovation Council, established in 1987, is chaired by the Prime Minister and encourages a systematic, whole-of-government approach.

Denmark has one of the highest levels of innovation spend internationally at 3.06% of GDP in 2017, prioritising research efforts into selected areas with greater societal challenges, for example: energy, the environment and climate. The Danish Government has also created a number of growth teams in areas where Danish businesses have strengths and potential to ensure optimal growth conditions and address barriers as well as providing opportunities for developing markets. These include: water, bio and environmental solutions; energy and climate; tourism and leisure economy; creative business and design; and digital growth.

A number of consultees recognised the importance of setting clear priorities for innovation in Scotland which were congruent with strategic sectors. This could either be where Scotland has major research strengths which could act as a pole of attraction for innovative international companies looking to invest; or where we already have highly innovative companies which would benefit from the encouragement of more applied research by the HE sector.

Focusing resources in developing the interface between universities and industry is important. Focus is slightly less important with smaller-scale knowledge exchange activities, such as initial university spin-outs, consultancy work with companies or licensing agreements, as this will be driven by bilateral HE-industry links or individual market-led initiatives. When it comes to developing large knowledge transfer projects which require bigger investments in activities at the HE-industry interface (e.g. SFC Innovation Centres, HEI-funded Innovation centres) or large capital investments to develop physical spaces to co-locate both major companies and SMEs into physical clusters, such as innovation zones and districts, this requires a degree of strategic planning and focus at national level. Indeed, many of these larger scale physical infrastructure developments are increasingly driven by HEIs with City and Scottish Government support (e.g. NMIS). No single small economy can excel in all the potential innovation areas and therefore some clarity of purpose is required.

How this focus should be achieved, or national priorities should be set, is less straightforward. In discussion with public agencies and industry groups, as well as HEIs, there is, unsurprisingly, no single view of which areas should be prioritised. There is also a strong view that this is not simply about simply setting out a list of priority sectors which will be the exclusive focus for receiving support. Taking a simple sectoral view is dangerous because traditionally governments and public agencies do not have a strong track record in 'picking winners'. It is also clear from what I have heard from industry that much innovation activity crosses sectoral boundaries and is built around enabling technologies. Some of the SFC Innovation Centres (e.g. CENSIS) are built around enabling technology themes. Industry also emphasised to me the benefits which they perceive from physical clustering activities which cut across different sectors but around enabling technologies (e.g. the impact which nanotechnology expertise can have in sectors as varied as Space technologies, quantum imaging, and Medtech). Another prism through which one could be focussing is 'mission-oriented investments', e.g. the national effort which will be required around achieving carbon neutrality by 2045. The SNIB's mission-oriented focus is also important in the setting of national priorities.

One important issue around mission-orientation is that it also depends on the resolution of the current Brexit crisis and Scotland's future. No small country can set the mission-orientation of its innovation strategy in isolation. The EU is currently defining the mission-orientation of its research and innovation investments as part of the definition of the Horizon Europe programme. If Scotland retains a close association with Horizon Europe then it should be setting its mission-oriented innovation strategy in a way which is complementary to that European effort.

We are also not starting with a blank sheet of paper. Some of these sectors and areas of technology on which Scotland's innovation effort is currently focused have already been identified by the Enterprise Agencies, by SFC in the formation of the Innovation Centres (some of which are defined wholly or partially by sector and some by technology area), and by HEIs, in setting up translational units to drive innovation from their research base.

6. Conclusions and Recommendations

I believe that there would be benefits for Scotland, in terms of setting our ambition for the country, to highlight more clearly those areas where there is real critical mass, where Scotland has a competitive advantage and where Scotland could add significantly to major innovation efforts or missions at UK or EU level. While there might always be a temptation to be comprehensive in the approach taken to innovation, it would perhaps be helpful to take a more selective approach.

I would favour an evolutionary approach, where the major players (SFC and the Enterprise Agencies), work with the HEIs to gradually sharpen the focus of Scotland's innovation strategy, at least in terms of the major areas for investment. This might involve setting some over-arching mission-led themes (which would need to feed in external developments e.g. our relationship with the EU research and innovation base) and linking these to the range of publicly-funded and university-funded knowledge exchange assets – whether sector or technology-based (e.g. as mentioned above precision medicine, life sciences and biotech; technology and engineering (including advanced manufacturing, quantum and nanotechnology); financial and business services (including fintech); and, creative, cultural and digital industries).

Finally, at a time of constraints in the public finances – which will only be exacerbated if the UK leaves the European Union as planned on 31st October – there will be an imperative to ensure that resources, such as REG and UIF, are invested as effectively as possible in terms of driving the highest quality research and the most impact from innovation activities. It may be helpful for SFC to prioritise further the highest quality research and incentivise collaboration in innovation through the distribution of UIF (which is currently under review). It may, if funding for REG and UIF is constrained by pressures on public funding, need to ensure that the system of allocation is more selective and also focuses on critical mass indicators in particular research units.

8) The Scottish Government should encourage SFC and the Enterprise Agencies, in consultation with the HE sector, to advise it on a clear focus for a national innovation strategy. The consultation should also ensure that this is congruent with the Scottish Government's priorities in key areas of policies which would naturally fit into a mission-oriented approach to innovation policy.

- This may involve the 'focus' being defined as a hierarchy of priorities (i.e. a small number of missions sitting above a set of sectors and/or enabling technologies). Developing this focus should not be done in the abstract but needs to take cognisance of the existing major investments already made or in train by the Universities.
- Indeed, as part of driving innovation, SFC and the Enterprise Agencies will need to ensure that HEIs' major investments in innovation are known and their place within the national strategy is fully understood.
- Presenting a focused national innovation strategy will also be helpful as a signal to potential private investors – whether from industry already in Scotland or potential inward investors.
- Once a hierarchy of priority areas is established for innovation in Scotland, one issue will be how best to provide a place for information exchange between Universities, public agencies and industry in these areas. The HE sector (through Universities Scotland), Scottish Government and NDPBs have a number of interactions at sector leadership level. At industry sectoral level there are already a number of industry leadership groups (ILGs) involving industry leaders and Scottish Government officials and ministers. Higher Education is represented very occasionally on these ILGs but the main business of these groups is rarely around research and innovation. Many focus on more immediate short-term industry priorities and, when they focus on HE, it tends to be around skills needs. A small number of industry representatives on ILGs also feel that HE members of these groups do not cascade the dialogue through the sector but tend to develop linkages within their own universities or networks. There may be a merit to consider the landscape of leaderships groups involving industry, HE, and the Enterprise and Skills Agencies. Without duplicating what currently exists there could be value in establishing industry-HE leadership groups with public agencies in order to provide focus to common initiatives. HE would need to be represented at the appropriate leadership level (i.e. at a specialist level) but able to commit the institution to national strategies.
- The setting of a hierarchy of priority areas for Scotland will also require SFC and the Enterprise Agencies to consider the number and scope of the current Innovation Centres to ensure that these match the focus of the national innovation strategy. Some of the focus could be achieved by 'nudging' the scope of existing ICs.
- SFC should consider whether it has the appropriate resources, particularly in its analytical areas linked to supporting research and innovation, to carry out this additional work.

9) The Enterprise and Skills agencies should seek to align their investment streams more closely to help drive innovation from the research base. The agencies have already begun to do this. The Scottish Government should also consider aligning other relevant streams of funding in this area.

- For example, areas such as CSO (Health) and RESAS currently make important investments in innovation and research and these would benefit from greater alignment with national priorities, under the auspices of a more visible part of the national innovation landscape. While recognising that the aim of this innovation spending is different (e.g. CSO (Health), spending is aimed at driving healthcare innovation rather than economic activity *per se*), there may be benefits in greater co-ordination across the Scottish Government. Although some of the funding schemes through CSO (Health) and RESAS are relatively small, these could exert significant leverage, if aligned with SFC and Enterprise Agency funding on particular strategic initiatives.

While the focus of this report is our national aspirations, we should not forget the importance of HEIs in their particular geographies. A number of respondents emphasised the importance of HEIs in *place-making activities* in Scotland. This is clear from the many positive exemplars in HE-industry collaboration, where public R&D or universities' own investments have helped to leverage major industry investments in innovation (e.g. the Medicines Manufacturing Innovation Centre[50], the Informatics cluster in Edinburgh[51],

6. Conclusions and Recommendations

the National Manufacturing Institute Scotland[52], the Clinical Innovation Zone around the Queen Elizabeth University Hospital[53], Dundee Life Sciences[54], and Aberdeen's Oil and Gas Technology Centre[55], to name a few). There are clear examples from Europe, the USA and dynamic economies in Asia, that clustering activities around major investments by universities can help drive inward investment, spin-outs, new high-growth SMEs and foster economic growth. It is also clear that major city-region economies play a key role in assisting this innovation-based growth because of cities' important roles in attracting and retaining talent. Scotland's universities are also cited as a major reason for Scotland's success in attracting R&D FDI projects[56].There is also a natural interface here with the City and Regional Growth Deal strategies.

Furthermore, with the importance of 'place' in the UK industrial strategy, there may be increasing opportunities for Scotland's Universities to lead or co-lead important place-based investments[57].

The Brookings Institution study on global cities highlights how talent, innovation and export activities interact in larger urban areas to drive economic growth and prosperity, when combined with strong enablers around infrastructure and governance[58]. Universities are central to the talent and innovation elements of these place-based growth strategies.

Different versions of place-making have been developed in the most successful cities. For instance, the 'anchor plus' model uses city-centre developments around anchor institutions such as research universities which have a rich mix of anchor companies with strategic linkages to these HEIs. These are combined with a rich mix of related firms, entrepreneurs and spin-off companies involved in the commercialisation of innovation – or, alternatively the 'reimagined urban areas' model which links together the industrial regeneration of former industrial districts or waterfronts and the activities of research universities and anchor companies, with the same innovation mix.

In essence this is a new version of the traditional sector clustering model but with less dependence on single sectors, and instead a greater emphasis on the external economies of the city: with linkages across a mix of local SMEs and anchor companies (many of which will be global in nature and involve inward investment), and typically clustering across similar technologies or dependent on external economies driven by high-level/graduate skills.

Similarly, the OECD has emphasised the positive link between city size and productivity growth across a number of countries. Indeed, the UK's position is atypical within the OECD comparators because of the distortions caused by the dominance of London and the South-East. In comparison, in other European countries, productivity growth is much more closely-associated with larger cities[59].

International evidence has highlighted the impact universities can have on their local economies. For example, a recent study of living alumni of the Massachusetts Institute of Technology found that these alumni have started 6,900 companies headquartered in Massachusetts which generate worldwide sales of about $164 million[60]. A similar study of Stanford University alumni found that these alumni have created 18,000 firms that are headquartered in California, generating annual worldwide sales of about $1.27 trillion.

There are some important lessons here for Scotland.

First, place-making is increasingly a feature of successful economies and these are built around more holistic economic development policies. Rather than individual interventions, successful city-regions (such as Barcelona, Pittsburgh, Gothenburg) are seeking to develop integrated strategies for urban regeneration and growth. This requires all the relevant actors – national and local government, universities, and economic development agencies and other government agencies – to work much more closely together in a co-ordinated way.

