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Review of the Disruptive Technologies Innovation Fund

DEPARTMENT OF BUSINESS, ENTERPRISE AND INNOVATION

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This paper has been prepared by IGEES staff in the Department of Business Enterprise and Innovation. The views presented in this paper do not represent the official views of the Minister for Enterprise, Trade and Employment.

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Executive Summary

The Disruptive Technologies Innovation Fund (DTIF) was established in 2018, as one of four funds launched under the National Development Plan (NDP). It is planned that a total of €500 million will be allocated through the fund out to 2027 for co-funded collaborative projects involving firms and research partners developing disruptive technologies. This early review of the programme examines the rationale for a programme funding disruptive technologies. The review sets out a programme logic model to allow for improved monitoring and evaluation of the programme. It assesses the clarity of DTIF's objectives and how these relate to the projects funded, it looks at how the programme fits in to the Irish research, development and innovation (RD&I) support landscape and makes recommendations for the programme going forward. The review also profiles the programme's activity to date:

- The DTIF awarded funding to 43 projects, 27 of which were awarded under Call 1 and 16 under Call 2.
- €140 million in funding was awarded across these two calls, with €75 million awarded in Call 1 and €65 million awarded in Call 2.
- 159 project partners have received approval for funding to date comprising 63 SMEs, 25 MNCs and 26 RPOs – with a number of firms and RPOs being involved in more than one project.
- Funding has primarily been awarded to the projects within the areas of Health and Wellbeing and ICT – accounting for €109 million of funding allocated.

KEY FINDINGS

- There appears to be a strong rationale for a publicly funded programme making significant investments in disruptive technologies. The funding provided through DTIF reduces risk for participating firms thereby helping to bring these technologies forward. If successful, the innovations emerging from DTIF offer Irish companies a route to compete in (and potentially disrupt) global markets. This would increase employment in those sectors and drive Irish exports and output.
    - These issues can be better examined in an ex-post review examining programme outcomes. An ex-post evaluation could also potentially compare the outcomes for projects funded against those not successful in gaining DTIF funding, in order to better ascertain the impact of DTIF funding.
    - The review finds that the concept of disruption was not always understood. In some cases, it was felt there was a focus on the radical elements of the innovation rather than the way in which it may disrupt markets.
- The review finds that DTIF is a distinct new programme among other RD&I supports to enterprise. A combination of the scale of funding available for projects, the focus on collaboration and commercialisation, in combination with its funding of disruptive innovation sets the fund apart from other RD&I supports available in Ireland.
- The DTIF appears to be aligned with a number of international case studies, including Germany and the EU, which recognise the importance of SME partnerships for innovation.
- The review finds that the programme is working towards achieving its stated objectives. It is funding significant innovations which could potentially capture global markets.
    - The innovations which DTIF is funding are high-risk, high-return - public funding is intended to help ensure that these technologies are brought forward.
    - By lowering the risk profile of the innovations, the fund is also encouraging private co-investment along with DTIF funding.

- In line with its objectives it has maintained a focus on collaboration and building on previous publicly-funded research.
- It has secured strong involvement from SMEs within project consortia.
- The scale of projects funded and the focus on collaboration has ensured that the DTIF is sufficiently different from other RD&I supports, ensuring additionality.

RECOMMENDATIONS

- The DTIF should be clearer in the type of innovations it is seeking to fund, in particular, whether these are disruptive or radical in nature (or indeed both). This should be made clear to firms as it could impact the number and type of applications being made and approved for funding.
    - An increased focus on disruption would place focus on customers being over-serviced by the current market offering, the capture of non-consumers through either low-end market disruption or the creation of a new niche market.
- The DTIF should maintain its focus on SMEs as the drivers of disruptive innovation. The literature points to the important role of smaller firms in introducing disruption to the market.
- The DTIF could explore challenge-based funding, or more sectoral-focused calls, as a way to further develop interest and applications from certain sectors and address a broader spectrum of societal challenges as laid out in the National Planning Framework.
    - DTIF was not established to fund projects from any one area - its focus being on the quality and disruptiveness of applications. However, it may be important to maintain interest from other sectors over the programme's lifetime so that the programme maintains a variety of application types and can impact on a wider range of markets.
    - While a narrower challenge-based approach may be difficult to reconcile with the DTIF - due to its focus on disruptive innovation and market impact, broader challenges involving sectoral calls could be an avenue to maintain strong applications to the programme.
- The programme should closely monitor the progress of projects. Upon completion of projects the main outputs should be recorded. In setting out a programme logic model for the DTIF the review has offered increased clarity on the intended outcomes of the programme.
    - These outcomes should be monitored as projects come to a close and monitoring should continue post-funding to establish whether the fund is truly disrupting markets
- A short process review in the next year focusing on the application and monitoring process of the programme should be considered.

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Introduction

Over the last two decades Ireland has invested significantly in building RD&I capability in both public research organisations and the enterprise base in order to enhance the innovation performance of enterprises and their ability to develop and commercially exploit intellectual property (IP) generated in Ireland.

The Disruptive Technologies Innovation Fund (DTIF) was established in 2018, as one of four funds under the National Development Plan (NDP). €500m in funding is committed under the NDP for the DTIF, to be allocated over ten years, from 2018 to 2027, for co-funded collaborative projects involving businesses and research partners. Applications to the Fund are expected to address the development, deployment and commercialisation of disruptive technologies to deliver new solutions through investment in the development and implementation of new products and services.

In 2018 under DTIF Call 1 27 projects were approved for funding totalling over €75 million in commitments over the three years to 2021. The projects funded represent the health, food, ICT and manufacturing sectors in Ireland. In December 2019, a second tranche of projects was announced under DTIF Call 2. The 16 approved projects under this call span life sciences, medical devices, ICT, artificial intelligence, blockchain, manufacturing and environmental sustainability in the waste and energy sectors. Call 2 will share €65 million out to 2022.

The objective of this interim evaluation is to develop a framework to systematically assess the efficiency and effectiveness of DTIF in achieving its objectives. Based on the results of the first two calls of DTIF, this exercise will also provide a preliminary assessment of progress towards the objectives.

The objectives of this evaluation are to:

- Set out the rationale for State intervention and relevance of DTIF in the context of R&D policy and wider enterprise policy;
- Assess how the DTIF is aligned with the 14 Research Priority Areas 2018 to 2023, including Decarbonising the Energy System;
- Assess the clarity of the objectives and the target population, in terms of quantification of the expected outputs, outcomes and impacts wherever possible;
- Based on the outcome of the first two calls under DTIF, profile the projects and participation.
- Assess how the programme is interacting with other supports and identify potential synergies with other programmes;
- Assess the quality of the procedures for implementation, monitoring and evaluation, particularly with regard to ongoing data requirements.

To do this the evaluation will establish a programme logic model (PLM) for the DTIF. Embedding a PLM for DTIF will ensure that the objectives are clear and measurable, that the target population is defined, and that the most appropriate metrics are identified, together with mechanisms for data collection so that the programme can be fully evaluated on an ex-post basis in future.

What is Disruptive Technology?

The Disruptive Technologies Innovation Fund seeks to invest in truly 'disruptive technologies' in order to aid their application to commercial use. Disruptive technologies are defined within a programme documents as those technologies that significantly alter the way we work and live and the way that businesses or entire industries operate. A 'Questions and Answers' document used for the launch of the DTIF expands upon this stating that;

"Disruptive technology is that which has the potential to drastically alter markets and their functioning and significantly alter the way that businesses operate. While it involves a new product or process, it can also involve the emergence of a new business model. Disruption is not about technology alone but the combination of technology and business model innovation."

This aligns well with the understanding of disruptive technology in the literature, where the term 'disruptive innovation' is now used to a greater extent. The literature agrees on the importance of the business model element of disruptive technology or innovation. Indeed, it is from the business model element that 'disruption' emerges as it is a process where new firms with generally fewer resources challenge incumbent firms. New firms typically enter in the 'low-end' of the market with a new product. The way in which they disrupt often is not based only on their 'technology' but can be often driven by incumbent firms being myopic and listening too carefully to their existing customers thereby leaving segments of the market open. Christensen and Raynor, 2003 state this well "In essence, rarely is the technology inherently disruptive, but rather the business model (enabled by new technologies) has a disruptive impact on incumbents' value creation and market position". More modern views of 'disruptive technology' also posit the view that the innovation can itself create its own market, where the product enters on a 'new-market' foothold which then enters and pervades other markets and thereby disrupts them (Christensen, 2015)[1]. Govindaragan and Kopalle (2006) state that there are four defining features of a disruptive innovation[2]. It should:

(i) be inferior on the attributes that mainstream customers value;
(ii) offer new value propositions to attract a new customer segment or the more price sensitive mainstream market;
(iii) be sold at a lower price; and
(iv) penetrate the market from niche to mainstream.

This 'disruptive innovation' described above is contrasted against 'sustained innovation' which is based around product or process improvement, both incremental and large. Sustained innovation targets the same customers and market segment as current offerings and focuses, and it aims to increase a firm's market share of the same segment. While sustained innovations can also be radical in nature they are crucially defined as maintaining the same market structure and serving the same customers in better ways. That sustained innovations can often be either small or large improvements in technical capability does not mean that 'disruptive innovation' is only focused on large technical developments – with the quality of the technology in disruptive innovation often being lower than that in the main market which it seeks to disrupt. Govindarajan and Kopalle set this out clearly by splitting innovations along three characteristics: radicalness, disruptiveness and 'competency destroying' – each with different values. Indeed, the distinction between disruptive

[1] https://hbr.org/2015/12/what-is-disruptive-innovation
[2] Govindarajan, V. and Kopalle, P.K. (2006). The usefulness of measuring disruptiveness of innovations ex post in making ex ante predictions. *Journal of Product Innovation Management*, 23, pp. 12–18.

innovation and more destructive/radical innovation has caused confusion and mislabelling.[3] The gap between disruptive and radical innovation is clear when one considers that old technology in one industry brought together with some new elements may be considered disruptive in a different industry.[4] Radical innovation involves a major change in technology, but unlike disruptive innovation it reinforces the existing business model while disruptive innovation represents a major change in that business model.[5]

Disruptive innovation does not always imply that new entrants will totally replace incumbents in the market, or that disruptors must be start-ups. However, typically disruption is viewed as difficult to identify for incumbents for the following reasons, from Govindargan and Kopalle[6]:

(i) the mainstream market does not value the innovation's particular package of performance attributes at the time of product introduction;

(ii) the innovation performs poorly on the attributes of mainstream customers value;

(iii) the innovation is first introduced in an emerging or insignificant niche market;

(iv) there is not necessarily a word-of-mouth effect, or opinion leadership, or respect among peers at play for the niche customer segment that finds disruptive innovations attractive; and

(v) the disruptive product offers a lower margin and may therefore be ignored by incumbents who are serving larger and more attractive segments.

The characteristics set out above can mean that identifying disruption before it occurs is difficult. As with investment in any innovation, it is not always clear that this investment will be a success – and as such there is risk involved. Christensen (2015) makes clear that not all disruptive innovations will be successful, and often there are multiple firms attempting a similar disruption. It is a mistake to claim a firm is disruptive by virtue of its success.[7]

One additional distinction to consider is how the fund itself views disruption. As referenced above while the programme guidance is clear and agrees with the literature in its definition of disruptive technology, the guidance also includes reference to novel technology as also qualifying for funding as specified under the scoring for 'Strength of Disruptive Technology'. A technology having characteristics which could be described as 'novel' does not necessarily imply that it is disruptive – which is a narrower concept. The inclusion of novel in programme guidance may suggest that the programme is open to funding what would be considered 'radical innovation' – innovations which are a significant step up for the technology and push the performance frontier but, as stated above, reinforce the business model. Hopp et al (2018) state that radical innovations 'stem from the creation of new knowledge and the commercialization of completely novel ideas or products'.[8] While these type of innovations can be destructive in their own right in terms of taking market share for a firm (often more destructive than 'disruptive innovation'), they are distinct from disruptive innovation for the reasons stated above.

[3] https://www.academia.edu/1625844/A_reflective_review_of_disruptive_innovation_theory
[4] Rosli, Ainurul & Beltagui, Ahmad & Candi, Marina. (2017). Understanding disruption in innovation ecosystems: an effectuation perspective.
[5] https://hbswk.hbs.edu/item/how-big-companies-can-out-run-disruption
[6] https://paginas.fe.up.pt/~ee07011/documentos%20no%20site/docs%20pesquisados/Disruptiveness%20of%20innovations%20-%20measurement%20and%20an%20assessment%20of%20reliability%20and%20validity.pdf
[7] https://hbr.org/2015/12/what-is-disruptive-innovation
[8] https://hbr.org/2018/04/what-40-years-of-research-reveals-about-the-difference-between-disruptive-and-radical-innovation

Rationale

In this section we discuss the rationale behind State investment in disruptive technologies and further, the rationale in the specific way in which DTIF seeks to invest in disruptive technologies based on its objectives.

The DTIF's objective as set out in the Call 1 Reference Document for Applicants are:

- To support enterprises in Ireland to exploit the enterprise opportunities associated with "disruptive technologies" by de-risking collaborative projects.
- To support enterprises in Ireland to collaborate together and with the public research system in order to engage with and be prepared for challenges associated with new "disruptive technologies" that will have a transformative impact on the way we work and live in the future.
- To build on research undertaken in Ireland and to leverage that research further by supporting the delivery and exploitation of new technology-based solutions from that research.
- To foster deeper and wider RD&I collaborations between the public and private sectors in key technology areas and in particular to support collaborations between large firms and SMEs in Ireland.
- To strengthen spin-out, spin-in and other start-up activity associated with disruptive technology.
- To prepare Irish enterprises and public bodies to engage in European and global partnerships around the development and deployment of disruptive technologies.

Further detail on the DTIF's objectives is available in programme documents, which set out how the fund as a whole will operate beyond its specific aims with enterprises. The fund is intended to:

- align with the Enterprise and Innovation Priorities including Ireland as a global innovation leader;
- fund projects on the RD&I spectrum that are truly disruptive, i.e. those that significantly alter the way we work and live and the way that businesses and/or entire industries operate;
- be significantly different to existing programmes to ensure additionality;
- leverage non-Exchequer funding, including through co-funding with industry;
- ensure collaboration between companies, research performing organisations (RPOs) and public sector organisations as much as possible;
- as per Government decision of 6 March 2018, operate in line with the revised Research Priorities Areas 2018-2023;
- see the development and application of these technologies for commercial use to guarantee the jobs of the future.

DOES DISRUPTIVE TECHNOLOGY REQUIRE STATE INVESTMENT?

The primary objective of the DTIF is to invest in truly disruptive technology. It is clear from the initial discussion clarifying what disruptive technology is, that it has the potential to significantly alter the way markets operate. Guo et al (2019) state that disruptive technologies (if successful) can rapidly gain market share, meaning that potential marketplace disruption can be turned into a real business opportunity.[9] This view is shared by Schwab, who believes that the importance of disruptive innovation is increasing as the general pace of innovation is quickening.[10] Disruptive innovations capable of bringing significant change to markets – for the companies bringing through this disruptive innovation - there are potentially significant rewards in the form of increased market share. For incumbent companies who can successfully identify potential disruptive innovations to their market, investment in disruptive innovation offers a way to protect and grow their market share.

From an Irish enterprise perspective, the rationale for investment in 'disruptive technology' or 'disruptive innovation' is clear. This investment has the potential to significantly increase global market shares of Irish companies, and of companies operating in Ireland – both of which have potential to increase employment and make a significant contribution to the Irish economy.

The above sets out the strong rationale for general investment in disruptive technologies. However, this does not mean that it is an area which requires State investment. We will now explore some specific reasons why the State might invest in disruptive technologies.

Overcoming Risk

Disruptive innovation is typically a risky proposal, with the path towards innovation so unclear that the incumbents in a market have often not identified it themselves. This innovation often enters at the low-end of the market meaning that initially the final business prospects may not be clear to private investors. Government support can reduce the level of risk faced by private firms and thereby increase activity focused on disruptive innovation from what it may otherwise have been, meaning that projects which may not have commenced without public funding will do so. This support is particularly important for SMEs where access to finance issues and the availability of collateral means investment in innovation by SMEs is often lower than it should be, and these difficulties are compounded by the risky nature of disruptive activity[11]. This points towards significant difficulties which a smaller, potentially disruptive firm may have in investing sufficiently in innovation itself. State support in this area can help these companies overcome these funding issues. Research has shown that small businesses may overestimate the risks associated with growth and innovation (Allison, 2006) – leading to lower than ideal level of innovation in practice. This risk is particularly relevant to disruptive innovations where smaller, opportunistic players can compete with larger businesses. If perceived risks are preventing adequate investment in disruptive innovation, then State funding can help mitigate this risk and contribute to increased investment in the area. Small firms may struggle with raising significant capital for innovation as the required levels of investment for innovation may require a higher level of R&D intensity compared to larger firms[12].

[9] https://www.sciencedirect.com/science/article/pii/S0040162518306656
[10] https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/
[11] https://www.esri.ie/publications/estimating-an-sme-investment-gap-and-the-contribution-of-financing-frictions
[12] https://www.diw.de/documents/publikationen/73/diw_01.c.526461.de/dp1546.pdf

It is also possible that larger firms may have a broader, more planned approach to their investment in innovations. In these firms State funding towards potentially disruptive projects could mean that innovations are pursued which otherwise would not have been an investment priority for the firm.

Where the outcomes and future level of success for potentially disruptive technology are unclear it may particularly suffer from a dearth of investment when moving from TRL 3 'proof of concept' to TRL 7 'system prototype demonstration in operational environment' - often referred to as the 'valley of death' due to a lack of academic or private sector investment. Venture capital or investors may wish to invest at a later stage in the process where outcomes are more certain. This reluctance to invest by private firms can mean that there is a less than ideal level of investment in potentially disruptive technology. Without State investment many technologies may never receive sufficient private investment to progress.

Collaboration

Fostering collaboration between firms provides strong reason for State funding of disruptive technology and as such it is an explicit objective of the fund.

Investment in disruptive innovation may be hindered through firms being unwilling to share information, even if it contributes to mitigating risks through cost and resource sharing and enabling growth for all firms involved. There is evidence to support the theory that inter-organisational collaboration has a positive relationship with innovative performance. Reasons for this can involve access to complementary assets, the transfer of knowledge, as well as the simple reduction of risks involved in R&D by spreading the costs across multiple parties[13]. By attaching conditions which private firms must meet in order to be awarded funding, the State can encourage collaboration to a greater degree than it would happen otherwise. Collaboration can be quite effective for aiding in bridging the valley of death through dissipation of costs and risks as above. Through enhancing collaboration, the DTIF encourages firms to bridge the valley of death. Of course, the fund also contributes to firms overcoming the valley through direct grant aid, stepping in where private investment may be lacking to encourage innovation.

Encouraging collaboration is also positive for medium to larger firms that may be incumbents and active in the target market. A particular feature of disruptive innovation is that managers within incumbent firms may be focused on fulfilling the needs of their current group of customers through improved product or service provision in a similar vein to their current offering[14]. Collaboration may allow these firms to have a wider view of potential disruptions to their market, while contributing resources or expertise which smaller firms may lack. Indeed, collaboration has been shown as a way in which incumbents can survive disruption of the market, with this collaboration possibly involving the acquisition of disruptive capabilities, or indeed using collaboration as a defence mechanism.[15]

State involvement can also encourage further collaboration between the research sector and firms which may lead to increased commercialisation of research performed, as well as a wider set of disruptive innovations be brought to market. Through State investment in disruptive technologies it can allow for a level of collaboration which may not occur otherwise, this collaboration will bring about a rise in the total level of disruptive innovation from what it might otherwise have been, and

[13] https://onlinelibrary.wiley.com/doi/abs/10.1111/j.0737-6782.2005.00120.x
[14] Arend, Richard J. "Defending against Rival Innovation." *Small Business Economics*, vol. 33, no. 2, 2009, pp. 189–206.
[15] https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-8691.2009.00507.x

due to the sharing of resources and knowledge it may mean that such innovations have a greater chance of success than they would have had with firms acting alone.

The discussion above has also provided strong rationale for some level of State investment in disruptive technology, as it can de-risk projects and enhance collaboration among firms, it also offers a way to govern this change by steering towards major societal and economic challenges. This in turn can lead to a greater number (or likelihood) of disruptive innovations than would otherwise be the case.

FUNDING MODEL FOR STATE SUPPORT OF DISRUPTIVE TECHNOLOGY

The DTIF is set up as a grant-based fund, providing 50% of costs to the enterprise partners in eligible projects. Another possible way to support research in disruptive technology would be to adopt a more investment-based fund where the State would seek either equity in companies developing disruptive technologies or would seek to ensure a certain return based on the performance of projects outputs.

The funding model used by DTIF should be considered in light of its rationale. The DTIF has a strong focus on collaboration between firms. This emphasis on the involvement of multiple organisations would likely present a challenge to establishing the fund on a more investment-based intervention from which the State could expect a return. For example, investment in the form of equity in participating businesses would strongly discourage the involvement of MNCs who would likely be unwilling (or indeed unable) to give up equity. This is a similar issue for RPOs, whose research activity has the objective to generate knowledge and to transfer it to firms. While SME investment through equity is possible, a consideration is the current equity value of SMEs participating in the fund compared to the size of funding available. While an equity investment could be suitable for SMEs, it may be not for larger companies such as MNCs or for RPOs for the reasons above. Therefore, if part of the rationale of the DTIF is to foster collaboration among all the above organisations and if the equity funding would not be appropriate for non-SMEs, another funding model should be considered.

