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Spending Review 2019

Analysis of Science Foundation Ireland Research Grants

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Executive Summary

Key Trends and Features of SFI Spending

- In 2017, SFI accounted for 23.4 percent (€173.3 million) of total Government spending on R&D.
- SFI's largest programmes, in terms of the value of awards between 2012 and 2017, were the Research Centres Programme (36.4%); the Investigators Programme (19.2%); and the Research Infrastructure Programme (10.4%).
- The 14 National Research Priority (NRP) areas accounted for 85 percent of the value of awards between 2012 and 2017.
- The NRP areas which accounted for the largest proportion of the value of awards were: Processing Technologies and Novel Materials (16%); Therapeutics (11%); and Data Analytics, Management and Security (9%).
- Of all funding leveraged by Research Centres from Private Enterprise, 76 percent of cash funding comes from Multinational Corporations (MNCs), whilst 16 percent comes from Small and Medium Enterprises (SMEs). 53 percent of in-kind funding comes from MNCs whilst 39 percent comes from SMEs. This may reflect the greater financial capacity of MNCs to provide cash, but the larger, relative capacity of SMEs to provide in-kind funding.

Key Findings

Enterprise Linkage and Funding

- The following trends are apparent with regard to SFI's links with industry:
    - Overall, the number of collaborations between SFI researchers and both SMEs and MNCs has increased between 2013 and 2017. The ratio of MNC to SME companies that collaborate with SFI is approximately 50:50. A single company may have multiple collaborations, however. The number of collaborations has been increasing more rapidly for MNCs than SMEs, with 54 percent of collaborations with MNCs and 36 percent with SMEs in 2017 compared to 47 percent and 44 percent respectively in 2013. The number and type of collaborations varies considerably across NRP Areas, suggesting different areas of interest for SMEs and MNCs.

    - SFI Research Centres attracted €158 million of research funding between 2013 and 2017 from private enterprise and a further €152 million from international sources. The Exchequer also contributed €111 million through other Exchequer sources, such as Enterprise Ireland. Research Centres have secured significant levels of funding from enterprise and international sources, though other Irish Exchequer sources account for a large share. Greater amounts of leveraged funding does not necessarily mean SFI funding will decrease. Rather, SFI funding, through cost-sharing conditions attached to the Research Centre Programme, is being used to secure additional funding from other sources. It is unclear, however, what the longer-term impact on the Exchequer or the R&D Portfolio will

be of SFI funded researchers drawing down more funding from the EU and industry. This may have an influence on the priority areas of researchers and consequently on SFI funding over time.

- Of the Postgraduates and Postdoctoral Researchers who remained in Ireland, there was an increasing share who took up employment in a private sector R&D role as their first destination after leaving a SFI funded role. In general, SFI has not met its target for the share of trainees to enter industry as a first destination following completion of their SFI funded role. SFI analysis suggests that a time lag exists between trainees leaving a SFI team and moving into industry, with a significant share of team-members in employment in the private sector a decade after a SFI award. Further data would be needed to determine the occupation, income, and skills-utilisation of these individuals over time.

Effectiveness

- Evaluating the longer term effectiveness and impact of funding for scientific research is challenging. This paper references some broad indicators which suggest effectiveness in terms of scientific quality, insofar as these indicators correlate with the timeline of SFI.
- 2.63 percent of SFI publications are in the top 1 percent of citations, whereas the average is 1.64 percent across all Irish scientific publications. This suggests the top researchers in the country are drawing down SFI funding and that SFI processes may be increasing the quality of work.
- Ireland rose from 48th to 11th globally in the last 13 years in terms of the quality of its scientific research (target is to remain in top 20). Furthermore, in terms of individual subject rankings, Ireland is 1st in the world in Animal and Dairy, 1st in Immunology, 2nd in Nanotechnology, and 2nd in Agricultural Sciences.
- A number of SFI programme-level evaluations have suggested evidence of effectiveness and impact. The challenge for SFI is to consider data collection and analytical techniques to seek to establish a more direct link to the longer term economic impact of their work.

Efficiency and Sustainability

- It may be prudent to more equally distribute SFI's largest expenditure components (e.g. Research Centre renewals) over time, rather than committing to a large component of expenditure in a single year. This would ease the commitment burden on the Exchequer if there is an economic downturn, and could help the Department of Business, Enterprise and Innovation respond to the, potentially competing needs of its different agencies with greater agility and flexibility.
- It is good practice that SFI grants contain sunset clauses.
- SFI has a commitment threshold of 90%/75%/60% over a rolling three year period.
- SFI has kept its cost of administration below its target of 5 percent.
- The use of independent international peer-review in SFI's grant award process to evaluate both scientific excellence and impact is acknowledged as good practice from an efficiency and governance point of view.

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1. Introduction

Science Foundation Ireland (SFI) is a national foundation for investment in oriented basic and applied research in the areas of science, technology, engineering, and mathematics (STEM) to assist the development and competitiveness of industry, enterprise, and employment in Ireland. SFI also has a role in promoting STEM engagement and education. This Spending Review paper will analyse SFI's spending on research grants. It follows on from previous Spending Review papers that focused on IDA Ireland and Enterprise Ireland, both large Agencies under the aegis of the Department of Business, Enterprise and Innovation (DBEI). SFI is the third large Agency under DBEI. A Spending Review of SFI is beneficial given the role it plays in the State's research and development (R&D) strategy, accounting for 23.4 percent (equivalent to €173.3m) of total Government R&D spending in 2017.[1]

SFI should be considered within the context of national Government policy. *Innovation 2020* – the current Government strategy on innovation – aims for "Ireland to become a Global Innovation Leader, driving a strong, sustainable, high-employment economy and a better society enjoying a good quality of life".[2] The rationale for this support for innovation is to contribute to increased productivity, sustainable economic growth, and job creation. Public investment in support of research, development, and innovation (RDI) is generally justified with respect to market and systemic failures that lead to sub-optimal private investment in RDI activities.[3] SFI, as the largest public funder of RDI activities in the State, is a large expenditure component in the delivery of the Government's strategy for driving innovation in Ireland.

SFI's estimated Exchequer allocation for 2019 is €206.6 million, which is an increase of 8 percent on 2018. The vast majority of this funding is used to administer grants to Higher Education Institutions (HEIs) for research in the areas of STEM, largely aligned with the Government's National Research Priority (NRP) areas.

This paper will review the rationale of public support for innovation; analyse the overall funding dynamics of SFI; analyse SFI grant awards by grant characteristics and activities; and analyse selected activities and outputs from SFI programmes, with a focus on those that can be linked to enterprise. There has been an emphasis in recent years on investment in science being aligned with the needs of the economy and society to deliver economic and social impact.

[1] Department of Jobs, Enterprise, and Innovation (2018). The Research and Development Budget 2017-2018. Page 17

[2] Department of Business, Enterprise, and Innovation. Innovation 2020. Excellence, Talent, Impact. Ireland's Strategy for Research and Development, Science, and Technology.

[3] Department of Jobs, Enterprise, and Innovation (2016). Economic and Enterprise Impacts from Public Investment in R&D in Ireland.

2. Rationale of Public Funding for RDI and Outline of Wider Policy Context

This chapter will outline SFI's evolving role in Ireland's enterprise and innovation policy and SFI's changing role within the context of broader State and European initiatives to support R&D.

The rationale for State support of RDI, as outlined by DBEI, is based on the concepts of market failures and systemic failures in the sector. Market failure refers to the sub-optimal outcomes that result from under-investment in RDI by the private sector, and the subsequent under-provision of positive externalities. Systemic failure refers to the under-provision of RDI resulting from systemic inefficiencies within existing market structures. For more on the rationale of State support for RDI, see Appendix 1: Theoretical Underpinnings of Public Expenditure in RDI.

Government Policy on Research, Development and Innovation

Innovation 2020 is the current Government strategy on innovation. Its aims include: to increase private spending on R&D in the economy; to increase the number of research masters and PhD enrolments to 2,250 per year by 2020; to increase the number of research personnel in enterprise to 40,000 in 2020; as well as increase the performance of the Irish RDI system in commercialising research and increase the number of innovation-active firms in Ireland. *Future Jobs Ireland 2019* is also a relevant strategy as it identifies a demand for a sufficient supply of skilled human capital to the Irish labour market. Specifically, the strategy states that SFI "Centres for Research Training will provide funding for the training of PhD and Research Masters students in areas of identified skills needs."[4]

According to DBEI, their focus over the years has been on increasing enterprise-oriented research activity and investment, within the enterprise base and the public research system.[5] SFI – given its legally defined role as a funding Agency for oriented-basic and applied research in STEM – should be considered within this policy context.

The Government introduced Research Prioritisation in 2012, which aligns the majority of competitively awarded public investment in research with 14 priority areas that have since been revised.[6] From a public expenditure perspective, it should be noted that the report states that the "selection of 14 areas did not imply parity in the allocation of investment between those areas".

[4] Government of Ireland (2019). Future Jobs Ireland 2019, page 53.
[5] Department of Jobs, Enterprise and Innovation (2017). Review of Capital Expenditure on Research, Development and Innovation (2000-2016).
[6] Department of Business, Enterprise and Innovation (2018). Research Priority Areas 2018 to 2023.

As the analytical sections of this paper focus on the time period 2012 - 2017 for SFI grants, the Government's Research Priority Areas (2012 to 2017) – with which most of SFI's funding during this time period was aligned – are displayed in the table below:

Theme[7]	National Priority Area
ICT	A. Future Networks and Communications
	B. Data Analytics, Management, Security and Privacy
	C. Digital Platforms, Content and Applications
	D. Connected Health and Independent Living
Health and Wellbeing	E. Medical Devices
	F. Diagnostics
	G. Therapeutics – Synthesis, Formulation, Processing and Drug Delivery
Food	H. Food for Health
	I. Sustainable Food Production and Processing
Energy Climate Action and Sustainability	J. Marine Renewable Energy
	K. Smart Grids and Smart Cities
Manufacturing and Materials	L. Manufacturing Competitiveness
	M. Processing Technologies and Novel Materials
Service and Business Processes	N. Innovation in Services and Business Processes

Innovation in the European Union

Ireland's innovation performance should also be considered in a European context in examining the rationale of State support for innovation. According to the European Innovation Scoreboard 2018, Ireland's performance has increased year-on-year (relative to the EU in 2010) since 2014 and by 8.5 percentage points between 2010 and 2017.[8] Nevertheless, in 2018 Ireland remained behind a group of innovation leaders in the EU, which comprises Sweden, Denmark, Finland, the Netherlands, the UK, and Luxembourg.

Within the EU, RDI investment has been identified as a priority through the establishment of the EU's latest over-arching research programme, Horizon 2020. Horizon 2020 is the EU's Framework Programme for Research and Innovation which has a budget of €77 billion over 2014-2020. It acknowledges that science and innovation are key factors to help Europe achieve smart, sustainable, and inclusive growth and solve pressing societal challenges. Additionally, this is also implicitly

[7] NRP Areas were revised in 2018. Themes were taken from the Refreshed Priority Areas 2018-2023. Themes may have slight differences in corresponding NRP names. See page 5: https://dbei.gov.ie/en/Publications/Publication-files/Research-Priority-Areas-2018-to-2023.pdf

[8] https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

acknowledged through the manner by which RDI is one method by which Government intervention in markets may be allowed by EU competition policy. There are state aid exemptions for RDI.

