An Roinn Post, Fiontar agus Nuálaíochta
Department of Jobs, Enterprise and Innovation

Review of Capital Expenditure on Research, Development and Innovation (2000-2016)

Input to the Review of Expenditure 2017

Executive Summary

DJEI Capital Investment in RDI is part of the wider National Innovation System

This paper presents the Review of Capital Expenditure by the Department of Jobs, Enterprise & Innovation (DJEI) on supports for Research, Development and Innovation (RDI). Expenditure is traced through a logic model from objectives to inputs, outputs, outcomes and impacts, concentrating on the period 2000 to 2015.

Modern innovation systems thinking draws attention to the highly non-linear nature of innovation and how it originates from multiple sources. As such, DJEI provides a portfolio of supports to target different sources of innovation. However, DJEI Capital Expenditure on RDI represents 53 percent of total direct public funding of RDI. In this regard, it is important to note that there are other significant areas of public expenditure– either directly via Government Departments and Agencies or through the R&D tax credit – that also play an important role in stimulating and incentivising innovation, though they are outside the scope of this assessment.

Policy objectives have evolved over time

The rational for State intervention is set out in the context of empirical evidence on the returns to innovation. Two thirds of economic growth in Europe in the period 1995 to 2007 is estimated to have derived from RDI. In addition the State has a role in addressing specific market failures such as risk, costs, access to specialist infrastructure and equipment, spillovers, capability shortages and co-ordination and information deficits. In this context, there is an array of barriers to innovation that require State assistance to optimise the environment for RDI activity.

DJEI's objectives for investment have evolved over time. The emphasis in the late 1990's was primarily on developing capacity and human capital in the system, with a progression to encompass a more dynamic set of supports which reflects policy objectives in more recent years for collaboration, commercialisation, in-firm R&D activities and research excellence. Interventions have been targeted at addressing different gaps in the system with linkages in-built to their design. For example, developing scientific excellence in the research base also promotes engagement and investment by Irish and foreign owned companies in Ireland and, in turn, enhance Ireland's attractiveness as a research base internationally for investment.

Policy has also evolved to include increased ambition for Ireland to be a global innovation leader through more emphasis on metrics, benchmarking and targets, in addition to aligning investment with areas for greatest market potential through the Research Prioritisation initiative.

DJEI investment yields a range of activities and outputs

In 2017, DJEI's capital allocation for RDI amounted to €364m. The allocation accounts for 66 percent of DJEI total capital of €555m and 8 percent of total Government Capital of €4,541.5m. In broad terms, the distribution of investment has shifted in accordance with evolving policy objectives. Funding was primarily targeted at building capacity and capabilities in the early 2000's to investment which is more evenly distributed in 2015 across the areas of commercialisation and collaboration (34 percent); direct firm investment (25 percent); capacity

and capability building (35 percent) and international collaboration (6 percent). There are a variety of outputs from investment including the number of firms engaged in RDI, PhDs, scientific awards, spin outs, licences, publications, collaborations and publications. Outputs are reflective of both quantity and quality in the system.

In this context, they do not always have a strictly linear relationship relative to investment and may take years of sustained investment to materialise. They may also be supported by private, international or other public funding. Their interrelationships are also important to note: investments in infrastructure and human capital have provided the subsequent foundation for downstream RDI activities in terms of commercialisation, collaboration and in-house innovation.

The impacts of innovation are demonstrated in the resilience and growth of RDI active companies

Impact from investment and activity is measured against the main policy objectives in the form of business investment in RDI, number of researchers, employment, exports and value added.

Data shows that enterprises are the primary driver of increasing investment in RDI in the economy, increasing from 66 percent of total economy expenditure on R&D (GERD) in 2006 to 72 percent in 2014. Key economic indicators show that non-RDI active firms were responsible for the greatest job losses in the recession, while innovation active firms display higher resilience and growth in terms of rates employment, export and value added. Pay levels in RDI active firms are 10 percent ahead of the agency average and 66 percent higher than the economy in 2014. In addition, the number of researchers in the enterprise base has increased by 67 percent to over 17,800 since 2006, indicating a major increase in knowledge transfer from public research to the private sector, which represents significant progress on a central innovation policy objective.

The base of innovative firms is growing, however, depth and scale remains poor

Looking at the DJEI client base (Enterprise Ireland and IDA Ireland), the number of innovation active firms has increased by 398 companies (20 percent) in 2014 relative to 2006. In relative terms, the proportion of innovation-active firms has increased from 55 to 60 percent of the total client base. Notwithstanding this improvement, there remain 40 percent of agency companies with no RDI investment and a further 23 percent with expenditure below €100k annually.