An alternative could be the State requiring a return based on the outputs of the programme. This would present a significant challenge in the formation of consortia which make agreements on the rights to outputs of each project. The administration of such a fund would be more difficult with a need for a different approach for each project. In particular, this could again limit the interest of larger companies in projects.

A third approach could be a loan-based or guarantee approach. This could indeed present an avenue for financing innovative projects. However, it does not deal with risk in the same way as it is currently the case with the fund. By awarding 50% of eligible project costs DTIF inherently shifts the ratio of risk to reward for participating firms, which can drive interest in potentially risky proposals. Agreeing loan finance between consortia members may also prove difficult, as each will have differing finance needs as well as risk appetite with regards to debt. While SMEs and mid-caps may benefit from the provision of debt funding for riskier projects, MNCs likely have the ability to raise their own finance – their involvement in DTIF currently being motivated by the reduced risk profile of projects. It is possible that once projects are emerging from DTIF, with likely outcomes

more certain, that larger European debt instrument specifically tailored for innovation projects could be appropriate such as the InnovFin programme promoted by the European Investment Bank.[16]

Choosing one of the two approaches – grant or investment – as more appropriate, has implications for the variety of organisations involved, each of which has its own priorities and interest in undertaking research of this type. For the collaboration-based calls as currently designed, with the objective to enhance collaboration and risk-sharing among various organisations, the most effective way to do so appears to adopt a funding model based on grant rather than a return-based investment. That is not to say that other types of interventions could not be explored which could be based more around an investment model.

[16] https://www.eib.org/en/products/blending/innovfin/products/index.htm

Alignment with national policy

DTIF REFLECTING WIDER POLICY CONTEXT

The above discussion demonstrated rationale for investment by the State in disruptive technology. However, the DTIF not only aims to make general investments in disruptive technologies, but to do so in a specific way which reflects the priorities of Irish innovation policy. The fund sets out to fund disruptive technology – as evidenced in the programme objectives – 'those that significantly alter the way we work and live and the way that businesses and/or entire industries operate'. This can include both 'disruptive' and 'novel' technology. The fund is set within the wider goals of Irish innovation policy and this may determine the direction of the fund, the types of projects it funds and how well these projects can match with potentially strict definitions of disruption.

The proposals are further intended to build on excellent scientific research and advance solutions, as part of the disruptive technology criteria for funding. A strict academic interpretation of disruptive innovation would also include innovations which are seeking not necessarily to progress a technology, but which are seeking to undercut a current technology which 'over-services' a market – not necessarily building on scientific research. This indicates a possible gap between what is being put forward for funding and strict definitions of disruptive technology. In this sense the fund would seem to be seeking innovations which are both disruptive *and* radical in nature. Further, DTIF aims to fund large-scale innovative projects, in particular it encourages projects in the region of €5-10 million of funding. This is highly significant funding in the context of Irish RD&I supports to enterprise. When viewed in a wider policy setting and focusing perspective on what is a reasonable investment for public funds, this element makes sense as there may be little practical rationale for a public fund to be investing in a potentially lower-risk venture which could be wholly supported privately. From this perspective, the inclusion of 'novel' technology in the criteria is a way to focus the fund on applications which would be more appropriate for public funding.

While SMEs are the main organisation type funded under the DTIF, the inclusion of multi-nationals possibly further distinguishes the fund from a strict definition of disruptive technology (SME dominant) and reflects the Irish policy context where international firms serve an important role as both employers and innovators. The inclusion of large firms also reflects that the fund seeks to build on excellent scientific research - a strength of larger firms as well as the research base in Ireland.

The focus of the fund on commercialisation of research is important – as the projects funded are intended to create jobs in the future. Again, this possibly distinguishes the types of projects which the DTIF can fund over a more academic interpretation of disruptive innovation - the route to economic impact needs to be clear. The focus on commercialisation could possibly further focus the fund on product innovations rather than process innovations or business model adaptations which are also open to funding.

The features point to a fund which is funding innovations beyond only 'disruptive innovation', these features reflect the policy context in Ireland but also demonstrate the funds alignment with national that policy.

The fund aims to encourage collaboration between firms and increased linkages between the research sector and industry. The basis for many of the programme's objectives can be found in national policy documents including Innovation 2020 and Enterprise 2025 Renewed which specifically sets out to 'position Ireland to the forefront of disruptive technologies'.

Ireland as a Global Innovation Leader/Leveraging Non-Exchequer Funding

Innovation 2020 and Enterprise 2025 Renewed both envision Ireland as a Global Innovation Leader. A key aspect of this is to increase investment in Research, Development and Innovation. Both strategy statements set a target for investment from private and public sources in R&D at 2.5% of GNP by 2020. The latest figures from the 2018/2019 R&D Budget Report show that Ireland's Gross Expenditure on R&D stood at 1.46% of GNP in 2018[17]. Generally, Ireland has lagged behind other countries in its investment in innovation on a GDP/GNP basis. While the 2019 European Innovation Scorecard classifies Ireland as a 'strong innovator', this is despite low scores allocated to the areas of R&D expenditure in the public sector and private co-funding of public R&D expenditure[18]. In order to become a Global Innovation Leader Ireland will need to become a strong performer in both of these areas.

The DTIF is directly aligned with increasing investment in this space due to its requirement for 50% co-funding from firms applying for DTIF funds. This directly supports this aim by bringing together public and private funding which will increase enterprise engagement in RDI. The DTIF further contributes towards the goal of Ireland as a Global Innovation Leader through its role in decreasing risk for private firms and thereby moving technologies forward along TRL 3-7 where, as discussed above, private investment can be lacking. Projects emerging from DTIF stand improved chance of further private investment once their outcomes have become clearer. This increased investment by the State should, in turn, lead to a further increase in private investment in 3-5 years.

As discussed above, a lot of disruptive innovation internationally is driven by smaller firms that disrupt the incumbents within a market. This feature of disruptive innovation is reflected within the DTIF's requirement that SMEs make up a part of each collaboration. This aligns with goals in Innovation 2020 around increasing the level of involvement by SMEs in innovative activity. It also aligns with recommendations from an Indecon evaluation of RD&I supports, which found that the majority of RD&I activity in Ireland was carried out by larger firms and that attention should be paid to increasing and deepening RD&I expenditures and to highlight pathways between schemes for SMEs. While it is likely that SMEs involved in DTIF are already active in the RD&I space (and so it is not necessarily concerned with broadening the number of SMEs which are active in the area of innovation), the DTIF does support increased RD&I expenditure from SMEs and provides an avenue for continued support of innovation activity in SMEs.

Collaboration and Increased Linkages

DTIF aims to increase collaboration between firms as well as increasing linkages between enterprise and the research sector. It aims to achieve this by requiring that a minimum number of independent partners make up each consortium applying for DTIF funds. This was 3 independent partners in Call 2 of the fund. It further requires that applications include a minimum of one SME and one other enterprise partner. This encourages both collaboration and increased linkages between the enterprise base and the research sector. Further, the quality of collaboration is included as one of the 4 main areas under the scoring system for applications.

This focus on collaboration within the DTIF is in alignment with actions set out under Innovation 2020. Action 2.12 seeks to 'Increase collaboration between firms and the public research system'. As explored earlier in the paper, there are benefits from collaboration both between firms, and across enterprise and research sectors as it leads to increased knowledge exchange, spreads investment costs and reduces risk. The DTIF increasing linkages also helps ensure that previous

[17] https://dbei.gov.ie/en/Publications/Publication-files/R-D-Budget-2018-2019.pdf
[18] https://ec.europa.eu/docsroom/documents/35896

research within the research sector is built on by the enterprise sector and is in turn commercialised to a greater extent. The DTIF specifically seeks to encourage collaboration between small and large firms, as well as with RPOs in order to build on previous research. While most *disruptive* innovations occur in smaller firms, this does not preclude involvement by larger firms. One clear reason for involving multi-national firms in the DTIF is for reasons of collaborating where they may have greater expertise or technologies than other firms.

Commercialisation

Innovation 2020 seeks to promote the commercialisation of products from publicly funded research, with a number of actions aimed at increasing the commercialisation of Irish research outputs. DTIF seeks to fund technologies from TRL 3-7, and to progress them along TRLs. Innovation 2020 sees the commercialisation of products from research as a way to help ensure the competitive advantage of Irish enterprise. The focus on commercialisation within DTIF helps ensure that the funding is going to technologies which will, in time, contribute to the Irish economy significantly and which are helping Ireland to compete globally.

The DTIF, which provides 50% grant funding of eligible costs for projects, requires 50% private funding as 'co-funding' from firms, is particularly helpful in this way[19]. DTIF is particularly aimed at Technology Readiness Levels 3-7, level 3 being experimental proof of concept, with technology at level 7 able to demonstrate a system prototype in an operational environment. [20] As stated earlier, technology in this area is often referred to as bridging the 'valley of death'. This is due to a dearth of academic or private sector investment. Venture capital or investors may wish to invest at a later stage in the process where outcomes are more certain. This reluctance to invest by private firms creates a strong case for State driven investment focused on the technology readiness levels covered by the DTIF. The State's investment through DTIF allows it to enable further private investment at later TRLs which will in turn create a pipeline of potentially disruptive technologies.

Addressing Challenges

DTIF was initially planned as a challenge-based fund within the National Development Plan. While this element was not specifically included in the scope approved by Government, it could be incorporated in future calls.

Innovation 2020 recognises that challenge-led innovation is an increasingly important concept and that stimulating solutions-driven collaboration will foster interdisciplinary consortia of enterprises, higher education institutions and public service delivery bodies to address major societal challenges. Interdisciplinary research is key to addressing such challenges and incorporating the 'human factor' is also vital. Societal challenges are typically highly complex, and the engagement of researchers from both Arts, Humanities and Social Sciences, and Science, Technology, Engineering and Maths can often generate more innovative solutions and new ways of approaching and thinking about problems.

The DTIF was announced as part of the National Development Plan 2018-2027, this is set within the National Planning Framework: Ireland: 2040 (NPF) which features 5 national strategic outcomes. The DTIF is aligned with the 5th national strategic outcome set out under the NPF: A Strong Economy Supported by Enterprise, Innovation and Skills. The NPF references the challenges of technological disruption for the economy.

[19] RPOs receive 100% of costs up to 50% of total project costs.
[20] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/support/faq/2890

Disruptive technology is also referenced within the NPF as a way of accelerating the achievement of all national strategic outcomes. The importance of Disruptive Technologies for the national economy is also seen in its inclusion in Future Jobs Ireland 2019 where the DTIF is featured as a deliverable under Ambition 1.5 ‘Increase the capacity of SMEs to engage in RD&I’ as well as supporting Ambition 2.4 ‘Encourage enterprises to exploit technology and business process improvements to increase productivity’. These are the Government’s longer-term ambitions for the jobs and the economy, demonstrating that Disruptive Innovation is seen as a core part of driving enterprise in Ireland.

The DTIF is a significant investment by the State in disruptive technologies and disruptive innovation. The references to disruptive technology and disruptive innovation across a range of national policy statements and strategies show the growing importance of disruptive innovation from a policy perspective. This increasing focus is based on strong rationale. Successful disruptive innovation can allow Irish firms to compete in global markets. State investment in this area can de-risk projects, increase collaboration and can increase the absolute level of private investment through co-funding. As emphasised by Christensen, not all of these investments will succeed at disrupting markets, but through increasing the number of disruptive innovations occurring in the Irish economy the DTIF is setting Ireland up for greater success in the area of innovation.

Programme profile

The paper now provides an overview of the DTIF to date. It discusses how the Calls under the fund have operated to date, then provides a profile of the applications, participants, funding and costs.

GOVERNANCE OF THE DTIF

The Department of Business, Enterprise and Innovation, launched the Calls and lead on this initiative with the support of its agencies. It also established and chaired a cross-agency Advisory Board comprised of nominated members of Science Foundation Ireland (SFI), Enterprise Ireland (EI), IDA Ireland, Department of Public Expenditure and Reform, Department of Education and Skills and the Department of Agriculture, Food and the Marine. The Advisory Board ensures that the objectives of the DTIF project are delivered and has the final decision on the projects selected.

The Advisory Board approves the process for selecting projects under each call of the Disruptive Technologies Innovation Fund (DTIF), delegates the eligibility checks and the administration of the funds to Enterprise Ireland, the evaluation process to approved panels of national and international experts. The Panel 1 comprised of national experts including nominees from the DBEI agencies i.e. Enterprise Ireland, IDA Ireland and Science Foundation Ireland, the Department of Agriculture, Department of Public Expenditure and Reform (DPER) and the Department of Education and Skills. and screened proposals by undertaking a preliminary assessment of the potential economic impact and financial sustainability of the project.

Panel 2 comprised of internationally renowned experts nominated by the members of the Advisory Board and evaluated the scientific, technical and likely commercial impact of the proposals. Panel 2 marked and ranked projects based on agreed eligibility criteria using an agreed marking scheme and the metrics that the Advisory Board recommended.

Once the assessment from the international experts is completed, the Advisory Board agrees the ranked list of projects recommended for funding and transmits the list of successful projects to the Minister for Business, Enterprise and Innovation for approval and decisions on funding.

The DBEI allocates the funding to the agencies for transmission to the successful projects according to whether they are HEIs or other RPOs (SFI), Irish-owned companies (EI) or MNC-led (IDA).

Regarding the post-award management, the Advisory Board provided advice the grants administration process and agreed any substantive changes to an approved project, including funding decisions above a threshold of €110,000. Finally, they advised on the framework of each call for funding applications to be run under the Disruptive Technologies Innovation Fund (DTIF)

COMPARISON OF CALLS

The DTIF has issued two Calls to date, in 2018 and in 2019. DTIF provides 50% grant funding of eligible project costs to enterprises, and 100% of eligible costs to RPOs. RPOs were allowed up to two-thirds of total project grant funding under the first Call, but this was limited to 50% under Call 2. There have been changes between the two calls, as the table below summarises:

Call 1	Call 2
• Minimum 2 partners with at least one SME • Minimum funding request €1 million • Research Performing Organisations (RPOs) including colleges and research institutes can receive up to two thirds of funding; • Two stage process involving an Expression of Interest (EOI) stage and a Full Application Stage	• Minimum of 3 partners with at least one SME and one other enterprise partner; • Minimum funding request €1.5 million; • RPOs including colleges and research institutes can receive up to 50% of funding; • One stage application process

In both Calls SME participation in consortia was mandatory, with a minimum of two participants, and no maximum limit. The lead applicant could be an SME, a large enterprise or an RPO. The minimum amount that applicants could request was €1 million in 2018. This increased to €1.5 million in 2019 after taking learnings from the first call.

Call 1 was a two-stage process, involving the initial submission of an Expression of Interest, followed by a full application at a later stage for those EOIs selected to submit one. This included underpinning project plans and cost sheets for each project.

Again, reflecting lessons learned in the first call, Call 2 was more simplified as it involved a single stage process, where only full application forms were required. Only those that were selected for funding were required to specify project plans and cost sheets.

Selection process under Call 1 and Call 2

The table below summarises the selection process of both calls.

Call 1	Call 2
• Call opens in June 2018 • Closing date for the receipt of the EOIs is 17 August 2018 • In September 2018 selected EOIs were invited to submit the full application • Remote evaluations between September and November 2018 • Interviews were held at the end of November 2018 • In December 2018 successful projects were announced	• Call opens in June 2019 • Closing date for full applications is 18 September 2019 • Remote evaluations between September and November • Interviews were held at the end of November 2018 • Announcement of successful projects in December 2019

The length of the process was around six months for both Calls: both opened in June and successful projects were announced in December of each year. Call 1 included a two-stage process within the 6 months, including expressions of interest and full applications. Expressions of Interest were initially reviewed by Enterprise Ireland staff for meeting minimum criteria before being invited to full application stage and on to full interview stage. Discussions with stakeholders suggest that industrial sector applicants felt the Call 1 deadlines were quite tight. For this reason a structured one-stage process, which allowed for a longer application time, was provided for in Call 2. Eligible applications were reviewed by independent international technical and commercial experts along the following criteria: Strength of the Disruptive Technology Dimension; Excellence of the Overall Proposal and Approach; Economic and Market Impact; Quality and Efficiency of the Collaboration.

PROGRAMME FUNDING

Overall, the DTIF awarded funding to 43 projects, 27 of which were awarded under Call 1 and 16 under Call 2. €140 million of the fund's total €500 million allocation has been awarded across the calls to date.

Funding confirmed for DTIF under the National Development Plan out to 2022 is as follows:

Table 1: Total Funding Allocated to DTIF (2019-2022)

Year	DTIF initial allocation
2019	€ 20 million
2020	€ 30 million
2021	€ 40 million
2022	€ 90 million

€180 million was committed under the NDP for DTIF to award out to 2022. Each annual allocation is subject to final confirmation in the Revised Estimates procedure. Across two calls to date the DTIF has awarded €140 million in total funding, with €75 million awarded in Call 1 and €65 million being awarded in Call 2.

OVERVIEW OF THE PROJECTS FUNDED

27 projects[21] were funded under Call 1 and 16 under Call 2. Among the topics funded, several projects covered the area of Health and Wellbeing, and in particular the fields of Diagnostics and Therapeutics. For instance, some projects are working towards the development of devices that help diagnose gastro-intestinal diseases, including cancer, in a more accurate way than existing machines, or others aim at the creation of a cardiac implant to treat stroke and arrythmia, or to treat sepsis, psoriasis and arthritis. In the field of ICT, some projects are developing faster network in support of a faster software operationalisation or are working on solutions that will solve the

[21] Full list of projects funded under Call 1 available here: https://dbei.gov.ie/en/What-We-Do/Innovation-Research-Development/Disruptive-Technologies-Innovation-Fund/DTIF-Awards-Under-First-Call-2018.html

problem capacity of optical telecommunication and data centre networks. New implants in support of mobility and devices for remote health monitoring are also being developed, with the potential impact of disrupting the market of mobility aid devices and to reduce the costs of hospitalisation and.

In the field of Energy, Climate Action and Sustainability, one of the projects funded intends to develop an energy system in which communities and consumers are empowered with the infrastructure necessary to generate their own electricity and ultimately being an integral part of the decarbonisation of their homes and communities. In the field of Food, a new system of fish farming, and in particular organic salmon production, is being developed, with the potential to be extended to other areas of fishing and farming.

16 projects[22] were funded under Call 2. Health and Well Being and ICT were once again the mostly funded areas. In particular, in Health and Wellbeing the successful projects are developing therapies to treat the Chronic Obstructive Pulmonary Disease, new drug delivery platforms and endoscope cameras that will allow clinicians to see around corners with greater precision than with current machines. In the field of ICT, projects funded are working towards the creation of an artificial intelligence platform able to process audio and visual data on device without having to transfer them to the cloud and with low power consumption. Other technologies are focusing on the creation of a platform to exploit videos in support of criminal justice and security, with the potential to be extended to the broader media and entertainment markets, or on the development of an artificial intelligence-based platform that will explain laws and regulations to facilitate doing business and consumer protection.

In the field of Energy, Climate Action and Sustainability, the projects under way are developing solutions to reduce the land-spread waste and to produce high quality renewable energy, and the creation of a zero-emission heat pump.

APPLICATION AND PARTICIPANT PROFILE

The table below shows the number of applications and awards for each of the two Calls:

Table 2: Applications to DTIF Call 1 and Call 2

	Total Expressions of Interest (EOIs)	Total Full Applications	Unsuccessful Applications	Successful applications
Call 1 (2018)	310	90	63	27
Call 2 (2019)	N/A	63	44	16

Source: own elaboration from Enterprise Ireland data

It should be noted that Call 1 was a two-stage process in which applicants were required to submit an Expression of Interest and only a selection of those would be requested to submit the full application. The Expressions of Interest were no longer required under Call 2, but only the applications. In Call 1 90 full applications were invited (reduced to 44 after remote evaluation) following review of the Expression of Interest, and of these 27 were successful. In Call 2, 63 full

[22] Full list for projects funded under Call 2 available here: https://dbei.gov.ie/en/News-And-Events/Department-News/2019/December/07122019.html

applications (including 3 incomplete ones) were received (reduced to 24 after remote evaluation), 16 were awarded DTIF funding and 44 were unsuccessful.

Based on full applications, Call 1 had a success rate of 30% for full applications while Call 2 had a success rate of 26%. An appropriate success rate can be important for maintaining interest from industry in a fund over time, while also (partially) indicating that the projects funded have demonstrated a high level of excellence.

Funding under the DTIF is available to SMEs, Multi-National Corporations and Research Performing Organisations, with a requirement that an SME be a partner in all applications under both Calls to date. The requirements for SME participation is likely to lead to a higher number of SMEs in the programme than other organisation types.

A profile of the participants that received funding is provided below, by organisation type. Within the DTIF a number of firms and RPOs were successful in gaining funding across more than one project, which is not reflected in Table 3 – this table focuses on the number of organisations active within the DTIF, the number of individual contracts across organisation type is explored further below.

Table 3: DTIF Participants by Organisation Type

Call 1			**Call 2**		
	All participants	Lead applicant		All participants	Lead applicant
SME	38	16	SME	25	11
MNC	12	2	MNC	13	2
RPO	16	8	RPO	10	3
Total	66	26	**Total**	48	16

Source: own elaboration from Enterprise Ireland data

Overall, 66 organisations successfully took part in Call 1, and 48 in Call 2, 114 organisations in total. These 114 organisations are active across 159 contracts within the DTIF (single firms active across two or more projects in places). 3 SMEs and 2 MNCs were active across more than 1 project under Call 1, while 16 RPOs had involvement in more than 1 project.