The Evolution of SFI's role in Irish Enterprise and Innovation Policy

The role of SFI in the Irish economy has evolved over time. SFI was originally established in 2000, as a sub-board of Forfás, to administer Ireland's Technology Foresight Fund.[9] The impetus to this development was the *Technology Foresight Ireland Report*, commissioned by the Irish Government in 1998. This report recommended the Irish economy be "repositioned, to be widely recognised internationally as a knowledge-based economy." It proposed that Ireland develop "world class research capability of sufficient scale in a number of strategic areas within our universities and colleges, research institutes and industry."[10] The ICT and biotechnology areas were identified as "representing, for the future, the engines of growth in the global economy" and "strategic technologies for the continued development of important national sectors." By focusing on these two strategic areas of technology, improved innovation across all sectors of the economy could be achieved.[11]

SFI was then established as a separate legal entity under the Industrial Development (Science Foundation Ireland) Act 2003 "to promote, develop and assist the carrying out of oriented basic research in strategic areas of scientific endeavour that concerns the future development and competitiveness of industry and enterprise in the State."[12] Initially, these strategic areas of scientific endeavour included "information and communications technologies (ICT), biotechnology, and other areas that concern economic and social benefit, long-term industrial competitiveness or sustainable development as may be prescribed from time to time by the Minister."[13] According to the OECD, oriented basic research is "research carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognised or expected current or future problems or possibilities."[14]

Since 2012, SFI have aligned the vast majority of their funding with the Government's Research Priority Areas. SFI acknowledge they can also fund research in "previously un-identified emergent areas of

[9] Science Foundation Ireland website, History Section: http://www.sfi.ie/about-us/about-sfi/history/
[10] Ibid., page 6.
[11] Ibid., page 36.
[12] Industrial Development (Science Foundation Ireland) Act 2003, section 7 (1) a.
[13] Industrial Development (Science Foundation Ireland) Act 2003, section 7 (3).
[14] OECD, Glossary of Statistical Terms: https://stats.oecd.org/glossary/detail.asp?ID=1924

national strategic opportunity, long-term industrial competitiveness, or environmentally sustainable development."[15]

The legally-defined functions of SFI were subsequently altered in the Industrial Development (Science Foundation Ireland) (Amendment) Act 2013 to include conducting applied research, which is "original investigation undertaken in order to acquire new knowledge directed primarily towards a specific practical aim or objective."[16] According to SFI, "the extension of SFI's remit to include applied research will enable the outcome of oriented basic research funded by SFI to be taken closer to market, which in turn increases the potential of research to yield commercial opportunities and jobs as well as other societal benefits."[17] In 2013, the role of SFI was also extended to the promotion and support of education in and engagement with STEM, as well as the development of an awareness and understanding of the value of STEM to society and the economy.

SFI operates alongside IDA Ireland and EI as pillars of Ireland's enterprise policy. IDA Ireland have stated previously that SFI funding has acted as a strong incentive for IDA client companies and noted that significant R&D investments have come to Ireland and developed strong links with SFI.[18] IDA Ireland also highlighted survey evidence that leading companies believe SFI is contributing to the development of skilled human capital in Ireland. SFI's activities may be considered within the context of EI and IDA Ireland offerings for client companies, given their interlinked roles in enterprise policy.

[15] SFI Annual Plan 2018.
[16] Industrial Development (Science Foundation Ireland) (Amendment) Act 2013, section 7 (a).
[17] http://www.sfi.ie/about-us/about-sfi/history/
[18] Indecon International Economic Consultants (2008). Value for Money Review of Science Foundation Ireland.

3. Overview of SFI's Income and Expenditure

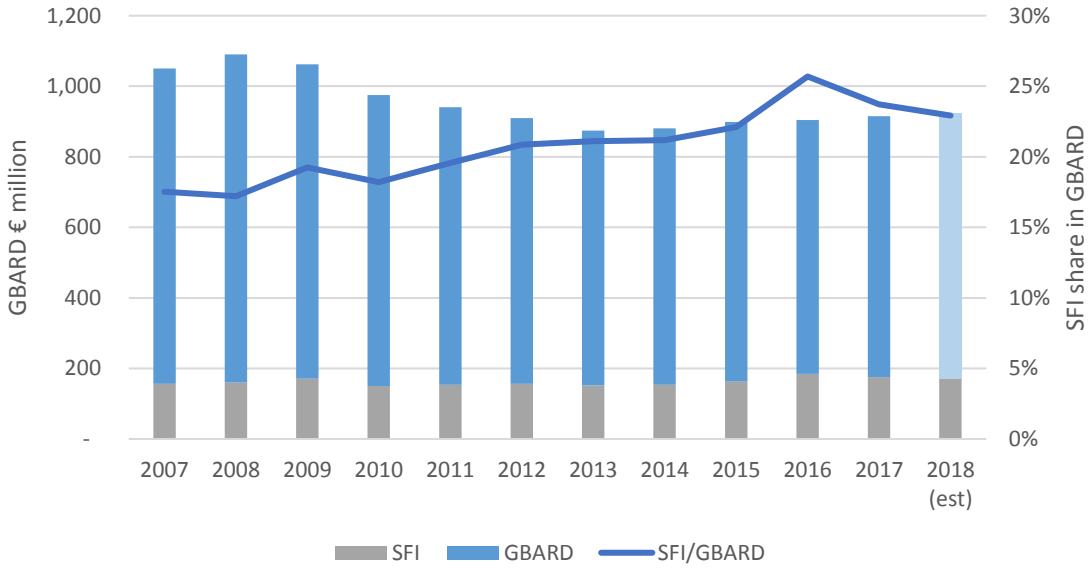
This section provides an overview of SFI's annual income and expenditure and considers SFI within the broader context of the Government's expenditure on R&D.

SFI's Budget within the Context of the Government's Budget Allocation for R&D

The Government, in 2017, spent €739.3 million (0.96% of total general Government expenditure) on R&D. SFI accounted for around 23% of this expenditure.

The Government Budgetary Allocation for Research and Development (GBARD)[19] in 2017 was €739.3 million[20], or 0.96% of total general Government expenditure. Between 2008 and 2013, there were year-on-year decreases in GBARD from €930.4 million to €721.7 million. Since 2013, there has been a small increase in GBARD. Previous work by the DPER illustrated that between 2000 and 2007, GBARD almost tripled in current prices.[21] Figure 1 below outlines the GBARD trend in current prices between 2007 and 2018. This graph illustrates that SFI's relative share of GBARD has been increasing over this time period; SFI is now the largest public funder of R&D in the State. As well as direct expenditure on R&D, the State also provides support through the R&D tax credit.

Figure 1: GBARD in current prices, € million, 2007-2018



Source: Eurostat, DBEI Research & Development Budget, and SFI Financial Data

[19] GBARD is all the funding allocated by the Government to R&D performed in all sectors of the economy.
[20] Department of Business, Enterprise, and Innovation (2018). The Research and Development Budget (R&D) 2017-2018.
[21] Department of Public Expenditure and Reform (2014). Cross-Cutting Issues in Relation to Expenditure on Science, Technology, and Innovation.

Analysis of SFI Annual Income

SFI relies on the Exchequer for the majority of its funding and does not generate revenue from its investments in RDI.

Total SFI income over the period 2007-2017 was €1.9 billion. The average annual income over this period was €172.2 million and income ranged from €158.9 million to €195.6 million.

Almost all of SFI's income over this time period was from the Exchequer, either directly through the annual Exchequer allocation to SFI, or indirectly, through co-funding from other publicly funded Research Agencies. Between 2007 and 2013, the Exchequer directly accounted for at least 99.4 percent of SFI's income each year through the Exchequer allocation to SFI.[22] Between 2014 and 2017, the direct Exchequer allocation as a share of total SFI income declined to 97.7 percent. This was largely due to co-funding from other publicly funded Agencies (such as Teagasc and the Marine Institute) increasing as a share of SFI income in these years. This co-funding is used to finance specific co-funded SFI research grants; it is separate from funding leveraged by SFI researchers from other sources, such as enterprise or the EU, which will be discussed in later sections. It is not possible to say whether this funding came from own-resource income or the Exchequer allocation to these Agencies, but it is likely Exchequer funding, and could be considered indirect Exchequer income for SFI. This increase in co-funding from other Agencies is an intentional shift in policy by SFI as one of the targets in *Agenda 2020* is to build joint funding instruments with other Irish and international Agencies.

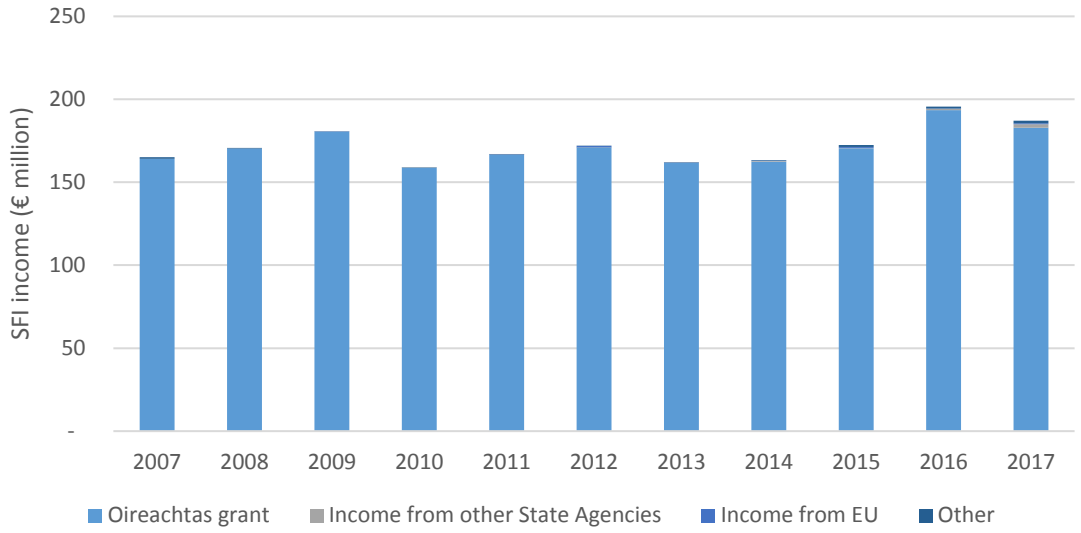
Other income sources for SFI, beyond the direct Exchequer allocation and co-funding from other Exchequer-funded Agencies, during these years included EU funding, grant refunds, profit on the disposal of fixed assets, and interest. These do not account for substantial shares of income. SFI does not generate revenue from its investment.[23]

Figure 2 highlights the evolution and distribution of SFI's income between 2007 and 2017. SFI's income increased year-on-year between 2007 and 2009. Between 2009 and 2014, SFI's income fluctuated around lower levels; and since 2015 it has increased again. It is notable that SFI is highly dependent on the Exchequer grant for its income, which is in turn distributed among its programmes.

[22] See Appendix 2 for Table.

[23] Other public research funding Agencies internationally – such as the Engineering and Physical Sciences Research Council in the UK and the Swiss National Science Foundation in Switzerland - do not make claims to the intellectual property rights arising from the research they fund. In the UK and in Ireland, the intellectual property rights generated from this publicly funded research often reside with the HEIs that generate it.

Figure 2: SFI income, 2007-2017, € million



Source: SFI Annual Reports

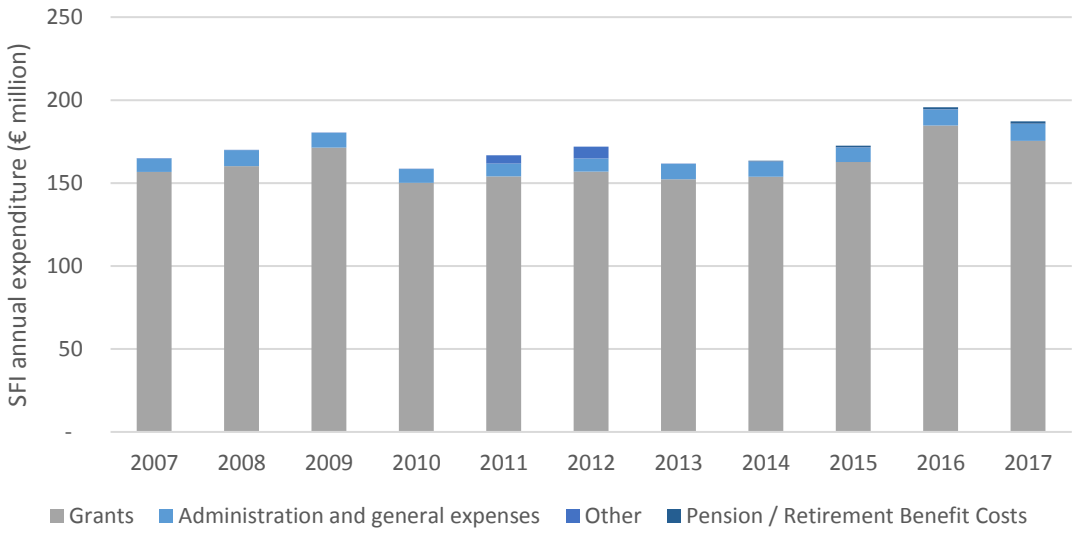
Analysis of SFI Annual Expenditure

- **Capital grants account for the largest share of SFI's annual expenditure.**
- **The cost of administration in SFI has remained below SFI's target of 5 percent.**

Total SFI expenditure over the period 2007-2017 was €1.9 billion. Average annual expenditure during this period was €172.1 million and expenditure ranged from €158.5 million to €195.7 million.