This represents a sizable cohort that is not meaningfully engaged in RDI. Recent research by the ESRI has been demonstrated that firms with greater varieties of products and markets have much better survival rates and ability to withstand shocks. Innovation is central to developing both the product or service mix and the organisational capabilities to internationalise.

The corollary is that the least innovative firms are most vulnerable to external forces. Therefore, this cohort with little or no RDI expenditure is most exposed to ongoing technological, market and geo-political change. Notably, 53 percent of foreign owned firms have no RDI expenditure in Ireland, which represents vulnerability in terms of their embeddedness.

DJEI funding leverages significant private and international investment

Impacts are also evident in the form of 'crowding in' effects of DJEI investment, particularly in leveraging investment from sources such as European Framework Programmes and private investment from the enterprise sector. Almost all DJEI investments require a minimum private contribution. Empirical analysis of DJEI RDI grants to firms shows grant winners experience a 19.8 percent higher RDI expenditure growth rate than 'similar' non-grant winners in the year after winning. The return per euro invested is about €12 increase in RDI expenditure relative to the average 'non-grant winning' firm. This declines to €1.64 when benchmarked against 'similar' non-grant winners, demonstrating grants help stimulate additional private investment.

In addition, there is evidence of increasing quality in the system. Ireland has increased to 10th position in global citation rankings. SFI funding calls have become increasingly competitive in recent years with reserve lists now in effect. A range of behavioural impacts are also evident from DJEI programme evaluations, including knowledge transfer, raised strategic ambitions, internationalisation, increased relevance of research, enhanced industry-academic linkages and the transformation and further embedding within the multinational base.

Innovation productivity is strong relative to competitors

There are indicators that the system performs productively relative to investment. Efficiency and effectiveness is assessed through a number of methods including: DJEI's performance metrics; the application of Research Prioritisation to align research with areas of greatest market potential; evidence of cost-benefit where available through evaluations and measures the agencies have put in place to evaluate and monitor performance and impact.

The performance gap is assessed with regard to Ireland's performance benchmarked internationally on key RDI indicators. The results show Ireland ranks 6th in the EU with regard to innovation performance but remains behind other innovation leaders and below average in the OECD and EU in terms of public and private investment. The fact that Ireland performs relatively well with comparatively low levels of investment is an indicator of efficiency and productivity in the system.

Continued Relevance

The continued relevance of investment is set out in a number of contexts:

- There is a demonstrated impact of innovation in driving productivity growth, which is the most sustainable basis for Ireland's economic growth and living standards overall. Relatedly, innovation is central to Ireland's competitiveness and the ability of companies based in Ireland to compete internationally.
- Non-RDI active firms were responsible for the greatest job losses within the DJEI base in the recession, while innovation active firms display higher rates employment, export and value added growth, and account for a disproportionately higher percentage of sales and exports. Innovation is clearly linked to the resilience of companies to survive in a crisis and higher growth rates overall.

- In the context of Ireland's ambitions to become a global innovation leader and in the face of continually changing market, technological and geo-political forces, there is an urgent need to both broaden the base of companies engaged in RDI and deepen the scale of investment within a level that at least matches our key competitors.
- Given the centrality of product and market diversity to survival rates, non-innovation active firms are most vulnerable to changes in the external environment. Recent Enterprise Ireland data shows that export growth to the UK has slowed from 12 per cent in 2015 to 2 per cent in 2016 indicating Brexit is already impacting on companies exporting to that market.
- Ireland's ability to leverage international research investment depends foremost on the quality of the research base nationally. RDI is accounting for an increasing share of multinational investments and increasing quality in the research base is reflected in Ireland's growing success in securing more European Framework funding. The impact is circular: increased international engagement based on excellence improves the quality of the research base domestically, which in turn enhances Ireland's reputation internationally as a location of choice for research activities.
- The review has found that Ireland performs relatively well in terms of innovation productivity when benchmarked internationally despite relative underinvestment and has delivered increasing quality as measured by global rankings.

Challenges and Policy Considerations

Notwithstanding the progress made to date in developing the National Innovation System from a low base, there are some challenges to be addressed in order to further enhance impact and effectiveness of funding throughout the system.