SMEs were the organisation type with the largest participation under both calls, as their inclusion was one of the requirements in both calls. SMEs were predominant as lead applicants, with 17 of 27 lead organisations (65%) in Call 1 and 11 out of 16 applicants (69%) in Call 2. Research Performing Organisations (RPOs) registered a significant participation in both calls, with 17 taking part in Call 1, and 8 as lead applicant, and 10 in call 2, with 3 as lead applicants.

Some RPOs (represented by individuals or teams of researchers) took part in several successful projects. The funding under both calls allocated to RPOs is set out below – showing the wide range of RPOs involved in the fund. The table provides the breakdown of the number of projects in which each RPO is involved in both Calls. It shows that the DTIF has engaged a considerable share of eligible Higher Education Institutes in Ireland as well as other publicly funded RPOs.

Table 4: Number of projects and total funding per RPO, both Calls

Call 1			Call 2		
RPO	**Number of projects**	**Total funding**	**RPO**	**Number of projects**	**Total funding**
National University of Ireland Galway	8	€7,560,835	University College Dublin	5	€3,882,898
University College Dublin	6	€7,014,113	National University of Ireland Galway	3	€6,271,029
Trinity College Dublin	5	€3,042,697	Trinity College Dublin	3	€3,011,476
Dublin City University	4	€3,588,515	Royal College of Surgeons Ireland	2	€2,201,113
University College Cork	3	€4,308,509	Tyndall National Institute	2	€2,870,180
Tyndall National Institute	3	€5,004,637	Dublin City University	2	€1,644,670
University of Limerick	2	€4,558,878	National University of Ireland Maynooth	1	€598,526
Dundalk Technology Institute	2	€982,473	Galway-Mayo Institute of Technology	1	€666,278
Dublin Institute of Technology	2	€994,546	NCAD	1	€481,901
CIT	1	€436,438	Irish Manufacturing Research	1	€1,341,496
International Energy Research Centre	1	€641,195			
Teagasc	1	€401,179			
Marine Institute	1	€303,397			
Royal College of Surgeons Ireland	1	€1,649,375			
Waterford Institute of Technology	1	€758,038			
HRB	1	€132,742			
Total		**€41,377,567**			**€22,969,567**

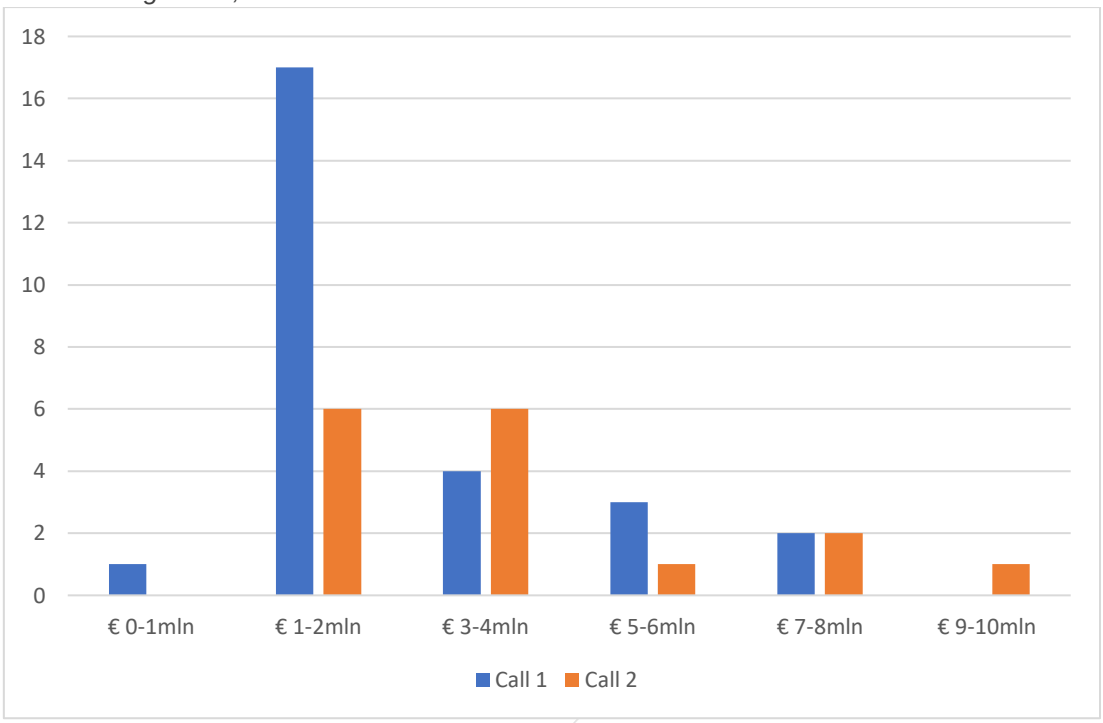
Source: own elaboration from Enterprise Ireland data

The National University of Ireland Galway, Tyndall National Institute, Trinity College Dublin and Dublin City University are the organisations that received the highest share of funds across the two Calls. This can be explained by the participation in more than one project, as according to the nature of the project, different researchers are involved. The University College Cork and the University of Limerick received a substantial share of support, but only in Call 1. Overall, the share of funds of the RPOs is lower in Call 2 (35%) than in Call 1 (52%), and this is due to the lower number of RPOs participating in the second Call as well as RPOs being limited to 50% of the grant aid to the project.

ALLOCATION OF PROGRAMME FUNDS

The histogram below shows the number of projects funded by the level of funding allocated, across the two Calls. The column with €1-2m includes all projects that apply for the minimum threshold required in each call – for Call 1 this was €1m while for Call 2 it was €1.5m.

Figure 1: Funding Scale, both Calls



**A single project in the €0-1mln category applied for €999,877 in funding under Call 1.*
Source: own elaboration from Enterprise Ireland data

The majority of projects under Call 1 applied for between €1- €2 million – with 17 of the 27 projects eligible for this level of funding. 4 projects were awarded between €3 million and €4 million in costs with 5 projects awarded in excess of €5 million. No projects over €9 million were funded under Call 1.

In Call 2, a lower number of projects were within the €1-2 million category, due to the increase in minimum funding thresholds. The majority of the projects were awarded an amount of funds between €2 and €3mln. 3 projects received funding of over €7 million each.

Funding allocated by organisation type

The table below presents the allocation of funding, as awarded to each organisation type. These figures are based on eligible costs after award amounts have been reviewed by Enterprise Ireland, for this reason they may differ slightly from provisional amount awarded by the Minister. The number of participants differ from the figures shown on Table 3 as here it takes into account the fact that some organisations participated in more than one project and is calculated with reference to the number of contracts signed. As a result, some beneficiaries are counted more than once.

Reflecting the fact that RPOs are eligible for 100% of their costs, they represent the largest allocation of funding under the DTIF to date – with €41m allocated under Call 1 and €22.9m [see table 4 on P19] under Call 2.

Table 5: Funding allocated by organisation type, Call 1

Organisation type	Number of project partners	Overall amount	Percentage	Average per organisation
SME	41	€31,072,044	45.68%	€757,855
MNC	14	€5,197,945	7.64%	€371,282
RPO	41	€31,752,066	46.68%	€774,441
Total	***96***	**€68,022,055**		

Source: own elaboration from Enterprise Ireland data, funding based on eligible costs
** Based on the data as of June 2020. Number of participating partners may differ from initial project award due to changes in the makeup of consortia*

Table 6: Funding allocated by organisation type, Call 2

Organisation type	Number of project partners	Overall amount	Percentage	Average per organisation
SME	25	€30,639,707	47.19%	€1,225,588
MNC	14	€10,383,655	15.99%	€741,690
RPO	20	€23,910,119	36.82%	€1,195,506
Total	***59***	**€64,933,481**		

Source: own elaboration from Enterprise Ireland data, funding based on eligible costs
** Based on the data as of June 2020. Number of participating partners may differ from initial project award due to changes in the makeup of consortia*

With reference to the percentages of funding allocation, those allocated to SMEs increased slightly - from 757k to 1,225k- in Call 2 compared to Call 1, and nearly doubled for MNCs, which reflected the changes made in Call 2 to enhance participation from the enterprise sector.

Funding Allocation to Firms, by Enterprise Agency

The table below shows the distribution of funding to firms by their Enterprise Agency client status. The highest number of beneficiaries are clients of Enterprise Ireland, and for this reason they also received the largest share of funding. In comparison with the RPOs, the funding received is similar in Call 1, but higher for firms in Call 2, with RPOs receiving significantly less funding in the second Call.

Table 7: Funding allocation to clients, by Enterprise Agency, Call 1

Agency	Number of project partners	Overall amount	Percentage	Average amount
Enterprise Ireland	44	€31,578,389	87.06%	€717,691
IDA Ireland	*10*	€4,242,205	11.70%	€424,220
Údarás na Gaeltachta	*1*	€449,395	1.24%	N/A
Potential agency client	*0*	0	0	0
Total	55	€36,269,989		

Source: own elaboration from Enterprise Ireland data, funding based on eligible costs

10 IDA clients received funding under Call 1, compared to 46 EI clients. EI clients also had a higher average allocation of funding compared to IDA clients.

Table 8: Funding allocation agency client type, Call 2

Agency	Number of participants	Overall amount	Percentage	Average amount
Enterprise Ireland	27	€32,052,717	79.97%	€1,187,138
IDA Ireland	11	€7,637,271	19.05%	€694,297
Údarás na Gaeltachta	0	0	0	0
Potential agency client	1	€390,300	0.97%	N/A
Total	39	€40,080,288		

Source: own elaboration from Enterprise Ireland data

** Tables 7 and 8 are based on the data received in June 2020, which may differ from the initial project award figures*

Similar to Call 1, Enterprise Ireland clients were better represented under Call 2 with 27 participants. IDA Ireland clients had 10 participants.

With reference to the fund allocation per agency client, Enterprise Ireland clients were allocated the highest share of funds, with a slight decrease between Calls. Given the requirement for an SME to be a participant in each project, and the number of SMEs awarded funding, this is in line with expectations. IDA Ireland clients saw an increase in the share, with an equal number of participants. Only one firm was a client of Údarás na Gaeltachta under Call 1.

Table 9: Overall funding firms-RPOs – both Calls

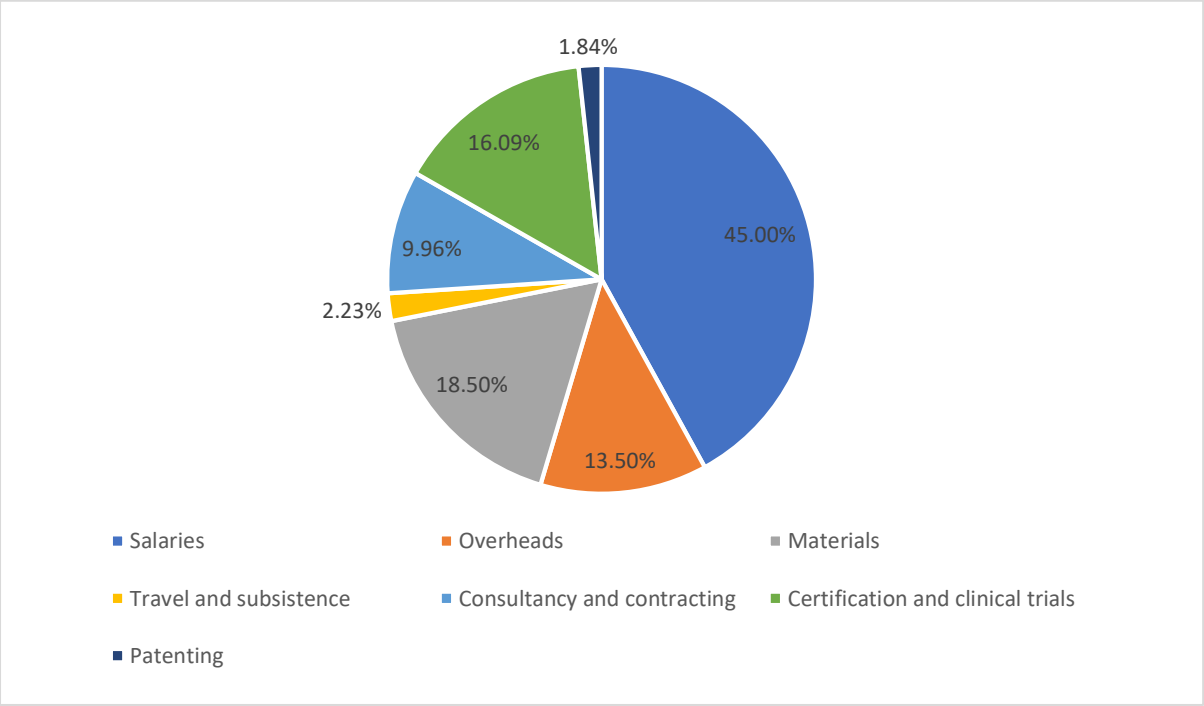
Call 1			**Call 2**		
	Participants	Overall amount		Participants	Overall amount
Total firms	50	€36,269,989	Total firms	38	€40,830,563
Total RPOs	16	€31,752,066	Total RPOs	10	€23,910,119
Totals	66			48	

Source: own elaboration from Enterprise Ireland data

COSTS

The charts below show the distribution of the costs by category of expenditure across the various lead organisations that received DTIF support in Call 1. Analysis is based on Call 1 lead applicants only, due to data availability.

Figure 2: Call 1 Lead Applicant Costs in Call 1, by cost category (SME only)

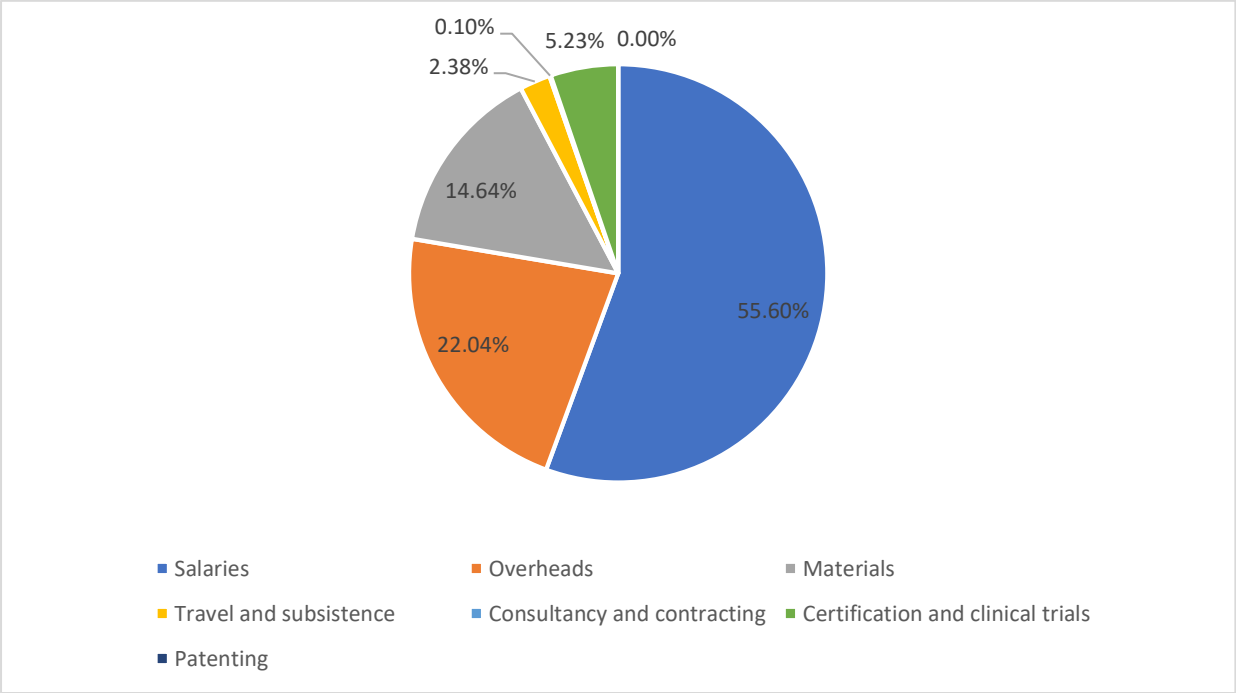


Source: own elaboration from Enterprise Ireland data

Regarding SMEs, nearly 45% of the total expenses for the lead applicant go to salaries of the staff involved in the execution of the project. Materials and Certification and clinical trials are the second and third highest expenses.

In the case of RPOs, the chart below shows that 55 percent of the costs incurred will cover salaries, followed by overheads and materials.

Figure 3: Lead Applicant (RPO) Costs in Call 1, by cost category



Source: own elaboration from Enterprise Ireland data

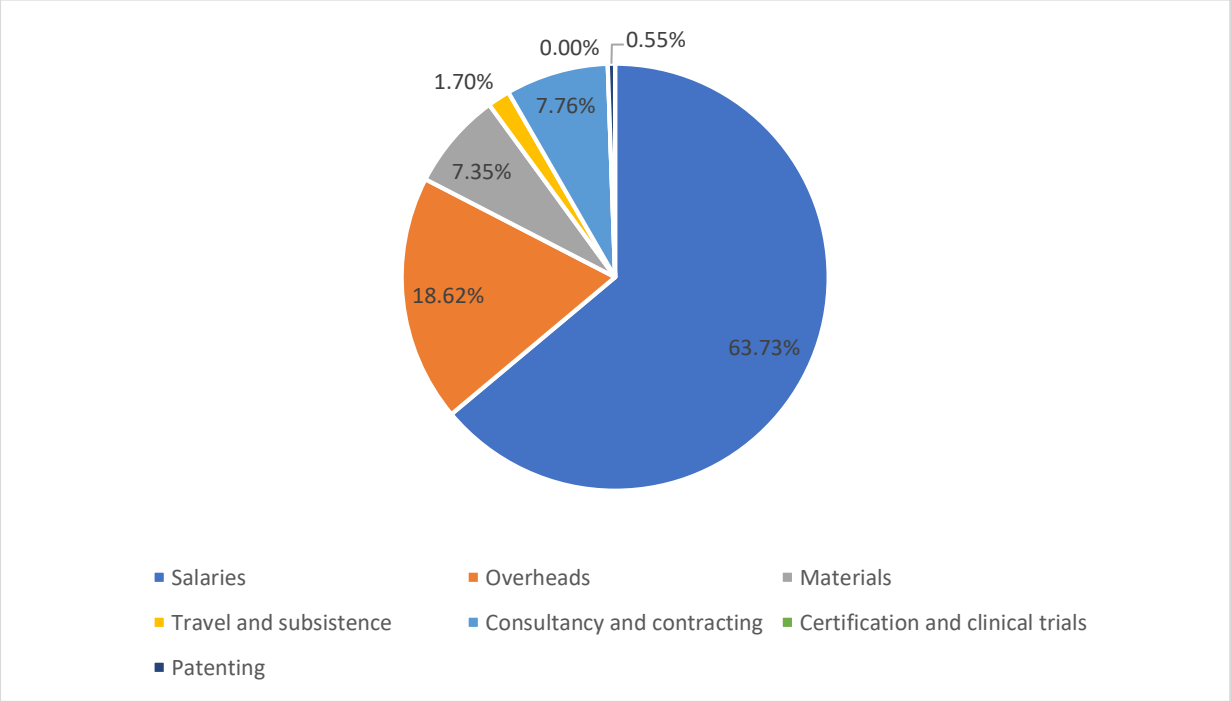
In relation to the new hires, the chart below shows that SMEs have a higher percentage of salaries paid to the new staff hired for the execution of the project, when compared to RPOs. The percentage is calculated in relation to the total salaries paid for existing and new staff. This possibly reflects SMEs increasing their capacity in certain areas relevant to DTIF projects while RPOs may already have had the necessary skill set and are building on their strength in these areas. It should be noted that with regard to the workload, existing staff – that are being paid from other sources – will have their time apportioned as a percentage of time they are allowed to devote to the execution of the DTIF tasks. New staff are those specifically hired as a consequence of the award of the supports to carry out the project activities.

Figure 4: Proportion of new hires to total staff, RPOs and SMEs Lead Applicants only, Call 1

Source: own elaboration from Enterprise Ireland data

With reference to SMEs, the chart below shows that salaries under Call 2 are still the item with the highest projected expenditure, 64%. This is as expected given the skills required under projects funded. Overhead costs account for the second highest percentage of costs, followed by consultancy and contracting costs.