Second, given Scotland's scale and the concentration of its major city-regions in a small geographic area, it is important to ensure that these strategies are linked and properly co-ordinated (e.g. the growth strategies for city economies such as Glasgow and Edinburgh, which in most other national contexts would be seen as a single city-region economy and not two separate economic entities).

Further Education Institutions also play an important role in their local economies and the economic impact of colleges in Scotland is being investigated further through the recently-announced review of the college sector.

10) While all universities can play a key role in their local and regional economies, there are further opportunities to be gained from maximising growth in City Region economies. Scottish Enterprise should, working with the other Enterprise Agencies, help Scotland's major City Regions and their component local authorities to develop city-based, place-making strategies with the universities and colleges in each City/City Region.

- This would involve each City Region setting out its priorities in terms of Scotland's priority innovation sectors and should also ensure that each City Region's place-making strategies capture the major research assets in the Universities. Some of this work is already under way. The emerging Regional Economic Partnerships should also consider the importance and role of their Higher Education Institutions in their economic development strategies.

11) The Scottish National Investment Bank (SNIB) should consider, with the Enterprise and Skills Agencies, what role it could play in respect of encouraging and incentivising place-based innovation activity which will drive the economy.

- This role sits naturally with the draft remit of the SNIB, given its focus on mission-based investments and its role to transform the economy through inclusive growth.

6. Conclusions and Recommendations

Understanding the value of public R&D

It is important to understand the 'value for money' of the current quantum of spending on HE-based R&D and the potential rate of return which accrues to the Scottish economy when government invests into funding streams such as the major investments from SFC and other agencies: e.g. the Research Excellence Grant, the Universities Innovation Fund, or strategic initiatives such as the Innovation Centres.

One issue which needs to be emphasised is that, although there are many statistical estimates of the spillover effects of public spending via university research and innovation on productivity at the UK level, there is less quantitative evidence on the size of the local spillover effects for the regions and nations of the UK. For Scotland more evidence in this area would be helpful. It would allow for a more informed debate on the appropriate level of public investment in R&D and its impact on Scotland's productivity, tax base and long-term economic growth.

12) The Scottish Government should work closely with SFC and the Enterprise Agencies to assess the rate of return from current spending, and the potential rate of return from future investments on publicly-funded R&D, in terms of Scotland's inclusive economic growth.

- This should be undertaken for the different types of public sector R&D (e.g. Higher Education, across other government departments) and interventions to capture both economic and wider social benefits. This will probably involve commissioning work which helps to extend the Government and the Enterprise and Skills Strategic Board's analytical unit's current economic modelling capacity to understand better the potential costs and benefits of current and future public R&D investments.

13) Given that, as is well understood from studies by Scottish Enterprise and NCUB, Scotland's industrial and business sector has a lower demand for innovation activities than other UK regional and national economies, SFC and the Enterprise Agencies should consider the implications of this for the balance of their innovation investments (e.g. in UIF and Innovation Centres). This could form part of the SFC's current review of UIF.

14) The Scottish Government should work with SFC and the Enterprise Agencies to benchmark our current levels of public R&D spending, and the outputs generated from this investment in Scotland's research base with some of the most dynamic small EU economies with similarly sized HE sectors.

This work will help frame a deeper understanding of the value R&D brings to the Scottish economy and communities and make the case for driving further innovative activities across the public and private sectors. Given that Scotland is operating in a wider competitive UK and European environment, benchmarking Scotland's competitive position is critically important.

Incentivising HE and industry

I now turn to the issue of how to optimise the impact of a given amount of research and innovation funding through grants such as REG and UIF.

As highlighted in Section 4, most of Scottish universities' externally-funded research projects are done at a loss in full economic cost (FEC) terms. REG provides some of the funding which universities need to make up that FEC gap. However, the majority of this funding to support research comes from non-publicly funded teaching which has allowed the Scottish and UK universities which are more prestigious to attract more international teaching income and has allowed them to underpin their research activities.

Not surprisingly, because of the large additional costs of supporting research activity, there has been a trend towards greater concentration of research funding. Successive REF exercises have seen a concentration of funding. In terms of REG funding, 90% goes to seven institutions (Aberdeen, Dundee, Edinburgh, Glasgow, Heriot-Watt, St. Andrews and Strathclyde); and 53% to the two largest universities (Edinburgh and Glasgow)[61]. A small number of HEIs in Scotland are responsible for securing the majority of European Research Council funding. The Universities of Edinburgh, Glasgow, St Andrews and Dundee secured 92% of ERC awards and 93% of the award value between 2014 and 2018 (with 49% of the RT FTE)[62]. A similar pattern is seen in other funding sources.

Looking at the incentives to HEIs to engage in innovation activity, there is no doubt that the introduction of 'impact' measurement in the 2014 Research Excellence Framework has changed behaviours as evidencing industrial engagement is rewarded directly through REG. As noted above in Section 5, I do not think that there is any evidence that there should be a shift away from the support of basic research towards innovation. The danger would be that it decreases the effectiveness and competitiveness of the Scottish HE research base at no gain in terms of BERD. The fundamentals of the research and innovation system works well: it is about ensuring that we can leverage more impact in terms of industrial activity through a better co-ordination of the innovation ecosystem as a whole. Because this is about changing behaviours rather than structures, it may be more difficult to make gains. As noted above in terms of recommendation 1, there are improvements to be made through much more joined-up working.

The evidence suggests that critical mass is important for driving impact. The best-performing universities in the UK at industry collaboration are also those with large numbers of high quality research outputs[63]. Research quality is correlated with the size of the group of researchers, though the optimal size depends on the discipline, however, smaller institutions and research groupings may also have specific sector expertise and be of regional and local significance. This understanding was a key driver for the creation of research pooling.

6. Conclusions and Recommendations

Hub-and-spoke models have been suggested as an effective way to ensure the research base is able to maximise impact and reach across a country.

Therefore, there may be some scope to encourage greater collaboration between those universities with greater resources to engage in research and innovation activity and those with less critical mass. To be clear this is not about forcing structural change in some aspects of innovation activity (e.g. merging Technology Transfer Offices (TTOs)), but at a regional level there may be scope for HEIs to drive greater collaboration, whether on TTO-type activities or in ensuring that larger-scale translational activities are open to smaller HEIs which wish to collaborate, through a hub-and-spoke model.

15) Universities should encourage greater collaboration (and where appropriate specialisation) between their KE and innovation activities.

- This may involve regional hub-and-spoke models, which would involve the larger HEIs with greater capacity to engage and co-ordinate innovation activities taking the lead. Given the heterogeneity in the way in which universities operate in these activities, it is difficult to be prescriptive on the areas where there should be more joint working but there will undoubtedly be gains in doing so. SFC may be able to play a role in brokering such discussions.

Given the constraints on public funding, there will be an imperative to ensure that the resources invested in REG and UIF are invested as effectively as possible, in terms of driving the highest quality research and the most impact from innovation activities. It may be helpful for SFC to prioritise further the highest-quality research and incentivise collaboration in innovation through the distribution of UIF (which is currently under review). It may, if funding for REG and UIF is constrained by pressures on public funding, need to ensure that the system of allocation is more selective and also focuses on critical mass indicators in particular research units.

16) If the quantum of funding is constrained by pressures in the public finances, SFC should consider focusing its REG and UIF funding in a way which maximises the impact for Scotland both in terms of UKRI leverage (both Research Council and Innovate UK/industrial strategy funding) and, more generally, the excellence of Scotland's research and innovation landscape.

- Focusing formulaic funding streams, such as REG and UIF, in those units which are able to leverage additional funding would need to be done sensitively to ensure that the balance of excellent research and innovation is maintained. This may, over time, produce a more differentiated HE sector in Scotland, if some HEIs have a greater ability to leverage in resources from external sources, but those HEIs that are less able to do so may also benefit through more intensive collaboration.
- This recommendation is basically suggesting that the funding distribution system could evolve over time to drive similar, broad-scope collaborations in both research and innovation across the country. This could produce benefits for Scotland in terms of the resources which the larger HEIs, which have greater financial muscle, could help deploy. The smaller HEIs would benefit in terms of being part of consortia with the larger HEIs.

17) SFC should consider the long-run sustainability of Scotland's universities' research and innovation activities and provide advice to Government during the next spending reviews, taking account of recommendations 12 – 14. Universities for their part will be developing the evidence base behind the sustainability of the research and innovation activity in the HE system. In developing the evidence base for this, the HE sector should be open about its ambitions for expanding its research activities and leveraging more income into Scotland from UK and other sources.

- Beyond the overall sustainability of research activities, REF 2021 will see major changes in the nature of the research evaluation exercise. The changes to REF have the potential for individual universities to be more selective in returning research outputs at unit of assessment level. This might produce a 'concertina-effect' with a flattening of high-level of outcomes towards the top-end in terms of grade-point-average outcomes. The current formula to distribute REG, even with a very high weight on 4* outcomes, could conceivably lead to a loss of funding for the best 4* research in Scotland. SFC will need to consider how best to handle this issue and advise Government appropriately. Given the interdependence of the Scottish research landscape with the rest of the UK and the EU, SFC will also wish to frame this advice on the basis of funding decisions in these other jurisdictions.

The landscape of research funding in the UK has fundamentally shifted with the creation of UKRI and the related development of the UK Industrial Strategy and the Industrial Strategy Challenge Fund (ISCF). SFC has been working closely with UKRI since its formation to support the new organisation, mindful of the challenges of bringing together Research Councils, Innovate UK and Research England in one UK body. SFC has helped to shape calls such as the Strength in Places Fund and joined other agencies to support Scottish successes in ISCF funding.

18) SFC should continue to work closely with UKRI to ensure that Scotland can take advantage of major investments in the UK Industrial Strategy where these are aimed at technologies and sectors in which Scotland has a competitive advantage. SFC, working closely with universities, Universities Scotland and the Enterprise Agencies, should ensure that UKRI and major third sector funders (e.g. Wellcome Trust, CRUK) understand Scotland's competitive advantage in areas of research-driven innovation. Scotland has the opportunity to attract greater investment if it brings together consortia across disciplines, universities, research institutes and business to make larger bids. SFC should work with universities, research pools, innovation centres and its partner agencies to increase ISCF investment through collaborative bids of scale.

6. Conclusions and Recommendations

Universities and commercialisation activities

In collecting evidence from business and industry organisations, it is clear that there are both very positive and very negative perceptions of universities' commercialisation activities. Much of the evidence base is inevitably anecdotal but, as with any system, there is room for improvement.

Mike Rees' review for Research England of university-investor links is instructive, as it shows that the UK universities perform well in terms of some dimensions of commercialisation activity compared with counterparts in the USA, which are usually regarded as at the leading edge of commercialisation[64] , including attracting income from industry and revenues from industry and revenues from spin-outs.

Looking at Scottish universities' commercialisation activities relative to the rest of the UK shows that Scotland performs well on a range of indicators and matches the UK in terms of the percentage of industrial contribution to research, although not in IP revenues.