Capital grants accounted for the largest share of SFI's annual expenditure during 2007-2017. Over this time period, capital grant payments accounted for between 91.3 percent and 95 percent of total SFI expenditure each year. This was followed by current expenditure, in the form of administration, pay, and general expenses which accounted for between 4.6 percent and 5.7 percent of total SFI expenditure each year. One of SFI's Key Performance Indicators (KPIs) as part of Agenda 2020 is the cost of administration; its associated target is to remain below 5 percent (of total commitments) per annum by 2020. In general, the cost of administration relative to total annual commitments ranged between 2 percent and 4 percent during 2007-2017, remaining below 3 percent since 2013.

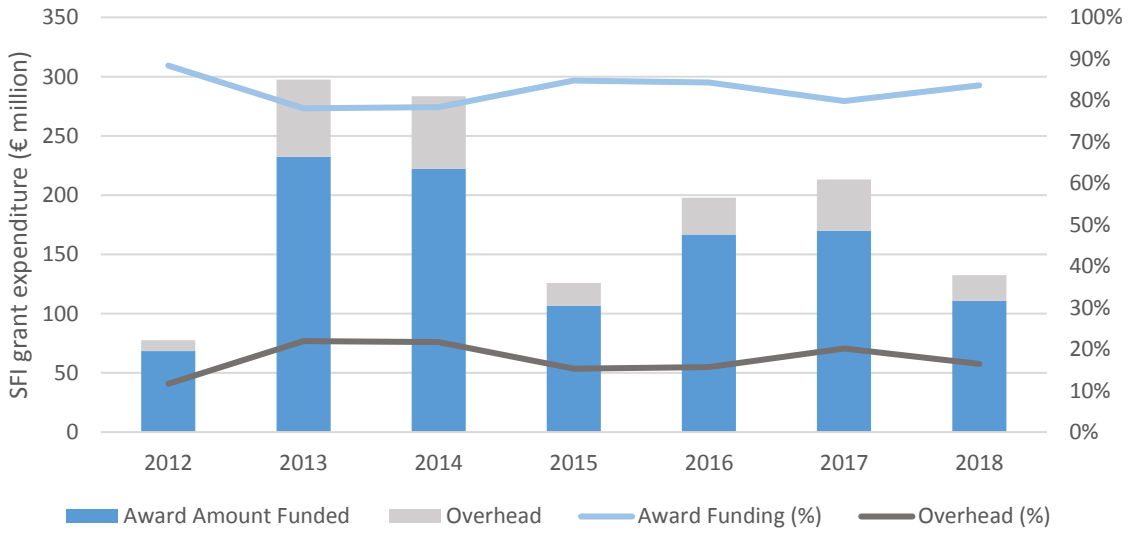
Figure 3: SFI annual expenditure, 2007-2017



Source: SFI Annual Reports

This funding can be further broken-down over the 2012-2018 period. As figure 4 shows, approximately 82% of SFI grants are direct awards, while the remaining 18% go towards the overheads of the programme/research project. This figure depicts the new grants committed to, and so differs from Figure 3 above, which depicts annual expenditure, and therefore, includes grant payments including the servicing of outstanding awards from previous years.

Figure 4: Composition of New SFI Grant Commitments by year, overheads and awards, 2012-2018



Source: SFI Financial Data

Outstanding Grant Commitments

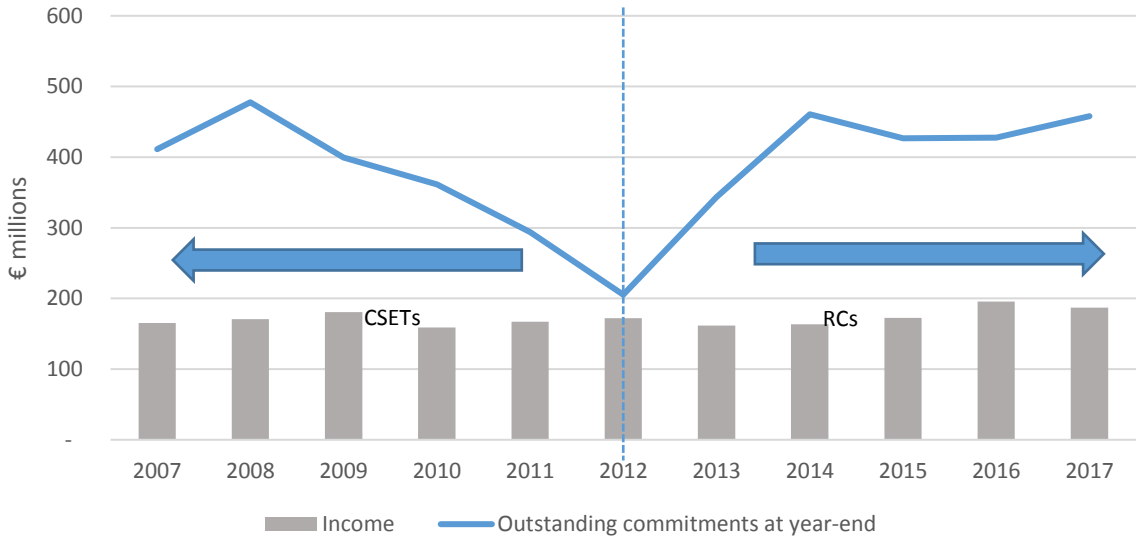
It may be prudent for SFI to aim to more equally distribute large grant commitments over time. Increasingly, SFI's largest expenditure component is accounted for by the Research Centres.

SFI should provide programme and cost benefit analysis reporting that shows outstanding commitments as a function of its realised and expected income.

Not spacing SFI's grant commitments may crowd out DBEI's ability to make commitments under other headings.

Figure 5 illustrates SFI's outstanding commitments on previously approved grants at year's end between 2007 and 2017. SFI's outstanding commitments ranged from €205 million to €478 million. Between 2008 and 2012, outstanding commitments declined year-on-year. Following that, there were year-on-year increases in outstanding commitments to €461 million in 2014. Outstanding commitments then fell and rose again in 2017, when outstanding commitments were €458 million. This trend was driven by a slowdown in the scale of new awards between 2008 and 2012, which may have been a response to the 2008 financial crisis given pressures on SFI's budget, and in part by SFI's transition from Centres for Science, Engineering, and Technology (CSETs) to Research Centres (RCs). The value of new awards granted annually largely determines the trend in outstanding commitments that can be seen in this graph.

Figure 5: Income and Outstanding grant commitments at year end, 2007-2017, € million

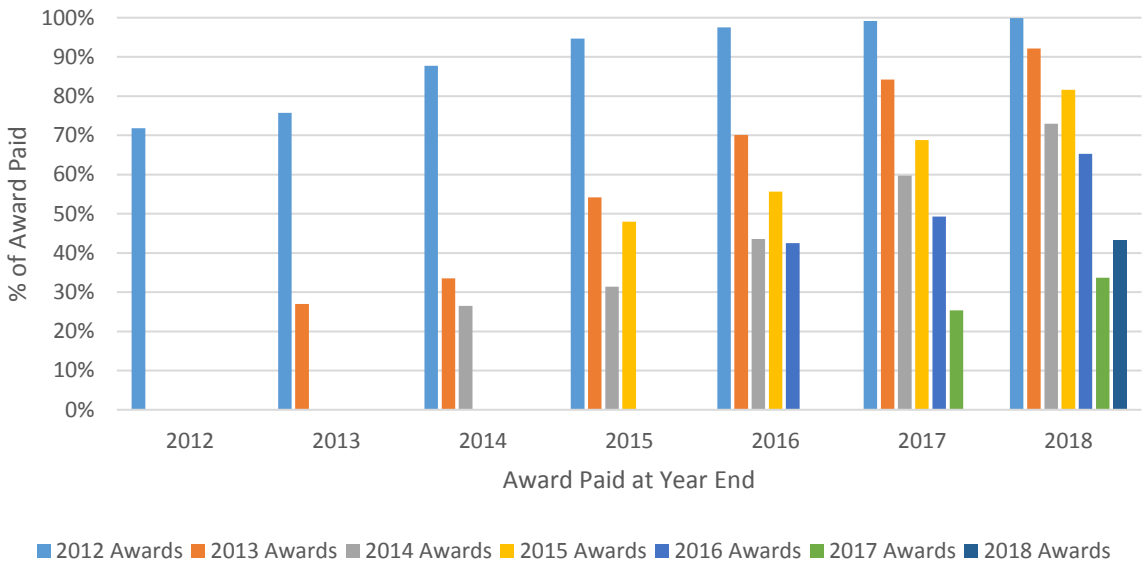


Source: SFI Annual Reports

Figure 6 shows the award payment trends by depicting the percentage of the award amount that has been paid by a given year. More than 70% of awards granted in 2012 were paid in 2012 and nearly the full amount was paid by the end of 2016. This may be an outlier given that 45% of awards SFI awarded

that year were under the Research Infrastructure Programme heading (see Figure 8), which provides scientific infrastructure, and, therefore, is more likely to be a once-off payment. For awards granted in 2013 onward, the tendency is for less than 50% of an award to be paid in the year it was granted.

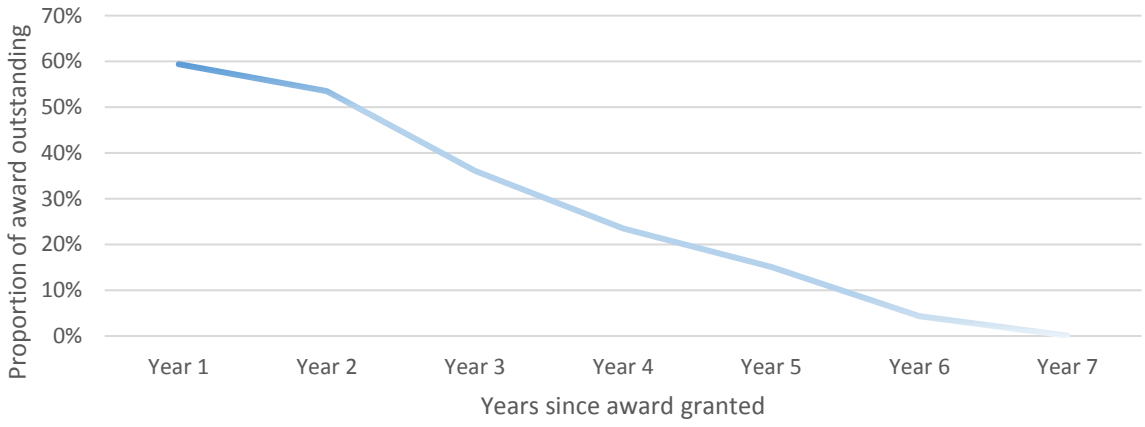
Figure 6: Percentage of Award Balance Paid by year end, 2012-2018



Source: SFI Financial Data

The average amount outstanding at the end of year 1, the year that the award was granted, is 59%. By the end of the fifth year, the average amount outstanding is 15% of the award amount. Figure 7 depicts the drop off rate of outstanding amount. Note: this is based on an average of the outstanding awards using data from 2012 to 2018. Therefore, the robustness of the trend decreases as the years increase, as there are fewer data points. The graph is, therefore, illustrative, not predictive.

Figure 7: Average award amount outstanding since the award was granted



Source: SFI Financial Data

Owing to data limitations it is difficult to illustrate the relationship between (both realised and expected) income and grant commitments. SFI has a commitment threshold of 90%/75%/60% over a rolling three-year period. Over 2007 to 2017, SFI's outstanding commitments averaged 225% of its annual income (Figure 5 above). It is, therefore, important for DBEI, when evaluating SFI and its programmes, to demonstrate that SFI's commitments as a function of income remain constant, and are not increasing, on the expectation that SFI's income will increase. The General Conditions of Sanction for Capital outlined in the public spending code[24] state that new contractual commitments should not exceed 75% of the Department's allocation in a given year, and 60% and 50% in subsequent years. SFI is one of a number of agencies under the aegis of DBEI, however, certain SFI properties may affect the management of these agencies. Notably, the SFI's lingering commitments, (which may take up to 7 years to terminate; Figure 7), may have an impact on capital allocations beyond SFI.