Figure 5: Call 2 Lead Applicant Costs, by cost category (SME only)

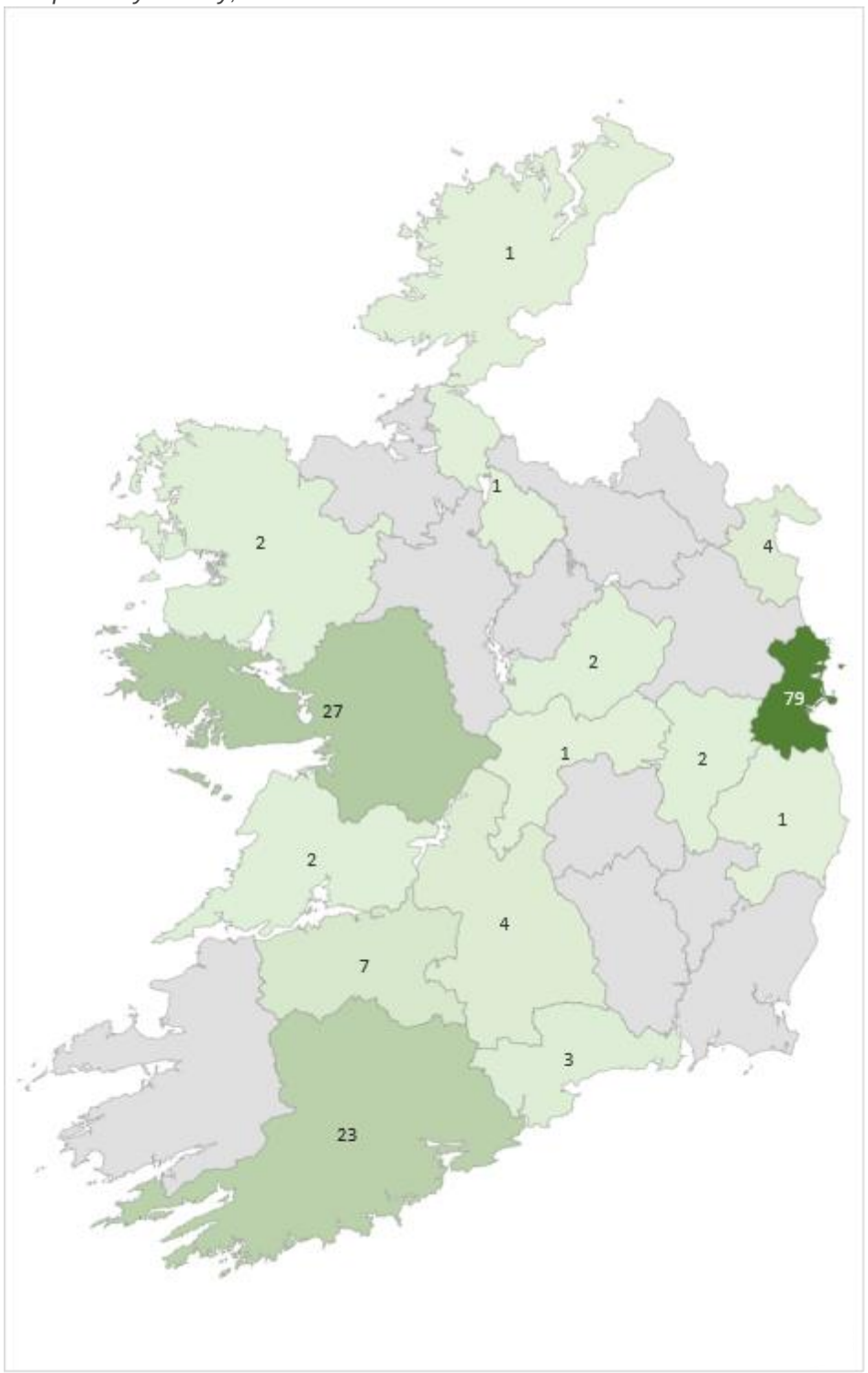


Source: own elaboration from Enterprise Ireland data

PARTICIPATION BY LOCATION

The map below sets out the participants across both Calls, by County - noting that some participants are counted twice due to involvement in more than a single project. Dublin accounts for 79 (50%) of the DTIF participant organisations to date, with Galway and Cork accounting for 27 and 23 participant organisations respectively. Limerick is the only other county with any significant numbers of project participants, though there is a wide regional spread of locations, with 15 counties featuring at least one project participant.

Figure 6: Participants by County, Call 1 and 2



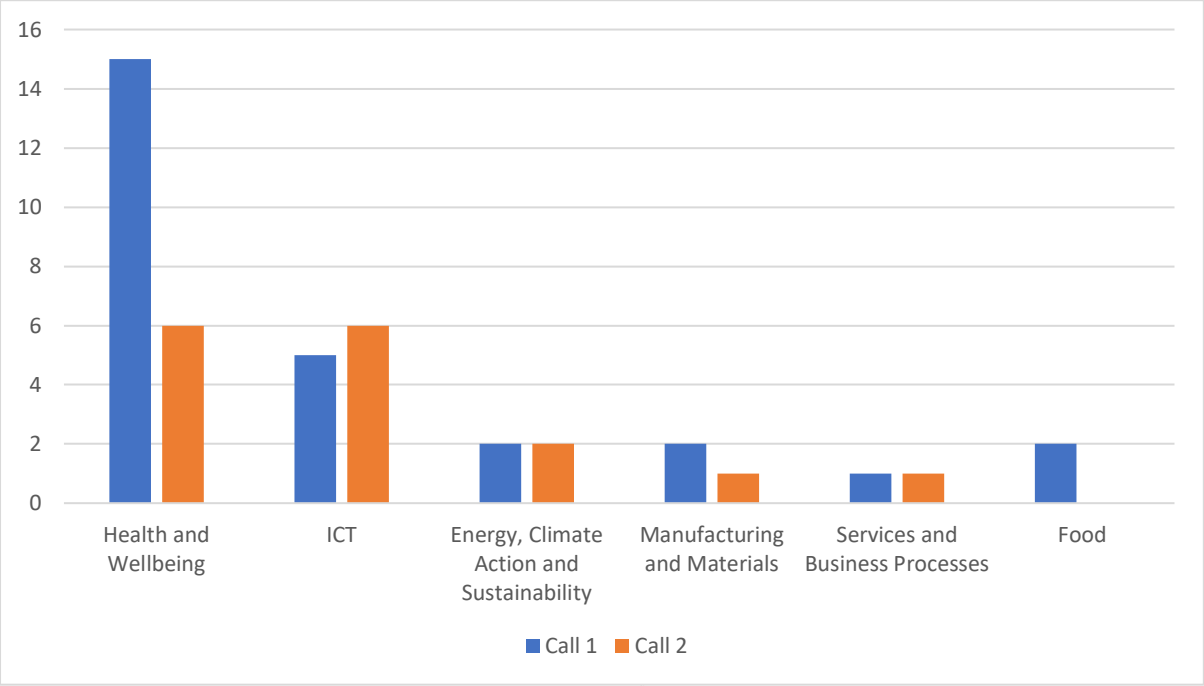
*Map provided by DBEI Innovation, Research and Development Programmes Unit

While the location of DTIF's participants is likely to be primarily driven by economic factors around where industry is located, efforts to maximise awareness by SMEs in counties outside of the main cities could increase the number of applicants from regions and ensure that applications for funding come from a wide range of applicants. While the geographical distribution shows a concentration of beneficiaries in the Dublin area, it is worth noting that 50% of the project partners are located outside Dublin, with projects operating in 15 counties, including Dublin.

ALIGNMENT WITH RESEARCH PRIORITY AREAS

The DTIF does not specifically seek to fund one Research Priority Area over any other. Projects are funded if they meet the selection criteria. However, to date there have been significantly different numbers of projects funded by Research Priority Area. This is demonstrated in the chart below.

Figure 7: Fund allocation per RPA and successful projects

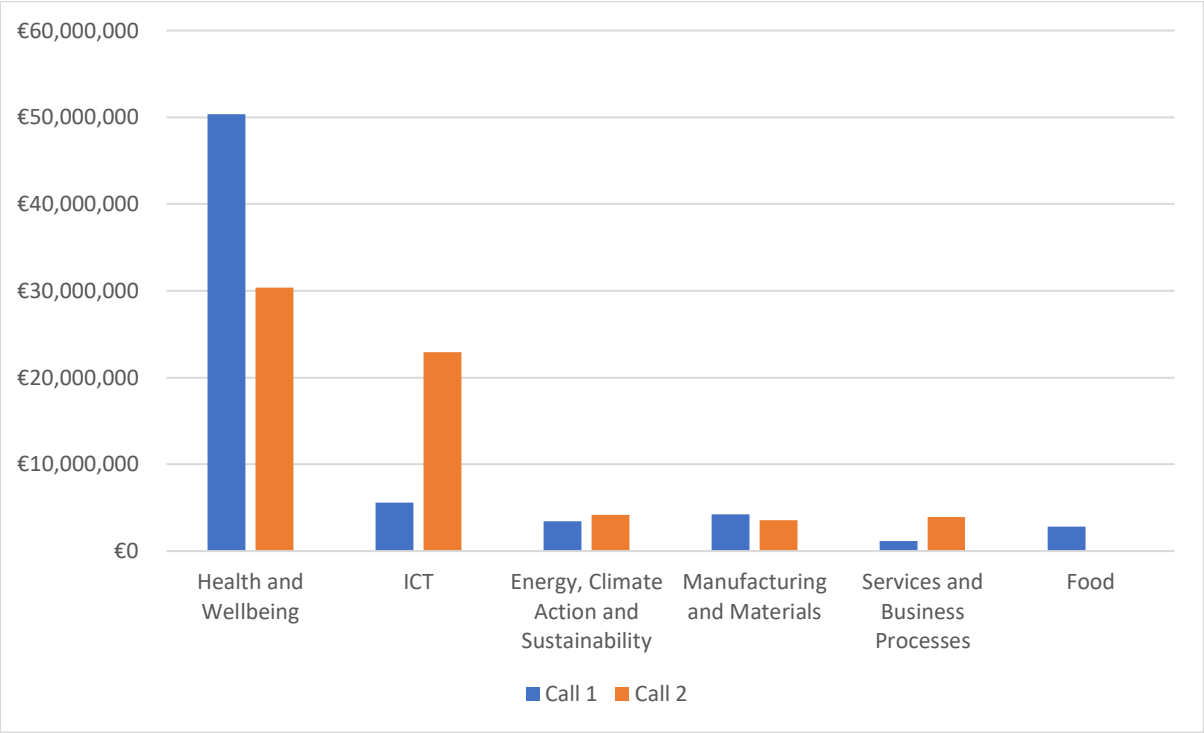


Source: own elaboration from Enterprise Ireland data

The above histogram compares the number of successful projects in both Calls. The Health and Wellbeing area heavily outweighs other areas in terms of projects funded. The second most funded area is ICT, which had 6 projects funded in Call 2 – the same number as Health and Wellbeing. Food as an RPA did not receive any funds in the second Call, while the remaining RPAs have a maximum of two projects. Only two projects per Call received funds under Energy, Climate Change and Sustainability.

The number of applications and of successful projects is a driver of the funding going to each RPA.

Figure 8: Fund allocation per RPA, both Calls



Source: own elaboration from Enterprise Ireland data

The above histogram reflects the previous one in terms of predominance of one RPA over the others with reference to the amount of funding awarded. Health and Wellbeing saw the highest share of funds awarded, in particular in Call 1. ICT is the second most funded RPA, in particular under Call 2, while other RPAs have had lower levels of successful applications in comparison. While there is no obligation for the DTIF to support all of the RPAs, it is still appropriate to note that the areas such as Energy, Climate Action and Sustainability have had a lower success rate under the DTIF. Whether it is important that all the RPAs receive support is a matter that goes beyond this evaluation exercise. The table below provides the funds allocated to each RPA and the average amount per project within the RPA.

Table 10: Total and average funding per RPA

RPA	Call 1		Call 2	
	Overall amount	**Average**	**Overall amount**	**Average**
Health and Wellbeing	€50,377,082	€3,358,472	€30,335,266	€5,055,878
ICT	€5,606,154	€1,121,231	€22,912,319	€3,818,720
Energy, Climate Action and Sustainability	€3,427,136	€1,713,568	€4,182,715	€2,091,358
Manufacturing and Materials	€4,236,667	€2,118,334	€3,564,677	N/A
Services and Business Processes	€1,135,760	N/A	€3,938,504	N/A
Food	€2,797,419	€1,398,710	€0	N/A
Total	**€68,022,055**		**€64,933,481**	

Source: own elaboration from Enterprise Ireland data

Under Call 1, Health and Wellbeing projects were allocated the highest amount of funds. The average is in line with the other areas because of the large number of projects, which are 15 according to the histogram above showing the number of successful projects per RPA. The second mostly funded RPAs are ICT and Manufacturing and Materials, although the average is calculated on a different number of projects, 5 for ICT and 2 for Manufacturing and Materials. Under Call 2 Health and Wellbeing still have the highest average funding, followed by ICT. However, the number of projects under Health and Wellbeing is lower, 6, while the total funding received is much higher than under Call 1. The same happens in ICT, where the number of projects, 6, and the overall amount both increased compared to Call 1.

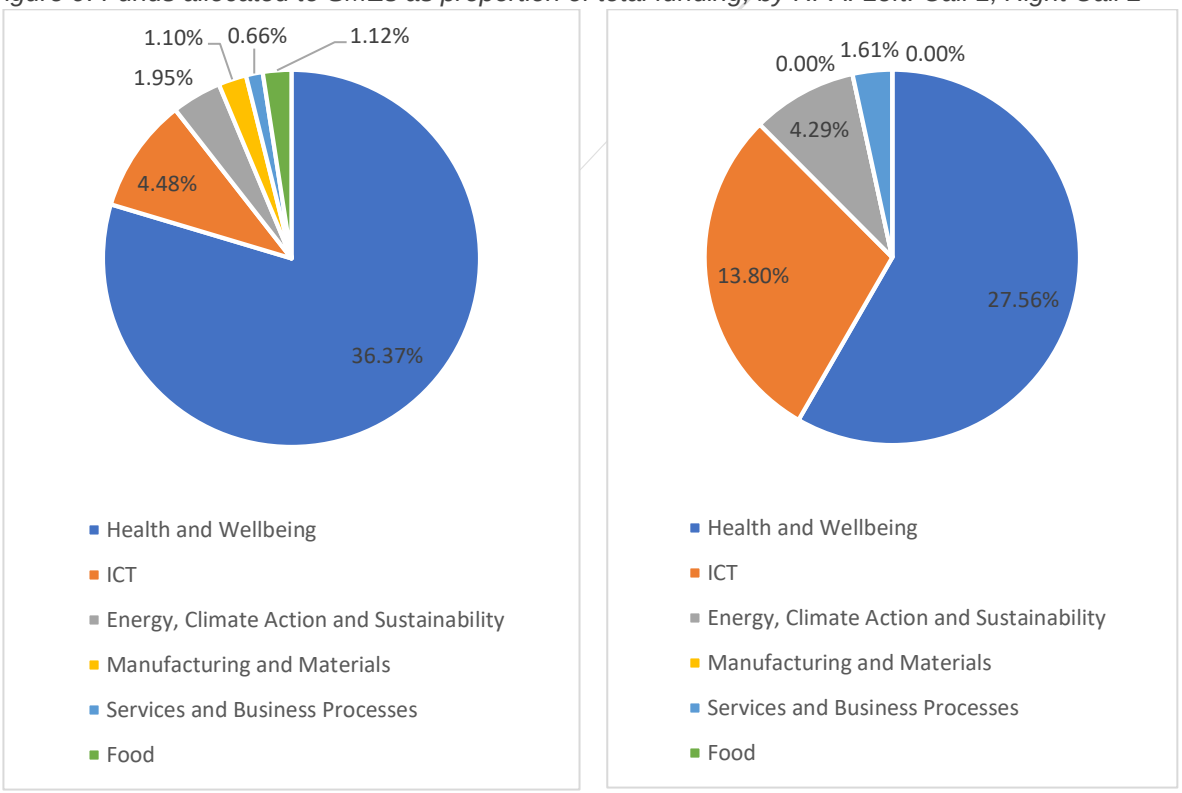
That Call 2 only had 1 full application stage resulted in a lower number of applications, but this meant that the applications which were submitted were more likely to meet the criteria for funding under the DTIF as they would be collaborations which had put effort into a longer application than was required under the Expression of Interest stage under the first call.

Possibly reflecting the success of Health and Wellbeing companies in the first call, there were a larger number of applications under this theme in Call 2 than other themes, with 6 of the 21 applications awarded funding.

Total funding awarded per organisation type and RPA

The pairs of pie charts below show and compare the fund allocation per RPA with reference to each organisation type.

Figure 9: Funds allocated to SMEs as proportion of total funding, by RPA: Left: Call 1; Right Call 2



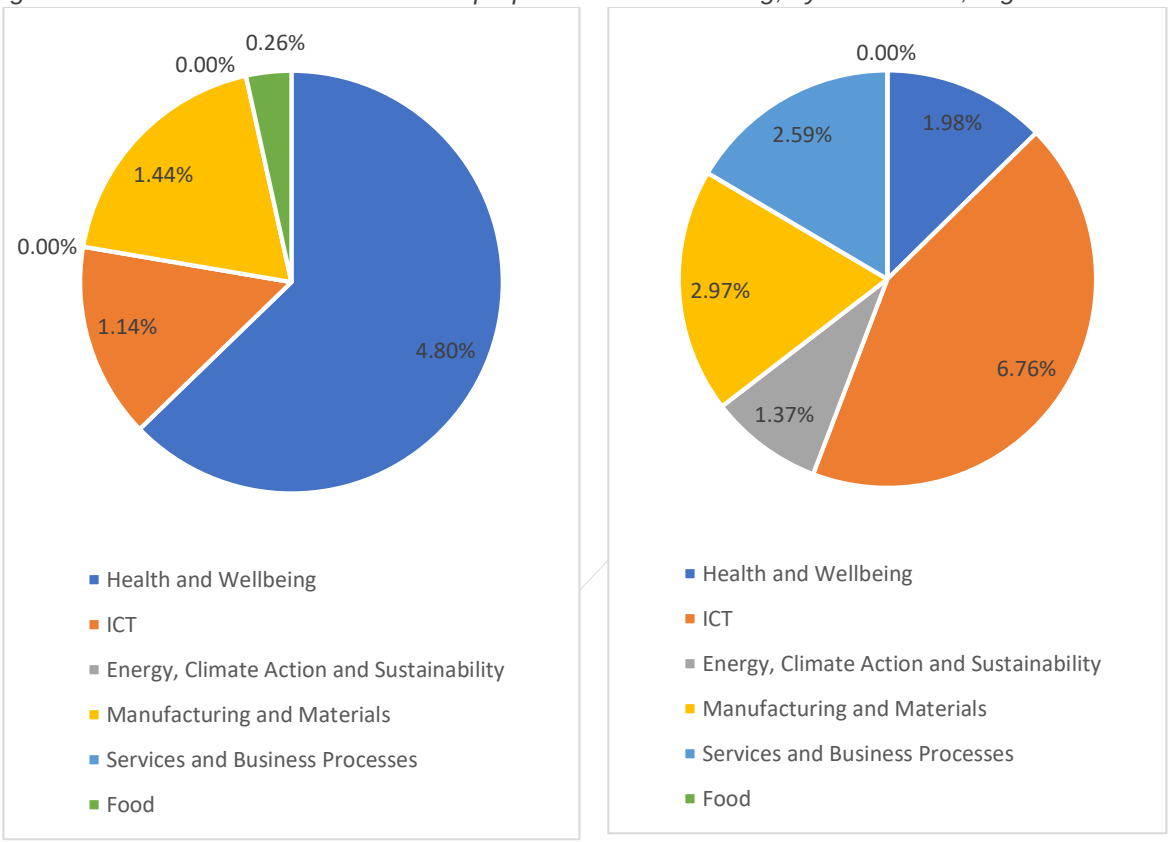
Source: own elaboration from Enterprise Ireland data

In relation to SMEs, Health and Wellbeing is the RPA in which SMEs received most of the funds, with similar percentages across both Calls, and followed by ICT, in which the percentage of funds allocated in Call 2 is around four times higher than in Call 1. Energy, Climate Action and Sustainability has a surprisingly high share of funding under Call 2, given that it only had 2 successful applications. This is due the large share of funds awarded to these 2 successful projects.

Overall, the percentages of funding awarded to SMEs appear to be in line with the conclusion that can be drawn from the total DTIF funding awards; Health and Wellbeing and ICT have the largest share of funds, in total and on average.

When it comes to MNCs, Health and Wellbeing has the highest share under Call 1, but it is ICT that predominates. Funds allocated to MNCs in the ICT area under Call 1 are slightly above 1 percent as a proportion of total funding, and jump to nearly 7 percent under Call 2, while MNC Health and Wellbeing decreased from nearly 5 percent in Call 1 to around 2 percent in Call 2. Funding to MNCS active in Manufacturing and Materials more than doubled its financial allocation between the two Calls.