Table 1: Commercialisation activity for the UK and Scotland

Metric	UK		Scotland	
	4-year average	2017/18	4-year average	2017/18
Total income from business and community interactions (£m)	430.33	454.04	47.41	45.42
Percent of UK total	100%	100%	10.4%	10.6%
Industrial contribution to research (£ million)	-	651.20	-	85.49
% industrial research	-	7.9%	-	8.0%
Number of patents granted	1316	1707	182	345
Percent of UK total	100%	100%	13.8%	20.2%
IP Income (£m)	129.34	162.84	8.10	7.61
Percent of UK total	100%	100%	6.3%	4.7%
Patents granted	1316	1707	182	345
Percent of UK total	100%	100%	13.8%	20.2%
Spin-offs	150	140	15	12
Percent of UK total	100%	100%	10%	8.5%

Source: HESA. NB: Income figures are not available for the 4-year period.

Inevitably individual HEIs' TTO operations do not have a single mission: they tend to focus on a number of objectives which rightly fit with the strategic KPIs for the institutions, ranging from patent-filing to negotiation on terms for commercialisation, to licensing agreements. Many of the issues they deal with are complex, and there cannot be a one-size-fits-all approach to commercialisation activity in HEIs any more than it could be prescriptive to businesses on adopting a single set of processes for negotiating external deals.

Nevertheless, as I say, there is bound to be room for improvement. For instance, prima facie, the standard terms for the share of intellectual property (IP) retained by HEIs in Scotland involve the retention of a high share of IP in spin-out creation compared with some other UK universities. A number of major universities in Scotland seek to extract more onerous terms from potential spin-offs and licensing activities. The nature of spin-off activity is changing over time, and some activity does not use complex and costly University infrastructure. Arguably universities in Scotland should commit to the national innovation effort by considering changing their policies and facilitating technology transfer.

Beyond IP share, which is only one dimension of commercialisation deals, I was told that businesses would still like to see an improvement in the speed of response, and a reduction in the 'friction' of commercialisation transactions. There is specialist help and support from, for example, the iCure programme developed by SETsquared or Frontier IP. The SETsquared Partnership is a business incubation network run by five English universities and is consistently ranked as one of the top university-based business incubators in the world. Scottish HEIs could perhaps also benefit by looking at the operations of well-established commercialisation offices in the UK which seem to attract positive comments from the business community (e.g. Cambridge, Imperial College, and University College London).

The sector collectively streamlined its terms and conditions for innovation vouchers. Enabled by Interface and Scottish Funding Council, Scottish HEIs agreed a series of downloadable, standardised legal agreements and documents. This has ensured that an SME undertaking its first collaboration with academia has a clear understanding of the ownership of the foreground IP, thereby saving time and money.

Further streamlining and benchmarking of commercialisation practice could simplify these processes further for businesses.

The other key issue is the lack of scale in some of Scotland's HE commercialisation operations because of the large number of HEIs. Mike Rees' review of the UK landscape highlights this markedly[65]. He notes that, in terms of the best-performing TTO operations, the complexity of creating spin-outs and dealing with commercial and legal work requires experience and that this is correlated with scale. The HEIs which have the experience of handling a greater number of complex deals will perform better. In terms of creating links with investors, scale also matters. As he notes, very few investors will wish to engage with a large number of small universities that may produce a very small flow of IP opportunities. As he emphasises: "sub-scale approaches to investor engagement result in a more transactional approach which usually manifests in more short term and often adversarial relationships". Finally, scale in commercialisation operations also allows a supply of experienced talent to lead and work in management teams of spin-out companies, through extensive alumni networks, which larger-scale HEIs can provide.

The issue for Scotland is whether we can reproduce the benefits of scale which have been reaped by some of the largest HEIs in the UK, and particularly Oxford, Cambridge and some of the London Universities. Some of Scotland's universities have a comparative scale to deal with the issues highlighted in the Rees review. Others do not, and the only way to reproduce the benefits is through collaboration. I address this in the recommendations below.

6. Conclusions and Recommendations

19) Universities should benchmark their terms and conditions for spin-outs and joint industry collaborations to optimise the terms and conditions offered to industry.

- One particular focus could be the share of IP retained by the institution, to match the very best offer which UK universities provide, with a view to encouraging more activity. It is important to emphasise that this is not just about IP share retained by universities but also around the willingness to reduce friction in commercialisation processes and increase innovation activity.
- SFC could monitor this effort and could tie the provision of REG and UIF grants to universities providing a 'best in class' offer in the UK. This may also help the retention of academics within Scotland who have the potential to engage in high-growth potential spin-outs – as opposed to taking these commercialisation ideas outside Scotland or indeed outside the UK, because more advantageous terms are being offered.

20) Similarly, universities should align their offering in terms of the quality of the commercialisation and research collaboration offer to Scottish-based industry collaborators (e.g. speed of response, ease of arriving at a licensing agreement). This could be an important part of the universities' contribution to a national innovation mission (see Recommendation 1).

- One issue for universities is the resource requirement of offering a high-quality service to all-comers. One possible way forward would be for SFC and the Enterprise and Skills agencies to agree with the universities whether HEIs could offer an enhanced provision to a number of high-growth high-potential Scottish-based companies, linking in with the business base segmentation set out in *A Trading Nation* (see Recommendation 4).

In line with Recommendation 15, given the importance of scale and experience in commercialisation activities, we should encourage greater collaboration between HEIs – with smaller HEIs benefiting from larger HEI hubs, given their expertise in the area of commercialisation. SFC could take this into account in the current review of UIF – which currently offers an 'entry-level' of funding to smaller HEIs. This shared resourcing may make the system more efficient and lead to greater specialisation in the sector.

One particular dimension of university spin-out activities which was highlighted to me is the apparent under-representation of women founders in commercialisation activities[66]. This is a UK as well as a Scottish phenomenon and clearly suggests that, as a country, we are not fully engaging with half of our talent base. This is something which the universities and the SFC should monitor.

21) Universities should commit to breaking down the barriers which currently exist in their academic career tracks which prevent a free movement of researchers from industry to HE and vice-versa. There has been some good progress in this area; however, there is the scope to do much more to incentivise movements from academia to research and innovation within industry.

- For instance, some funding agencies offer fellowship and secondment opportunities in both HE and industry/business. Some universities have also radically revised their academic career tracks introducing alternative posts such as 'research technologist' or 'industrial adviser' positions at senior/professorial levels. The introduction of 'impact' in the Research Excellence Framework and in REG funding also helps to make HEIs more porous.

22) Scottish Enterprise, SDI, and SFC could work with major Scottish Universities to provide an improved offer to inward investors wishing to locate major R&D activities to Scotland.

- Where inward investors are keen to locate new jobs to Scotland and major R&D roles to key innovation zones with an HE presence, Universities could be asked to provide an improved offer on joint IP produced by research work or a bespoke approach to commercialisation activities – these could be mediated by individual HEIs or, where the investment is linked to an Innovation Centre, by the IC.

[45] https://p.widencdn.net/egy4iz/ACAD_AS_BRO_a-metrics-based-assesment-of-scotlands-science-landscape_WEB
[46] https://www.heraldscotland.com/opinion/17760113.agenda-need-alumni-global-ambassadors/
[47] See https://www.gov.uk/government/publications/patient-capital-review
[48] See https://re.ukri.org/documents/2019/advice-on-university-investor-links-mike-rees-pdf/
[49] https://re.ukri.org/documents/2019/advice-on-university-investor-links-mike-rees-pdf/ see Table 7. This refers to seed, venture and growth deal funding.
[50] https://www.gov.uk/government/news/faster-medicine-56-million-innovation-centre-for-scotland
[51] https://ddi.ac.uk/
[52] https://www.strath.ac.uk/workwithus/nationalmanufacturinginstitutescotland/
[53] https://www.gla.ac.uk/research/beacons/precisionmedicine/ciz/
[54] https://www.lifesci.dundee.ac.uk/
[55] https://theogtc.com/
[56] Ernst and Young Scotland Attractiveness Survey.
[57] For an economic analysis see Philip McCann (2019) 'UK Research and Innovation: A Place-Based Shift?' https://www.ifm.eng.cam.ac.uk/uploads/Research/CSTI/UKRI_Place/McCann_-_UK_Research_and_Innovation_-_A_Place-Based_Shift_vFinal.pdf
[58] https://www.brookings.edu/project/global-cities/
[59] https://www.oecd-ilibrary.org/economics/what-makes-cities-more-productive_2ce4b893-en
[60] George Lan, Sophia Katrenko and Jennifer Burnett. 2015. "America's Knowledge Economy: A State-by-State review." http://www.csg.org/programs/knowledgeeconomy/Elsevier_ Report_2015.pdf
[61] SFC, Research Excellence Grant and Global Challenges Research Fund for AY 2018-19
[62] HESA
[63] Benna and Berche (2012), Managing research quality: critical mass and optimal academic research group size, IMA Journal of Management Mathematics, 23: p. 195 – 220.
[64] See https://re.ukri.org/news-events-publications/publications/independent-advice-on-university-investor-links-mike-rees-report/
[65] See https://re.ukri.org/news-events-publications/publications/independent-advice-on-university-investor-links-mike-rees-report/
[66] See a recent study funded by the EPSRC 'Gender and university spin-outs in the UK: geography, governance and growth' by Dr Heather Griffiths and Dr Anne Laure Humbert, Oxford Brookes University and University of Oxford.

TECHNICAL ANNEXES

Technical Annex A

List of stakeholders

Scottish Funding Council
Scottish Enterprise
Highlands and Islands Enterprise
Universities Scotland
Universities Scotland Research and Knowledge Exchange Committee, which included representatives from:

- SRUC
- Glasgow Caledonian University
- Royal Conservatoire of Scotland
- University of St Andrews
- Queen Margaret University
- Universities Scotland
- Interface
- University of Strathclyde
- University of Highlands and Islands
- University of Stirling
- University of West of Scotland
- University of Aberdeen
- University of Dundee
- Abertay University

Colleges Scotland
Edinburgh Napier University
Heriot-Watt University
Robert Gordon University
University of Aberdeen
University of Edinburgh
University of the Highlands and Islands
University of St Andrews
University of Stirling
University of Strathclyde
University of the West of Scotland
Fraser of Allander Institute, University of Strathclyde
Graeme Reid
Wellcome Trust
Interface
CENSIS
London Economics
CBI
Innovate UK
Elsevier
Converge
Royal Society of Edinburgh
OPTOS
SCDI
UKRI
SIE

Technical Annex B

Existing evidence base reviewed

- The Independent Review of the Innovation Centres Programme, chaired by Professor Graeme Reid, which published findings in September 2016;
- The Growing Value Scotland Task Force report, "The Step Change – Business-University Collaboration powering Scottish Innovation", published in May 2016;
- The Scottish Science Advisory Council report, "Business R&D in Scotland – A missing link", published in August 2009;
- The Enterprise and Skill's Review Phase 2 Innovation Report, published in June 2017;
- Scotland CAN DO Innovation Action Plan, published in January 2017;
- Universities Scotland Five Point Plan for Innovation, developed in 2015;
- The Royal Society of Edinburgh Discussion paper, "Entrepreneurial Education in Scotland", published in June 2015;
- The Dowling Review of Business-University Research Collaborations, published in July 2015;
- Lord Stern's review of the Research Excellence Framework, published in July 2016;
- The UK Science and Innovation Wave 1 – 3 Audits;
- The Review of Government Fund Research and Innovation in Wales, chaired by Professor Graeme Reid, published in December 2017;
- The Diamond Review of Higher Education Funding and Student Finance Arrangements in Wales, published in September 2016;
- University Knowledge Exchange (KE) Framework: good practice in technology transfer Report to the UK higher education sector and HEFCE by the McMillan group. September 2016;
- UK Government Patient Capital Review 2017
- Advice on university-investor links, Independent advice from Mike Rees for David Sweeney, Executive Chair, Research England, 2019;
- Gender and university spin-outs in the UK: geography, governance and growth, by Griffiths and Humbert, Forthcoming;
- Independent Review of the Scottish Funding Council's Research Pooling Initiative, Chaired by Professor Louise Heathwaite CBE FRSE, 2019.