Given, increasingly, SFI's largest expenditure component is accounted for by the Research Centres, which are six year awards, it may be prudent to aim to more equally distribute these, and other large commitments over time, rather than committing to a large component of future expenditure in a single year. This would increase transparency and would enable more prudent fiscal management, from an Exchequer perspective, as its pre-commitment levels, in any given year, would be lower, enabling it to deal with a downturn, or changing priorities, more easily. Additionally, these large commitments may affect DBEI's other agencies' ability to make capital commitments and to respond flexibly to emerging demands, as DBEI has Departmental commitment thresholds, of 85%/65%/51% over a three year rolling period. This, however, should be balanced with the potential administrative efficiency of having Research Centre calls for funding in large chunks, as well as any effects this may have on competitiveness. DBEI decides the appropriate thresholds for its individual agencies within this overall threshold.

[24] https://publicspendingcode.per.gov.ie/a03-general-conditions-of-sanction/

4. SFI Award Process

All SFI grants are evaluated with respect to scientific excellence and impact. SFI use international peer-review to evaluate the excellence and impact of grant applicants, which has been acknowledged to limit bias from a governance perspective. While the peer-review informs decisions about funding, the final responsibility for the decision lies with SFI.

This section provides an overview of SFI's decision-making process for awarding grants. SFI approves all of its awards through a competitive, international, merit-based process. In order to be successful in a grant application, a researcher must be able to demonstrate a proposed project's scientific excellence and its potential impact.[25] The weightings of each depend on the programme. A researcher's submission for an award must also be accompanied by a budget. Researchers can seek budget reallocations or a no-cost time extensions at a later stage, and these are evaluated by SFI.[26]

For SFI, the use of international, independent peer-reviewers is a central part of their decision-making process. It is common practice amongst small advanced economies to use international peer review because of the risks of bias and undeclared conflicts in smaller systems. Another stated benefit is that it also allows for evaluation by individuals with an appropriate level of expertise. Both Finland and Ireland only use international experts in their review process, at both the pre-proposal and full proposal stage.[27]

Impact is defined by SFI as "the demonstrable contribution that excellent research makes to society and the economy".[28] SFI defines impact broadly in eight categories: economic impacts; societal impacts; international engagement impacts; policy and public service impacts; health and well-being impacts; environmental impacts; professional services impacts; and human capacity impacts. Applicants are required to submit an Impact Statement to SFI which outlines how their proposed research would impact in any of these areas. Impact Statement requirements vary from programme to programme and are related to the objectives of a specific programme or funding call, but these requirements are listed in each call document. In nearly all cases, SFI use "international experts with specific/documented interests in impact evaluation from other jurisdictions to review and rank the impact statements of scientifically excellent projects." According to SFI, "reviewers assist in the process and make funding recommendations but do not make funding decisions. The final responsibility for evaluation and award decision lies with SFI."[29]

[25] SFI. Research in Ireland, the Benefit of Feedback.
[26] SFI Grant Budget Policy (2016)
[27] Harland and O'Connor (2015). Broadening the Scope of Impact.
[28] http://www.sfi.ie/funding/award-management/research-impact/
[29] http://www.sfi.ie/funding/sfi-policies-and-guidance/review/

5. Methodology and Limitations

The analysis to follow in this paper is based on SFI's SESAME database. SESAME is SFI's grant management system that is internationally recognised and is used by a number of agencies and public bodies in the US and Canada. SFI has been using SESAME to collect data on outputs from SFI researchers since 2013. According to SFI, SESAME represented an improvement on the system that existed previously. This paper's analysis of outputs is limited to 2013 – 2017 because the output data are more robust across these years.

This paper will not examine the impacts of SFI research grants. It is widely acknowledged that evaluating the impact of scientific research is challenging, as these impacts can take a long time to manifest and they can be difficult to attribute to specific interventions. Nevertheless, a number of Programme-level evaluations have been conducted on SFI previously, which suggest evidence of effectiveness and impact. Indecon (2017) published the *Interim Evaluation of Science Foundation Ireland Research Centres Programme* and Technopolis (2014) published the *Evaluation of Science Foundation Ireland's Principal Investigator (PI) Programme.*

There are limitations with the available data however. Firstly, outputs are self-reported by researchers on the system. This means that under-reporting or over-reporting of outputs and possible data entry errors could pose a limitation on the validity of any analysis that relies exclusively on these data. Furthermore, where an output could be attributed to more than one award or programme, the researcher may only attribute to one of those awards, which, again, poses some limitation. The data are also limited with respect to the longer term outputs and outcomes of grants. Recent changes to SFI's Standard Terms and Conditions will facilitate longer term data analysis going forward. For example, a clause now exists to allow for data collection for 10 years after an award. SESAME is being continually refined by SFI, which means year-on-year comparisons can be distorted by changes and improvements in how the data are collected. Inconsistencies in how data are collected over time can pose difficulties for analysis.

This paper will, using available data on the inputs, activities, and outputs of SFI grants, provide a financial and compositional analysis of SFI grants, as well as an analysis of activities and outputs associated with these grants.

The challenge for SFI is to enhance the collection of data to enable the evaluation of longer term social and economic outcomes and impacts of this research.

6. Trend and Composition Analysis of SFI Grants for R&D

The Programmes that accounted for the largest proportion of the value of awards were: Research Centres (36.4%), the Investigators Programme (19.2%), and the Research Infrastructure Programme (10.4%).

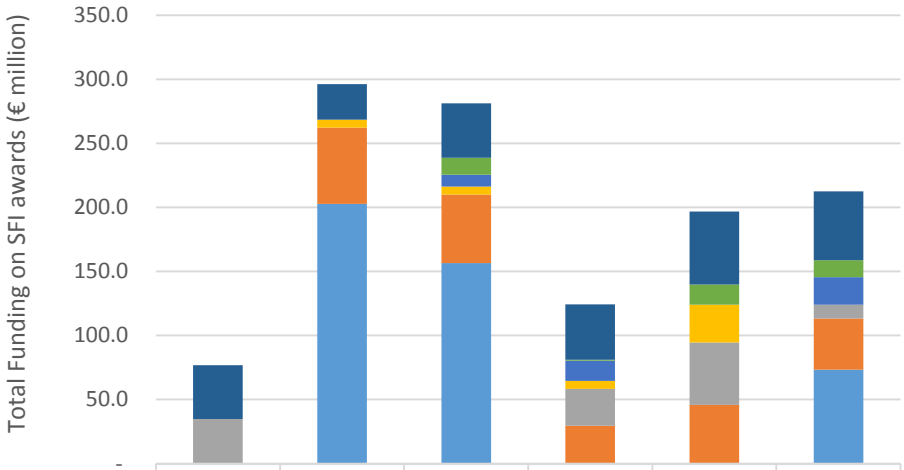
The 14 NRP Areas accounted for 85% of the value of SFI's awards. There is a high degree of variation in the amounts awarded to each NRP area per year.

The NRP areas to have received the most funding were Processing Technologies and Novel Materials (16%), Therapeutics (11%), and Data Analytics, Management and Security (9%).

This section of the paper will provide an analysis of the trend and composition of SFI grant awards during 2012 - 2017.

Figure 8 illustrates all SFI awards made during 2012-2017 by programme of expenditure. Grant awards represent multi-annual commitments that are paid out over time. These are not annual payments on grants; rather grant awards are any new grants that are approved in a given year. As can be seen in Figure 8, grant awards to a given programme are not necessarily made every year. For example, there were only awards to the Research Centres Programme in 2013, 2014, and 2017. Both the timing and amount of awards to the various programmes varied from year to year. During 2012-2017, SFI's Research Centres Programme accounted for 36.4 percent (€432.5 million) of grant awards, which makes this SFI's largest grant programme. SFI's Investigators Programme was the second largest, accounting for 19.2 percent (€228.6 million) of all grant awards made in this period. Together, these two programmes account for over half of all SFI awards made over the period. Other large components of SFI grant spending are the Research Infrastructure Programme (10.4%, or €123 million); the Research Professorship Programme (4%, or €48 million); the Spokes Programme (3.9%, or €46.4 million); and the Career Development Award (3.6%, or €43.1 million). A range of other programmes account for the remaining 22.4 percent (€266.3 million) of all grant awards made in this time period. SFI invests approximately equal amounts of its budget in individually-led awards (e.g. SFI Investigators Programme, Career Development Programme etc.) and in large Research Centre-led activities.

Figure 8: SFI Awards, 2012-2017, by Programme



	2012	2013	2014	2015	2016	2017
Other	42.0	27.9	42.3	43.4	56.9	53.8
Career Development Award (CDA)	-	-	13.4	0.6	15.8	13.3
Spokes Programme	-	-	9.1	15.8	-	21.5
Research Professorship Programme	-	6.2	6.2	6.2	29.4	-
Research Infrastructure Programme	34.9	-	-	28.8	48.7	10.6
Investigator Programme	-	59.4	53.5	29.6	45.9	40.2
Research Centres	-	202.7	156.5	-	-	73.2

(€ million)

Source: SFI SESAME Database

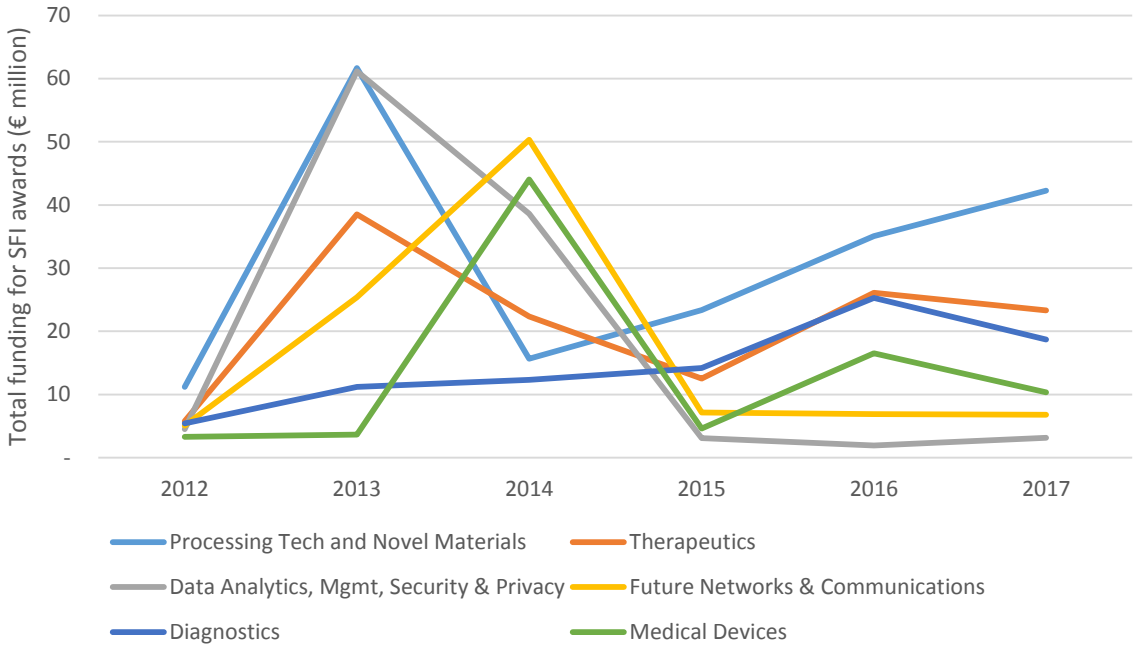
Figure 9 below illustrates all SFI awards made between 2012 and 2017 by NRP area.[30] Processing Technology and Novel Materials accounted for 15.9 percent (€189.3 million) of all awards made during this period, which makes it the largest NRP area for SFI research during this time period. Therapeutics: Synthesis, Formulation, Processing, and Drug Delivery was the second largest NRP area, accounting for 10.8 percent (€128.5 million) of awards. Data Analytics, Management, Security, and Privacy accounts for 9.5 percent (€112.5 million) of awards. Future Networks and Communications accounts for 8.6 percent (€101.6 million) of awards. Diagnostics accounts for 7.3 percent (€87.2 million) and Medical Devices accounts for 6.9 percent (€82.5 million) of all grants awarded during these years.[31] These NRP areas account for the largest proportion of SFI awards, but there are other NRP areas which funding is allocated to, although these are not represented in Figure 9. The variance in awards across NRP Areas is likely related to the variance in awards across programmes. Although the Government's

[30] The criteria that are used to select NRP areas can be found in: Department of Business, Enterprise and Innovation (2018). Research Priority Areas 2018 to 2023. These include that "the priority area is part of, or associated with, a large global market or markets in which Irish-based enterprises already compete or can realistically compete."