- There is a significant cohort of companies within the DJEI client base (IDA Ireland and Enterprise Ireland companies) that are still not engaged meaningfully in RDI. There is an urgent need to broaden the base of firms that are innovation active and deepen the scale of investment in order to enhance the resilience of the base to technological and market change and maximise growth potential.
- Aligned with this, there is a need to continue to diversify the mix of supports (such as company to company collaboration) and move towards more demand-led approaches. The recent European Commission Country-Specific Recommendation has recommended Ireland reduce reliance on the R&D tax credit and that more targeted policy mixes with more direct funding may better address the needs of Irish young innovative firms and exploit opportunities from the strong investing power of multinational companies. DJEI is currently reviewing its full range of programmes to establish where overlaps and complementarities may exist and ensure better transition between supports where needed.
- Continuing support of innovation is necessary to enable companies to diversify the product and market mix which has become particularly critical in the context of Brexit and firms that are currently over reliant on the UK market.
- A continued focus on research excellence is required regarding Ireland's ability to secure international funding, particularly European funding. As the next round of EU funding (FP9) gets underway, it will be important to ensure alignment with FP research priorities.

- The effectiveness of public funding of RDI depends on the health of the system as a whole. Innovation 2020 provides a mechanism for a joined-up whole of Government approach to research funding. It is important to retain this focus on the National Innovation System.
- There is a need to monitor the future supply of researchers to the economy with recent declines in PhD enrolment numbers likely to impact on skills availability in the coming years. It is also important to track their mobility after graduation at various points to assess their degree of transfer between the public and private sectors. SFI analysis finds that 53 percent of team-members are in the private sector 6-8 years after the end of the SFI award. Relatedly, the increase in collaboration activities has the unintended risk of retaining post-doctoral researchers longer in the public system with the potential for sub-optimal levels of mobility to industry.
- The significant reduction in new PRTLI funding from 2014 creates a risk to the ability of SFI and other funded research teams to effectively undertake their work in terms of access to appropriate buildings, equipment and personnel. This human capital and infrastructure provides a critical foundation for driving performance elsewhere in the National Innovation System.
- Future evaluation and analysis could be undertaken in the areas of: the impacts of Research Prioritisation; SME Innovation Pathways; Knowledge Transfer of PhDs to Industry; Sectoral and Size Dynamics; Enterprise Ireland Client Engagement Model.

Programme Logic Model – DJEI Capital Supports for Research, Development and Innovation (1998-present)

Objectives for DJEI

Phase I Technology Foresight (1998-2005)

- Significantly scaling up the R&D capacity and science and technology infrastructure in Ireland's HEIs and other public research organisations
- Strengthening the supports available to research students and researchers in third-level and state research institutes
- Directly supporting R&D capacity within the enterprise sector
- Increasing the quantity and quality of the R&D between institutions and companies

Phase II Strategy for Science Technology and Innovation (SSTI) 2006-2013

- To strengthen Ireland's enterprise base
- To move Ireland towards a knowledge economy through human capital investment
- To maximise the return on R&D investment to Ireland's economic and social development

Phase III Innovation 2020 (2015-2020)

Drive a strong sustainable economy and a better society underpinned by:

- Excellent research in strategically important areas that has relevance and impact for the economy and society
- A strong innovative and internationally competitive enterprise base, growing employment, sales and exports
- A renowned pool of talent both in Ireland's public research system and in industry that maximises exchange of talent and knowledge
- A coherent joined-up innovation ecosystem, responsive to emerging opportunities, delivering enhanced impact through the creation and application of knowledge
- An internationally competitive research system that acts as a magnet and catalyst for talent and industry

Inputs

- DJEI funding and investment via PRTLI, Enterprise Ireland, IDA Ireland, Science Foundation Ireland, Other Agencies around themes of:
  - Human Capital and Infrastructure
  - Knowledge Exchange: Supports for Commercialisation
  - Knowledge Exchange: Collaborations and Partnerships
  - Direct supports for RDI in companies
- Leverage of international investment (e.g. European Framework Programmes)
- Advisory supports (DJEI And Agencies, Governance)

Activities

Programmes which support:

- Human Capital and Infrastructure
- Knowledge Exchange: Commercialisation
- Knowledge Exchange: Collaborations and Partnerships
- Direct supports for RDI in companies
- International engagement (European Space Agency; European Framework Programmes etc.)