Technical Annex C

Additional evidence on the economic impact of HEIs in Scotland

Key facts on Scottish higher education institutions

There are 19 Higher Education Institutions (HEIs) in Scotland. In the 2017/18 academic year there were 247,110 students enrolled at Scottish HEIs, an increase of 9.9% since 2007/08. 91% of leavers engaged in further study or employment 6 months after leaving. The median salary 5 years after leaving Scottish HEIs was £27,100, compared to £25,800 for all providers in Great Britain.

There were 48,330 staff employed at Scottish HEIs in 2017/18 (22,840 on academic contracts and 25,495 on non-academic contracts). 13.4% of staff are of EU nationality and 8.8% are of non-UK, non-EU nationality. For academic contracts, this increases to 20.0% and 14.8% respectively.

Higher education leads to increased earnings over a graduate's lifetime[67], with benefits equating to more than £100,000 over the course of a person's working life[68], and there is evidence that the returns an individual receives from education are rising in the UK, suggesting the demand for graduate skills is rising faster than their supply[69]. Research conducted for the UK Industrial Strategy predicts that of the approximately 1.8 million jobs created between 2014 and 2024, 70 per cent of these will be in occupations more likely to employ graduates[70]. An educated population can also have wider positive societal impacts, such as improved health outcomes[71] and lower crime rates[72]. HEIs therefore play a critical role in meeting the future needs of business and the economy.

HEIs also have significant economic impact through knowledge exchange activities. Commercialisation, knowledge exchange, knowledge transfer, and technology transfer are terms that are often used interchangeably to define the process of applying university R&D to making a difference in society. Knowledge exchange covers the widest range of activities, reflecting the complex nature of relationships where there is a two-way flow of knowledge and the multiple routes by which that knowledge can make an impact. These routes include spin-out and start-up companies, licences to existing companies, research collaborations, contract research, consultancy, student placements, sharing of physical resources and innovation spaces which can lead to more rapid knowledge transfer as well as informal activities such as conferences, presentations and lectures.

Businesses can experience a number of positive impacts from collaborating with universities including:

- Behaviour impacts – for example, strategic changes in management, organisational changes;
- Innovation impacts – more innovation, increased R&D activity or patents;
- Economic impacts – increased productivity or increased employment; and,
- Social impacts – for example, new solutions to societal challenges related to health, environment, energy, etc.

Thus collaboration affects businesses and society in many ways and over different time periods (for example, the impacts on behaviour can be present nearly immediately after collaboration, where as social impacts may only present over the long-term).

Measuring university/business interactions in Scotland and the UK

HESA's HEB-CI database provides a consistent way of measuring direct interactions between universities and business. These are measures of activity which directly captures some of the forms of knowledge exchange discussed above. Clearly these do not measure the indirect effects discussed in the previous sections, but provide some comparative measures of activity. See table 2 on adjacent page.

HEIs in Scotland generate income from their research activities and interaction with businesses – total income from collaborative research involving public funding was £183.0 million (13% of UK total) in 2017/18, income from contract research was £119.6 million (9% of UK total), income from consultancy contracts was £77.7 million (16% of UK total), and income from Intellectual Property was £8.0 million (4% of UK total)[73]. Figure 2 shows that 2017/18 breakdown of income from business and community interactions by source. See figure 2 on adjacent page.

Income varies substantially between institutions. For example, income from collaborative research involving public funding ranged from £61.2 million at the University of Glasgow in the 2017/18 academic year to no income from this source at the Royal Conservatoire of Scotland[74].

Scotland's HEIs do more than a quarter of all the contract research between universities and SMEs in the UK. 29 percent of all consultancy undertaken with SMEs in the UK is done by Scottish universities.

Spin-outs and start-ups

In 2017/18, there were 215 new spin-outs and start-ups generated by HEIs in Scotland (5%), 1,154 active spin-outs (7% of UK total), and the estimated turnover of active firms generated by HEIs was £613.7 million (19% of UK total)[75].

[67] Blundell et al. 2005. 'Evaluating the impact of education on earnings in the UK: models, methods and results from the NCDS', Journal of the Royal Statistical Society: Series A, 169, p. 473 – 512.
[68] BIS (2013), 'Impact of university degrees on the lifecycle of earnings: some further analysis', https://www.gov.uk/ government/publications/ university-degrees-impact-on-lifecycle-of-earnings
[69] Machin and McNally, 2007. 'Tertiary Education Systems and Labour Markets', The Education and Training Policy Division report, OECD.
[70] UKCES (2016) 'UK labour market projections: 2014 to 2024', www.gov.uk/ government/publications/uk-labourmarket-projections-2014-to-2024
[71] Cutler DM, Lleras-Muney A. (2006) Education and health: evaluating theories and evidence. National Bureau of Economic Research: Cambridge, MA. Working paper 12352.
[72] Groot and Brink (2007), 'The effects of education on crime', Applied Economics, 42.3: 279-289.
[73] HESA, Higher Education – Business and Community Interaction survey
[74] HESA, Higher Education – Business and Community Interaction survey
[75] HESA, Higher Education – Business and Community Interaction survey.

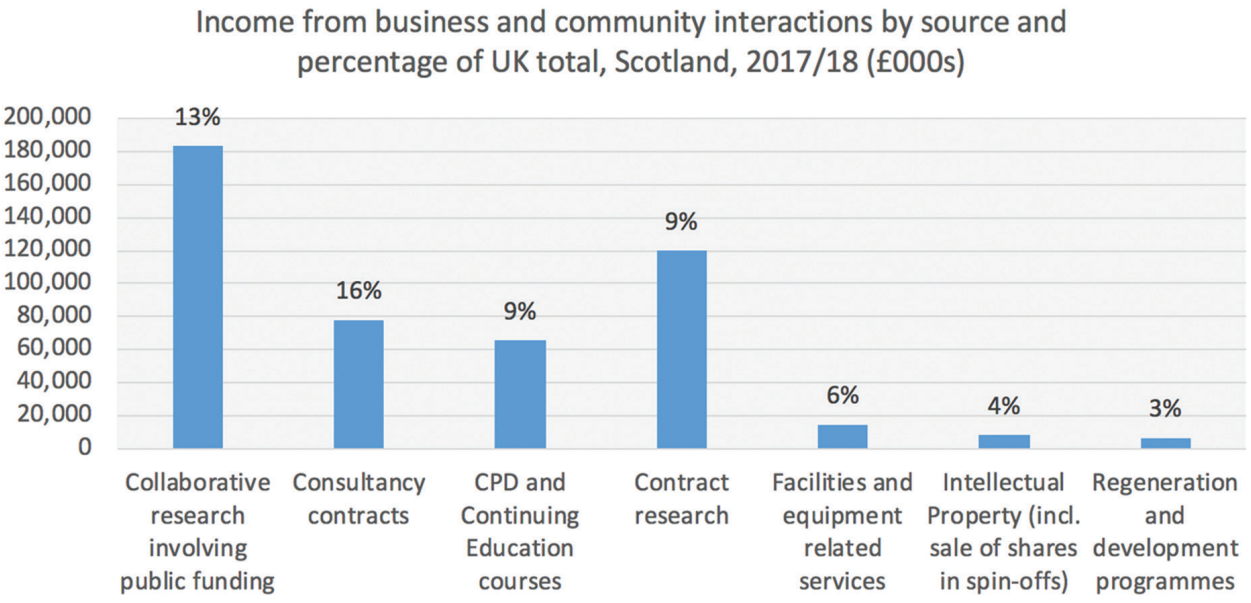
Technical Annex C

Table 2: Overview of university-business and community interactions

	England		Northern Ireland		Scotland		Wales	
	4-year average	2017/18	4-year average	2017/18	4-year average	2017/18	4-year average	2017/18
Total income from business and community interactions (£m)	3747.9	3560.5	136.1	113.5	474.1	454.2	182.3	175
Percent of total	82.5%	82.7%	3.0%	2.6%	10.4%	10.6%	4.0%	4.1%
Number of deals with SMEs	62140	63082	1223	1186	17493	19684	1209	1179
Value (£m)	166.4	180	4.2	4.9	31.8	33.9	5.3	5.1
Number of deals with large companies	20109	21824	494	402	4324	4498	1021	900
Value (£m)	533.8	564.6	7.2	6.8	79.9	85.1	11	11.4
Number of deals with non-commercial organisations	52521	56264	1922	1910	4153	3723	1960	2164
Value (£m)	965.9	995.5	30.7	41	89	92.7	19	18.7
Number of patents granted	1073	1280	32	31	182	345	30	51
IP Income (£m)	110.5	142.9	8.5	9.1	8.1	7.6	2.3	3.3
Graduate start-ups	3603	3559	19	34	151	177	279	254
Spin-offs	116	109	6	7	15	12	13	12

Source: HESA, Higher Education – Business and Community Interaction survey

Figure 2: Income from business and community interactions and percentage of UK total



Source: HESA, Higher Education – Business and Community Interaction survey

Technical Annex D

Scotland's research and funding performance

Research definitions

Discovery (or basic) research aims to acquire new knowledge, frequently through generating a hypothesis and challenging it. This process is an effective and reliable way to acquire new knowledge, though it can be challenging to predict the outcome of the research.

Applied research is aimed at achieving specific objectives and outcomes. This generally requires the knowledge base to be sufficiently well-developed. Research is often undertaken in partnership with the potential beneficiaries (e.g. business, government or third sector organisations).