[31] Research Centres are assigned a single NRP area by SFI, but in reality they can span multiple NRP areas. This may create noise in the data with respect to NRPs.

NRP policy aligns the majority of competitively awarded public funding for R&D with these NRP Areas, there is no indication of what the allocation of funding across these NRP Areas should be. One question that arises is what drives this allocation of investment across NRP areas, and whether there exists, an optimal allocation of spending between these areas for the State's long-term development. [32]

Figure 9: SFI Awards, 2012-2017, largest NRP Areas



Source: SFI SESAME Database

Around 85 percent of the value of SFI grants awarded between 2012 and 2017 were for research within the Government's NRP Areas. This seems to be in line with the Government's NRP policy, which states that the majority of competitively awarded public investment in research should be aligned with the 14 NRP Areas. Beyond this, these is no particular target for how much funding should fall outside these areas. The remaining 15 percent of awards were for projects outside the NRP Areas. €53 million of funding awards during this time period were for research projects outside the NRP Areas. 59 percent of these were in the Biotechnology / Biologics areas. €71 million of funding awards during this period were for Basic Biomedical Science.[33] Finally, €54 million were Non-Research Grants.

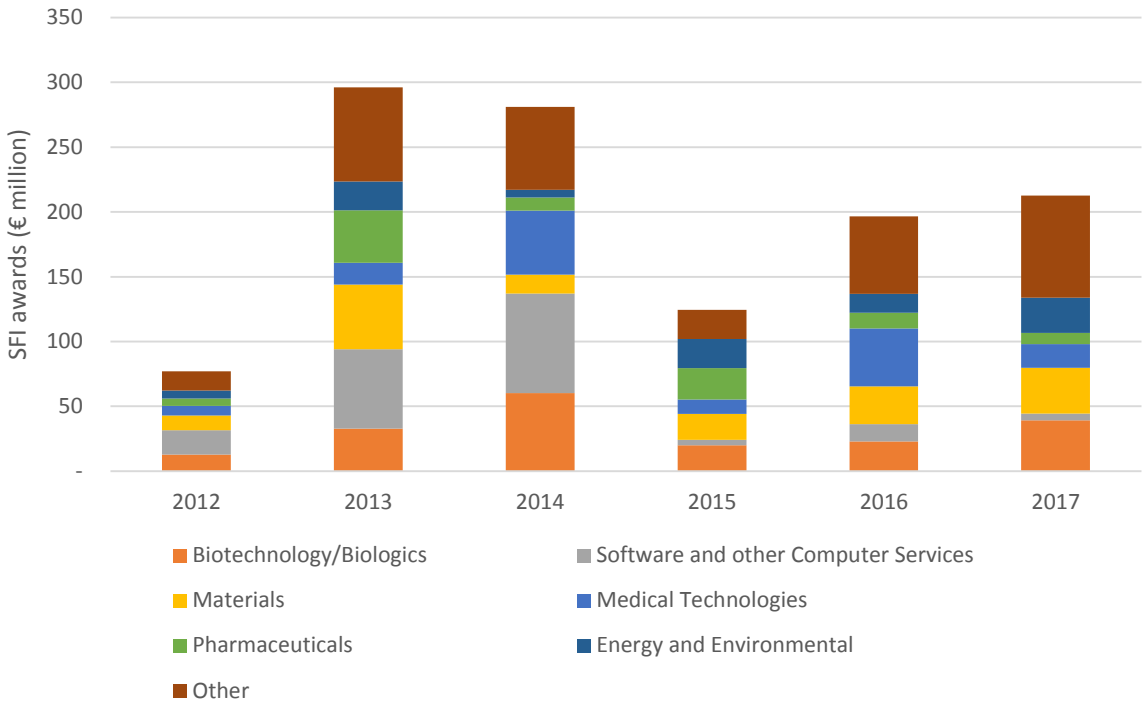
Figure 10 below illustrates grant awards made between 2012 and 2017 by industry. 15.8 percent (€187.7 million) of grants were for research associated with the Biotechnology / Biologics industries.

[32] For the Research Centres Programme, a strategic approach is taken for the allocation of funding across NRP areas. For the first call, all 14 NRP areas were the focus, but for the second call, NRP areas without an aligned Centre were prioritised.

[33] This is one of six platform science and technology areas highlighted in the NRP report as being necessary to underpin research in the 14 NRP areas. https://dbei.gov.ie/en/Publications/Publication-files/Research-Priority-Areas-2018-to-2023.pdf

15.1 percent (€179.7 million) of grants were for research associated with the Software and Computer Services industries. 13.5 percent (€160.4 million) of grants were for research associated with the Materials industry. 12.4 percent (€147.7 million) of grants were for research associated with the Medical Technologies industry. 8.5 percent (€101.3 million) of grants were for research associated with the Pharmaceuticals industry. Finally, 8.3 percent (€98.6 million) of grants were for research associated with the Energy and Environmental industries. The remaining 26 percent (€312.5 million) of grants were associated with other industries, were multidisciplinary, or were non-research grants.

Figure 10, SFI Awards, 2012-2017, by Industry



Source: SFI SESAME Database

SFI analysis of the Technology Readiness Levels (TRLs) of SFI awards via publications outputs between 2008 and 2016 shows that in 2016, 70 percent of all publications were in TRLs 1 and 2 – the lower end of the TRL spectrum. The share of publications in TRL 3 and 4 have been increasing since 2012. In 2016 these accounted for the remaining 30 percent of SFI publications. This may reflect SFI's transition to incorporate applied research in its mandate. Although reliable granular data on TRLs of grants awarded during 2012 - 2017 are not available, this SFI analysis illustrates that the majority of SFI awards are for lower TRLs, although since 2012 there has been an increase in the proportion of SFI awards in TRLs 3 and 4. That SFI predominantly fund research at the more basic end of the spectrum appears broadly consistent with the market failure rationale for public investment in STEM research.

7. Analysis of Activities and Outputs of SFI Grants for R&D

- **Commercial outputs are below target. However, data limitations may partly explain this. SFI have committed to working with EI to better track the progress of SFI funded intellectual property.**
- **SFI analysis of bibliometric data finds that 2.63 percent of SFI publications are in the top 1 percent of citations, whereas the average for any research funder in Ireland is 1.64 percent. Thus SFI publications are of relatively high quality.**

Selected Activities and Outputs at Agency Level

The following tables provide a high level summary of selected activities and outputs generated by SFI and its programmes over the period of interest. Notably, as there can be significant time lags associated with outputs being generated by inputs in research, the tables below do not give an accurate reflection of the outputs generated by awards granted over the 2013-2017 period. Instead they give a snapshot of all selected outputs over the period, many of which resulted from awards granted in previous years.

Given the data limitations and challenges with analysing the outcome and impacts of investment in science that were mentioned in section 5, this section will analyse a selection of activities and outputs for which data are available and which can be linked to the economy. A discussion of these activities and outputs will follow in this section, and subsequent sections will provide more in-depth analysis of non-academic collaborations, leveraged funding, and human capital.

Commercial outputs are difficult to monitor for SFI grants for a number of reasons. Firstly, commercial outputs often manifest with a considerable time lag, which poses a challenge from a data collection point of view. Because SFI generally funds research at lower TRLs, commercial outputs at a later stage may be more likely to be attributed to other grant supports that benefit RDI at more advanced stages. There are no particularly apparent trends in the commercial outputs data. Notwithstanding these issues, SFI's high level target for commercial outputs are 222 patents filed / awarded and 18 spinouts per annum by 2020. The commercial outputs figures outlined in the table below are below these targets, however, data limitations might partly explain this. SFI list an action in their *2018 Annual Review of Agenda 2020* to work with EI to better track the progress of SFI-funded Intellectual Property. If the data were more reliable, it would allow for more detailed analysis of the economic outcomes of SFI funding.

Table 1: Commercial outputs associated with SFI grants, 2013 - 2017

		2013	2014	2015	2016	2017	Total
Commercial Outputs	Licensed Technology	28	19	19	45	27	**138**
	Patents Awarded	12	20	29	9	23	**93**
	Patents Filed and Pending	57	43	47	67	53	**267**
	Spin-Out Companies	4	1	3	4	6	**18**

Source: SFI SESAME Database

Total publications associated with SFI awards (active and inactive) have remained broadly stable over these years. Indecon have recommended that SFI develop performance measures that better reflect the impact of publications.[34] SFI analysis of bibliometric data finds that in Ireland, 2.63 percent of publications are in the top 1 percent of citations; whereas the average is 1.64 percent, for any research funder in Ireland. This suggests that the funding for R&D provided by SFI has been producing scientific research of disproportionately high quality. Furthermore, Ireland now ranks 11th in the world in terms of the quality of its scientific research; an increase from 48th position 13 years ago.[35] Although a causal link between SFI and the improvements in Ireland's ranking cannot be directly established, this broadly correlates with the timeline of SFI. Furthermore, SFI is now the largest public funder of R&D in the State, and SFI papers are of a relatively high quality. In terms of individual subject rankings, Ireland is 1st in the world in Animal and Dairy, 1st in Immunology, 2nd in Nanotechnology, and 2nd in Agricultural Sciences.

Table 2: Publications associated with SFI grants, 2013 - 2017

		2013	2014	2015	2016	2017	Total
Publications	Total publications	2,758	2,467	2,664	2,411	2,712	**13,012**

Source: SFI SESAME Database

Non-Academic collaborations will be the focus of a subsequent sub-section but the number of academic collaborations associated with active SFI grants have been increasing during 2013 – 2017. These are not discrete collaborations, rather they count the total number of collaborations in each year. The trend, however, is upwards.

Table 3: Academic Collaborations associated with active SFI grants, 2013 - 2017

		2013	2014	2015	2016	2017	Total
Academic Collaborations	Total Academic Collaborations	2,065	2,542	2,630	3,128	3,408	**Totals excl.**[36]

Source: SFI SESAME Database

[34] Indecon (2017). Interim Evaluation of Science Foundation Ireland Research Centres Programme
[35] SFI Annual Report 2017.
[36] Totals have been excluded in circumstances where the output or activity may span multiple years.

In terms of the composition of SFI research teams, PhD and Postgraduate researchers are by far the largest cohorts. These will be considered in greater detail in a later section but it is worth noting the increase over time in team members across the cohorts. These are not discrete, so the same team member can be present across years in this table, but the number of SFI team members has been increasing during 2013 – 2017. As can be seen from Table 4, SFI funds across the career spectrum from early-stage researchers to mid-stage career researchers and research leaders, through individual and collaborative awards.

Table 4: Composition of research teams funded by SFI grants, 2013 -2017

		2013	2014	2015	2016	2017	Total
Team Composition	Postdoc Researchers	801	800	844	953	1,006	**Totals excluded** [37]
	PhD Students	1,145	1,093	1,164	1,301	1,314	
	Masters Students	90	85	103	107	120	
	Award Holders	451	468	529	508	545	
	Funded Investigators & Co-Investigators	388	218	380	380	451	
	Research Assistants	149	182	209	257	259	
	Other	394	407	565	665	746	

Source: SFI SESAME Database

Analysis of Leveraged Funding

- **During 2013 – 2017, Private Enterprise committed €158m to SFI Research Centres; International sources committed €152m; other Exchequer sources committed €111m; and other sources committed €12m.**
- **76 percent of cash funding from enterprise came from MNCs and 16 percent of cash funding from enterprise came from SMEs. Start-ups and other account for the remainder. This reflects MNCs greater capacity to commit cash to Research Centres.**
- **53 percent of in-kind funding from enterprise came from MNCs and 39 percent of in-kind funding came from SMEs. While MNCs provide more cash funding, SMEs have the capacity to contribute significant levels of in-kind funding.**

This section will provide analysis of funding leveraged by SFI Research Centres. While this will not capture all funding leveraged by SFI researchers, it will capture the vast majority of funding leveraged from private enterprise. The Research Centres Programme, with its focus on attracting funding from, and collaborating with, industry, is aligned with the objective of increasing the relevance of research for industry. Since 2012, SFI has established a network of 17 Research Centres. Funding leveraged by

[37] Totals have been excluded in circumstances where the output or activity may span multiple years.