Outputs

- **Academic Outputs**
  - ☐ PhDs / Post Docs
  - ☐ Scientific Awards/Excellence
  - ☐ Publications
- **Commercial Outputs**
  - ☐ Licenses, Options, Assignments
  - ☐ Spinouts
  - ☐ HPSU Spin Outs
  - ☐ Collaborations
- **Company Outputs**
  - ☐ No. of companies investing in RDI
  - ☐ Significant R&D performers
  - ☐ Large R&D performers
  - ☐ No. of FDI RDI projects
  - ☐ Value of FDI RDI projects

Outcomes and Impacts

Primary outcomes

- Increased investment in BERD/GERD
- Increased employment, sales, exports, value added, productivity, payroll vs non RDI firms
- Scientific Rankings

Wider impacts

- New knowledge and research discoveries
- Increased R&D activity
- Leverage effects
- New business creation / spin out companies
- Enhanced capabilities of firms
- Resilience/sustainability of firms to shocks
- Regional benefits/clusters
- Knowledge transfer and mobility of researchers between industry/research institutes
- Increased FDI Research Activity, Attraction, Embeddedness
- Reputational benefits: measures of excellence e.g. International Rankings, Awards, Journals, Attraction

1. Introduction

1.1. Background

This paper presents the Review of Capital Expenditure by the Department of Jobs, Enterprise & Innovation (DJEI) on supports for Research, Development and Innovation (RDI). The review was requested by the DJEI Vote Section of Department of Public Expenditure & Reform (DPER) as an input to the Comprehensive Review of Expenditure 2017 ("the Spending Review") by Government. The structure and approach is informed by guidance on public expenditure analysis provided by the Irish Government Economic and Evaluation Service (IGEES) which has outlined key evaluation questions for Government Departments in the Spending Review.

1.2. Objectives and Scope

The objectives of this review are to take a top down analysis of total DJEI funding of RDI and to trace that investment through its main activities, outputs and impacts across the main themes of investment. It also assesses the rationale for investment, process for prioritisation of resources, measures for assessing performance and effectiveness and justification for continued investment. The review adopts a programme logic model (PLM) to structure the analysis. It sets out the objectives of DJEI investment in RDI, inputs, activities, outputs and impacts.

DJEI funding supports a range of programmes aimed at developing different aspects of the National Innovation System (NIS). To simplify the approach for the purposes of the review requirements, the expenditure and programmes have been grouped into five major themes which broadly reflect the major activities of DJEI investment:

- **Capacity and Capability Building** Supports – supports that develop human capital and infrastructure;
- Supports for **Commercialisation** (i.e. generating commercial value from research within the public research system) **and Collaboration** (i.e. industry-research partnerships);
- **Direct Enterprise** Supports (e.g. grants for in-house R&D); and
- **International** Programmes (e.g. Ireland membership of international research organisations; European Framework Programmes for Research).

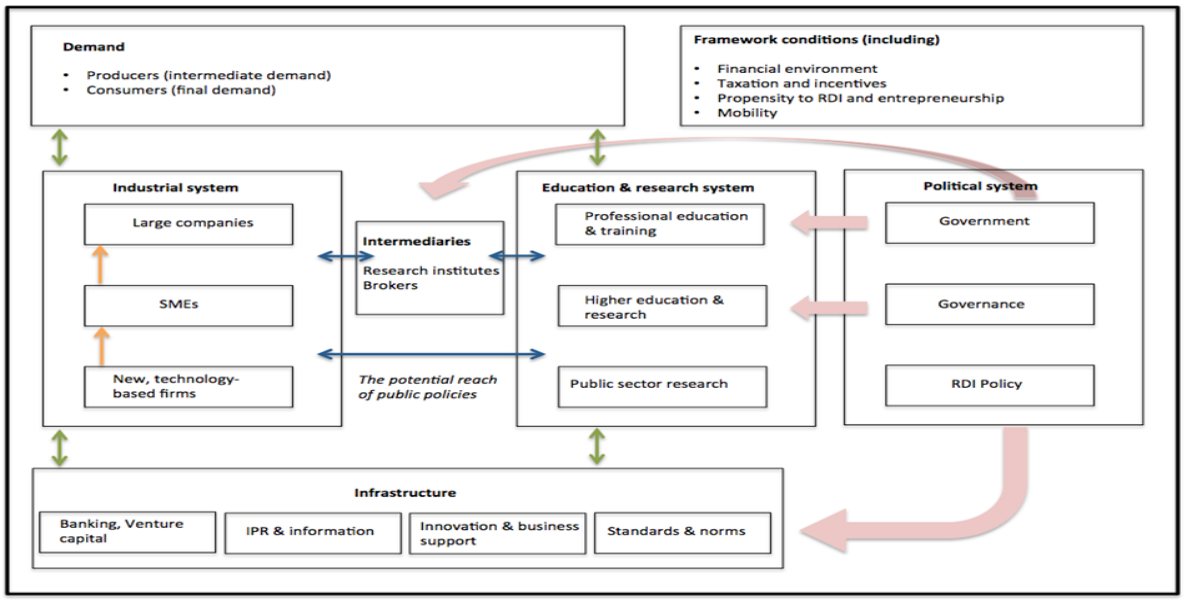
DJEI has selected to focus on the years 2000-2015 as the years of investment as this period bridges the three major national strategies for Science and Innovation. Outputs and Impacts are assessed from the period 2006-2015 as a means of allowing some time effect for assessment of investment and illustrating that Ireland's National Innovation System is relatively nascent and has been developed from a low base.