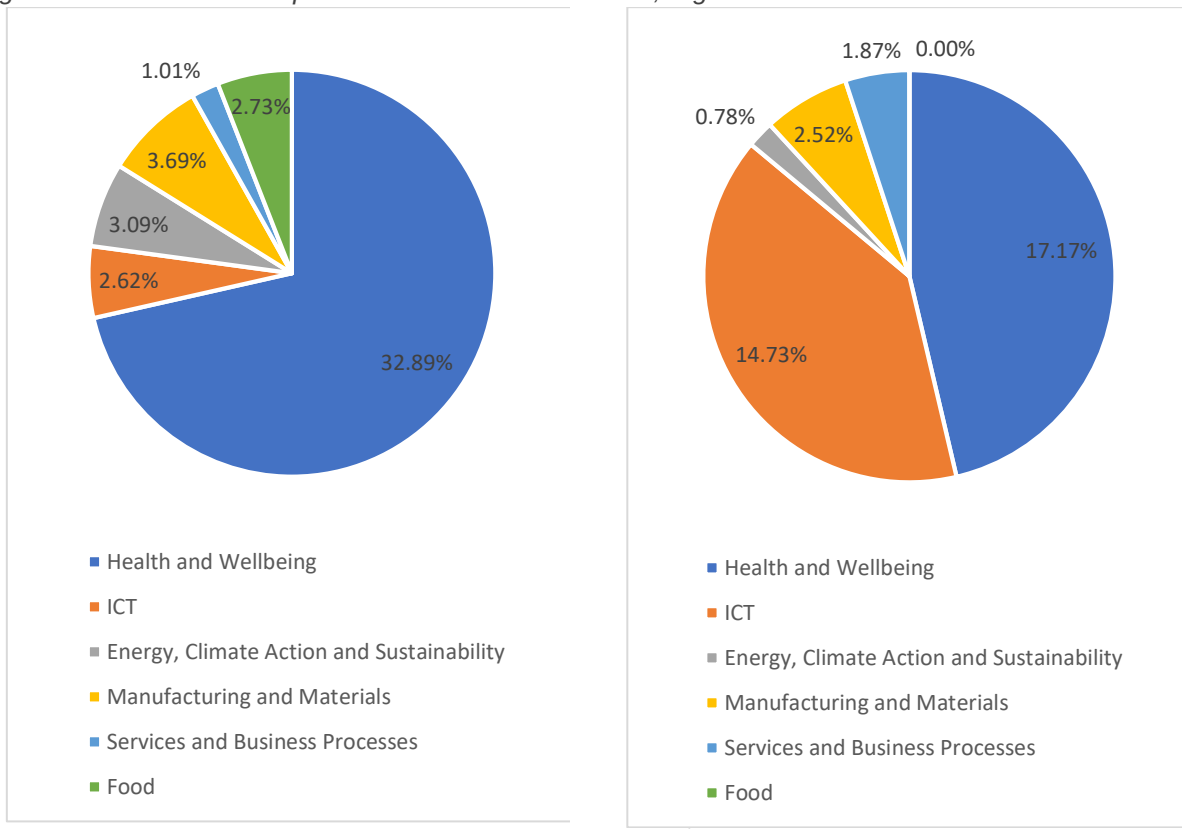
Figure 10: Fund allocation to MNCs as a proportion of total funding, by: Left: Call 1; Right Call 2



Source: own elaboration from Enterprise Ireland data

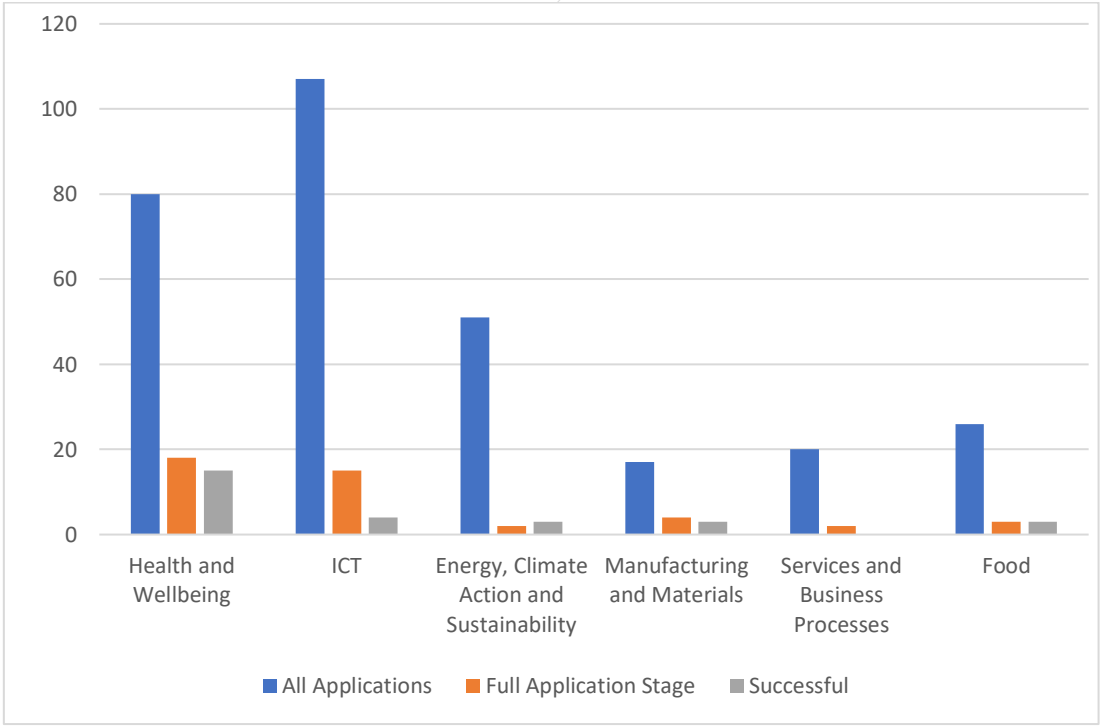
When examining funds awarded to RPOs, Health and Wellbeing is again the RPA that received the highest level of funding (37 percent under Call 1 and 20 percent under Call 2). Regarding the other RPAs, they share similar percentages of funds allocated, ranging from around 1 percent to around 4 percent in Call 1. Under Call 2, ICT jumps to nearly 13 percent of fund share, while the remaining RPAs did not receive funds or have very low percentages, around 2 percent of the total funds.

Figure 11: Fund allocation per RPA and RPO: Left: Call 1; Right Call 2



Source: own elaboration from Enterprise Ireland data

Figure 12: All Applications, Full Application Stage, Successful Applications under Call 1, by RPA



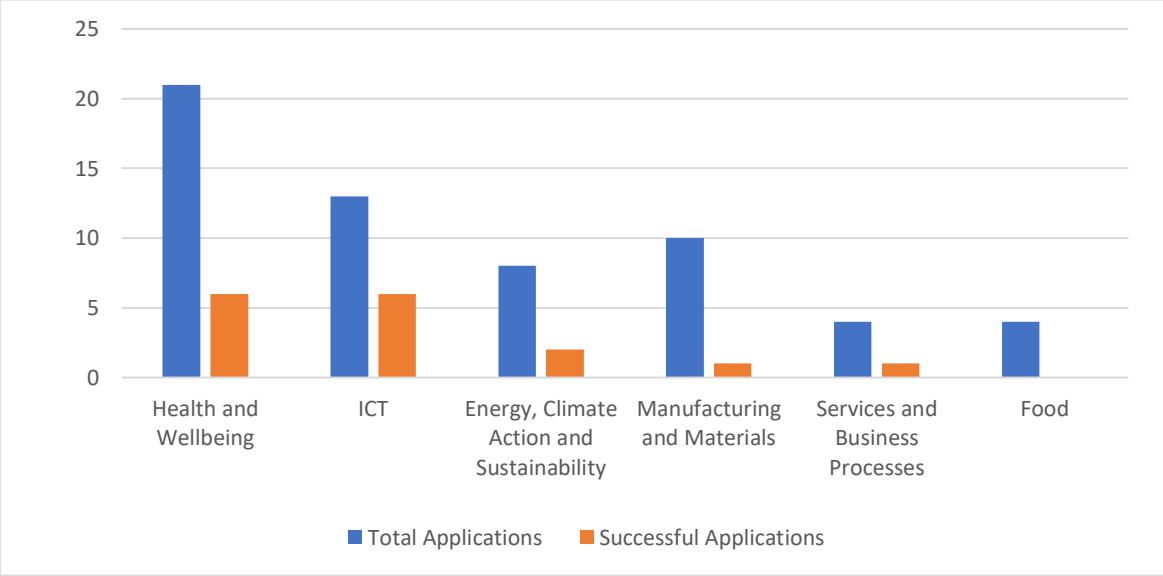
Source: own elaboration from Enterprise Ireland data

There are distinct differences in the success rate of projects by RPA in Call 1. Only 4% of the initial expressions of interest were successful in the area of ICT. While there was a lower level of

expressed interest in the area of Health and Wellbeing, these applicants demonstrated a higher success rate of 19% which led to this area leading in terms of DTIF funding applications. The area of Energy, Climate Action and Sustainability also shows a very low level of success from initial expression of interest moving through to successful application with only 2 of the initial 51 Expressions of Interest deemed appropriate for funding. Services and Business Processes was the only area with no projects funded under the first stage, while the area of food had two projects funded. It should be noted here that any consortia across the country could submit an Expression of Interest, and the level of preparation may have varied widely depending on the preparedness of firms in each sector for funding for high-end research projects such as those funded through DTIF.

The sifting of projects through the Expression of Interest stage in Call 1 meant that a higher proportion of those projects which made it through this stage were ultimately successful in securing funding. However, the large drop off between the Expression of Interest stage and the full application stage led to a change in approach for the second call which only had a full application stage prior to applicants being selected for interview. This is charted below.

Figure 13: Total and Successful Applications under Call 2, by Research Priority Area



Source: own elaboration from Enterprise Ireland data

ANALYSIS OF UNSUCCESSFUL INTERVIEWED APPLICANTS

Whether a project is funded or not ultimately is decided by its meeting the assessment criteria. An analysis of those applications which reached the interview stage but were unsuccessful shows the reasons provided for their lack of success. This is detailed below for Call 1 for the 44 projects which were interviewed under Call 1. A more detailed analysis of Call 2 by Research Priority Area follows.

Table 11: Unsuccessful Applications, by Criteria not met

Criterion	Number of applications by unmet criterion
Strength of the Disruptive Technology Dimension	12
Excellence of the Overall Proposal	15
Economic and Market Impact	11
Quality and Efficiency of the Collaboration	13
Total Unsuccessful (Interviewed) Applications	17

Source: own elaboration from Enterprise Ireland data

Out of the 44 projects that reached the interview stage under Call 1, 17 were unsuccessful. Projects were marked on the basis of how well they met the Selection Criteria. They were then ranked with only those meeting the minimum threshold of 60 marks in all four Selection Criteria making it onto the ranked list. The table above shows that most unsuccessful (interviewed) applications did not meet the minimum threshold on multiple criteria, and that the issues for these projects were not concentrated in any one area. 11 projects failed on more than 3 criteria. This suggests quite a gap in the quality of application (as viewed through the lens of the selection criteria) between the projects which were funded and those that weren't.

Table 12: Criteria Provided for Unsuccessful Applications under Call 2, by RPA

RPA/Criteria	Strength of Disruptive Technology	Economic Impact	Overall Excellence	Collaboration	Ineligible	**Total Unsuccessful Applications**	**Total Applications**
Health and Wellbeing	7	4	7	3	4	**15**	**21**
Energy, Climate Action and Sustainability	3	3	3	4	1	**6**	**8**
Manufacturing and Materials	5	7	5	5	2	**9**	**10**
ICT	3	4	4	3	2	**6**	**13**
Innovation in Services and Business Processes	2	1	2	3	0	**3**	**4**
Food	2	1	1	1	2	**4**	**4**
Total	22	20	22	19	11	**44**	**60**

Source: own elaboration from Enterprise Ireland data

Looking broadly the 4 main reasons provided for projects being unsuccessful under Call 2 shows a fairly even distribution.

The RPA of Manufacturing and Materials had only one project approved for funding from 10 applications. Of the 9 unsuccessful applications, 5 failed due to the strength of the disruptive technology. A lack of strength in the disruptive technology dimension was a reason provided in approximately half the unsuccessful applications across all Research Priority Areas and approximately one in three of all applications, based on total number of applications it was a more prevalent issue for firms under the Manufacturing and Materials area. Proposals in this RPA also struggled to convince evaluators of their economic impact with 7 of 10 total applications failing on this criterion. Beyond this 9 of the 10 projects were unsuccessful across multiple criteria, suggesting a sizable gap between applications and the minimum criteria for funding. Whether the proposals emerging in this area are naturally unsuited to Disruptive Technology, or whether incoming proposals in this area need further engagement in preparation for making an application may be worth consideration.

In contrast, the economic impact of Health and Wellbeing proposals was in general reviewed positively by evaluators, with only 4 out of the 21 total applications in that area failing on this criterion, compared to 20 across all RPAs out of the 60 full applications. The lack of strength of the project's disruptive technology was provided as a reason for failure in a third of the total applications (half of the unsuccessful applications) – which was in line with the average for the Call as a whole.

ICT was the RPA with the highest success rate under Call 2, with 50% of all applications being funded. The unsuccessful applications failed on a wide number of areas rather than based on one specific area.

The area of Energy and Climate Action and Sustainability had a lower level of initial applications under Call 2 than in Call 1, with 8 full applications made. Of these, two were successful. Reasons for failure were broadly spread across all areas, with a lack of strength of the disruptive technology, a lack of economic impact and a lack of overall excellence given as a reason on 3 instances each. Half of the applications under the area of Energy and Climate Action failed for reasons of collaboration – generally where there was an insufficient sharing of workload between partners. The success rate in this area was broadly in line with the average success rate of the fund with 25% of applications being funded, compared to 28% of all applications under Call 2. A way of increasing the number of projects funded under this area would seem to be related to encouraging a greater number of suitable applications as generally a low number of applications was associated with a low number of total projects funded.

A low number of applications in the areas of Innovation in Services and Business Processes and Food appears to be a trend across both calls, which in turn is impacting on how many projects are funded under these areas. Lower numbers of applications could itself be linked to the lower success rate under Call 1 – if groups of firms had low scores on applications under the first call, they may not make a subsequent application.

The success rate of proposals is an important indicator for the fund. It is worth noting that overall the success rate of the fund is comparable to other research funds, indicating a competitive application process, and one which is not oversubscribed. While a programme such as the DTIF may expect a low success rate due to the specific nature of what it is trying to fund, it is important that certain sectors do not become disinterested in the fund – which could impact on the level of applications. The DTIF does not have a remit pertaining to any one research area, however a continuous low success rate in certain Research Priority Areas could lead to a lower level of interest and a lower level of applications from the industry sector which falls within that RPA.

One reason for the small number of applications from the less successful RPAs could be that it is to some degree reflective of the natural strengths of the Irish research and 'industrial research' base in terms of the number of firms and researchers able to collaborate on projects appropriate for the DTIF.

It may also be the case that even aside from the strengths of the Irish industrial research base that certain areas lend themselves better to the application of 'disruptive innovation'. Effort applied to increase the level of applications from those RPAs with a low number of applications would mean that there is a greater chance that there will be a more even distribution of successful projects across RPAs. This will only apply of course if proposals of good quality come forward which meet the selection criteria. As witnessed under the first call, a high level of interest may not translate into projects funded. One way of increasing the number of applications could be through trying to increase the clarity in what meets the fund's definition of disruptive innovation. Another method of increasing interest in the fund could be through a more challenge-based approach for certain calls, which could result in more focused applications on specific themes.

Programme Additionality and Alignment with other programmes

The DTIF explicitly seeks to be different to other programmes in order to ensure additionality. A recommendation of the Indecon Review of RD&I Supports in 2017 was that Irish RD&I supports to enterprise be streamlined and that pathways between programmes should be clearer for firms. It is therefore important that the DTIF is additional to other programmes and that it is making a unique contribution in moving Ireland forward as a Global Innovation Leader.

One of the principal aims of the DTIF is that it intends to fund projects which are truly disruptive. It is aimed at proposals which are on Technology Readiness Level 3-7 which may be navigating their way to commercialisation. The DTIF itself aims to be sufficiently different from other programmes to ensure additionality of the funds allocated. The differences between DTIF and other enterprise R&D supports are now explored.

In order to compare DTIF to ensure it is additional to the grant supports already available to enterprises and researchers aimed at innovation, the paper has set out a wide range of innovation focused RD&I, infrastructure and training supports available to firms and researchers below. It then examines how DTIF differentiates itself from these other supports along the lines of its focus on disruptive technology, collaboration, commercialisation, and the scale of funding associated with the programme. The comparisons below are wide ones, a programme being included does not imply that that programme shares a large number of characteristics with the DTIF.

Table 13: Innovation focused R&D Grants

Fund	Objectives	TRL
Campus Incubation Facilities	• Provides entrepreneurship with a supportive environment that assists them in bringing their idea to market, aimed at helping to reduce the risk aversion to failure. • Provide occupants with access to resource including business development, financial and marketing advice in the form of mentoring, as well as proximity to research and development teams and facilities that otherwise would not be publicly available. • Aimed at: Researchers	N/A
Future Innovation Prize	• To support development of novel, potentially disruptive, technologies to address significant national and global challenges. • To support the formation of high-performance interdisciplinary teams based on integration of diverse STEM disciplines and complementary skillsets. • Aimed at: Researchers	1-3
Strategic Research Clusters	• Create clusters of internationally-competitive researchers from academia and industry, particularly Irish-based industry • Support internationally leading investigations across disciplines that are essential to developing and strengthening Ireland's industrial and commercial base • Create awareness among academic-based researchers of industrial road maps and research goals • Aimed at: Researchers	1-3
Industry Fellowship Programme	• Maximise the economic and societal impact of Irish state-funded research and resources, by enhancing industry-academia collaborations through the funding of collaborative industry-academia research projects. • Foster impactful innovation by supporting industry-informed research and the exchange of knowledge and expertise between academia and industry. • Enhance the breadth of training of researchers, and their employability. • Aimed at: Researchers	1-3
Innovation Partnership	• Increase collaborative research projects between companies and knowledge providers • Increase the level of R&D in the private sector • Increase the level of commercialisation activity in the Higher Education Institute. • Use academic knowledge and expertise to gain competitive advantage • Aimed at: Firms and Researchers	4-9
Innovation Vouchers	• To drive an on-going innovation cultural shift within small enterprise by promoting and encouraging a transfer of knowledge between Ireland's public knowledge providers and the small business community and creating greater synergies between the two. • Aimed at: Firms and Researchers	4-9
Exploring Innovation Grant	• The aim of the Exploring Innovation grant is to support better planning of R&D, Innovation or International Collaboration projects through encouraging companies to do some strategic thinking around disruptive technologies and taking time to look outside of their own organisations for inspiration and for guidance. • Aimed at: Firms and Researchers	Early
Commercialisation Fund	• Transform research output from academic institutions into innovative new products and spin-outs • Effect a change in the approach to research by academics, to create potentially commercially valuable output • Realise potential of Higher Education sector in developing new products and processes that have potential for commercialisation Through licensing to existing industry or through the creation of spin out companies • Aimed at: Researchers	4+

Table 14: Broader R&D Supports

Programme	Objectives
Knowledge Transfer Ireland (KTI)	• KTI aims to support business and the research base to maximise innovation from State funded research by getting technology, ideas and expertise into the hands of business, swiftly and easily for the benefit of the public and the economy. Knowledge Transfer Ireland takes a national perspective on the knowledge transfer (KT) system in Ireland. • Aimed at: Firms
SFI Research Centres	• To achieve, maintain and enhance research excellence and leadership. • To deliver significant economic and societal impact – research excellence with impact. • To increase the level of industrial and commercial investment in R&D activities with existing Ireland-based companies, and furthermore to attract large Foreign Direct Investments in corporate R&D laboratories. • To spin out new, high-technology start-up companies that have the potential to raise external angel or venture funding. • Aimed at: Firms
Technology Centres	• The Technology Centre programme is a joint initiative between Enterprise Ireland and IDA Ireland. It allows Irish companies and multinationals to work together on market focused strategic R&D projects in collaboration with research institutions. The 10 Technology Centres in the programme are resourced by highly-qualified researchers who provide a unique ecosystem for collaboration in areas identified, by industry, as being strategically important. • Aimed at: Firms
Technology Gateways	• Harness the applied research expertise in the Institute of Technology (IoT) sector for the benefit of Irish industry; • Provide a Source/ Evaluation of technological and applied research expertise which is relevant to local nationally- based industry on an open-access basis. • Increase the level of collaboration between industry and the IoT sector; Contribute to greater innovation activities in Irish industry. • Aimed at: Firms
Technology Transfer Offices	• The programme aims to sustain and develop appropriate skills within the TTOs, for the management and commercialisation of intellectual property (IP), and to facilitate meaningful knowledge transfer interactions between Irish RPOs and Irish industry. • Aimed at: Researchers and Firms

DISRUPTIVE TECHNOLOGY

Two other programmes look to fund research aimed at developing Disruptive Technology – these include the Future Innovator Prize and the Exploring Innovation Grant listed above. It is important to note that outside these two grant programmes, none of the other programmes recorded specifically support the development of disruptive technology.

While both funds aim, in some way, to aid the development of disruptive technology there are a number of key differences when compared to the DTIF. The Future Innovator Prize is targeted primarily at academic researchers in public research performing organisations as opposed to the industry which DTIF focuses on. The scope of the DTIF is also wider: to date the Future Innovator Prize has focused on advances in Artificial Intelligence, while DTIF is active across all of the Research Priority Areas. The Future Innovator Prize is aimed at an earlier Technology Readiness level than DTIF. The Exploring Innovation Grant which is also targeted at an earlier Technology Readiness level, is not exclusively aimed at disruptive innovation and is only aimed at helping organisations start looking towards innovative ideas rather than investing funds in their development.

The scale of DTIF funding is another differentiator from the other grant programmes promoting disruptive technology. For example, the Future Innovator prize only covers one prize of €2m in contrast, while the Exploring Innovation Grant only provides €35,000 per firm.

While these programmes do aim to increase the level of disruptive technology they are doing so in distinctly different areas and with a different focus to DTIF. Differences include the scale of funding and the targeting of academic researchers rather than firms. The commercial focus of DTIF is a key area where it differentiates itself from these programmes.

COMMERCIALISATION

DTIF is not the only grant funding which is focused on commercialising innovative activity. EI's Commercialisation Fund aims to convert the outputs of state funded research into innovative new or improved products, services and to potentially establish companies. Crucially the fund is not aimed at specifically at disruptive innovations, in contrast to the DTIF. The scale of funding available through the Commercialisation Fund is also lower, as it provides grant funding to projects with costs between €85,00 and €350,000. This means that the DTIF is likely to be funding larger, more ambitious projects – projects which have potential to significantly disrupt markets.

The target audience of the two funds are also distinctly different. The Commercialisation Fund is specifically targeted at researchers and aims to commercialise their outputs, or indeed potentially establish new companies based on this research. while the DTIF focuses on developing disruptive innovations through already established enterprises. In this sense the DTIF may act as a follow-on fund for companies established through the Commercialisation Fund which may be earlier in the maturity of their processes.

The focus on collaboration within the DTIF is another differentiator when compared to the Commercialisation Fund. The DTIF promotes collaboration between SMEs, RPOs and MNCs. Even if the DTIF was not entirely focused on disruptive innovation this difference in the collaborative feature alone would be a distinguishing feature of the fund compared to the Commercialisation Fund.