SFI researchers outside of the Research Centres Programme is not captured in this analysis, due to data limitations. Given the size of the Research Centres Programme, however, funding leveraged by the Centres should be indicative of the level of international (such as EU) funding that SFI researchers are attracting.

A previous IGEES paper raised a concern about the comparatively low levels of private sector funding for R&D in Ireland.[38] Thus, it is important to consider the amount of funding provided to Research Centres by private enterprise. SFI Research Centres are required to attract 30 percent of their annual budget (10% cash and 20% in-kind) from the private sector. It appears that these cost-sharing conditions have resulted in considerable funding from private enterprise for these centres. As of December 2018, SFI report that Centres had a cost-share of 17 percent cash and 43 percent total cost-share from industry. SFI's target is for 50 percent of overall centres' funding to be non-Exchequer. As of November 2018, non-Exchequer sources accounted for 47.8 percent of all funding.[39]

During 2013 – 2017, the Research Centres leveraged €433 million of funding from Private Enterprise, International sources, other Irish Exchequer sources, and other sources. Private Enterprise accounted for €158 million of this money, International sources accounted for €152 million[40], and other Exchequer sources accounted for €111 million. €11.9 million was provided by other sources. SFI committed €432 million to the Research Centres Programme over these years.

The significant contribution of other Exchequer sources to the Research Centres, beyond the funding provided to them by SFI, raises questions around the sustainability of these various streams of Exchequer funding for the Centres. Important questions, such as whether or not Exchequer funding, through Agencies and Departments, crowds out private investment; or whether the complex interplay of public institutions in the space could lead to overlapping supports and allocative inefficiencies. These issues should contextualise SFI's engagement with public and private organisations.

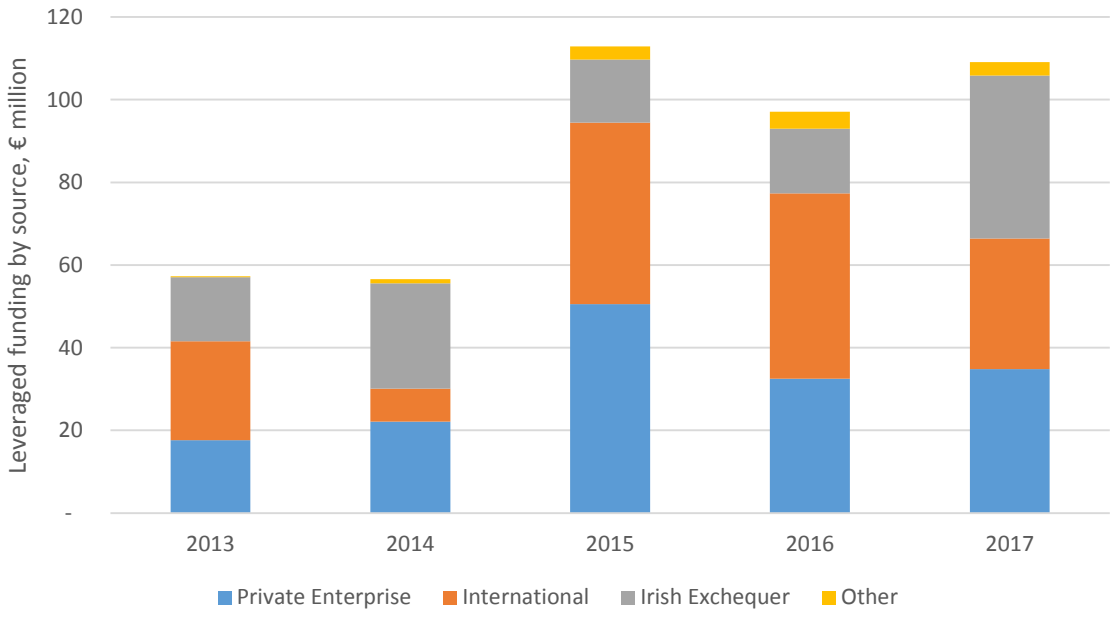
Enterprise Ireland awards account for over half of other Exchequer funding, while Agencies such as the Marine Institute and other Departments account for the remainder. This funding may reflect how various components of the national research system interact with regard to SFI, insofar as SFI-funded research could be brought closer to the market by other Agencies and Departments. However, there may be trade-offs, such as deadweight loss and crowding out, associated with working with public

[38] https://igees.gov.ie/wp-content/uploads/2014/02/Cross-Cutting-Issues-in-Relation-to-Expenditure-of-Science-Technology-and-Innovation.pdf
[39] SFI. 2018 Annual Review of Agenda 2020
[40] This is mostly EU funding. Ireland is now a net contributor to the EU.

institutions. Further work would be required in order to appraise the sustainability of these various streams of Exchequer support.

SFI data indicate that during 2013 -2017, 76 percent of cash funding from enterprise was committed by MNCs, while 16 percent was committed by SMEs. 53 percent of in-kind funding was committed by MNCs while 39 percent of in-kind funding was committed by SMEs[41]. This reflects the greater financial capacity of MNCs. While SMEs may not have the same financial capacity to provide cash funding to the Centres, they are able to provide in-kind funding for the Centres. In-kind funding can be equipment, personnel etc.[42] MNCs have higher average commitments in monetary terms than SMEs, with the average cash commitment for MNCs around €149,000 and around €50,700 for SMEs. Whereas SMEs have higher average commitments in-kind, with the average for MNCs around €152,600 and €174,200 for SMEs. It is worth repeating that the ratio of SMEs to MNCs engaging with SFI is 50:50, however, the extent of these activities may vary.

Figure 11: Leveraged funding by research centres, by funding source, 2013 - 2017



Source: SFI SESAME and Research Centre Data

[41] Remainder comes from start-ups and other.
[42] http://www.sfi.ie/funding/sfi-policies-and-guidance/budget-finance-related-policies/

8. Non-Academic Collaborations

Overall, the number of collaborations between SFI researchers and both Small and Medium Enterprises (SMEs) and Multinational Corporations (MNCs) has increased between 2013 and 2017.

The proportion of collaborations with MNCs has increased from 47% to 54% from 2013 to 2017 compared with 44% to 36% for SMEs over the same period.

High Level Review of Non-Academic Collaborations

The table below shows the high level non-academic collaboration outputs for the period 2013-2017. Notably this is not a metric of all discrete collaborations, but rather the number of new, or continuing collaborations in each of the given years. The ratio of SMEs to MNCs engaging with SFI is approximately 50:50, companies, however, may have multiple collaborations, which is what this section analyses. Totals have been excluded, to ensure there is not double counting, as a single collaboration may operate across multiple years.

Table 5: All Non-Academic Collaborations over 2013-2017 period

		2013	2014	2015	2016	2017
Non-Academic Collaborations	with MNCs	480	654	711	918	900
	with SMEs[43]	447	565	509	673	609
	with Government Departments/Bodies	66	84	81	109	115
	NGO/ Charities/ Foundations	19	27	30	40	48
	with Other[44]			7	5	
	Total Non-Academic Collaborations	1,012	1,330	1,338	1,745	1,672

Source: SFI SESAME Database

While remaining cognisant that Non-Academic Collaborations cannot be viewed as discrete outputs associated with a particular year, it is apparent that the total number of collaborations trended upwards. The total proportion of collaborations with Government Departments and Bodies, as well as NGOs, Charities and Foundations has remained reasonably stable at 6% and 2% respectively.

[43] SMEs are defined as enterprise which have less than 249 employees, and an annual turnover not exceeding €50m or an annual Balance Sheet of total not exceeding €43m.

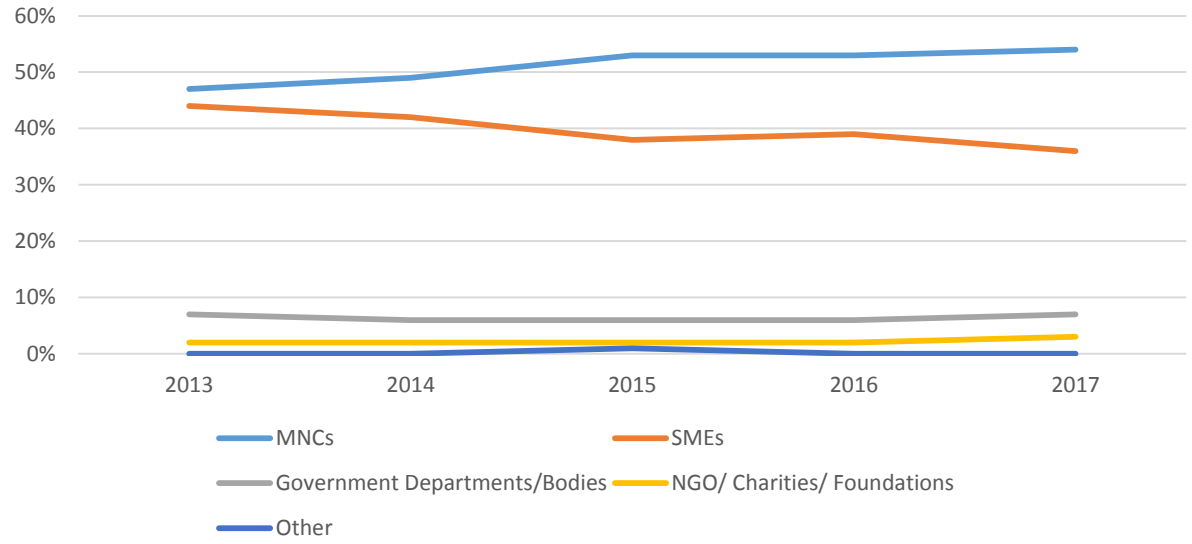
[44] These are (usually) large companies that do not operate internationally and so do not fall into the category of MNCs.

Table 6: Non-Academic Collaborations, by organisation type, in relative terms, over 2013 to 2017 period

		2013	2014	2015	2016	2017	Average
Non-Academic Collaborations	with MNCs	47%	49%	53%	53%	54%	51%
	with SMEs	44%	42%	38%	39%	36%	40%
	with Government Departments/Bodies	7%	6%	6%	6%	7%	6%
	with NGO/ Charities/ Foundations	2%	2%	2%	2%	3%	2%
	with Other	0%	0%	1%	0%	0%	0%
	Total Non-Academic Collaborations	100%	100%	100%	100%	100%	100%

There does appear to be a divergence within enterprise, however. The proportion of collaborations with MNCs has increased, while the proportion with SMEs has decreased. This could be taken at face value to imply that MNCs are both more active with SFI and that this disparity is increasing. Or given that the activities are not discrete, collaborations with MNCs could span a greater period of time, thereby exacerbating a relatively small divergence in trend. Regardless, the ratio of collaborations between MNCs and SMEs has changed to favour MNCs. These figures account for MNCs and SMEs that are based both in Ireland and abroad.

Figure 12: Non-Academic Collaborations by participant type per year, 2013 -2017



Non-Academic Collaborations by NRP Area

Improvements in SFI's data collection methods enable more in-depth analysis of awards granted from 2013 onwards. This section will analyse the data of awards from 2013-2017 with respect to the relationship between funding and output activities. The Table below depicts Non-Academic Collaborations by activity area. These are groupings made by the authors, but informed by the revised NRP areas 2018-2023. For a full breakdown of Non-Academic Collaboration by NRP area see Appendix 3.