1.3. Evaluating Investment in RDI – A Complex Landscape

The benefits of the approach adopted is that it presents a high level view of the various ways in which DJEI investment leads to economic, human capital and scientific impacts. The approach is however limited in that it cannot provide a simple quantification of the impact of the investment. Practically, this can only be done at programme or firm levels. It is important to also note that DJEI funding only accounts for approximately half of total public funding in RDI.

Therefore, this review excludes other major public expenditures on RDI through various Departments and Agencies and the R&D tax credit, which also have significant impact and influence on the innovation landscape and performance. A further complication is the interactions between innovation actors. In the past, the traditional assumption was that there was a linear progression from investment in basic research leading to more applied research and through to commercial impact. Modern Innovation Systems thinking, however, recognises that innovation is highly non-linear and is generated through a system of interdependent actors including: supporting infrastructure; framework conditions; the policy system; education and research systems; industry and consumer demand. An example of the interdependencies in a National Innovation System is presented below.

Figure 1.1 National Innovation System – Generic Example



Source: Erik Arnold and Stefan. Kuhlman (2001)[1]

The RDI system is therefore by necessity a busy environment. A portfolio of short, medium and long-term supports are required to build capability and capacity throughout the system and it is the cumulative impact of these supports and their interactions that stimulate and incentivise RDI activity in the economy. In this context, DJEI funding is directed at developing a number of complementary aspects of the national innovation system. This 'portfolio' approach is recommended at EU level as necessary and "likely to have greater effect than an imbalanced system which simply tries to reinforce one or two successful measures".[2]

In addition to the issue of multiple supports, another major challenge with evaluating public investment in RDI is the time lag effects between the initial investment through to emerging

[1] https://www.regjeringen.no/globalassets/upload/kd/vedlegg/forskning/rapporter/2001-rcn-eval/2001-rcn-evaluation-background-report-no-12.pdf?id=2248274

[2] European Commission Joint Research Centre (2002) Research & Technical Development (RTD) Evaluation ToolBox https://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/assessing_the_socio_economic_impact_of_rtd_policies_2002.pdf

results, commercialisation and enhanced competitiveness. For example, the Swedish Innovation Agency (VINNOVA) estimates a 10-20 year timeframe before the impacts of RDI interventions can be traced through to socioeconomic level.[3] Aligned with this is the challenge of isolating the attribution or "causal effects" of the support, particularly when the ambition is to assess the macroeconomic impacts as suggested by the IGEES guidelines. The focus in this review is more on how a programme of actions brings about discernible value and impacts rather than determining the exact share that can be claimed. Given these complexities, in practical terms, this review does and should not attempt to isolate and quantify the causal impact of DJEIs investment. Indicators of impact are drawn from a number of sources, including national indicators, programme evaluations and empirical research. Rather, the added value from this review is primarily about:

- Providing clarity about DJEI investment in RDI and its role in supporting and developing the National Innovation System;
- Ensuring there is strong rationale underpinning the investment;
- Tracing through how that investment translates to outputs which have economic value and benefits;
- Ensuring there are appropriate and robust processes for decision-making and monitoring performance and effectiveness of the supports provided; and
- Identifying any gaps in the evidence which may require deeper analysis from a Public Expenditure perspective.

1.4. Structure and Methodology

The report is structured in the following sections:

- Section 2 assesses the rationale for public investment in RDI, including the evolution of national innovation policy and a brief review of the literature on why State intervention occurs;
- Sections 3, 4, and 5 examines the objectives, inputs, activities and outputs from the investment by DJEI, primarily across the themes of Capability and Capacity Building; Commercialisation and Collaboration; Direct Firm Supports; International Programmes;
- Section 6 identifies the main 'first order' and 'second order' impacts related to the investment and outputs;
- Section 7 provides an assessment of how the effectiveness of the investment is monitored and evaluated by DJEI and its agencies and with Section 8 outlining the case for continued relevance of investment in this area; and
- Section 9 makes some conclusions and policy considerations.

The review draws on existing data sources within DJEI and the Agencies in addition to secondary evidence sources such as empirical research and literature.

[3] Vinnova (2012) Impacts from Innovation Policy http://vinnova.se/upload/EPiStorePDF/va-12-01.pdf

2. Rationale for Public Policy Intervention

Review Questions

- Assess why public policy intervention is necessary and issues around market failure, etc.