A 2016 review by the Department of Jobs, Enterprise and Innovation estimated annual public investment in commercialisation of HEI output at approx. €35 million and funding focused on

collaboration at €101 million in the years up to 2015[23]. This puts in context the scale of the €500m total funding allocated to DTIF as a significant investment facilitating innovation in these areas, with single application awards being made in excess of €1.5 million in Call 2 of the DTIF.

COLLABORATION

There are a number of programmes aimed at increasing the level of collaboration between industry and academia. Two of the larger programmes are SFI Research Centres and the Technology Centre programme – a joint initiative by EI and IDA. However, these programmes are differentiated from DTIF in terms of how they operate, the type of collaboration and the types of projects which they focus on.

Research Centres funded by SFI have a strong collaborative element, as they aim to encourage collaboration across HEIs in order to facilitate research into areas attractive to industry. The Research Centres are mandated to collaborate with industry, with both sides expected to make a material contribution to projects. In terms of how the collaboration works there appears to be a greater focus on developing the industry-academic relationship under the SFI Research Centres. While this is still an important component of DTIF, the DTIF has an added focus on collaboration between firms. This can be seen through the fact that some collaborations under DTIF do not involve an RPO – with the collaboration between industrial partners meeting the programme criteria. This focus on industrial collaboration within the DTIF, particularly by SMEs reflects another difference between the two programmes. This feeds through to the different Technology Readiness Levels which are targeted by the respective programmes. Research Centres are targeted at a much earlier level of Technology Readiness of 1-3, while DTIF funds proposals at levels 3-7. Another key difference between SFI Research Centres and DTIF is the level of participation by small-medium sized indigenous firms. The DTIF requires that an SME partner be involved with each consortium and that each consortium be made up of a minimum of 3 partners (2 partners under Call 1). DTIF also requires that there be an additional enterprise partner specifically involved in addition to the SME. This term setting on the nature of the collaboration, and that the collaboration focuses on a specific project clearly distinguishes the DTIF from the Research Centres, with greater indigenous SME participation evident under DTIF. A 2017 Indecon review of RD&I supports to businesses showed that 60% of firms accessing Research Centres were foreign-owned firms.[24] This contrasts with DTIF where only 15% of the total funds allocated have gone to IDA clients, while 48% of funds were awarded to SMEs and 36% to RPOs. The combination of the DTIFs SME focused collaborations at a higher Technology Readiness Level clearly distinguishes it from the SFI Research Centres as a support.

Another programme which is aimed at supporting collaboration on RD&I by firms is the EI-IDA Technology Centre programme. The technology centres are categorised as 'industry-led' research centres. They focus across a range of technology maturities from levels 4-9, and so go beyond DTIF in how close to market the technology may be. Like DTIF, there is a mix of small and large enterprises accessing the Technology Centres – operated through a membership system. The membership system drives collaboration in a broader sense than what might be seen in DTIF, with members feeding into the broad research programme of the Centre. The collaborations within Technology Centres often pursue technology adoption, rather than the more blue-sky approach of proposals for DTIF. When a firm wants to undertake company-specific research this could be funded under an Innovation Partnership. The funding provided through Innovation Partnerships

[23] https://dbei.gov.ie/en/Publications/Economic-and-Enterprise-Impacts-from-Public-Investment-RD-Ireland.html
[24] https://dbei.gov.ie/en/Publications/Publication-files/Indecon-Review-of-RDI-Supports-%E2%80%93-Executive-Summary.pdf

does not typically exceed €200,000, and so differs quite fundamentally from DTIF in what it can achieve in terms of progressing a disruptive innovation.

SME PARTICIPATION

As referenced in the section above – participation by SMEs in consortia is a key requirement for proposals to be approved for funding, with SMEs allocated 48% of all DTIF funds to date. This focus on SME participation aligns with the idea of disruptive technology in the literature where disruptive innovations often emerge from smaller firms. Indeed, research on high-tech industries has shown that firm size is negatively correlated with the success of a disruptive innovation. [25] Indeed, a willingness for a large incumbent firm to innovate disruptively means that it must have a high willingness to cannibalise its current market, and usually for a lower margin product.[26]

The requirement for SME participation also aligns with recommendations from a 2017 OECD report on SMEs in Ireland which highlighted a perceived poor performance of Irish SMEs on productivity measures and recommended increased inter-firm networking as a route to productivity spillovers, which the collaborative element of DTIF provides. While the SMEs which benefiting from DTIF are often pre-revenue firms, which are already R&D, active may not have been the target of this recommendation – larger firms collaborating with smaller firms may encourage further collaborations among a wider group of firms. The OECD report also recommended strengthening the offer of grants focused on R&D and innovation towards SMEs.[27] The DTIF progresses both recommendations through its requirement for collaborations between SMEs and others.

The strength of SME participation can be seen in the nature of their participation, as they represent the majority of lead applicants under DTIF, with 17 of 27 lead applicants in Call 1 and 10 out of 16 applicants in Call 2. That the innovation is being primarily driven by SMEs demonstrates the difference in the collaborative nature of the DTIF when compared to SME participation in Research Centres, Technology Gateways, or Technology Centres.

The collaborative element is a key consideration when looking at the involvement of SMEs. While there are a range of supports towards increasing the R&D performance of SMEs, the DTIF aims to do this in a collaborative project-based manner. Other R&D supports with significant SME participation such as InterTrade Ireland's Fusion Programme, Innovation Partnerships, and the R&D fund are typically focused on more incremental innovations (based on funding levels compared to DTIF). This does not necessarily preclude the involvement of potentially larger innovations in these programmes – but their objectives are not focused specifically on larger and potentially disruptive innovations as are found in the DTIF. The nature of disruptive innovation means that SMEs applying for the fund are likely to be quite developed in their R&D capabilities and may have availed of these other supports to drive previous innovation but require greater funding for the type of innovation intended under DTIF. In this way DTIF enables SMEs to participate in much larger projects than they may have the resources for otherwise.

[25] Christensen and Raynor 2003; DeTienne and Koberg 2002; Tushman and O'Reilly 2002 as in Yu and Hang (2010) A Reflective Review of Disruptive Innovation Theory
[26] Govindarajan, V. and Kopalle, P.K. (2004). How legacy firm can introduce radical and disruptive innovations: theoretical and empirical analyses. AOM 2004 Conference best paper, BPS: A1–A6.
[27] https://dbei.gov.ie/en/Publications/Publication-files/SME-and-Entrepreneurship-Policy-in-Ireland.pdf

SCALE OF FUNDING

Indeed, the scale of funding awarded to each project under DTIF is a further differentiator when compared to other programmes. Supports for research for larger innovations funded through EI may be handled through the R&D fund. The R&D fund is focused on developments which involve:

- the resolution of some technical challenges,
- be non-routine and;
- represent a 'step-up' for the company in terms of the level of RD&I capability.

The three requirements above indicate that the R&D Fund is therefore more typically focused on incremental technological development or 'new to firm' innovations compared to projects funded under DTIF. This is also reflected in the grant funding under the R&D fund which is capped at €650,000. DTIF (post Call 1) in contrast is intended to only fund projects with a minimum of €1.5 million in grant funding. The size of such projects is fundamentally different in scale, and through this, their intended outputs.

While there are a number of programmes which share features with the DTIF, no single grant support available in Ireland covers the same number of features, in the same way. DTIF aims to bring technologies forward along the Technology Readiness Levels at a later stage than most grant funding, it aims to do so through project-focused collaboration between the industrial and research sector. A further distinction is the level of funding available through DTIF which is also larger than that available from other programmes, meaning projects are likely to be seeking larger innovations more likely to disrupt markets. That DTIF is doing the above with a focus on disruptive innovation means that it is aiming to fund distinct innovations at a different (later) stage than alternative grants, making it a unique grant in the Irish enterprise support landscape. This highlights the importance of the fund maintaining its focus on truly disruptive innovations, in order to be truly additional to other programmes.

International comparison

There can be important lessons gained from looking at other programmes seeking to fund disruptive innovation internationally. On a general note, there is limited information on programmes similar to DTIF undertaken outside Ireland. In some cases, a language barrier prevented access to policy sources.
Another important caveat is that all R&D is the product of a specific socio-cultural setting. While some countries may appear similar and generate similar R&D systems, it may be the case that what is valid for one country may not be for another. This in turn poses a challenge to the comparability of two or more innovation systems, and the R&D policies of two or more countries, and means it is not always possible to transpose the practice adopted in one country to another.
Information on innovation programmes was available from Denmark, UK, Japan and Germany.

We compare Ireland's approach to funding disruptive technology to other countries along a number of lines including; policy documents, sectoral area, how the disruptive dimension is defined by those countries, whether it include a challenge-based approach, how it treats collaboration, is it focused on commercialisation of research, how the programme views the risk of investment, and the eligibility requirements for funding.

DENMARK

The strategic policy of reference, although it is not the only one, is Research 2025, a catalogue of 19 proposed research themes. These themes refer to the societal challenges that Denmark will face in the future. A number of research needs are derived from these challenges.
The societal challenges are described both in terms of both problems and opportunities arising in the future, and research and creation of new knowledge are seen of great importance on addressing and preventing the problems and to realise the potential opportunities. The research needs are not confined to a single discipline but require a multidisciplinary work and they need to be translated into practical solutions that will produce tangible effects on the society.
The above information introduces the other criteria used for this international comparison: the concept of challenge and of disruptive dimension. Regarding the challenge element, this mostly refers to the R&D activity as a way to address the societal challenges, it is not a feature of the R&D activity. This means that as long as the R&D activity helps addressing these challenges, it can be of any type, such as incremental, radical or indeed disruptive innovation. Research 2025 clarify that the research could lead to the production of new and original ideas to address the societal challenges, but this in itself does not equal saying that the research must be disruptive or alter significantly the market or the business operation, or the consumer behaviour. On the contrary, in the way it is put in the Danish experience, it is the societal challenge that orients the R&D activities and the research operates within a specific policy framework.
For this reason, the economic and market impacts and the commercialisation are not the only two criteria used to assess the innovation. The Danish strategy does not clearly say that economic and market impacts and commercialisations are not included, rather talks about impacts on the society. In the application, candidates are required to provide information on the strategic relevance of their project, in terms of societal, industrial, technological position strengthening, and value creation. Examples of this are the cost reduction for the society, the reduction in the environmental footprint, the optimisation of business processes.
In the same applications, candidates must also provide the measure of the technological and societal readiness levels. The former is a known concept and refers to the innovation itself, while the latter is a novelty of the Danish Innovation Fund, as it refers to of assessing the level of societal adaptation of the innovation. If the level of societal readiness is low, then the applicants have to

work more towards a more realistic transition. Innovation here refers to the technical side, but more in general the concept applies to anything that produce a change to which the society has to adapt. The way the calls are managed is thematic. The information available shows that the funds are granted through competitive thematic Calls, where candidates apply within a specific area. The eligible applicants can be academic institutions, enterprises and public sector organisations, and the fund accepts applications from firms outside of Denmark. The size of the applicants is not specified in the documents examined, and it could be concluded that any type of firm or academic institution could access the funds if they are able to meet the societal challenges.

UNITED KINGDOM

The Industrial Strategy Challenge Fund is part of the wider industrial strategy of the UK. As seen for Denmark, the challenges here are mainly societal, such as ageing, digitalisation, health, AI and climate change and environment. However, with reference to industry, the challenges refer to the increase in productivity and earning power of British firms.

The word “disruptive” is not mentioned, but the concept appears several times to qualify any innovations that has the impact of altering significantly the market/industry/business operation and has a transformative power. A training programme is also included to address any skill issues emerging from the disruption (upskilling, skill creation, etc.) and targeted to those workers that will be affected by the innovation and need to requalify for the renewed job market. One of the pillars of the White Paper for Industrial Strategy is the production of ideas, and among the example listed there are some innovations that had the potential to alter segments of the market, such as the bagless vacuum cleaner, or the World Wide Web. The R&D activity can be radical or incremental, as long as it addresses the societal challenges (or grand challenges) and increased the firm productivity. However, throughout the White Paper, the R&D expected outcomes are described as activities that will revolutionise the productivity in all sectors and implement a dramatic change.

Collaboration is not always a requirement. Some of the Calls for funding, which are thematic, allow only one firm to apply, without having to form a consortium with other firms. Within the broader ISCF a sub-programme operates to support academic institutions wanting to pursue a research of this type. However, the Industrial Strategy White Paper recognises the importance of collaboration among firms and academic institutions, and the central role of start-ups and small enterprises in driving segments of innovation that may have an important economic and societal impact.

Regarding the lead applicant, it is only firms, of any size, that can apply. Academic institutions, or any research organisation, cannot lead the project.

The economic and market impacts are not defined, but it can be inferred from the documents analysed that the diffusion of the innovation in society and improving the position of the United Kingdom as a leader in innovation are two key determinants of applications success. In the same way, the cost reduction and the increased efficiency of several organisations such as the NHS are among the expected outcome of projects going through the UK Industrial Strategy Challenge Fund. Commercialisation is mentioned as one of the objectives of the production of the ideas, as it is the channel that supports the adoption of the innovation. The examples provided are mainly taken from the consumer perspective. According to the examples provided, the alteration of the market was not as big as an entire business operation, but still significant for certain segments of the market. This is the example of the lithium battery, which disrupted the market of disposable batteries and at the same time lengthened the life of the products using them.

The level of risk associated to the research funded does not seem to be mentioned, despite all the reference to revolution and dramatic change.

GERMANY

The strategic policy of reference in Germany is the High-Tech Strategy 2025, which laid down thematic priorities and sectors that shows particular dynamism, have great potential for growth and employment, and show a high need for innovative solutions to pressing issues.

The Federal Agency for Disruptive Innovation is a recently established Agency which has been established to drive disruptive innovation in Germany. It has not yet funded any projects as its managerial setting is currently being defined. However, three pilot projects have been funded and are about to commence their activities. All of them will undertake medical research in the area of diagnostics and therapeutics.

Regarding R&D activity, there is no mention of the disruptive dimension of innovation, although it appears that this is underlying idea that permeates the whole R&D research.

The economic impact is not defined, as the focus of the R&D activity seems to be to address these important societal challenges. As the German Agency is not yet operating, it is not possible to give a profile of eligible applicants – whether they are SMEs, larger firms or research performing organisations. However, the High-Tech Strategy 2025 provides useful information on the type of organisations that are at the centre of the R&D and some other important features of the German model. SMEs are considered important drivers of innovation in Germany, through their specialisation, the strong customer loyalty, the cooperation with large companies and academic institutions, and their regional roots (e.g. their link with the territory). Although the disruptive dimension is not defined, the recognition of the role of SMEs seems to suggest that Germany is aware that the innovation that small enterprises undertake can have the potential to disrupt the market or at least to radically alter it. In order to do so, the access to knowledge for SMEs has to be strengthened and so has the support to internationalisation of SMEs innovation activities.

With market- and application-oriented funding offers, SMEs will be specifically supported in maintaining and strengthening their competitiveness and innovative strength.

Financial support is market oriented, and application oriented. These are other ways to say that a commercialisation aspect is taken into account.

Risk is not explicitly considered within the Agency documentation.

JAPAN

The strategic documents at the basis of the Japanese R&D policy are the Japan Revitalisation Strategy and the Comprehensive Strategy on Science, Technology and Innovation. As seen for the other case studies, Japan as well intends to fund R&D to address grand societal challenges.

Unlikely from the other case studies, who translates the research product into an innovation with an impact on the market is a project manager appointed for this purpose. While the support will go to the enterprises or academic institutions pursuing the research, it is the project manager that will work on the application of the innovation to commercialise product. The Impact Programme is the main source of funding, although it is not managed in the same way we have in Europe, with Calls for funding.

The market and economic impacts, and most importantly, the disruptive dimension, appear to be central in the Japanese experience. The risk of the disruptive innovation is not necessarily high, although it is recognised that without running into high risk, sometimes it is not possible to have a high impact. However, the same strategic document on the Impact programme clarifies that even low risk projects may have a significant impact.

EUROPEAN UNION

The EIC Accelerator is one of the main supports available to enterprises at a European Level to undertake R&D activities, although it is not the only one available and there are also some other interventions available to firms to carry out research specifically on disruptive innovation. Only

SMEs can apply for the EIC Accelerator supports as a lead applicant, and from 2019 applications from individual firms are accepted and no longer in a consortium. Large enterprises, academic institutions and individual scientists are not eligible to apply as lead applicants. However, they can be part of the projects as third party or subcontractors. The type of innovation supported appears to be radical, and other types of innovations are explicitly excluded in the criteria adopted to assess the proposals. However, the EIC Transition to Innovation initiative specifically supports disruptive innovation projects, which are those encompassing innovative concepts, products and services that create new markets and at the same time set up new regulatory frameworks, values and models. These ultimately disrupt and/or overtake existing markets and displace existing technologies and ways of doing business and deliver services.

The concept of disruption here is in line with the literature on disruptive technology, although the EIC Accelerator utilises a test that from the standpoint of the consumers assesses the disruptive dimension: can a large segment of the population access the existing product? If currently they can't for budget or access reasons, a disruption may occur if a cheaper or more accessible alternative is made available. From the standpoint of incumbents, who are the other important category included in the test, if all of them are affected by the new product, then it can be categorised as disruptive. If some of them are not, then the innovation is sustaining the improvement of their existing products. This may be one of the reasons why only SMEs, which are the drivers of disruptive innovation, are the sole eligible applicants to the EIC Accelerator support, and large companies are only allowed to cooperate as subcontractors or third parties.

The level of risk is one of the important concepts of the EIC Accelerator, but it must be assessed in conjunction with the nature of the project: incremental or sustaining innovations even if carrying high risk, will not be funded, while when high risk – and high reward- are associated with radical and disruptive innovation the projects will be supported. Disruptive technology is funded in areas such as artificial intelligence, life science, health, nanotechnology and low carbon. The EIC Accelerator has a support specific for sustainability and climate change, and it is called EIC Accelerator Green Deal. The type of research funded is on radical innovation and the level of risk associated with these projects is high. As the EIC Accelerator is a support for enterprises, the market and economic impacts are specifically assessed, and applicants are required to clarify how their proposed projects will have an impact on the market. However, another tool, the Innovation Launchpad specifically supports the market and competition analysis and the commercialisation process of the innovation. The aim is to turn the results from the funded projects into economic and societal innovations with a real impact on the society.

LESSONS FROM INTERNATIONAL PROGRAMMES

- All the above case studies have in common the objective to address important societal challenges. What differs is the way these are achieved. In the case of Denmark, as many different types of organisations can apply for the support, it is likely that these challenges will be addressed in different ways and by different actors. In the case of the DTIF, which is a fund primarily designated for enterprises, some of the areas appear that may not be achieved through industrial research. This is possible if we consider what shapes the Danish experience, where the focus appears to be more on addressing these challenges rather than creating market opportunities on its own. As the DTIF carries a lot of objectives, it is slightly reductive to expect that these are solely addressed by firms and market forces and solely through disruptive innovation. On the other hand, if the DTIF intends to retain only the market forces and the market impact, and the firms, it has to downsize its objectives and clarify which of these could be achieved solely by the private sector. Or include more actors and a broader spectrum of R&D (incremental, radical, etc.) and broaden its mandate.
- In all these case studies, the societal challenges appear to be a sort of umbrella within which the broader R&D activity and the disruptive dimension in particular operates. The UK in

particular recognises that the disruptive innovation may happen when pursuing R&D research, and many examples from the history of the UK are provided, although some of them appear to be radical or incremental innovations.

- The size of firms is not always central in the disruptive innovation funds examined (this included funds which have a broader focus on market impact – including disruptive innovation - as in the UK). Only Germany and the UK place significant importance on putting the SMEs at the centre of the innovation process. Germany also emphasises the links that SMEs have with the territory and their role, as start-ups, in introducing innovations that have the potential of a significant impact on the economy as in the case of disruptive technology, although this also applies to other types of R&D activity. The European Commission also recognises the central role of SMEs in driving high-impact innovations as in the case of disruptive technology. For example, in Calls under the EIC Accelerator where a consortium is required, only SMEs can act as lead applicants, while MNCs can only be partner. None of the case studies considered rule out larger companies in delivering important innovations. In particular, the DTIF appears to be closer to the German and the EU funds in recognising the central role of SMEs in undertaking disruptive innovation research and more broadly in R&D.
- The collaboration element does not always emerge in the same way as is in DTIF. In some case it was not possible to find any reference to consortia between SMEs, multinationals and academic institutions. Only Germany recognises the importance of the collaboration between SMEs and multinationals, while the other cases studies seem to have an established network of firms and academic institutions, that are already working cooperatively as a part of their R&D work. For instance, Denmark places importance on the collaboration between industry and academia but does not specifically outline the merit of possible cooperation between firms of different size. In the UK and under EU funding, forming a partnership or a consortium with other organisations is not always a requirement to access the funding, but collaborations are still encouraged depending on the Call requirements.
- The DTIF experience appears to be aligned with the above case studies regarding the collaboration between firms and academic institutions, and closer to Germany in attempting to foster the collaboration between SMEs and MNCs within the same industry.
- Challenge here is only the societal challenge, not the nature of the R&D. In fact, in some case, as long as the R&D addresses the societal challenges, it does not matter if it is incremental, radical or disruptive. The DTIF is expected to address these challenges with only disruptive innovation.
- Aside from Japan, risk is not defined anywhere. This is likely because in order to address the societal challenges, a high-risk project is not always necessary.
- With reference to the selection criteria, the EU experience appears to share aspects with DTIF. Projects are selected on the basis of the novelty and ambition of the technology breakthrough, the non-incrementality of the research proposed, the measures in place to disseminate and use the results, with an eye for the communication of the findings to the different target audience.