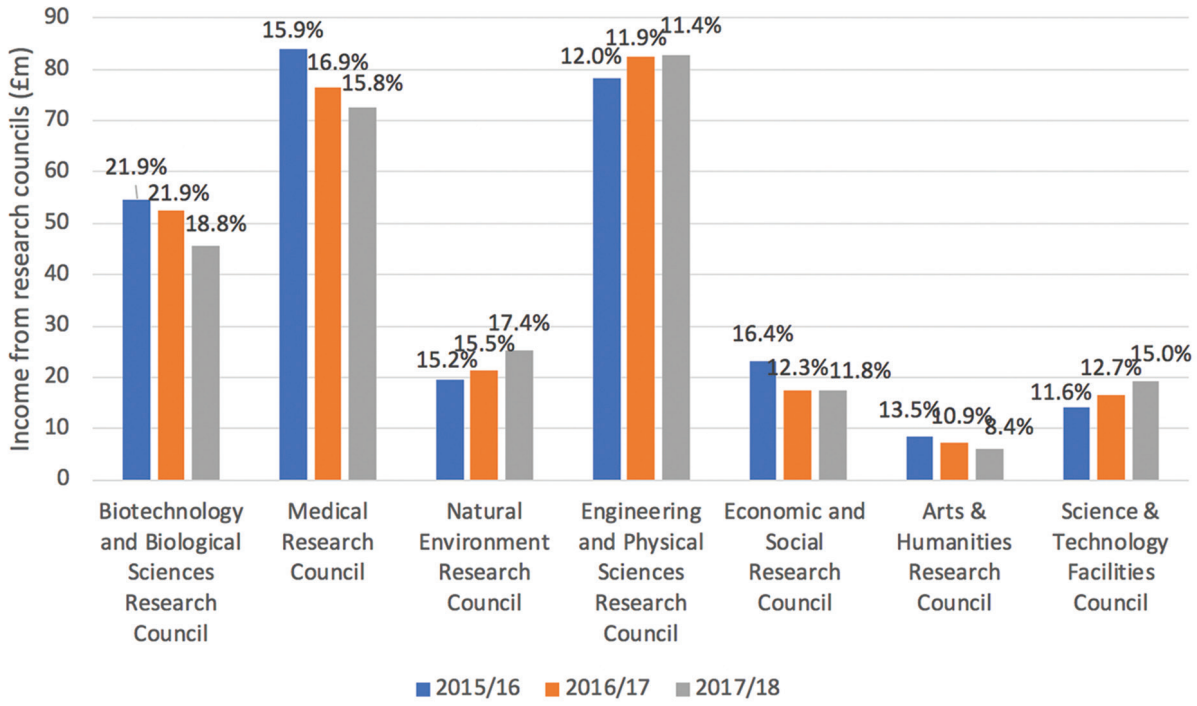
Translational research aims to bridge pure and applied research – it is carried out with the expectation that it will produce a knowledge base to form the background to the solution of current or future problems or possibilities.

The boundaries between types of research can be blurred, with discoveries being made during applied research and applications being identified during discovery research. It is also not a linear process and knowledge transfer occurs in all directions. The balance between discovery, translational and applied research depends on the particular discipline and research and specific knowledge and understanding is required to make sound judgments about the appropriate balance.

Scotland performs highly on measures of the quality and impact of academic research. A recent report by the Scottish Science Advisory Council found Scotland to have the highest average number of publications per researcher between 2007 – 2016, compared with all other comparator countries in the report[76]. Scotland also has the highest number of citations per researcher out of the UK and comparator nations in the report – the average number of citations per researcher in the period 2007-2016 was 16.03 in Scotland, 12.66 in Wales and 9.81 in the UK as a whole. It is interesting to note that collaboration with industry positively impacts on the citation profile of Scotland's HE institutions. Corporate collaborations achieve a higher Field-Weighted Citation Impact (FWCI) of 3.84, compared to 2.1 for all publications[77].

In terms of the performance on attracting research income from UKRI, Scotland generally performs well, although there is evidence of less success in attracting major strategic Research Councils assets (figure 3).

Figure 3: Research council income for Scottish HEIs, 2015/16 – 2017/18 (£m and % of UK total)



Source: HESA. Research grants and contracts – breakdown by source of income and HESA cost centre.

Technical Annex D

There are a range of other UKRI funding streams[78]. Some of the key funding streams are outlined below.

Innovate UK

Innovate UK, part of UKRI, is the UK's innovation agency. It funds business and research collaborations to accelerate innovation and drive business investment into research and development.

Scotland as a whole seems to under-perform the UK as a whole in terms of accessing Innovate UK funding, though academia performs relatively well (reflecting Scotland's strength in HERD).

Average grants are generally lower with, on average, only 5.4% of the value of UK grants awarded in Scotland between 2003/04 and 2018/19. Academia in Scotland, (universities and higher education institutions) on the other hand, performs relatively well in accessing funding: a higher proportion of total grants awarded in Scotland is to academia than the UK average. On average, between 2003/04 and 2018/19, 11.6% of total grants were awarded to academia in Scotland compared to 6.4% for the UK.

Industrial Strategy Challenge Fund

The Industrial Strategy Challenge Fund (ISCF) is part of the UK Government's Industrial Strategy, the long-term plan to raise productivity and earning power in the UK. The fund is a core pillar in the government's commitment to increase funding in research and development by £4.7 billion over 4 years to strengthen UK science and business.

As of June, consortia based in Scotland have been allocated over £88m through the Industrial Strategy Challenge Fund, including:

- The UK and Scottish governments are working alongside industry to deliver a £56m Medicines Manufacturing Innovation Centre in Glasgow.
- The Industrial Strategy Challenge Fund is providing £14.3m to the ReFLEX (Responsive Flexibility) Orkney project at the European Marine Energy Centre, which will demonstrate a first-of-its-kind Virtual Energy System (VES) interlinking local electricity, transport and heat networks into one controllable, overarching system.
- Three Scottish companies received more than £1.7m to develop cell-based therapeutics, digital self-management services for lung patients and systems to provide real-time decision support in care of trauma patients this autumn.
- £10 million has been committed to I-CAIRD as part of the ISCF. This brings together a pan-Scotland collaboration of 15 partners from across academia, the NHS, and industry to work with innovative SMEs to answer clinical questions, and solve healthcare challenges more quickly and efficiently.

Strength in Places Fund

Strength in Places Fund (SIPF) is a competitive funding scheme that takes a place-based approach to research and innovation funding, to support significant regional growth. UKRI shortlisted twenty-four projects, from pharmaceuticals to aerospace, and transport to the creative economy, to receive early-stage funding to develop full-stage bids that could lead to significant economic growth in places across the UK.

Each of the shortlisted projects from the first wave of UKRI's Strength in Places Fund has been awarded up to £50k in early-stage funding which will allow applicants to develop full-stage bids. Teams behind these projects will then submit these bids to UKRI in late-2019, with four to eight of the strongest set to receive between £10m and £50m each to carry out projects designed to drive substantial economic growth.

Four bids from Scotland have been shortlisted:

- Accelerating the 4th industrial revolution across Scotland's Central Belt: this University of Strathclyde-led project aims to boost the economic impact of the burgeoning Industrial Biotechnology sector in Scotland's Central Belt.
- Clyde Waterfront Innovation Campus: this University of Glasgow-led bid, will accelerate innovation in the manufacture of new technology based on photonics, optoelectronics and quantum technology.
- Global Centre of Excellence in Open Banking (COB): led by Fintech Scotland, the COB intends to have significant social and economic impact across many markets by developing a fairer, healthier economic situation for people.
- The Living Lab: led by the University of Glasgow, the 'Living Lab' aims to drive economic growth in Glasgow through real world implementation of precision medicine.

EU Funding

Horizon 2020

The Horizon 2020 programme was established by the European Union to help secure Europe's global competitiveness in research and innovation. Businesses, universities, charities and other organisations can access funding support for European research and innovation projects. Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over seven years (2014 to 2020).

Data for UK totals as at 28th September 2018 showed Scotland had 10.1% of the UK organisations participating in the scheme and received 10.8% of UK funding (€550m from a total of €5,101m). Seven Scottish universities were in the UK top 50 Higher or Secondary Education Establishments.

[76] Comparator countries include Denmark, Finland, Ireland, the Netherlands, Sweden, Israel, Norway, New Zealand, Singapore and Switzerland.
[77] Scottish Science Advisory Council (2019). A Metrics-Based Assessment of Scotland's Science Landscape (2007 – 2016).
[78] https://www.ukri.org/funding/funding-opportunities/

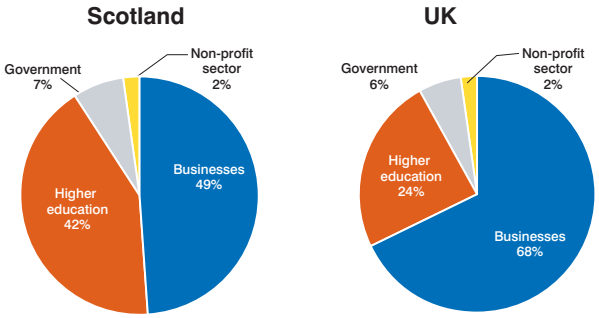
Technical Annex E

Scotland's innovation performance and wider context

Scotland's overall innovation performance is mixed, with areas of strength but also some notable challenges. Gross Expenditure on Research and Development (GERD) was 1.63% of GDP in 2017, placing Scotland 20th (of 37 countries) in the OECD. This is an increase of 0.35 percentage points since 2008, but remains below the UK, EU and OECD averages. Scotland has narrowed the gap with the UK and the EU to 0.06 percentage points, while the gap with the OECD remains 0.74 percentage points.

A large proportion of Scotland's GERD is attributable to the Higher Education sector, relative to the UK and international comparators. The proportion of R&D spend attributable to the HE sector was higher in Scotland than any other OECD country in 2017. Figure 4 illustrates the composition of GERD in Scotland and the UK.

Figure 4: Gross expenditure on research and development by sector, Scotland and UK, 2017



Source: Scottish Government, Gross Expenditure on Research and Development 2017

Scotland's Higher Education Expenditure on Research and Development (HERD) was 0.69% of GDP in 2017, placing Scotland 7th in the OECD (top quartile). HERD as a percentage of GDP is unchanged since 2008. On this measure, Scotland outperforms the UK (by 0.29 percentage points), EU (by 0.25 percentage points) and OECD (by 0.28 percentage points) averages.

Scotland's Business Expenditure on Research and Development (BERD) in 2017 was 0.80% of GDP in 2017, placing Scotland 23rd in the OECD (third quartile). This is an increase of 0.35 percentage points since 2008. However, a gap remains with the UK (0.35 percentage points), the EU (0.49 percentage points) and the OECD (0.87 percentage points).