2.1. Introduction

This section sets out the various market failures and rationales for policy intervention by the State in RDI activity, drawing from national and international sources.

2.2. Policy Rationale

The current strategy, *Innovation 2020*, situates State support for RDI as a public good that is essential for driving economic growth. According to the strategy, the primary rationale for Government investment in innovation is "*to develop a competitive knowledge-based economy and society and to drive innovation in enterprise, develop talent, and maximise the return on our investment for economic and social progress*". Government intervenes to address market failures that hold back innovation. Investment in research and development increases economic productivity, competitiveness, improves quality of life, health, and has social and environmental outcomes.

Productivity is the primary determinant of sustainable long-term growth and living standards. The OECD identifies the fostering of innovation as one of the key policies to sustain productivity growth[4]. A recent European Commission report points to a number of studies looking at the returns to innovation and rationale for public investment in RDI:[5]

- Two-thirds of economic growth in Europe from 1995 to 2007 is derived from research, development and innovation;
- Research and innovation accounted for 15 percent of all productivity gains in Europe in the period 2000 to 2013. For Ireland it is estimated to be 30 percent;
- The private rate of return for enterprises from investment in RDI is estimated to be 10 to 30 percent. Rates of return are estimated to be higher for those companies that proportionately invest more in R&D; and
- Some studies have calculated the economic returns to public R&D to be around 20 percent i.e. for every 100 euros of public R&D invested, the economy expands by 120 euro.

Historically, the key drivers of economic growth were investment in physical capital and labour. However, stagnating, aging and declining populations coupled with diminishing marginal returns on physical capital investments have lead OECD countries to establish new sources of

[4] OECD (2015) The Future of Productivity

[5] DG Research and Innovation (2017) The Economic Rationale for Public R&I Funding and its Impact

productivity growth in the form of innovation[6]. Investment in knowledge-based capital and innovation in particular, drives productivity through new, higher value-added products and services, and more efficient business processes[7]. Firm Investment in knowledge-based capital is viewed as increasingly important for enhancing absorptive capacity of firms.

Furthermore, the societal rationales for investment in RDI are wide ranging, from areas as diverse as housing, the environment and labour mobility. Research improves the quality of life through innovation in a number of areas. For example, one of the pillars of the current European Framework Programme for Research (Horizon 2020) is developed around seven grand challenges that RDI can help to address:

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Climate action, environment, resource efficiency and raw materials;
- Inclusive, innovative and reflective societies;
- Secure societies - protecting freedom and security of Europe and its citizens.

The OECD's view is supportive of public investment in science and innovation: "*Governments must continue to invest in future sources of growth, such as education, infrastructure and research. Cutting back public investment in support of innovation may provide short-term fiscal relief, but will damage the foundations of long-term growth*". [8] Complementary to this, research by the European Commission states that "*a number of market failures are directly linked to investment decisions in RDI. High risks, sunk costs, market uncertainty, lack of full appropriability of results, or unavailability of funding, all induce underinvestment in R&I below what is socially desirable. To maximise the spill-overs that the creation and diffusion of knowledge generates, public funding for R&I is needed.*" [9] Specific market failures relating to RDI include:

- **Risk and Transaction Costs**: The risks of RDI investment may be high and the return on investment may have a long tail. The economic returns to RDI are often not accrued for many years. Private investors may be unable to accurately assess the risk involved.

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

[7] Computerised information (software and databases); intellectual property (patents, copyrights, designs, trade marks); and economic competencies (including brand equity, firm-specific human capital, networks joining people and institutions, organisational know-how that increases enterprise efficiency, and aspects of advertising and marketing). New Sources of Growth – *Knowledge-Based Capital Driving Investment and Productivity in the 21st Century*, OECD, 2013.

[8] OECD Innovation Strategy: Getting a Head Start on Tomorrow.

[9] European Commission: Economic Rationale for Public R&I Funding and its Impact.

- **Sub optimal investment**: Despite the importance of research and innovation for firms, firms under-invest in research due to the risk of spill-over benefits to other firms. There is therefore a case for the State to co-invest in order to address sub-optimal investment by firms in RDI as spill-overs have benefits to the economy beyond the firm.
- **Capability Failures:** In terms of developing research capabilities, the long run returns to human capital can act as a deterrent to individual and firm level investment, coupled with the fact that not all the benefits may accrue to the firm (through employee turnover)[10].
- **Co-ordination and Information Failures:** The new "systems" approach to industrial policy has placed increased emphasis on the role of the state as a coordinator/networker that develops strategies in partnership with industry[11]. The State can manage coordination failures between institutions and facilitate knowledge transfers between institutions such as HEI's and businesses in different stages of the innovation process[12].