Programme Logic Model

The table below illustrates the Programme Logic Model, utilised to carry out this ad interim evaluation.

The Programme Logic Model (PLM) is intended to map out the logical steps in terms of the inputs, activities, outputs and final outcomes and impacts which emerge through the implementation of a programme. Inputs into the programme lead onto activities which are funded under the programme. Outputs emerge directly from these activities. The outcomes are the initial changes and benefits which occur as a result of the activities and outputs. The impacts follow on as longer-term effects of the programme. A PLM for the DTIF is outlined below. Set alongside the PLM are metrics which can aid measurement of programme performance in each area.

Table 15 Programme Logic Model and Metrics

PLM category		Metrics
Input	DBEI funding	Financial allocation
	Co-funding from firms	Amounts made available
	DBEI/EI time and staff, plus other agencies and department involved, as members of the Advisory Board	Number of FTEs managing and monitoring programmes
	Buildings	
Activities	Project Selection	Number of project applications; number of projects approved; number of successful/unsuccessful projects by RPA and by Region
	Management of relationships, client meetings	Number of meetings organised/frequency by DTIF administrators
	Conferences, webinars, networking, site visits to Ireland, ministerial visits, personal development initiatives	Number of events organised/frequency Social Media Tweets Press Release \ TV Ministerial events Presentations / stands at events No of case studies [e.g., in official reports]
	Governance of Programme and Monitoring of the project progress	Projects started; offers withdrawn; projects terminated; projects completed. project progress against pre-set milestones and indicators listed under Outputs as monitoring activities take place; assessment of issue affecting the progress and solution adopted to address them
	Project closure	Assessment of final tasks, reporting of conclusion of the projects
Outputs	Pre-commercial research outputs and disruptive technology progressed	Work packages, as set out in funding application More detailed indicators of activity: Number of data sets created; number of tests performed; number of clinical trials; number of software developed; number of prototypes developed; number of interfaces created; number of batches of components created; number of statistical analysed created
	Formation of collaborative relationships/events/networking	Number of collaboration entities

Outcomes (3-5 years)	Increase in R&D activity of firms participating in DTIF (at commercial stage and earlier in cycle)	DTIF Fund Expenditure, including co-funding Variation in Enterprise R&D Expenditure (Pre-Post comparison of levels of research expenditure per firm prior to DITF and after DTIF)
	Increased innovation intensity in SMEs going through DTIF	Level of investment in innovation by participating SMEs during and post the DTIF project (amount invested, pre-post comparison)
	Increased collaboration between industry and RPOs	Number of collaborating entities that remain after DTIF project is completed (number of projects and R&D schemes they collaborated in after the completion of the DTIF project. Assessment after 3-5 years)
	Commercialisation of new products and services	Number of licenses granted/sales agreement signed
	Leveraged funding from variety of sources	Successful application for further R&D funding at national and European level Level of Private R&D funding (pre-post comparison as above) Private investment post-DTIF (Pre-post comparison)
Impacts (7+ years)	Disruption of product markets	Significant market share taken by DTIF product (sales levels of old and new products) Loss of market share for existing products
	Changing Job/Employment Profile	Reduction in disrupted jobs/Creation of new jobs/upskilling opportunities (survey of roles through firms post DTIF)
	Change in consumer behaviour/business behaviour and operations	Change in sale profile/organisational changes to existing business models (pre-post comparison of sales data of old and new products; assessment of consumer behaviour – mainly qualitative analysis, on a periodical basis, e.g. every 1-2 years to assess)
	Spillovers from disruptive innovation to other sectors	Loss of market share of the existing products/changes in existing business models (sales, as for disruption)
	Spillovers to MNC and SME	Adoption of innovative solutions/innovative processes by MNC and SME (Assessment of firm behaviour (qualitative analysis on a periodical basis, every 1-2 years); assessment of changes in the processes as a consequence of the adoption of the innovation, such as increased performance; quicker delivery of products and services; sales)

The above table provides a further specification of the various components of the Programme Logic Model and summarises the possible indicators to assess them.

INPUTS

The inputs to the DTIF are the financial supports available to the beneficiaries, which overall amount to €500 million. Of these, €75 million have been awarded to 27 beneficiaries in 2018, and €65 million have been awarded to further 16 projects in 2019. Co-financing of €239 million (to date) from the beneficiary organisations are also financial inputs of the DTIF which for enterprise seeking support from the DTIF is 50% of the total project costs.

Human resources include the staff from the Department of Business, Enterprise and Innovation, Enterprise Ireland, other Government Departments and Agencies involved, the international panels of experts involved in the selection of the participants, while DBEI and Enterprise Ireland only are involved in the management of the awardees, the monitoring of their progress and the project closure. The inputs are not quantified in the same way outputs, outcomes and impacts are, but are more the pillars upon which the DTIF relies. Without a financial allocation, staff dedicated to the programme implementation and the physical location where the initial implementation of the DTIF takes place, it will not be possible to have the other components of the PLM. Therefore, what is being assessed at input level is the existence of these elements.

ACTIVITIES

The activities are the main ongoing activities at an overall programme level from the perspective of the programme managers. The activities as specified here are those activities from which the programme outputs will emerge. The research activity funded through DTIF are not enumerated within the activities and the focus is on activity at the programme level which facilitates the research.

The activities from the perspective of the awarding bodies are the administration of the DTIF calls, the selection of the participants based on applications, the award of the support, and the subsequent monitoring of the projects through the submission of periodical progress reports. These activities are monitored through ongoing progress reports at a project level and also monitored at a fund level in terms of a profile providing a breakdown of the applications and successful projects.

According to the table above each activity is linked to a set of indicators that measure its or describe the type of tasks associated to them. For example, the selection of applications will be measured through the number of successful projects. This activity will in turn result in the allocation of funding to recipients which will enable them to perform the tasks connected with the implementation of the projects and to produce the outputs measured through the set of indicators listed in the table.

The activities are measured through the number of projects approved/rejected, and how these relate to the RPAs and distribute geographically. Conferences, webinars, and social media posts are the tasks pertaining the communication activities, which are aimed at updating the public on the progress of the DTIF, advertising the calls, and provide information about the funding and the selection criteria.

The monitoring of the funded projects is another large set of tasks which is undertaken throughout the life of the projects (around 3 years at present), and it is ongoing in many ways under current DTIF processes. From the perspective of the programme managers, monitoring includes the assessment of the project progress through the submission of periodical reports, and quantification of the tasks completed as a percentage from the total, and against the milestones that each project set. Enterprise Ireland staff are involved in these processes, with funding drawdown tied to

progress reports. The monitoring activities also include the quantification of the interim project outputs which are reported below, following a review of the project proposals:

- Work packages progressed/complete
- number of data sets created (where the project involves data analytics and machine learning)
- number of tests performed: these can be product tests and validity tests, and we can further measure the successful rate through the ratio successful tests/total tests;
- number of clinical trials, and as above successful/total;
- number of software developed, in ICT mainly;
- number of prototypes developed;
- number of interfaces created;
- number of batches of components created;
- number of statistical analyses completed

The relationship between the monitoring activities and the outputs is that the tasks that the DTIF perform to monitor the advancement of the projects allow to assess how much the beneficiaries produced in terms of quantifiable outputs. In this sense, there is also a relation between the activities undertaken at project level and those undertaken by the DTIF administrators, in which these monitor how much work has been done to make the project advance.

The current monitoring activities include information on possible problems arising during the execution of the tasks and of any meetings happening weekly or monthly among the consortia partners to review the progress of the project.

OUTPUTS

The outputs here have been defined as the direct outputs emerging from the activities of the programme. The outputs are generally be observable during the execution of the project tasks and by the end of DTIF funding. The outputs with regard to DTIF are the research outputs and progression of the disruptive technology in the form of tests conducted, components or interfaces built, as a part of the final product. Outputs measured during the execution of the project tasks can be seen as intermediate outputs – these are set out within the applications as the primary work packages of the projects. New products or processes emerging at the completion of the project and measured through indicators such as trademarks or patent registered, are to be considered final outputs. The variety of outputs specified here demonstrate the wide breadth and non-uniform research activity undertaken through the DTIF and can present difficulty in terms of measurement.

Most of the projects funded under Call 1 commenced in the second half of 2019 and carried out less than one-year worth of the planned tasks. As a result, it is not possible to provide any detailed information on the intermediate outputs that the projects funded produced. Enterprise Ireland is monitoring the progress of each project through progress reports.

The immediate output of the programme is the technology which has been progressed. This can be measured in-part through invention disclosures, licensing, patents registered, trademarks, papers published as well as looking at (in some cases) new products or process which have emerged from the project. One issue with measuring the outputs of a programme like the DTIF is that the outputs from each project are not uniform. Unlike a programme focused on seeking to increase the number of PhDs for instance, the DTIF is intended to progress potentially disruptive technologies further towards market. Some of the projects will be at an earlier stage entering the programme, likewise some may be progressed more than others through the programme. In some cases, the metrics suggested above may not reflect in full the progress the technology has made. In this case it may be appropriate to seek confirmation that the technology has moved through

technology readiness levels upon project completion, and where this is an appropriate measure of technology maturity.

Another key feature of the DTIF is the collaborative element, which can be measured through the number of consortia which are formed through the programme and will demonstrate early success of the programme in this way.

The indicators used to perform the monitoring activities are also a way to measure the overall output of pre-commercial research outputs and disruptive technology progressed. As the project activities advances, the various indicators used to monitor the project progress should lead to a final product at the conclusion of the research. The formation of collaborative relationships and networking is the other important outputs expected from the implementation of the projects, and it is assessed through the presence of the consortia required to apply to the DTIF supports.

OUTCOMES

The outcomes are defined here as the changes which occur to those firms that participated in the programme. The outcomes here are in part determined by the fact that DTIF products are not intended to be market ready by the end of their funding and reflect effects which may emerge over a 3-5 year period from the time of initial funding. However, some initial outcomes may occur sooner, in tandem with DTIF funding such as increased expenditure on research and development. The outcomes are the next logical steps in the PLM emerging from the activities and outputs.

An increase in R&D activity and investment in disruptive innovation should be seen by firms going through DTIF and will be a direct outcome of the programme. This will involve funding directed at disruptive products but will also involve capabilities developed through the fund and in future directed into further research for different products. Increased collaboration between and among industry and Research Performing Organisations is another outcome of the programme.

One of the features of DTIF is that the products and processes emerging from the fund may not be yet be ready for market. However, the fund is intended to have progressed these technologies along TRL levels and to have brought them closer to market. As a result, the potential market impact of the outputs should be clearer and should enable firms to leverage further private investment aimed at commercialising the new products/ processes and services.

Measurement of outcomes is critical for being able to gauge the success of a programme such as DTIF. Below are some suggested measures of the early outcomes emerging from DTIF.

- Increased R&D expenditure in those firms going through (and post) DTIF
- Increased participation in other R&D programmes
- New standards developed (this may be a qualitative indicator, and can be assessed after the innovation is introduced in the market)
- Spin-in and Spin-Out Activity/Further private investment in product
- Number of projects in which the partners of the DTIF consortia cooperate outside the DTIF
- New agreements signed to sell the product/bring product to market

As there typically remains some time to market after exiting DTIF continued high business expenditure on Research and Development is one way to measure the success of the programme in terms of firms investing in innovation. The DTIF is intended prepare Irish enterprise to engage in partnerships around the development of disruptive technologies, and on-going collaborations should be monitored. The can involve further engagement with European grants, it may also take the form of increased spin-in or spin-out activity in firms going through DTIF as the commercial

value of the output becomes clearer. These outcomes from DTIF will better position Ireland as a Global Innovation Leader.

In the years exiting DTIF the product should be brought forward towards market. Further invention disclosures, licensing activity, patent registrations should also be expected as the product comes closer to market. This should involve new standards being developed and agreed as a way of delivering the product to market, as well as agreements made to bring the product to market.

Outcomes mainly relate to the firms going through DTIF. The outcomes can therefore be monitored through ongoing surveying of firms emerging from DTIF in the years after funding has closed out.

IMPACTS

The impacts of the programme are the longer term, wider effects emerging from the programme and may go beyond just the firms involved in the programme and start impacting on markets and economies – potentially globally if the technology is truly disruptive. Depending on how mature the technology is when emerging from DTIF the impacts could take anywhere up to at least 7 years to become apparent. It is noted that disruptive innovations can sometimes take time to take root before leading to disruption of other market segments. In other situations, the impact may display nearly immediately once the innovation is introduced to the market, and possibly disruptive impacts could be observed in less than 7 years, although this is not always the case and it may depends on how the consumers welcome the innovative product.

A key impact of the DTIF is the disruption of product markets. This will have significant impacts on employment profiles, with job roles becoming obsolete and requiring upskilling or creating ex novo new job profiles as well as leading to changes in both consumer and business behaviour. The nature of disruptive innovation and technology means it may lead to unexpected benefits and spillovers to other sectors of the economy.

Below are suggested measures which should be tracked for those products emerging from the DTIF.

- Market share gained by the new product vs market share lost by older products (Alternatively sales/revenue of new product in the absence of ability to track market share);
- Comparison pre vs post with the jobs associated with both the old and the new products
- Comparison pre vs post with the consumers habits associated with the old and the new products
- Comparison pre vs post with the business behaviour associated with the old and the new products

This paper discussed earlier that the possession of disruptive qualities in a product is not enough to ensure its success when it comes to market. However, these products have the potential to disrupt markets and rapidly gain market share if they are successful. Therefore, a reasonable metric of the success of any disruptive innovation is the degree to which it replaces previous products in the market through sales and market share. This should be monitored from the launch of any product or service which has been funded through DTIF.

From this disruption a number of other impacts should emerge including increased employment in the new product – particularly if it is focused on global markets. Consumer market behaviour in terms of use of new products against older products can also be a metric for success of the programme.

Programmes which are focused on sustaining incremental innovations may not have trackable impacts on market share of firms, as many firms may be competing in a similar manner. The disruptive nature of the innovations funded through DTIF (assuming they have true disruptive potential) means that these products should take market share and have sales increase in a measurable manner and which should allow for a long-term determination of the success of DTIF as a way of increasing Ireland's engagement with disruptive technology.

Monitoring framework

It is important that proper data collection procedures are in place through the life of DTIF in order to monitor the performance of projects, their outputs and, in time, their associated outcomes and impacts which will allow for an evaluation of the programme.

The above PLM provides a framework to monitor the projects inputs, activities and outputs throughout the life of the programme, as well as lower level metrics to measure these areas in better detail.

The DTIF appears to have a robust monitoring process in place to monitor programme activity to date, with reports maintained on applications and approvals, the governance of the programme and in particular the progress made in those projects approved.

As projects come to a close it is important that a record of the major outputs of each project is maintained. The maintenance of a report on the output of projects will allow evaluators in future to identify if stated project goals were reached within the timeframe allowed under DTIF funding and will provide information on what has emerged from projects funded. Given the wide range of projects going through DTIF and the varying degree of advancement and closeness to market measures of the outputs could include the patents and trademark registered or the papers published, as well as the actual disruptive product itself. Most of the projects going through DTIF will deliver an output – however that is distinct from the output leading to its intended outcomes and impacts, as a product may not find market success.

It is important that there is continued monitoring of firm activity through DTIF and after DTIF funding in order to ascertain the more immediate outcomes and the longer-term impacts. The key goal of DTIF is to disrupt markets.

The PLM also provides a possible path to build the ex post evaluation of the DTIF. The ultimate results of the Fund will display some years after the projects are completed. The above PLM distinguishes between outcomes and impacts and suggests the indicators that an ex post evaluation should use to measure them.

Some outcomes will be more immediate while others may take longer to emerge, depending on how advanced the product is upon the close out of DTIF funding. One of the more immediate outcomes which should be monitored is a rise in disruptive R&D expenditure by firms going through the DTIF and emerging from DTIF. A key part of this could include looking at further private investment following the end of DTIF funding. This would demonstrate that DTIF has brought the product to a stage where the risk level has been lowered and private investment can step in. The collaboration (and continued collaboration) between the consortia partners is another important outcome that an ex post evaluation of the DTIF should consider as one of the main objectives of the Fund is to support the cooperation among SMEs, MNCs and RPOs. This will require ongoing monitoring of firms who have been involved with DTIF.

EX POST EVALUATION

The impacts from DTIF will only emerge a number of years after the completion of the projects. An ex post evaluation will mainly focus on assessing whether the DTIF has led to the stated significant

alteration of the market and of the business operations. An important measure could be to assess whether the disruptive innovation funded would happen in any case without the DTIF, given the level of risk of some of the projects. The comparison between the awardees and a cohort of non-beneficiaries that applied for the DTIF supports but were not successful could provide useful information on whether without the financial support of the Fund the intended disruptive innovation would be progressed in any case.

With reference to the disruption of the market, and in relation to the funded projects, the first important indicator of the disruption is the sales of the new product and the market share of this product and existing ones. Sales data will also demonstrate changes in consumer behaviour, i.e. how much consumers adapt their preferences to the new products and modify their habits to fit into the innovation. Consumer behaviour can also be assessed through a qualitative analysis taking place on a periodical basis, such as every 1-2 years, to assess whether their overall habits changed as a consequence of the innovation. For instance, a new product may result in saving a considerable amount of time that consumers will devote to something else. Organisational processes, where relevant, are another important indicator of the impact of the disruptive innovation. Firms that adopt the new solution will find themselves in the situation of having to modify significantly their processes following the introduction of the new product. This aspect is also important to assess whether there has been a spillover between SMEs and MNCs, in which both benefit from the innovation in terms of adopting new processes or products. The change in the job profile is the last important impact that an ex post evaluation should consider. If an innovation has been truly disruptive then it should have an impact in the jobs market in terms of reduced employment among competitors and increased employment in firms who have gone through DTIF. If the market has been disrupted there may also be increased employment in other firms who have started further development of this product.

While collecting data on these outcomes is fundamentally different from ongoing monitoring of the projects themselves, they provide key data to allow for a determination on whether the DTIF is achieving its intended goal of market disruption. Monitoring of the outcomes will better inform future investment in disruptive innovation – as it will allow for insight on which areas saw more success over the long-term, or whether different approaches between Calls had any impact on the final success of projects for example.

Progress towards Objectives

As discussed in the rationale section, the fund seeks to fund significant innovations which include both 'disruptive' and 'novel' technologies. From the perspective of funding these large innovations which may not have been funded otherwise the fund appears to be achieving its stated objectives. The projects which the DTIF has funded to date represent significant innovations including projects which will progress quantum computing, develop improved drug delivery systems, develop AI platforms and more. Based on international evaluators assessments, these innovations are likely to have significant impact on their respective markets, or indeed, even establish new markets. All projects were deemed to be successful on the main criteria of having a strong disruptive technology dimension – including building on excellent scientific research, having a strong economic and market impact, strong collaboration as well as being as excellent overall.

Below, certain objectives of the fund are discussed in terms of their clarity, the progress towards these objectives and some considerations for the programme.

DISRUPTIVE TECHNOLOGY

The DTIF aims are to aid the development of disruptive technologies as set out clearly in the programme objectives. Indeed, the programme looks to have funded a number of projects which could be deemed potentially disruptive. This is not inherently simple, as the definition of what is and isn't a disruptive technology can be difficult to define, particularly ex-ante. This is core part of the reason such innovations can be overlooked by incumbent firms.

The fund aims to fund technology's which are 'truly disruptive' – as set in the Call 1 Guide to Applicants:

"disruptive technology is taken to mean that which has the potential to significantly alter markets and their functioning and significantly alter the way that businesses operate. While it may involve a new product or process, it can also involve the emergence of a new business model. Disruption is about the combination of technology and business model innovation."

This aligns well with Christensen's (who coined the term) view of disruptive technology. He states disruptive technology is a process whereby a smaller company with fewer resources is able to successfully challenge established incumbent businesses. Entrants that prove disruptive begin by targeting those overlooked segments, gaining a foothold by delivering more-suitable functionality - frequently at a lower price. Entrants then move upmarket, delivering performance that incumbents' mainstream customers require, while preserving the advantages that drove their early success. When mainstream customers start adopting the entrants' offerings in volume, disruption has occurred.[28]

In guidance to applicants under Call 2 it is stated that the proposals applying for funding should

- Alter markets;
- Alter the way business operates;
- Involve new products or the emergence of new business models.

However, this understanding of disruption did not always carry through to the applications. In some applications, the understanding of disruptive innovation was focused on increased performance or the reduced costs arising from the introduction of the innovation – this would be more commonly

[28] https://hbr.org/2015/12/what-is-disruptive-innovation

viewed as ‘sustaining innovation’ (whether that is incremental or radical), rather than ‘disruptive innovation’. In some cases, the assessors themselves questioned the disruptive nature of successful projects (it is acknowledged that the unclear nature of how a disruption may occur is part of what makes it difficult for incumbents to recognise).

While the above are some of the indicators used to define the disruptive dimension, applicants did not always clarify what markets and business operations would be significantly altered if the proposed solutions were implemented. This is also the argument of some of the international assessors who in some cases expressed the view that the approved projects were not truly disruptive as there is no clear indication of this dimension, nor of the impact on the market and business operation.