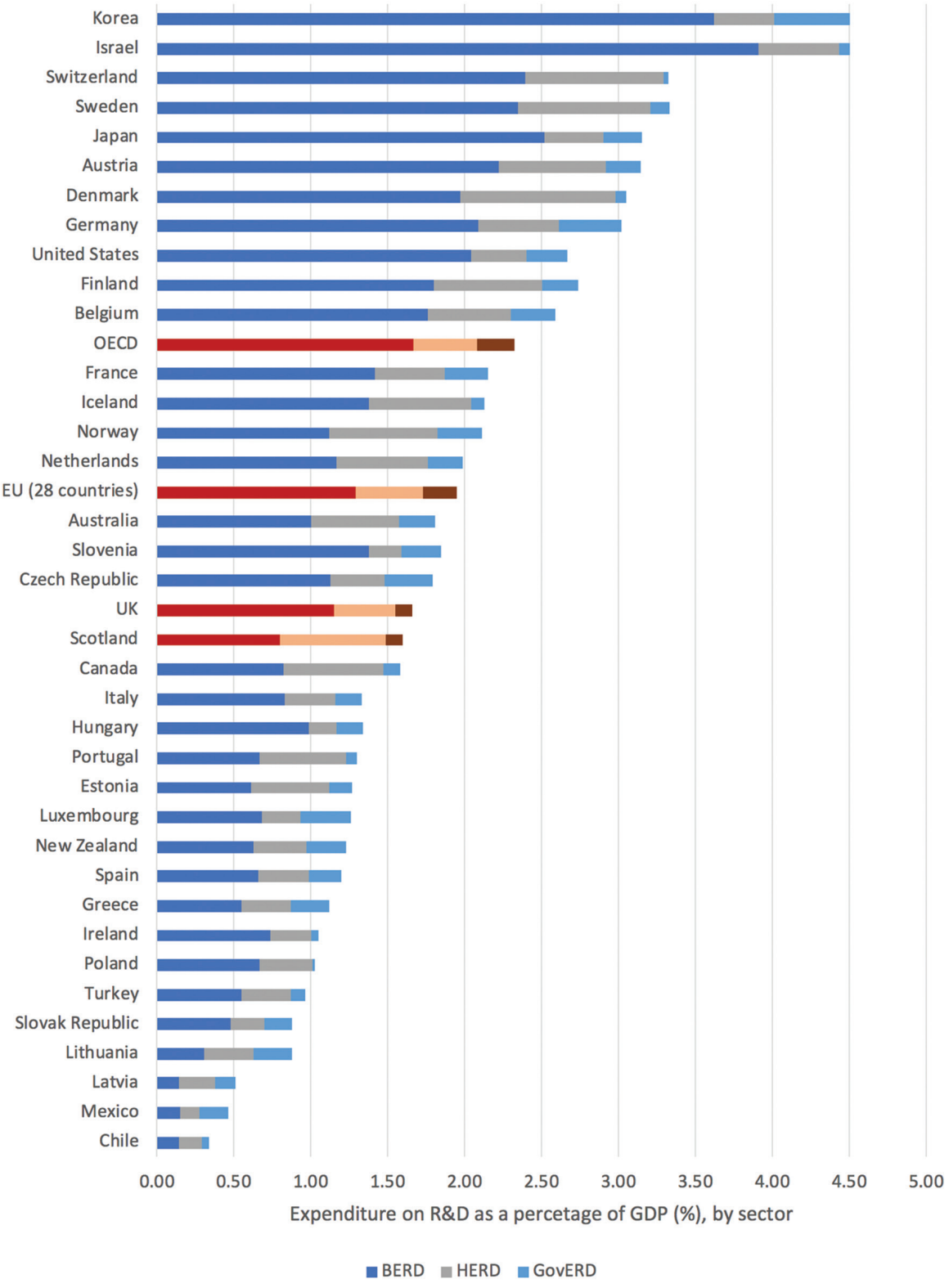
Scotland's BERD performance partly reflects its industrial structure but also a lower business expenditure on R&D in innovative sectors[79]. In 2016, the five most R&D intensive industry sectors in the EU accounted for 2.6% of Scotland's jobs, compared with 3.3% in the UK and 7.3% in Germany, and 35.3% of Scotland's BERD expenditure, which is much lower than countries such as Croatia (highest at 78.2%), Germany (64.7%) and Austria (47.9%). In Scotland, the sectors accounting for the greatest proportion of R&D spend are: miscellaneous business activities (24.8%); pharmaceuticals (13.1%); and consumer electronics and communication equipment (10.8%). Over time, Scotland has seen a shift in the share of R&D spend from large, foreign-owned manufacturing firms to smaller domestically-owned service sector firms, which reflects the changing industrial structure.

R&D expenditure in Scotland is concentrated in a small number of large businesses. In 2017, five businesses accounted for more than one third (37.8%) of Scottish R&D expenditure. This is a sizeable share of the total R&D expenditure and an increase from 2016 (25.7%); however, it represents a fall in the dominance of the top businesses since 2001 when the top five businesses accounted for just over half of BERD expenditure.

[79] Within the EU, the most R&D intensive industry sectors (in terms of BERD spend per job) are:
- Manufacturing - pharmaceuticals (SIC 21)
- Manufacturing - computer, electronic and optical products (SIC 26)
- Manufacturing - electrical equipment (SIC 27)
- Manufacturing - motor vehicles and other transport equipment (SIC 29-30)
- Services - Scientific research and development (SIC 72)

Technical Annex E

Figure 5: Expenditure on research and development (GERD) as a percentage of GDP (%) by sector, 2017



Source: Scottish Government, Gross Expenditure on Research and Development 2017

Technical Annex F

International practice

To inform this work, a review of international systems and approaches was undertaken. While a whole host of factors, including the wider ecosystem and culture, will determine the success of a particular approach or policy (and therefore cannot be directly transplanted), there are still lessons that can be learnt for Scotland.

A key piece of work in this space is the 2014 NESTA report, which looked at innovation in five countries with similar population sizes to Scotland – Finland, Estonia, Israel, Singapore and the Basque Country[80]. The themes identified through this case study approach included: the importance of applied research; openness to the world; strong but flexible institutions; a sense of national mission in undertaking innovation; and, a government whose policies support innovation.

The challenges outlined for Scotland in the report include: how to have a national vision for innovation with an internationally open and connected economy; how to do applied research well given the excellent reputation for basic research; how to embrace public and social innovation; and how to create adaptive and effective innovation institutions.

The NESTA report and the following case studies highlight that countries that have been successful in levels of business innovation often have a strong national commitment and focus on innovation. Although direct comparisons are generally not possible, the evidence suggests that the scale of Scotland and the UK's support for innovation is significantly lower than international comparators[81].

Switzerland

Switzerland performs very well in terms of nearly all available indicators of science, technology and innovation. Switzerland has a strong and varied industrial research base. It comprises both large, R&D-intensive multi-national enterprises which are at the forefront of industrial research and a large number of innovative SMEs.

Two ministries are responsible for science, technology and innovation policy making and strategy. Both the national government and regions have powers and funding for higher education. An advisory council serves as a strategic steering body. There are two separate and independent funding organisations, one of which is responsible for the funding of science and the other for the funding of more applied research.

The two major funding institutions are KTI (Commission for Technology and Innovation) and SNF. KTI tries to improve links between science and industry and co-finances market-oriented research, provided that the industrial partners contribute to the project. A number of programmes address certain technology fields or certain stages in the lifecycle of firms.

SNF is by far the most important initiative for project-based and programme-based science funding. It supports basic research in all disciplines, with excellence as its main criterion. It funds first and foremost individual, bottom-up grants for researchers, along with scholarships and various programmes ranging from bottom-up networks to top-down priority-setting activities.

Corporate tax arrangements (which are set at the regional level) are also an important policy instrument.

Basic research seems to be a relatively more important part of the research portfolio than in other countries. A large share of BERD undertaken in Switzerland comes from international organisations compared to other OECD countries and industry funding of HERD tends to be high.

In the Swiss case, the strengths are that they have a major industry presence in major areas of R&D with a highly innovative sector and hence the absorptive capacity is different from Scotland's[82].

Swiss HE system

There are 12 universities in Switzerland (including two federal institutes of technology), as well as a number of universities of applied sciences and other higher education institutions.

Denmark

With a similar size to Scotland and, as one of the top performers on innovation spend, Denmark is an interesting comparator for Scotland. Denmark spends the most on Higher Education Research and Development of all OECD countries at 0.98% of GDP and spends more than 3% of GDP on Research and Development.

A large part of innovation in Denmark is dominated by the public sector. In the past 10 years, public investment in research and education has been extensively boosted. Today, the public sector invests more than DKK 18 billion (€2.4 billion) annually, equivalent to 1 per cent of GDP, in research and innovation. The investments have contributed to Danish research being of the high quality it is today, the doubling of the number of PhD students, and the development of an innovation system that is considered well-functioning internationally[83].

Innovation policy

The public sector prioritises investment (approximately DKK 1 billion annually, or €130 million) in selected areas with great societal challenges and particular business or societal potential e.g. energy, the environment and climate. RESEARCH2020, which was released in May 2012, forms the basis for the prioritisation of public investment in Danish strategic research[84].

RESEARCH2020 contains five visions: a society with a green economy; a society with health and quality of life; a hi-tech society with innovation capacity; an efficient and competitive society; and, a competent, cohesive society.

Growth teams have also been established in areas of business strength and opportunity to identify and address barriers to growth and opportunities for market development. Growth teams have been established in the following areas:

maritime; water, bio and environmental solutions; energy and climate; tourism and leisure economy; creative business and design; health welfare solutions; food; and, ICT and digital growth.

Innovation networks

The Innovation Networks are a key intervention in the HE/business interface. They work extensively on matchmaking company needs and the knowledge of HEIs. Innovation networks are sector-specific and cover: product and design, ICT, energy, environment, services, health, food, construction and transport. Participation in the networks has increased considerably and almost doubled between 2011 and 2016. More than a third of the participating companies have established collaborations with higher education institutions as a result of their participation.

A recent study found participation in the Innovation Networks to increase labour productivity and total factor productivity by almost 7 and 13 percent respectively after four years[85]. In addition, participants in the Innovation Network programme are about five percentage points more likely to participate in other Danish innovation programmes in the subsequent four years.

HE entrepreneurship ecosystem

Danish universities invest heavily in supporting the ecosystem for entrepreneurship – the universities and partners located at the university campuses (or in proximity) supply a number of services to entrepreneurs and potential entrepreneurs, such as incubators, advisory services, facilities, training, funding opportunities, matchmaking services, etc.

In addition: all Danish universities have established technology transfer offices (TTOs) tasked with:

1) scouting, patenting and commercialisation activities;
2) providing counselling to researchers wishing to commercialise research with promising prospects.

Most universities have established student incubators and research parks at, or close to, the campus containing flexible office spaces, labs, meeting facilities, etc.

At some universities, the research park also welcomes private sector providers with expertise in patenting, business development, etc. as well as providers of risk capital (including innovation incubator operators).

Most of the universities have developed local competitions and events promoting student entrepreneurship. Moreover, a number of both curricular and non-curricular courses in entrepreneurship are delivered at the universities.

Danish HE system

There are five types of higher education institutions in Denmark: universities; business academies; university colleges; institutions in architecture and art; and maritime educational institutions. There are eight universities awarding bachelor's degrees, master's degrees and doctoral degrees.

Finland

Since a deep recession in the early 1990s, Finland has transformed into one of the most innovative and productive countries in the world. It became a world leader in electronics, led by the global domination of Nokia in the late 1990s and early 2000s. It invests heavily in R&D (more than 3 per cent of GDP). Technology and gaming remain a key strength, even though Nokia is no longer a world-leader in handsets and shed 24,500 jobs in 2012 and 2013[86].

Finland's transformation builds on a long–standing and widely-held belief in the importance of innovation as part of the future direction of the country. The Finnish Government put innovation at the heart of its response to the crisis of the early 1990s, maintaining spending on technology in the face of wider cuts. Since then, the level of research and development investment has increased by a factor of five, buoyed by the ambitious R&D targets set by the government throughout the past 20 years. Notably, much of this increase has been driven by increasing amounts of R&D in the private sector.

Finland was strongly impacted by the global financial crisis and technological change leading to the decline of Nokia's handset business and has suffered a recent decline in BERD however, Finland has important innovation assets and recent reforms have emphasised the importance of innovation and collaboration.

Innovation policy

In Finland, innovation has been increasingly placed at the heart of government policy with active coordination taking place at the highest level. The Research and Innovation Council, established in 1987, is chaired by the Prime Minister. It has the input of the Finance, Education and Employment Ministries which has encouraged a more systemic, whole–of government approach. In 2008, Finland enshrined this concept in its National Innovation Strategy, introducing a broad–based innovation policy that linked the innovation to the "highest possible long–term benefits for the national economy and society".