A mixture of these market failures can result in the national innovation system not performing to its potential and limiting impacts for growth. In parallel, in order to maximise their effectiveness, it is important to ensure that in designing interventions, State supports minimise rent seeking behaviour, deadweight and displacement (see Section 7 re: Efficiency and Effectiveness)..

[10] Department of Jobs, Enterprise & Innovation (2015) Evaluations Synthesis Report.

[11] See OECD Warwick, K., (2013), Beyond Industrial Policy; Emerging issues and new trends. *OECD Science, Technology and Industry Policy Papers*, No. 2, OECD Publishing. http://dx.doi.org/10.1787/5k4869clw0xp-en; See also Lenihan, H. (2011). Enterprise policy evaluation: Is there a 'new'way of doing it?. *Evaluation and Program Planning*, *34*(4), 323-332.

[12] See Salmenkaita & Salo (2002), Rationales for Government Intervention in the Commercialisation of New Technologies

3. Objectives and Evolution of RDI Policy in Ireland

Review Questions

- *Assess the validity of objectives.*
- *Has anything happened during the implementation of the programme to make the programme more, or less, relevant?*
- *Is programme design being kept up to date to take account of the changing external environment?*

3.1. Introduction

This section sets out the core objectives for DJEI investment in RDI activity and a review of how policy objectives have evolved throughout the review period (2000 to 2015).

3.2. High Level Objectives

There has been broad consistency in what has been regarded as the core activities or elements of the National Innovation System and in what linkages between them are required to support knowledge creation, knowledge diffusion and innovation that result in economic and societal impact. These interrelated elements that shaped public investment in R&D[13] since 2000 are:

1. **Knowledge Exchange System**: strengthen the system of knowledge exchange through three main channels: formal collaborations, human capital mobility and knowledge transfer infrastructure.
2. **Publicly performed research and human capital**: develop the capacity and capability of publicly performed research and to build a world class research system within Higher Education Institutes (HEIs) based on research excellence through investments in human capital, infrastructure and underpinning sciences and technologies.
3. **Enterprise R&D Base**: broaden and deepen the enterprise R&D base, its absorptive capacity and its ability to develop and commercialise intellectual property.
4. **Public sector research**: invest in Government research organisations and funding programmes to underpin public policy.

The National Innovation System has developed to date through sustained investment across these main pillars. In addition, there are three distinct phases which shows how the system has evolved according to changing policy priorities. This provides context for interpreting the inputs, activities and outputs form DJEIs supports for RDI.

[13] It is noted that enterprise activity in non-R&D based innovation also forms part of the national innovation system and while the national RDI policies encourages such behaviour in firms, public investment to date has been primarily focused on supporting R&D-based activity.

- **Phase 1**: Technology Foresight Exercise and the National Development Plan, 2000 – 2006
- **Phase 2**: Strategy for Science Technology and Innovation and Research Prioritisation Exercise, 2006 – 2015
- **Phase 3**: Innovation 2020, 2016 – 2020.

The summary objectives of these phases are presented below. More detailed narrative on the evolution of policy objectives is provided in Appendix I.

Figure 3.1 Evolution of RDI Policy Objectives

Some key milestones in the evolution of the National Innovation System are outlined below.

Key Milestones

1998 Technology Foresight Exercise

1999 Establishment of Programme for Research in Third Level Institutes

2000 Establishment of Science Foundation Ireland

2000 Enterprise Ireland Innovation Partnerships Programme

2003 Enterprise Ireland Commercialisation Fund

2006-2013 First Strategy for Science, Technology and Innovation

2007 Enterprise Ireland Technology Transfer Strengthening Initiative

2008 Enterprise Ireland Technology Centres Programme

2012 Research Prioritisation Exercise

2013 Establishment of Knowledge Transfer Ireland

2013 Broadening SFI mandate to incorporate applied research

2015 Innovation 2020

Within the overall national innovation strategy developed across Government, DJEI's primary objective over the years has been to use various levers (investment in human capital, supports for commercialisation and collaboration and direct firm supports) to increase enterprise-oriented research activity and investment, within both the enterprise base and the public research base. Leverage between supports within the system have also been emphasised in the policy design, for example, the role of SFI in research excellence also incentivises engagement and investment by Irish and multinationals and enhances Ireland's attractiveness as a research base internationally for investment. Similarly, Enterprise Ireland's Commercialisation Fund and Innovation Partnerships also promote mobility of researchers to industry.