Table 7: Non-Academic Collaborations by Activity Area and Company Type, associated with active SFI grants awarded 2012 - 2017[45]

	Gov. Depts. & Semi-States	Foundations, Charities, NGOs	MNCs	SMEs	Total	MNC to SME Ratio
ICT	1.81%	0.83%	21.01%	12.68%	36.34%	1.66
Health and Wellbeing	0.67%	0.26%	9.58%	9.42%	19.93%	1.02
Food	0.52%	0.52%	7.51%	5.23%	13.77%	1.44
Energy, Climate Action and Sustainability*	2.33%	0.41%	3.73%	4.71%	11.18%	0.79
Manufacturing and Materials*	0.31%	0.16%	7.87%	4.35%	12.68%	1.81
Services and Business Processes	0.10%	0.05%	0.83%	0.00%	0.98%	
Basic Biomedical Science (BBS) (Non-NRP)	0.16%	0.00%	1.14%	0.78%	2.07%	1.47
Non-Research Grant	0.47%	0.16%	0.57%	0.41%	1.60%	1.38
Other (Research Outside NRP Areas)	0.10%	0.10%	1.04%	0.21%	1.45%	5.00
Total (%)	**6.47%**	**2.48%**	**53.26%**	**37.78%**	**100.00%**	
Total Discrete Collaborations	**125**	**48**	**1,029**	**730**	**1,932**	**1.41**

Based on this activity analysis, ICT has the highest rate of collaborations, accounting for 36 percent, or 702, of all collaborations. This sector also has the second highest rate of MNC collaborations compared to SMEs. This may imply that economies of scale are a significant component in realising gains that may result from collaborations in this area. This intuition may also hold true for the Manufacturing and Materials area, which has the highest MNC to SME collaboration ratio, of 1.81. It is unclear to

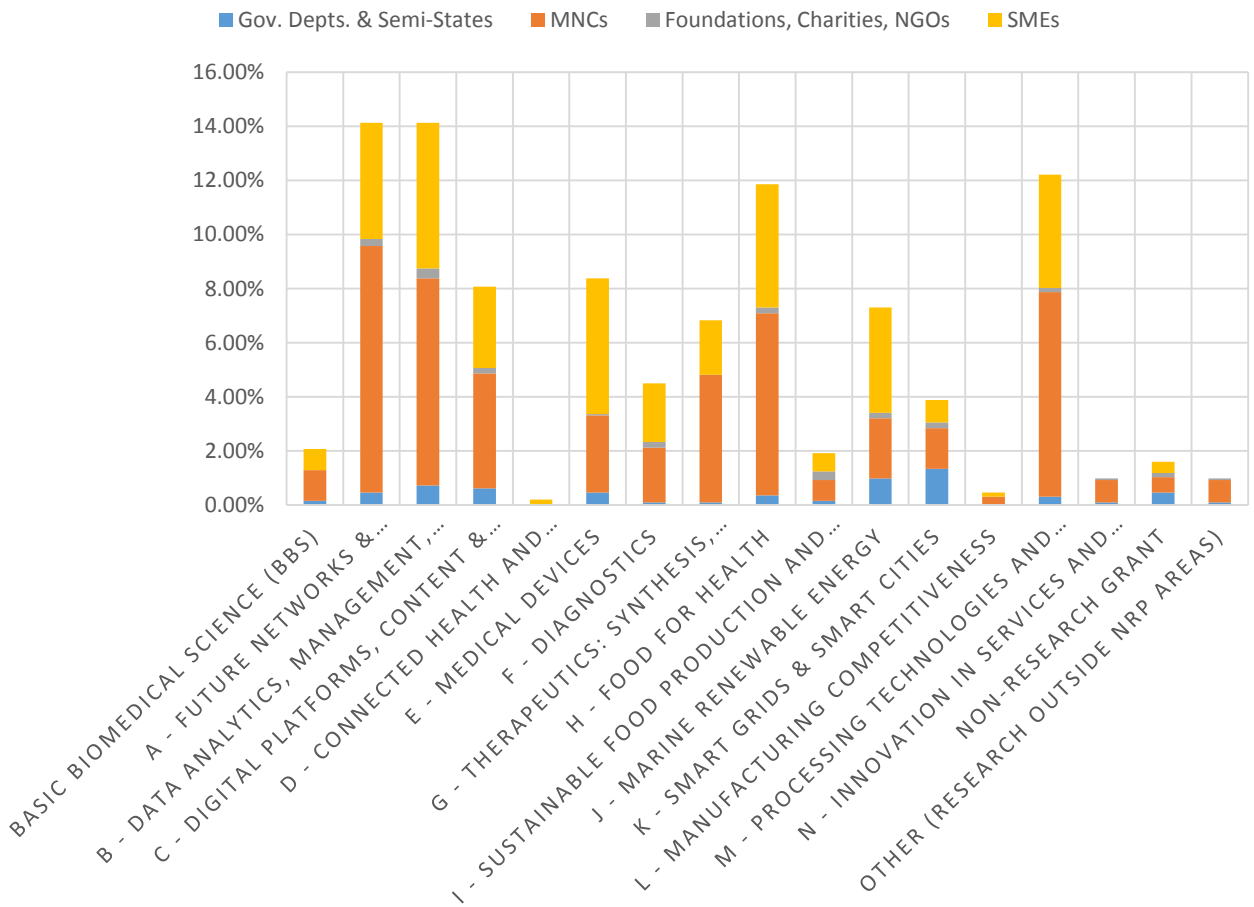
[45] These figures are seen as indicative as output data are unavailable for 2012.

what extent barriers to entry play a role in these areas, and subsequently SMEs scope to engage with SFI.

Energy, Climate Action and Sustainability is the only area in which SMEs have a higher rate of collaboration than MNCs. This area accounts for 11.2 percent of all NRP collaborations and has the second fewest number of NRP collaborations, after Services and Business Processes.

As mentioned, these areas can be decomposed into the 14 NRP areas, which in turn can be depicted graphically, below.

Figure 13: NRP Collaboration by Institution Type on awards granted 2012-2017[46]



[46] Distribution is indicative as output data are unavailable for 2012.

Analysis of Human Capital and Link with Economy

- **The share of Postgraduate and Postdoctoral Researchers who remain in Ireland leaving a SFI team to take up employment in a private sector R&D role has increased from 17 to 33 percent during 2013 - 2017.**
- **According to SFI analysis, a time lag is associated with team-members moving to the private sector. 9-12 years after a SFI award, 47 percent of team members are in the private sector.**

This section of the paper will consider SFI's role in developing skilled human capital for Ireland's labour market. SFI aims to have 50 percent of trainees departing to take up employment in the private sector as a first destination by 2020. The *Report of the Special Group on Public Service Numbers and Expenditure Programmes* (2009) raised concerns about the under-employment and forced emigration of PhD graduates in the context of increasing investment in these skills, indicating that there was not sufficient demand amongst the enterprise base in Ireland for these skills. Although a different economic context exists currently, there remains a need for evidence of demand for these skills in the labour market. This section aims to provide some preliminary information on the employment of SFI researchers after departing from a SFI team.

Table 8 below provides information on the share of SFI Masters, PhD, and Postdoctoral Researchers who remain in Ireland working in a private sector R&D role as a first destination between 2013 and 2017. Of Postgraduate and Postdoctoral Researchers who remain in Ireland, the share moving on to these roles increased from 17 percent to 33 percent during this time period. During the same period there was a declining trend in the percentage of these researchers who left a SFI team to pursue postdoctoral research in a HEI from 35 percent to 18 percent. Acknowledging the limitations of the relatively short time-series, this suggests there may be some substitution between higher education and the private sector, with researchers becoming more likely to take up employment in the private sector in recent years. This might reflect a cyclical trend.

Table 8: Of SFI team members who remain in Ireland, percentage working in private sector (R&D role) as first destination

SFI Team Member Position	2013	2014	2015	2016	2017
Postgraduates (Masters)	24%	17%	13%	4%	25%
Postgraduates (PhD)	17%	18%	26%	19%	32%
Postdoctoral Researchers	15%	20%	22%	30%	35%
Total	**17%**	**19%**	**23%**	**23%**	**33%**

Source: SFI SESAME Database

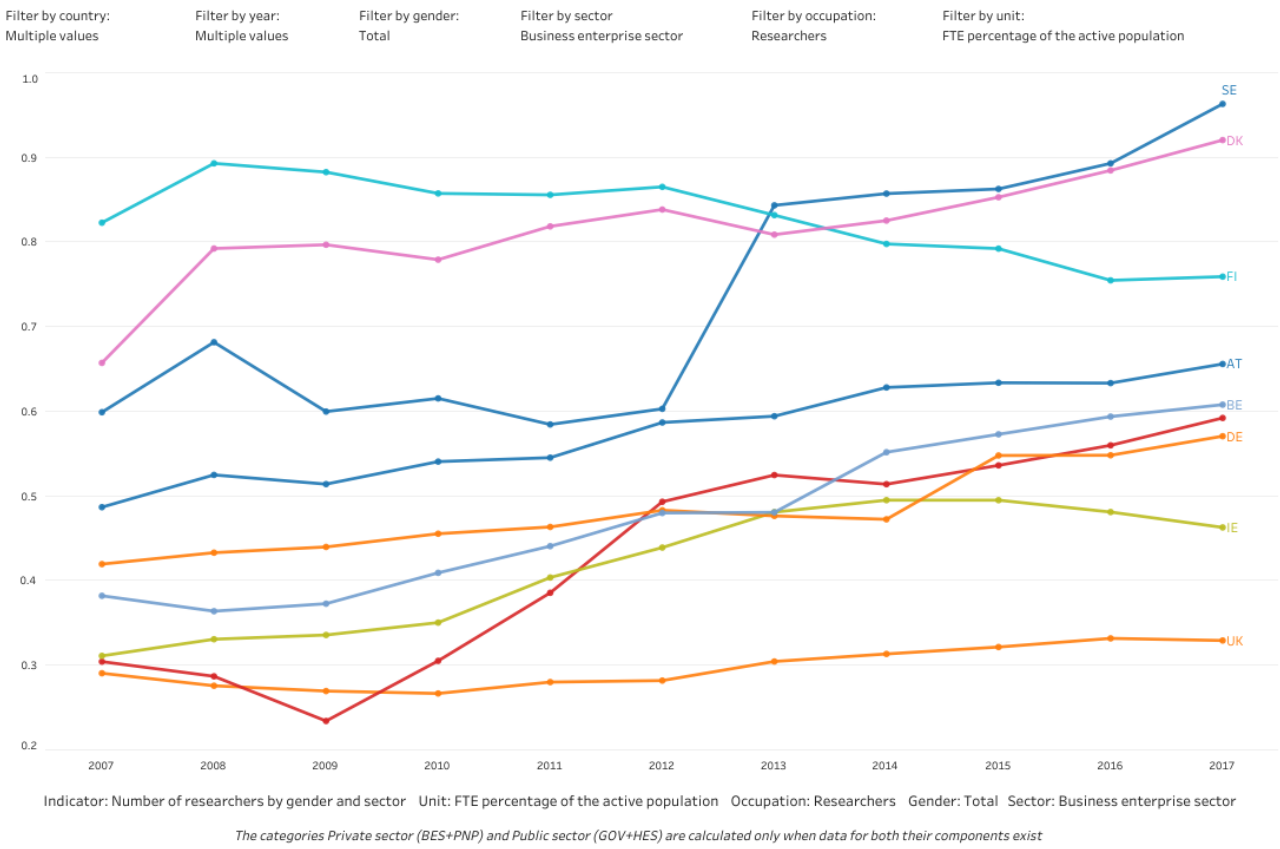
Overall, between 2013 and 2017, the percentage of Postgraduates and Postdoctoral Researchers who departed from a SFI team and remained in Ireland ranged between 58 percent and 63 percent.

In-house analysis by SFI using a different data source suggests that there is a time lag effect at play for SFI team-leavers taking up employment in industry. The analysis suggests that during the period 0-3 years and 3-6 years after a SFI award, 32 percent and 34 percent of team-members respectively are employed in the private sector. Whereas 6-9 and 9-12 years after a SFI award 53 percent and 47 percent are employed in the private sector. The analysis also suggests that PhD and Masters Students were more likely to be working in the private sector (41 percent and 55 percent respectively) than Postdoctoral researchers (30 percent), which follows a global trend.[47] This analysis is limited, however, insofar as it provides no additional information on the occupation, income, skills-utilisation of the researcher.