Guidance to assessors states when scoring the application on the strength of the Disruptive Technology dimension proposals should demonstrate “strong potential to develop and deploy *novel* or “disruptive” technologies in a setting relevant to Ireland and relevant to market opportunities for Ireland”. The reference to novel technology is also included in the eligibility criteria under Call 1 and Call 2. It may be the case that a focus was placed on this novel element, in combination with economic impact in approving applications under the strength of their disruptive technology. When assessing the proposals, in some cases the evaluators referred to the novelty element of the innovation, not to the disruptive dimension – which in turn may lead to firms being approved for their novelty rather than having a focus on the disruption. The high-risk of some of the projects was considered on a number of occasions in the evaluators’ assessments, with a higher risk level helping ensure that DTIF support is warranted. The conclusions and decisions of the international assessors is not questioned here as the ‘novel’ element is clearly stated in the eligibility criteria. Having a focus on novel element of an innovation is not the same as saying that those projects were not disruptive at all. Further, as discussed above – disruptive innovation is a very particular process where the innovation usually provides lower quality service and enters through a niche market -. The use of novelty could open the fund up to radical innovations – which can prove to be more *destructive* to markets than a smaller disruptive innovation. This is explained well by Yu and Hang:

“disruptive innovation is not equal to destructive innovation. A technological innovation that has superior performance in key dimensions with a relatively low-cost structure would directly invade the mainstream market and cause more serious destructive effects than a normal disruptive innovation that focuses on low cost but initially lower performance.”

This is particularly true for some of the projects funded under Health and Wellbeing which is the area which received most funding under Call 1. Proposals relating to the treatment of a diseases while typically representing a technological innovation, do not present any significant change in the way they enter the market or in how they will eventually disrupt the market as they will be delivered in much the same way to the same customers (hospitals) as currently competing products in the market. These projects may represent significant innovations (radical) and improvement on technology which will improve the quality of the product for customers, but this is distinct from the narrow definition of disruptive innovation. However, the assessment process shows some confusion around the concept of disruption, as the focus is mostly on the innovative solution itself and how it represents a replacement of the existing products, without any reference on how its implementation significantly changes the way the market operates. In some of the assessments “disruption” was understood as a way to replace the existing solution- product innovation where older technology is replaced occurs both in disruptive innovations and sustaining innovations. If this is occurring through gradual improvement rather than change in business model then it would be better defined as a sustaining innovation, albeit potentially radical, rather than a disruptive one.

There are some conclusions which emerge from this discussion. In some cases, it was felt that the proposal was focused on the novel element of the innovation and lacked a focus on the disruptive elements as they relate to the market and business process. This lack of clarity on a difference was seen in both the applications and in some of the assessments. The objectives of the programme and the guidance to applicants are clear in their alignment with the traditional view of disruption. However, if the disruptive element is not sufficiently strong in some proposals then it will not flow through to *all* the activities and outputs. This in turn will impact on the intended outcomes and impacts of the programme. If the DTIF is intended to fund larger 'sustaining' innovations then this should be made clearer in the criteria possibly with less focus on the business model aspects which are more in line with the idea of disruptive innovation.

Innovation, even if it is not categorised as 'disruptive' still has the potential to lead to a wide range of economic and social benefits. The inclusion of 'radical' innovation along with 'disruptive' innovation could be an option for the fund in future. This may not, in practice, present a major change for the fund – from examination of project assessments for the first two calls it seems that the focus of the evaluators on the 'Strength of the Disruptive Technology' criteria could be better aligned with radical innovation than disruptive. This assessment is based on the use of language in assessments which focus on 'fundamental novelty, new technologies, discussion of non-incremental innovation, there being no mention of price or the low-end of the market, no focus on non-consumers within the current market, a focus on increased performance (disruptive innovations can have lower performance due to market being overserved by incumbents). As discussed in the opening of the paper – radical innovations represent a significant step up for a sector and also have the ability to capture market share (due to improved performance over competitors). The inclusion of radical innovation could still focus the fund on major innovations – innovations which have the ability to capture global markets. This would ensure that the fund remains focused on projects which push the envelope, which can help ensure jobs for the future. This could potentially also provide stronger rationale and clarity within the fund in terms of the involvement of larger firms.

If, however, it is strictly intended for disruptive innovation then there could be stricter guidance on its definition offered to both applicants and the international assessors. It is possible that a framework for assessing the 'disruptiveness' of each technology could be a useful tool for both the applicants and the assessors in bringing greater clarity to the disruptive element. A framework to assess the disruptiveness of technologies was developed by Guo et al and an item along these lines introduced into the application process or the assessment may bring increased clarity on what is understood to be disruptive and what is not.[29] Their paper proposes assessing disruptive technology along its technological dynamics as well as the market place dynamics. Some suggested areas of consideration could include:

- how much the new solution is integrated with the existing product;
- potential of leading of the innovation in the adoption of the new product or fostering the existing markets;
- timing of the solution being introduced in the market;
- easiness of diffusion, through the commercialisation route, or the licensing;
- how much the new solution simplifies the existing situation;

[29] Guo, Jianfeng & Pan, Jiaofeng & Guo, Jianxin & Gu, Fu & Kuusisto, Jari, 2019. "Measurement framework for assessing disruptive innovations," Technological Forecasting and Social Change, Elsevier, vol. 139(C), pages 250-265.

- if the innovation belongs to a niche market, or has the potential to create a new one;
- the profitability of the networks of firms operating in similar sectors;
- the presence of a reduction of costs if the innovation is introduced;
- how much the innovative solution will affect the existing business operation and more in general the industry and the job market

Other key area which could also be considered in selection of projects with a disruptive nature could focus on whether the new product or innovation targets overserved customers, is it likely that the innovation can move up market without response from competitors, can it improve performance overtime while also retaining low costs, and whether existing players can respond to the disruption.[30]

Consideration of the disruptive aspects above by both applicant and assessors may lead to greater focus on the disruptiveness of the innovations emerging from the fund, at both at initial application stage and throughout the project. Disruptive innovation is a relative phenomenon – what is disruptive for one market may be sustaining for another – it is important that the applicants describe how their proposal will disrupt a specific market. Another consideration is if it is doing this from the low end of the market – typically a key feature of a disruptive innovation. If an application is not able to answer convincingly on these fronts, then it is likely that the proposal is better classified as a sustaining innovation – whether that is incremental or radical. The paper acknowledges that this is considered to a point within the 'economic impact' criteria but proposes that this should be more tightly linked to the disruptive criteria also.

All projects were aligned with both the Research Priority Areas and the National Strategic Outcomes under the National Planning Framework not only by indicating the other NSOs they were addressing, but also and more importantly by providing a link to the societal challenges as presented in the National Planning Framework. Similarly, all projects were judged as likely to have both large economic and market impacts.

Some of the medical treatments funded for example pointed out that the diseases that they are aiming to treat are particularly common among the elderly, and this in turn would address the societal challenge of the ageing society. In a similar way, regarding the projects funded under the area of Energy it could be argued that the innovation they are developing will not truly disrupt the existing market practice, nevertheless these were well aligned to the research priority area Decarbonising the Energy system and therefore addressing the National Strategic Outcome on climate action.

In terms of maturity of the innovation, this was the area in which all the projects funded were strong. Most of the successful applications provides an accurate demand analysis to justify the proposed solution, and this suggests that the introduction of the new product would immediately adapt to the market. Again, this is particularly the strength of the projects funded under Health and Wellbeing, and some of the ICT areas, which identified a broad population that would benefit from the innovation (e.g. elderly, those affected by chronic diseases, etc.)

CHALLENGE-BASED FUNDING

DTIF was established with the view that a challenge-based element could be developed within the fund. Currently within the fund, the focus is on the market and economic impacts, and on commercialisation which means the fund is progressing the wider societal outcome under Project Ireland 2040 of a strong economy.

[30] https://hbr.org/2015/05/teslas-not-as-disruptive-as-you-might-think

This review of international programmes offered some considerations for the DTIF in Ireland. It is possible that the use of challenge-based funding could help overcome some of the difficulties faced by low success rate of some sectors within the DTIF. It could focus applications on a certain area as part of a call – collaborations could emerge in these sectors to tackle a very specific problem or challenge which has been framed to them. In this way applications could be encouraged from a large range of areas over time. This could work through potential participants sharing their capabilities prior to formation of collaborations aimed at addressing the challenge. Over time this could help maintain interest from sectors where there has been a low success rate.

An issue with specific challenges as they relate to the DTIF could be the focus of the fund. The primary focus of the fund is on helping enterprises to introduce disruptive products or services that have a market impact and can be commercialised. Given the commercial nature of these – it may be difficult to align the fund with a specific narrow call, as the focus is on commercialisation of a product leading to market disruption. This could change the nature of the fund, where addressing the challenge itself is the main objective, rather than market disruption – distinctly different.

An additional consideration regarding the challenge-based proposal is the disruptive element of the fund. As was made clear in the Rationale section – disruptive innovation is a very particular process with specific features (first introduced in an emerging or insignificant niche market, mainstream market does not value proposition). Attaching these conditions to a very particular challenge could prove difficult – as a proposal that could address the challenge would, by definition, have very specific properties. If a challenge-based funding approach was to be considered in the future of DTIF, it may be necessary to include wider definitions of innovation within the eligibility criteria for funding such as widening the definition to also include radical innovation while maintain the focus on an innovations ability to capture global markets. This would mean that the main objectives of DTIF are kept, but that particular calls could be run for certain sectors. This measure could potentially encourage a greater spread of applications regionally. It is possible that with a level of direction (in form of a targeted challenge) firms may have capabilities to innovate to match the challenge – particularly when they can leverage the capabilities of other firms. However, such a change represents a large departure for the fund and would have to be considered quite deeply before being pursued.

An alternative measure which could be considered is to have calls focused on a single Research Priority Area – thereby seeking interest from a very concentrated cohort of enterprises and consortia. Again, this may help the formation of consortia, while also focusing firms on a specific area.

COLLABORATION

The collaborative objective of the DTIF is very clear and follows through in terms of the inputs and activities. The collaborative criteria are made clear in the Call 1 and Call 2 Reference Documents for Applicants. Similarly, the ‘quality and efficiency of the collaboration’ is one of the 4 main criteria in deciding whether an application meets the minimum threshold for funding and is a core part of the evaluator’s assessments. The applications and assessments make clear the importance of the collaborative element to consortia being approved for funding. Consortia are scored positively for taking advantage of and complementing each other’s strengths. A strong focus is placed on the SME role within the projects, and it is intended that SMEs have an integral role in each project as one of at least two enterprises involved in the consortia. A single company within a consortium having too great, or too small of a role counts against a collaboration in their assessment.

From an ex-ante perspective if this focus on collaboration follows through to the actual research on the disruptive innovation, firms will gain experience in collaborating among 3, 4 or even 5 partners on a single project. This should lead to gains in terms of increased future openness to collaboration. In particular collaboration is occurring between SMEs, MNCs and the publicly-funded RPOs. In this way we see collaboration flowing through from the objectives right through to

achieving a change in outcomes as specified in the PLM. The collaborative element of DTIF was highlighted in the comparison with other programmes also.

As highlighted above – the literature shows that smaller firms are typically the drivers of disruptive innovation, with larger firms less likely to develop successful disruptive innovations. Why then does the DTIF include MNCs? From the point of view of building on excellent scientific research, MNCs are well placed to make a significant contribution to the fund, by excluding such firms the DTIF may be removing the possibility of funding a number of potentially significant innovations. The involvement of MNCs in the DTIF also brings advantages for the SMEs and RPOs involved. The advantages for SMEs lie in access to greater technical capabilities and possibly greater resources. For example, one application references an IDA client as a world leader in a technology area which will provide access to equipment to progress the project. Another advantage for larger firms is gaining access to and developing innovations which they may have been unaware of otherwise (knowledge sharing). The involvement of large enterprises with smaller ones in combination with RPOs should to some degree encourage spin-in activity. Particularly if the project has been successful in its initial goals then it may make sense for a larger company to take this innovation fully in-house. Disruptive innovation often occurs among smaller companies through innovations that are not foreseen by larger firms as they are too focused on incremental quality improvements to their current customers. Larger firms can either choose to set up separate divisions to compensate for this or they can look to buy in the innovative activity. To some degree the DTIF facilitates this through its focus on collaboration, although the collaboration is not necessarily between large and small firms, the DTIF allows for large firms to enter into the consortium and to engage on developing innovations which it may not have seen otherwise. One area where there could be further consideration, is how to encourage further collaboration within the DTIF between large firms and SMEs. To date the collaboration has focused to a greater degree on collaboration between academia and industry (SMEs) and less on the interaction between SMEs and multi-nationals and large firms. As discussed above – one possible way to focus collaboration *between* firms is possibly through the introduction of a challenge element where firms competencies are advertised prior to the formation of consortia to address a challenge.

From an Irish enterprise policy point of view, that multinational enterprises may use DTIF to protect their market share may not be a significant concern. If the innovation emerging from the DTIF is being driven by indigenous SMEs it may lead to increased FDI into Ireland in the form of a potential takeover.

This still represents a positive economic benefit from productive activity arising from Ireland's SME base. The innovation activity will have taken place in Ireland and will contribute to Ireland's position as a Global Innovation Leader regardless of corporate form. The innovative activity remaining in Ireland is a key consideration. In those cases where a large company was the lead partner it was highlighted in a limited number of instances that the role given to indigenous SMEs in those cases was, at times, quite marginal. The evaluators noted that in the allocation of tasks some SMEs were relegated to a minor role in the execution of the project. In one instance assessors expressed concern that the involvement of a large multinational could lead to the innovation being brought out of Ireland.

As stated above there are benefits to including larger (and multinational) companies in the DTIF, in relation to their R&D capabilities bringing scientific excellence to the fund, and the spill overs which may pass on to smaller Irish SMEs. The participation of SMEs is an area where the fund has performed well, with high participation rates. A suggestion for future calls is that the DTIF maintains its focus on SMEs, that the collaborations should ensure that any role given to SMEs is central to the consortium –or indeed by requiring SMEs to be lead partners in all consortia. This would ensure greater involvement by SMEs, it would mean that they are critical to the project's outcomes and required to engage further with MNCs and RPOs which would better ensure

spillovers. This would also align with the concept of disruptive innovation typically being driven by smaller companies, rather than the incumbents in a market.

The above discussion on the collaborative element of DTIF also highlights that an increase in spin-in and spin-out activity is a highly likely outcome of DTIF and the consortium applications to date would support this supposition. The degree to which this outcome is seen among firms exiting out of DTIF could be examined through a subsequent evaluation.

BUILDING ON PREVIOUS RESEARCH

That the innovation activity funded through DTIF is at least somewhat driven by previous publicly funded research is made clear in the applications of firms which reference research activity funded through SFI and EI. A review of payment data on EI client firms (who represent the majority of enterprise types) who were approved for DTIF funding shows that they have a successful record of gaining approval for a wide range of R&D grants. With 60 firms gaining approval for a total of €33 million in grant funding (not just R&D grants) from EI over a 10-year period. This demonstrates that firms can move through different grants – with examples of grants accessed including Innovative HPSU, Company Development and the R&D Fund. HPSUs themselves often emerge from nationally (and EU) funded research itself. That they are now engaging collaboratively with RPOs and MNCs is a positive for Ireland's move to becoming a leader in innovation.

One avenue which the DTIF could explore is greater participation from SFI Research Centres and EI-IDA Technology Centres which has not been a feature of the fund to date.

In summary, the objectives of the DTIF appear to be clear and match its activity to date well. The DTIF has funded a wide range of potentially disruptive projects, which represent large innovations capable of taking a share of global markets. The objectives of the programme flow through to its activities, into the outputs and therefore should be seen in future outcomes. In particular, the collaborative element both between large firms and SMEs, and between industry and RPOs is strong. One area where increased clarity may be of benefit is in the area of the disruption itself. As discussed, this area is difficult to define, and the fund has distinguished itself a as unique enterprise grant support. However, the disruptive element is one of the key objectives of the fund. If this is insufficient clarity on what is and is not disruptive in the selection of project, then this will be carried through to a lack of impact in the programme outcomes.

Recommendations

- The DTIF should be clearer in the type of innovations it is seeking to fund, in particular, whether these are disruptive or radical in nature (or indeed both). This should be made clear to firms as it could impact the number and type of applications being made and approved for funding.
  - Both disruptive and radical innovations can offer routes to increased global market shares for Irish firms.
  - Applications often focus on the large quality improvement which their innovations bring about – a feature of radical innovation.
  - Disruptive innovation is a very specific phenomenon – where a product, often with lower quality initially, can take significant market share from incumbents through the incumbents 'over servicing' the current market. This process should not be confused with radical innovation which is concerned with major developments in a technology or process. Both types of innovation can quickly take market share in global markets. Currently the innovations funded don't discuss how the market segment they seek to disrupt is an over-serviced market segment, or how it plans to capture non-consumers of that market – both of which are common features of disruptive innovation.
  - Clarity on whether the fund is funding disruptive or radical innovations would bring about changes in the preference for SME funding versus larger firms.

- The DTIF should maintain its focus on SMEs as the drivers of disruptive innovation. The literature points to the important role of smaller firms in introducing disruption to the market.
  - The review recognises the importance of larger firms in providing expertise and knowledge and sharing risks within consortia with SMEs. The fund similarly offers larger firms avenues to innovate disruptively.

- The DTIF could explore challenge-based funding, or more sectoral-focused calls, as a way to further develop interest and applications from certain sectors.
  - The funding to date has been concentrated in the areas of 'Health and Wellbeing' and 'ICT', a challenge-based approach could focus on other RPAs for a specific call.
  - This would allow the fund to address specific challenges over time, possibly in line with the societal challenges as laid down in the National Planning Framework.
  - While it is critical that criteria for funding are met, challenge-based funding could also provide a focus for firms in the formation of consortia over more open-natured calls.
  - Lessons from international challenge-based programmes show that programmes which seek to achieve broader social challenges tend to be focused on broader definitions of innovation, while also not having too many competing objectives.
  - However, a challenge-based approach may be more suited to radical innovation which presents a major step-up in technology rather than disruptive innovation. If focus is maintained on disruption, more sectoral calls could be an avenue to maintain strong applications to the programme.

- The programme should closely monitor the progress of projects. Upon completion of projects the main outputs should be recorded. Further engagement with firms emerging from DTIF is crucial for evaluation of the programme as the outcomes can then be measured.
  - This Spending Review has set out a Programme Logic Model to establish a basis for future evaluation.
  - Continued monitoring and future evaluation will allow for an assessment as to whether the products funded through the programme have truly disrupted market, and whether the programme is achieving its intended outcomes and impacts.
  - It will make also help clarify the degree to which further funding was required post-DTIF, which will help demonstrate the degree to which the fund de-risked investments.

- A short process review in the next year focusing on the application and monitoring process of the programme should be considered. This would provide feedback on how firms have experienced of DTIF to date. This could point to more detailed indicators for monitoring the interim progress of projects.

Conclusion

This evaluation of the Disruptive Technologies Innovation Fund has considered the rationale for the programme. It has established that there appears to be a strong rationale for a programme such as DTIF. The review of literature made clear that disruptive innovations can be risky, and it may be difficult to secure private investment to bring these technologies to market. The fund helps to de-risk these projects, and thereby offers Ireland a way to compete globally as an innovation leader through increased disruptive innovation. This type of innovation can lead to significant social and economic benefits, and as innovations continue to accelerate it is important that Ireland is able to compete in this way.

The DTIF has a focus on collaboration both within industry and across to the research sector. This collaboration has the potential to drive further engagement on innovation beyond DTIF. The collaboration was clear in the Programme Logic Model which was set out, as it flows through from the objectives, to the activities, outputs and finally to the outcomes and impacts.

The PLM sets out clearly how it is intended that the DTIF will achieve its objectives, and the potential final impacts of the inputs to the programme. In particular, the fund will lead to increased investment in innovation through increased collaboration between industry and RPOs at a more mature stage of technology readiness. This will lead ultimately to the launch of new disruptive products into markets. These products will have the potential to alter significantly markets and lead to increased global market share for Irish firms. This will have significant impact on employment and business in Ireland. A number of ways in which these outcomes and impacts can be measured are suggested for further evaluations. It is important that these outcomes are monitored in future years in order to properly assess the impact of the programme. The current monitoring procedures of the projects appears robust, through ongoing progress reports which can be used to monitor the more immediate activities and outputs of the programme.

At this early stage the DTIF looks to be progressing a number of its stated objectives - based on an initial profile of the programme and in the assessment of the objectives. There is also activity across a number of Research Priority Areas, though encouraging greater activity in some RPAs is something which could be further considered. The collaborative element is strong throughout the consortia and the projects which have been funded look to have potential for significant economic impact. The fund is also clearly supporting the delivery of technology-based solutions building on prior Irish research.

Some areas for further consideration are suggested. The fund may have to consider if there is more focus on the ‘novel’ aspect of the technology or the ‘disruptive’ element and to make this clearer in the programme guidance. In some cases, it was felt there was a focus on the radical elements of the innovation rather than the way in which it may disrupt markets. While the projects funded represent significant innovations and have the potential for large economic benefits, there may need to be increased clarity on what is meant by ‘disruptive technology’ in the guidance to applicants and assessors. If the disruptive element is not featured as strongly in the activities of the programme, then this will have implications for the outcomes and impacts of the programme. This was found to be more common in applications under the Health and Wellbeing Research Priority Area. Some further indicators are suggested within the evaluation as a way to highlight to firms and assessors the disruptive element of the innovation.

There was consideration of the role which SMEs play in the programme. There has been considerable focus given to this by programme managers through the requirement that SMEs must be a part of each consortium. In a limited number of cases, the role of the SME was more marginal.. If SMEs do not play a core role in a consortium it may limit the benefits in terms of collaboration and spillovers for SMEs and may result in little disruptive innovation truly taking place within SMEs

in these particular cases. This evaluation recommends that the programme maintains continued focus on ensuring that SMEs have a core role in all consortia.

More generally, as projects funded under the first call begin to close out, it is important that there is continued monitoring of the outcomes for the firms and products which have gone through the programme. In this way it will be possible to establish whether the innovations funded through the programme are indeed disrupting markets.