Finland's national innovation agency, Tekes, was recently merged with Finpro, the body that helps SMEs scale up internationally and encourages FDI into Finland, to form Business Finland. The intention is to offer an improved platform for innovation and support start-ups and SMEs to scale up more quickly.

Public engagement

Finland has also found ways to engage the general public in national conversation about the direction of the country. Finland Foresight, in 2012, asked citizens to come forward with ideas on Finland's future and the possibilities that lie ahead.

Research funding

In Finland, a comprehensive reform of state research institutes and research funding occurred in 2014–2017. This changed the structure of state research institutes, many of

Technical Annex F

which have been consolidated into larger units. This helps them to make clearer focused choices and build larger co-operation models with the companies.

Finnish HE system

Finland has 10 multidisciplinary universities, four specialised universities (which focus on economics, technology, defence and the arts) as well as a separate system of tertiary education with 26 polytechnics.

Norway

Norway has a high level of HERD (0.71% of GDP in 2017) and BERD above the level in Scotland (1.1% of GDP in 2017).

For the past two decades there has been a focus on commercialisation of research from HEIs in Norway and several initiatives have been launched to support the development of patents, spin-offs and licences. In addition, there has been an increased emphasis on collaborative research between HEIs and the public/private sector, seen in the increase of the number of collaborative research programmes and in funding of these activities. Collaborative research receives the largest public budget allocation. Both commercialisation of research and mobility between sectors are also prioritised.

There are several schemes for collaborative research projects. According to qualitative evidence, large schemes that run for several years, such as cluster and centre programmes, seem to impact the largest HEIs in the way that they plan and co-ordinate the applications in advance of the calls as partnership in these are recognised as important for knowledge transfer[87].

The HEIs report to the Ministry of Education and Research and are incentivised on education and research through performance-based funding. The Ministry of Trade, Industry and Fisheries funds programmes in the Research Council of Norway which supports the commercialisation of research and research projects in industry.

In 2016, the Ministry of Education and Research introduced development contracts to stimulate a differentiation in the individual HEIs' profile. The development contracts may involve targets such as commercialisation of research, collaborative research and mobility. It has not yet been decided whether the development contracts shall include funding but this could incentivise the HEIs to develop and emphasise different channels of knowledge transfer. Recently, the Ministry of Trade, Industry and Fisheries called for suggestions for instruments that might incentivise researchers to participate in spin-off creation and licensing of research. A recent report argues that the current practices of IP ownership at the HEIs should be reconsidered and that a larger share of the ownership should be in the hands of the inventor.

Evaluations of programmes administrated by the different intermediary agencies emphasise that the funding enhances the interaction on research and education between HEIs and industry/public agencies but that it is difficult to trace or to attribute innovations in industry to specific programmes.

Norway HE system

Norway has eight universities, nine specialised universities and 24 university colleges as well as a range of private university colleges.

Until 2005, there were only four universities in Norway, located in Oslo (since 1811), Bergen (1948), Trondheim (1968) and Tromsø (1972). Since widening the definition of university, additional institutions have converted to universities.

Incentivising innovation

Countries use a range of fiscal levers to incentivise innovation – Ernst and Young's Worldwide R&D Incentives Reference Guide summarises the key R&D incentives provided in 45 countries. According to their annual global outlook for tax policy, 14 of 41 jurisdictions (34%) surveyed are forecasting new or more generous R&D incentives in 2018 (compared with 22% in 2017), with nine of the 14 enhancing their R&D incentives for the second year in a row.

Singapore, for example, increased its tax deduction for labour costs and consumables incurred on qualifying R&D projects performed in Singapore from 150% to 250%; likewise, Poland has increased its similar deduction, from 100% to 200%, effective 1 January 2018. Austria, Denmark, Hong Kong and New Zealand have or are considering introducing completely new R&D incentives in 2018.

Not all countries are changing their R&D incentives in this way; in common with recent years, a small subset of nations (Australia, Czech Republic, Russia and Vietnam) continue to target their R&D incentives more tightly.

[80] https://media.nesta.org.uk/documents/when20small20is20beautiful20final.pdf
[81] BIS (2013), BIS Analysis Paper: Insights from international benchmarking of the UK science and innovation system. According to the paper, it is challenging to produce a definitive view on the amount of public sector funded innovation spending. In the absence of reliable statistical sources, the report looked at comparable innovation bodies in the UK, Germany and Finland. The comparison indicates that the UK's public sector support for innovation is very low. The overall judgment was that this overall level is unlikely to allow the UK to maintain or develop its leadership in science and innovation; and that higher levels of investment would likely provide very substantial returns in terms of benefits to the economy and society.
[82] https://www.oecd.org/switzerland/oecdreviewsofinnovationpolicyswitzerland.htm
[83] http://s3platform.jrc.ec.europa.eu/documents/20182/232200/DK_Innovation_Strategy_201212_Final.pdf/bcc1e915-5330-4c17-ac21-297fe5d035f5
[84] http://s3platform.jrc.ec.europa.eu/documents/20182/232200/DK_Innovation_Strategy_201212_Final.pdf/bcc1e915-5330-4c17-ac21-297fe5d035f5
[85] https://www.tandfonline.com/doi/abs/10.1080/10438599.2017.1374045?journalCode=gein20
[86] https://www.bbc.co.uk/news/business-31044810
[87] Bourlag et al. (2019), The policy mix for knowledge transfer between science and industry in Norway: Case study contribution to the OECD TIP Knowledge Transfer and Policies project.

Technical Annex F

Figure 6: International R&D incentives

Country	Accelerated depreciation on R&D assets	Cash grants	Expedited government approval process	Financial support	Income tax withholding incentives	Infrastructure/land preferential price	Loans	Patent-related incentives	Reduced social security contributions	Reduced tax rates/ preferable tax rates	Tax allowance	Tax credits	Tax deduction (including super deduction)	Tax exemptions	Tax holiday	VAT reimbursement	Other
Argentina	√	√							√	√		√		√		√	
Australia												√					
Austria		√					√					√					
Belgium	√	√			√		√	√		√		√	√	√		√	Notional interest deduction
Brazil	√			√	√		√	√					√				
Canada	√	√		√			√			√		√					
Chile	√	√		√								√	√				
China										√			√	√	√		
Colombia		√		√								√				√	Tax discount
Czech Republic		√											√	√	√		
France	√	√						√	√	√		√			√		
Germany		√					√										
Hungary		√						√	√	√	√	√	√				
India	√	√		√			√	√	√	√			√		√		
Indonesia	√									√	√						
Ireland	√	√		√				√				√		√			R&D tax credit on R&D buildings
Israel		√		√	√			√		√			√				
Italy								√				√	√				
Japan												√					
Lithuania	√							√		√			√				
Luxembourg	√	√					√	√						√	√		
Malaysia		√		√							√		√	√	√		
Mexico		√										√					
Netherlands	√	√		√	√		√	√	√	√		√	√				
New Zealand		√										√					
Norway		√		√			√		√			√					
Philippines										√			√	√	√		
Poland		√										√	√	√			
Portugal		√					√	√				√	√				
Romania	√												√	√			
Russia	√								√	√		√	√	√	√		
Singapore		√											√				
Slovak Republic		√				√		√				√	√				
Slovenia		√		√		√	√						√				
South Africa	√	√											√				
South Korea												√					
Spain	√	√					√	√	√			√		√			
Sweden									√					√			
Switzerland	√			√			√			√					√		Reduced tax rates for license income
Thailand	√	√					√						√		√		
Turkey		√			√			√	√				√	√			
UK	√	√					√	√		√		√	√				
US												√	√				
Vietnam				√		√				√		√		√	√		Free training

Source: EY – Worldwide R&D Incentives Reference Guide 2018

Technical Annex G

Scotland's Innovation Funding Ecosystem

University specific strategy and activity – this includes:
- Sector or technology specific institutes such as University of Strathclyde's Oil and Gas Institute
- Contract R&D
- CPD
- Consultancy

Scotland specific funding – this includes:
- SFC Innovation Voucher scheme (SME focus) + Advanced Innovation Vouchers
- Innovation Centre programme – collaborative projects, industrial PhDs, MSc placements
- Scottish Government programme and initiatives – for example, NMIS
- SFC strategic funding, including the University Innovation Fund
- Scottish Enterprise – for example, High Growth Ventures programme, R&D Grants
- Highlands and Islands Enterprise
- Converge Challenge
- Scottish Institute for Enterprise (SIE)

UK-wide (including UKRI) funding – including:
- Industrial Strategy Challenge Fund
- Knowledge Transfer Partnerships (KTP)
- Strength in Places Fund
- Research Councils
- City Deals
- Catapults
- Industrial PhDs

European Commission
- H2020
- ERDF

Technical Annex H

Chief Scientist Office (CSO) funding

CSO's[88] remit is to support and increase the level of high-quality Health and Social Care Research conducted in Scotland for the health and financial benefits of our population.

The CSO's annual budget is around £67 million. The National Institute for Health Research, funded by the Department of Health to support Health and Social Care Research in NHS England, has an annual budget in excess of £1 billion.

This is comprises three main components:

- Around 60% of CSO's budget is distributed by allocation to the Scottish NHS Boards to meet the additional costs associated with hosting research.
- An annual contribution to the National Institute for Health Research to allow Scottish-based researchers to apply for funding via the large, UK-wide NIHR research funding schemes. These cover all clinical areas.
- Direct research funding. CSO runs a number of funding programmes. These include two grant funding schemes, covering Experimental Medicine and Health Services Research; a small grants scheme for pilot work; and funding for a limited number of Clinical Fellowships.

NHS Board allocations

Allocations are based on an activity-based funding model. The delivery vehicle is NHS Research Scotland (NRS). NRS funding is invested in infrastructure and personnel and designed to maximise the number of clinical trials that the NHS can support as well as ensure that these trials are delivered to time and target.

In FY 18/19 this infrastructure supported 1118 non-commercial and 504 commercial clinical studies that together recruited 33,745 patients.

NIHR contribution

CSO contributes annually around £10 million to the UK-wide research funding pot to allow Scottish-based researchers access to large research-funding programmes run by NIHR. These programmes cover:

- Health Technology Assessment
- Efficacy and Mechanism Evaluation
- Public Health Research
- Health Service and Delivery Research

Historically, Scottish-based researchers annually win awards in excess of the £10 million invested by CSO.

Direct research funding

CSO runs two response-mode funding committees covering Experimental/ Translation Medicine and Health Services/ Population Health research.

Additional funding is provided for a catalytic grants scheme, clinical fellowships at the pre- and post-doctoral level, and a programme of co-funding with health research charities.

In addition to the above, the CSO also makes investments in response to particular strategic imperatives. Examples include:

The Precision Medicine Ecosystem (PME)

A £4 million investment announced by the First Minister in 2016, PME involved two PM projects in Pancreatic Cancer (Precision Panc) and Multiple Sclerosis (Future MS) – £650K funding each – and £2.7 million for bioinformatics infrastructure development. Both projects were delivered through the SFC-funded Scotland Stratified Medicine Innovation Centre at the QEUH but recruited patients from across Scotland.