Figure 14 below shows the share of the active population (in terms of full-time equivalents) working in a research role in business and enterprise in Ireland between 2007 and 2017. The trend has been increasing over time, particularly since 2010 until 2014/2015 when there was a peak, after which the trend was declining. As one of SFI's stated objectives is to increase the number of skilled researchers working in industry, it is worth considering the share of the active population in Ireland who are working as researchers in industry. In 2017, the share of the active population working as researchers in business and enterprise was 0.15 percentage points higher than in 2007. Despite that, when compared to other advanced economies, Ireland's share of the active population who are working as researchers in business and enterprise is comparatively low. For example, in Sweden and Denmark, over 0.9 percent of the active population are working as researchers in business and enterprise, whereas in Ireland it is 0.46 percent. A question that emerges is whether Ireland's comparatively low share of researchers working in business and enterprise is due to supply constraints or demand constraints. If it is due to supply constraints, then one might expect a greater share of SFI team-leavers to be departing for industry. On the other hand, if it is due to demand constraints, this would raise questions around the rationale and appropriate level and composition of this funding for postgraduate research.

[47] SFI LinkedIn Human Capital Tracking Exercise (unpublished).

Figure 14: Researchers in the business enterprise sector as share of active population



Source: Eurostat

9. Key Findings & Conclusion

The key findings of this Spending Review are as follows:

Enterprise Linkage and Funding

- The following trends are apparent with regard to SFI's links with industry:

1. Overall, the number of collaborations between SFI researchers and both SMEs and MNCs has increased between 2013 and 2017. The number of collaborations has been increasing more rapidly for MNCs than SMEs with 54% of collaborations with MNCs and 36% with SMEs in 2017 compared to 47% and 44% respectively in 2013. The number and type of collaborations varies considerably across NRP areas suggesting different areas of interest for MNCs and SMEs. The ratio of SMEs to MNCs engaging with SFI is approximately 50:50, however, a company may have multiple collaborations.

2. SFI Research Centres attracted €158 million of research funding between 2013 and 2017 from private enterprise and a further €152 million from international sources. The Exchequer also contributed €111 million through other Exchequer sources, such as Enterprise Ireland. Research Centres have secured significant levels of funding from enterprise and international sources, though a large amount of funding has also come from other Irish Exchequer sources. Greater amounts of leveraged funding does not necessarily mean SFI funding will decrease. Rather, SFI funding, through cost-sharing conditions attached to the Research Centre Programme, is being used to secure additional funding from other sources. It is unclear, however, what the longer-term impact on the Exchequer or the R&D Portfolio will be of SFI researchers drawing down more funding from the EU and industry. This may have an influence on the priority areas of researchers and consequently on SFI funding over time.

3. Of the Postgraduates and Postdoctoral Researchers who remained in Ireland, there was an increasing share who took up employment in a private sector R&D role as a first destination after their SFI-funded role. In general, SFI has not met its target for the share of trainees to enter industry as a first destination following completion of their SFI-funded role. SFI analysis suggests that a time lag exists between trainees leaving a SFI team and moving into industry, with a significant share of team-members in employment in the private sector a decade after a SFI award. Further data would be needed to determine the occupation, income, skills-utilisation of these individuals. SFI should continue to improve occupational data collection on SFI researchers to demonstrate outcomes.

Effectiveness

- Evaluating the longer term effectiveness and impact of funding for scientific research is challenging. This paper references some broad indicators which suggest effectiveness in terms of scientific quality, insofar as these indicators correlate with the timeline of SFI.
- 2.63 percent of SFI publications are in the top 1 percent of citations, whereas the average is 1.64 percent for all Irish scientific publications. This suggests that SFI research is disproportionately high quality and that SFI processes may be enhancing the quality of the work.
- Ireland has risen from 48th to 11th globally in the last 13 years in terms of the quality of its scientific research (target is to remain in top 20). Furthermore, in terms of individual subject rankings, Ireland is 1st in the world in Animal and Dairy, 1st in Immunology, 2nd in Nanotechnology, and 2nd in Agricultural Sciences.
- A number of SFI Programme-level evaluations suggest evidence of effectiveness and impact. The challenge for SFI is to consider data collection and analytical techniques to seek to establish a more direct link to the economic impact of their work.

Efficiency and Sustainability

- It may be prudent to aim to more equally distribute SFI's largest expenditure components, such as Research Centre renewals, over time, rather than committing to a large component of expenditure in a single year. This would ease the commitment burden on the Exchequer if there is an economic downturn, and could help the Department of Business, Enterprise and Innovation respond to the, potentially, competing needs of its different agencies with greater agility and flexibility.
- It is good practice that SFI grants contain sunset clauses.
- SFI has a commitment threshold of 90%/75%/60% over a rolling three year period.
- The use of independent international peer-review in SFI's grant award process to evaluate both scientific excellence and impact is acknowledged as good practice from an efficiency and governance point of view.
- SFI has kept the cost of administration below its target of 5 percent.

Further Questions

- The evidence suggests MNCs have a greater capacity to engage with SFI programmes, and thus may benefit disproportionately as a result. Further research, using existing data, could go some way to determining to what extent this is the case.

- Further to the previous question, the extent to which SFI responds to current and/or future market conditions by meeting demand from the enterprise base, responding to market failures, or generating a supply side response by creating centres of excellence, could be explored by linking SFI engagements and contextualising them within microeconomic data.
- Further research could appraise the totality of Government expenditure programmes on R&D in Ireland, to outline the rationale of these various streams of funding and how they relate to each other, and determine whether this system is efficient. A lack of clarity concerning this could result in deadweight losses and crowding out.
- Improved data availability on the occupations, sectors, and incomes of SFI trainees over the course of their careers could in the future allow for detailed analysis of the long-term economic impact of this funding for developing human capital. Ideally, this could be linked to enterprise data of existing labour market requirements.
- As SFI does not generate revenue from its investment in RDI, further research could evaluate whether there are lessons from other Agencies that might apply to SFI.
- Contract stipulations concerning whether or not a company engaging with SFI can claim related expenditure as part of an R&D tax credit may have an Exchequer impact. An R&D tax credit could be seen as either a double subsidy, insofar as the company benefits from the Exchequer through SFI resources and outputs as well as an R&D tax credit. Alternatively precluding this may discourage participation resulting in sub-optimal outcomes.

Appendix 1: Theoretical Underpinnings for Public Expenditure in R&D

Market failure, in this case, refers to the economic and societal sub-optimal outcomes that may arise from a lack of private provision of R&D. This is because the allocation of resources by private funders of R&D is based, arguably, on the benefit they accrue. This, therefore, does not incorporate the positive spill-over effects, such as the dissemination of knowledge in society and the increased human capital in the labour force. Subsequently, from a societal perspective, commercial operations may lead to under-investment in R&D. This effect is compounded when one considers that small firms may have limited resources to commit to R&D, and, that certain types of R&D, namely "pure basic research", are not immediately linked to a commercial objective.

R&D is also provided for owing to systemic failures, including:

1. Co-ordination failures – a lack of co-ordination across firms, public research organisations, and the public sector resulting in a sub-optimal level of knowledge transfer, and thus innovation;
2. Capability failures – where the capacity for RDI is not sufficient amongst actors. For example, inadequate absorptive capacity in firms or public research organisations may prevent optimal R&D outcomes in the State; and
3. Infrastructural failures – where the physical or human capital infrastructure for RDI is not sufficient, and thus State intervention is often justified on this basis.

Additionally, DBEI cites empirical evidence for returns on innovation, resulting from State support, noting that two thirds of economic growth in Europe between 1995 and 2007 is estimated to have derived from RDI.[48]

[48] Department of Business, Enterprise, and Innovation (2017). Review of Capital Expenditure on Research, Development and Innovation (2000-2016).

Appendix 2: SFI income, expenditure, and annual Exchequer allocation, 2007-2017

Table 6: SFI income, expenditure, and annual Exchequer allocation, 2007-2017, €, 000

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Income	165,108	170,657	180,523	158,853	166,894	171,973	161,797	163,431	172,408	195,636	187,193
Expenditure	165,038	169,943	180,362	158,509	166,772	171,890	161,728	163,457	172,489	195,650	187,170
Surplus	70	714	161	344	122	83	69	-26	-81	-14	23
A.E.A	164,066	170,418	180,398	158,705	166,642	171,039	161,550	162,365	170,439	193,469	182,933
A.E.A as % of income	99.37%	99.86%	99.93%	99.91%	99.85%	99.46%	99.85%	99.35%	98.86%	98.89%	97.72%

Source: SFI Annual Reports. Authors' own calculations. Note: A.E.A is Annual Exchequer Allocation

Appendix 3: Non-Academic Collaborations by NRP Area associated with Active Grants Awarded, 2012-2017 [49]

		Gov. Depts. & Semi-States	Foundations, Charities, NGOs	MNCs	SMEs	Total	MNC to SME Ratio
ICT	A - Future Networks & Communications	9	5	176	83	273	2.12
	B - Data Analytics, Management, Security & Privacy	14	7	148	104	273	1.42
	C - Digital Platforms, Content & Applications	12	4	82	58	156	1.41
Health and Wellbeing	D - Connected Health and Independent Living				4	4	0.00
	E - Medical Devices	9	1	55	97	162	0.57
	F - Diagnostics	2	4	39	42	87	0.93
	G - Therapeutics: Synthesis, Formulation, Processing and Drug Delivery	2		91	39	132	2.33
Food	H - Food for Health	7	4	130	88	229	1.48
	I - Sustainable Food Production and Processing	3	6	15	13	37	1.15
Energy, Climate Action and Sustainability	J - Marine Renewable Energy	19	4	43	75	141	0.57
	K - Smart Grids & Smart Cities	26	4	29	16	75	1.81
Manufacturing and Materials	L - Manufacturing Competitiveness			6	3	9	2.00
	M - Processing Technologies and Novel Materials	6	3	146	81	236	1.80
Services and Business Processes	N - Innovation in Services and Business Processes	2	1	16	0	19	
	Basic Biomedical Science (BBS)	3		22	15	40	1.47
	Non-Research Grant	9	3	11	8	31	1.38
	Other (Research Outside NRP Areas)	2	2	20	4	28	5.00
	Total	**125**	**48**	**1029**	**730**	**1932**	**1.41**

[49] These figures are seen as indicative as output data are unavailable for 2012.

	Gov. Depts. & Semi-States	MNCs	Foundations, Charities, NGOs	SMEs	Total	Total
Basic Biomedical Science (BBS)	0.16%	1.14%	0.00%	0.78%	2.07%	40
Non-Research Grant	0.47%	0.57%	0.16%	0.41%	1.60%	31
Other (Research Outside NRP Areas)	0.10%	1.04%	0.10%	0.21%	1.45%	28
A - Future Networks & Communications	0.47%	9.11%	0.26%	4.30%	14.13%	273
B - Data Analytics, Management, Security & Privacy	0.72%	7.66%	0.36%	5.38%	14.13%	273
C - Digital Platforms, Content & Applications	0.62%	4.24%	0.21%	3.00%	8.07%	156
D - Connected Health and Independent Living	0.00%	0.00%	0.00%	0.21%	0.21%	4
E - Medical Devices	0.47%	2.85%	0.05%	5.02%	8.39%	162
F - Diagnostics	0.10%	2.02%	0.21%	2.17%	4.50%	87
G - Therapeutics: Synthesis, Formulation, Processing and Drug Delivery	0.10%	4.71%	0.00%	2.02%	6.83%	132
H - Food for Health	0.36%	6.73%	0.21%	4.55%	11.85%	229
I - Sustainable Food Production and Processing	0.16%	0.78%	0.31%	0.67%	1.92%	37
J - Marine Renewable Energy	0.98%	2.23%	0.21%	3.88%	7.30%	141
K - Smart Grids & Smart Cities	1.35%	1.50%	0.21%	0.83%	3.88%	75
L - Manufacturing Competitiveness	0.00%	0.31%	0.00%	0.16%	0.47%	9
M - Processing Technologies and Novel Materials	0.31%	7.56%	0.16%	4.19%	12.22%	236
N - Innovation in Services and Business Processes	0.10%	0.83%	0.05%	0.00%	0.98%	19
Total	6.47%	53.26%	2.48%	37.78%	100.00%	
Total Individual Grants	125	1029	48	730		1932

Quality Assurance Process

To ensure accuracy and methodological rigour, the author engaged in the following quality assurance process.

- ✓ Internal/Departmental
  - ✓ Line management
  - ✓ Spending Review Sub-group and Steering group
  - ✓ Peer review (IGEES network, seminars, conferences etc.)
- ✓ External
  - ✓ Other Government Department
  - ✓ Advisory group
  - ✓ Peer review (IGEES network, seminars, conferences etc.)