Scottish Genomes Partnership (SGP)

A collaboration of Scottish Universities and NHS Scotland building on £15m investment by the Universities of Edinburgh and Glasgow in whole-genome sequencing capability. CSO (£4m) and MRC (£2m) are supporting SGP over four years (until February 2020) to provide a platform for generating and using genomic data and developing genomics in Scotland.

[88] https://www.cso.scot.nhs.uk/csoapproach/

Technical Annex I

Good practice case studies

There are numerous examples of successful university, industry and public sector collaborations across Scotland – the impact that these can have in terms of job creation, inclusive economic growth and regeneration in their region is significant and numerous industrial partners are involved in the projects below.

While the selected examples below are by no means a comprehensive list of the excellent work going on across Scotland, they demonstrate that, if the right infrastructure, the world-leading research and an effective innovation ecosystem are available, industry will make use of it.

National Manufacturing Institute Scotland (NMIS)

The NMIS will comprise:

- A digital factory to develop the processes and technologies to address companies' manufacturing challenges and opportunities;
- A skills academy to provide advanced manufacturing training and upskilling for individuals at all levels of their career;
- A collaborative space to enable companies and their supply chain to work on new projects without disrupting their existing production lines.

The Scottish Government has committed £48 million to NMIS, which will be managed through Scottish Enterprise, with the University of Strathclyde, who will host the Institute, contributing £8 million. This is in addition to £8.9 million for a Lightweight Manufacturing Centre (LMC) which is the first step in developing NMIS. Companies are able to engage with NMIS through the LMC and through early skills activity like the NMIS Industrial Doctorate Programme.

The Scottish Government, Scottish Enterprise and the University of Strathclyde are working in partnership alongside organisations including Highlands and Islands Enterprise, Renfrewshire Council, Scottish Funding Council and Skills Development Scotland to deliver NMIS.

Medicines Manufacturing Innovation Centre (MMIC)

The MMIC is a new centre to help companies develop processes and technologies for manufacturing medicines. By supporting both start-ups and multi-national pharmaceutical companies, it is intended that the speed in which new medicines reach the market will increase significantly.

It is hoped that the new investment into UK medicines manufacturing will help the country access a global market said to be worth £98 billion.

Supported by Scottish Enterprise (£15 million), UK Research and Innovation through Innovate UK (£13 million), GSK and AstraZeneca (£7 million each), the MMIC is one of the early projects across the UK to receive funding from the UK's Industrial Strategy Challenge Fund.

The proposal for the centre has been developed with significant industry input. The project was led by the Medicines Manufacturing Industry Partnership (MMIP), which consists of a number of pharmaceutical companies including GSK and AstraZeneca. The MMIP, alongside the Centre for Process Innovation (CPI) in partnership with the Centre for Continuous Manufacturing and Crystallisation (CMAC) led by the University of Strathclyde, will run the centre.

Clinical Innovation Zone, Queen Elizabeth University Hospital

The University of Glasgow leads the world-renowned Clinical Innovation Zone (CIZ), which provides 22,000 square feet of high specification units designed to foster open innovation and offers a unique opportunity for industry to work together with academics and clinicians within the Queen Elizabeth University Hospital in the growing field of Precision Medicine – in which Scotland has the genuine potential to lead the world.

Already, the Clinical Innovation Zone is creating an eco-system unparalleled anywhere else in the world and is delivering real results – seeing industrial partners relocating to and investing in Scotland from Europe and from as far afield as California.

The CIZ is also home to the University's Imaging Centre of Excellence (ICE) and the Stratified Medicine Scotland Innovation Centre (SMS-IC), a partnership between universities, the NHS and key business partners, global biotechnology company Thermo Fisher Scientific, and biomedical informatics company Aridhia Informatics – and which acts as the gateway to Scotland's world-leading Precision Medicine ecosystem.

QuantIC, UK Quantum Technology Hub in Quantum Enhanced Imaging

Led by the University of Glasgow, QuantIC brings together over 120 researchers and more than 30 industrial partners in a collaborative venture to revolutionise imaging across industrial, scientific and consumer markets.

QuantIC's purpose-built innovation space at the University campus allows industry to co-locate with researchers and facilitates industrial access to the Hub's facilities and has to date invested over £4m in 39 industry-led projects and 14 PhD studentships, leveraging £3m for industry.

The industrial partnerships already flourishing around the quantum agenda led by QuantIC, as well as the academic expertise based at the University of Glasgow, will be a key building block of the new University-led Clyde Waterfront Innovation Campus – planned to be a world-leading innovation cluster in enabling technologies, including quantum, nanofabrication and photonics.

University of Dundee Drug Discovery Unit

The Drug Discovery Unit (DDU) was established in 2006 to translate world-class biology research in to new de-risked targets and candidate drugs. The initial focus was on Diseases of the Developing World, in which the university has an outstanding international reputation. The DDU is housed within purpose-built facilities at the University of Dundee School of Life Sciences.

Technical Annex I

The Innovative Targets Portfolio (ITP) can accept high-quality, commercially-viable projects in any therapeutic area as long as the approach is novel, the project addresses unmet medical need and the pathway to the clinic is clear.

The DDU is also developing an Antibacterial Drug Discovery Accelerator working in collaboration with senior investigators across the UK and beyond to create a step-change in the discovery of new anti-microbial drugs.

The DDU seeks to identify novel therapeutic targets and mechanisms of disease and aims to deliver pharmacological lead compounds with supporting data in an animal and/or tissue model of disease. Its strategy taps into a wealth of world-class academic research that is of tremendous industry interest in the current market but has, until recently, remained untranslated.

The DDU was established in 2006 with support from multiple funders, including the University of Dundee. Infrastructure funding has come mainly from the Scottish Funding Council, the Wellcome Trust, the European Regional Development Fund, the Wolfson Foundation, Scottish Enterprise, the Scottish Universities Life Sciences Alliance and ITI Life Sciences Scotland.

Project-based funding has come from the Wellcome Trust, Medical Research Council (MRC), Bill and Melinda Gates Foundation, Medicines for Malaria Venture (MMV), Drugs for Neglected Diseases initiative (DNDi) and Scottish Funding Council, among others.

Innovation Centres

Funded by the Scottish Funding Council with support from Scottish Enterprise and Highlands and Islands Enterprise, the Innovation Centre programme was first launched in 2012. Since then, £120m (2013-18) has been invested in eight Innovation Centres across a range of key sectors. The common aim is to help businesses increase the pace of innovation.

The eight funded Innovation Centres include:

- Construction Scotland Innovation Centre (CSIC)
- Scottish Aquaculture Innovation Centre (SAIC)
- Stratified Medicine Scotland Innovation Centre (SMS-IC)
- The Data Lab
- The Digital Health & Care Institute
- The Industrial Biotechnology Innovation Centre (IBioIC)
- The Innovation Centre for Sensor and Imaging Systems (CENSIS)
- The Oil & Gas Innovation Centre (OGIC)

Professor Graeme Reid chaired an independent review of the Innovation Centres programme in 2016[89].

Data-Driven Innovation in Edinburgh

The Data-Driven Innovation initiative is part of the Edinburgh and South East Scotland City Region Deal and aims to help organisations and citizens benefit from the data revolution.

Working together to deliver the 10-year programme are the University of Edinburgh and Heriot-Watt University, whose experts will collaborate with industrial partners on data-based projects in the public, private and third sectors.

The programme will increase the contribution of university research and in-demand graduate skills to the region's economy, launching more spin-out companies, attracting start-ups and established businesses as well as driving public and private sector investment.

Five data-driven innovation 'hubs' have been created, housing expertise and facilities to help 10 industrial sectors become more innovative through data. The University of Edinburgh hosts the Bayes Centre, Edinburgh Futures Institute, Easter Bush campus and Usher Institute for Population Health Sciences and Informatics. The National Robotarium is a collaboration between Heriot-Watt University and the University of Edinburgh.

Supporting the work of the hubs is a new super-computing facility for the secure and trustworthy analysis of datasets which will be unique within Europe.

InGAME

A new multi-million pound Innovation for Games and Media Enterprise (InGAME) project will establish a dedicated research and development centre for the Dundee video games cluster with a view to driving product, service and experience innovation across the industry. InGAME is one of nine Arts and Humanities Research Council's (AHRC) Creative Clusters announced across the UK, with the University of Edinburgh's data innovation partnership leading the only other Scotland-based project.

Led by the city's Abertay University, in partnership with the University of Dundee and the University of St Andrews, the project will offer a high-level resource to local, Scottish and UK games companies, benefiting from significant funding from the Creative Industries Clusters programme and the Scottish Funding Council. Games industry partners include 4J Studios, All4Games, BBC, Beano Studios, Biome Collective, DeltaDNA, Microsoft, Outplay Entertainment and Sony Interactive Entertainment Europe, while business and cluster development will be supported by Creative Dundee, Creative Scotland, Elevator UK, Interface, Dundee City Council, Scottish Enterprise, TIGA, UK Games Fund and UK Interactive Entertainment and V&A Dundee.

InGAME will take a highly collaborative approach, with artists, designers and creative writers co-located with technologists and business specialists. SME games studios will have access to the partners' expertise, engaging in creative experimentation, utilising new and emerging games technologies, exploring new audiences, and forming interdisciplinary working relationships. With the ability to rapidly prototype and test ideas, InGAME will also develop experimental processes for the generation of original creative content while promoting the diversification of new products and markets.

Technical Annex I

Advanced Forming Research Centre

The AFRC was established in 2008 at the University of Strathclyde. The AFRC is one of seven high value manufacturing (HVM) Catapult centres, the only one in Scotland. HVM Catapult centres offer business access to world-class equipment, expertise and collaborative working opportunities.

The Advanced Forming Research Centre is a globally-recognised centre of excellence in innovative manufacturing technologies, R&D, and metal forming and forging research.

The AFRC helps to fill the gap between fundamental academic research and industry. It helps companies to turn innovative technologies and ideas into a commercial reality that will increase their competitiveness, boost their business and secure the manufacturing sector in Scotland and the UK for generations to come.

The AFRC offers world-class expertise and cutting-edge technologies that help firms develop solutions that bring about real business benefits for companies of all sizes from across the UK and internationally.

National Decommissioning Centre

The University of Aberdeen is the recognised leader in offshore oil and gas decommissioning and is home to the National Decommissioning Centre. Established with government support, through the Oil and Gas Technology Centre (OGTC), this multi-million-pound centre of excellence works in partnership with government and industry to deliver research and training aimed at transforming oil and gas decommissioning and mature field management.

Combining industry expertise with academic excellence, the Centre aims to work in partnership with companies to become the global leader in R&D focused on reducing costs, extending field and asset life, and transforming the conventional approach to de-commissioning.

Linking industry demand and expertise with academic capability and skills will help create competitive advantage, not only for the oil and gas industry but for decommissioning challenges in the wider energy sector, for example, in offshore renewables. The NDC will also collaborate with R&D institutions and innovation centres across the country active in late-life asset management and decommissioning, and partner with fishing, marine, safety and environment organisations in the UK and internationally.

[89] http://www.sfc.ac.uk/web/FILES/InnovationCentres/Independent_Review_of_Innovation_Centres_Programme_-_29_September_2016.pdf