3.3. Conclusions

- The core priorities for DJEI for innovation have held broadly similar over time in terms of building capacity and capability in the form of: broadening and deepening RDI activity in the enterprise base; the need to invest in human capital and infrastructure in order to strengthen the base; strengthening collaboration between the public research system and enterprise through supports for collaboration and commercialisation; and a focus on recognised excellence and engagement internationally.
- These objectives and associated investment and supports are seen as complementary and necessary to support in parallel in order to develop the system as a whole. This aligns with the portfolio approach to innovation which is recommended internationally.
- The emphasis on these objectives has evolved. The early emphasis on investment in human capital and infrastructure was a necessary prerequisite for the subsequent increased policy focus on commercialisation, collaboration and international excellence.
- Research Prioritisation was a responsive approach to the crisis and redirection of resources towards areas with market potential and economic return for Ireland.
- Current innovation strategy continues to focus on areas of strategic importance, in addition to ambitious targets for Ireland to become a Global Innovation Leader.

4. Inputs – Analysis of DJEI Investment in RDI

Review Questions

- How does the programme fit with other programmes of the department or other departments?
- Provide a detailed analysis of spend for specific area of interest – trend and composition.

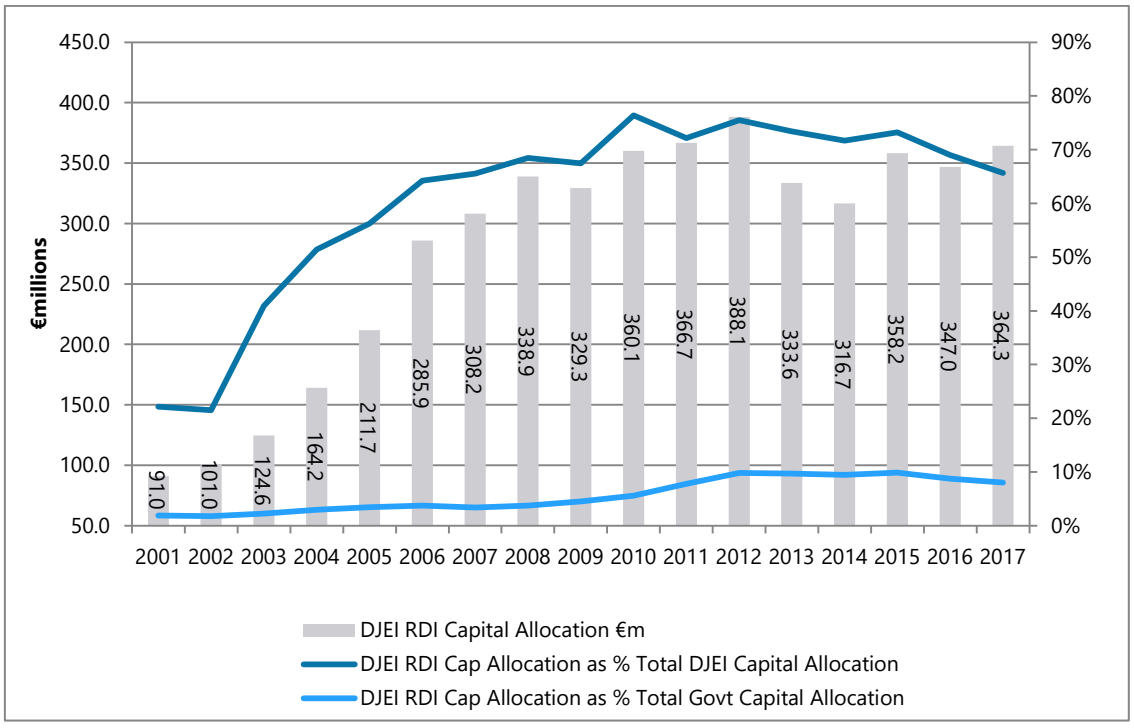
4.1. Introduction

This section presents an analysis of DJEI expenditure on RDI from the perspective of DJEI's total capital spend; relative spend of agencies and major programmes and expenditure by the broad theme associated with the main RDI objectives (capacity and capability building, commercialisation, collaboration, direct firm supports and international). Due to differences in data sources, there are some variations between total figures (for example, estimates versus outturns).

4.2. Context – Total DJEI investment in Capital Expenditure

The following data is based on the Revised Estimates in Public Expenditure. In 2017, DJEI's total capital allocation for supports for RDI amounted to €364m. This accounted for 66 percent of DJEI's total capital allocation of €555m and 8 percent of total Government Capital allocation of €4,541.5m in that year.

Figure 4.1 DJEI Total and RDI Capital Allocations



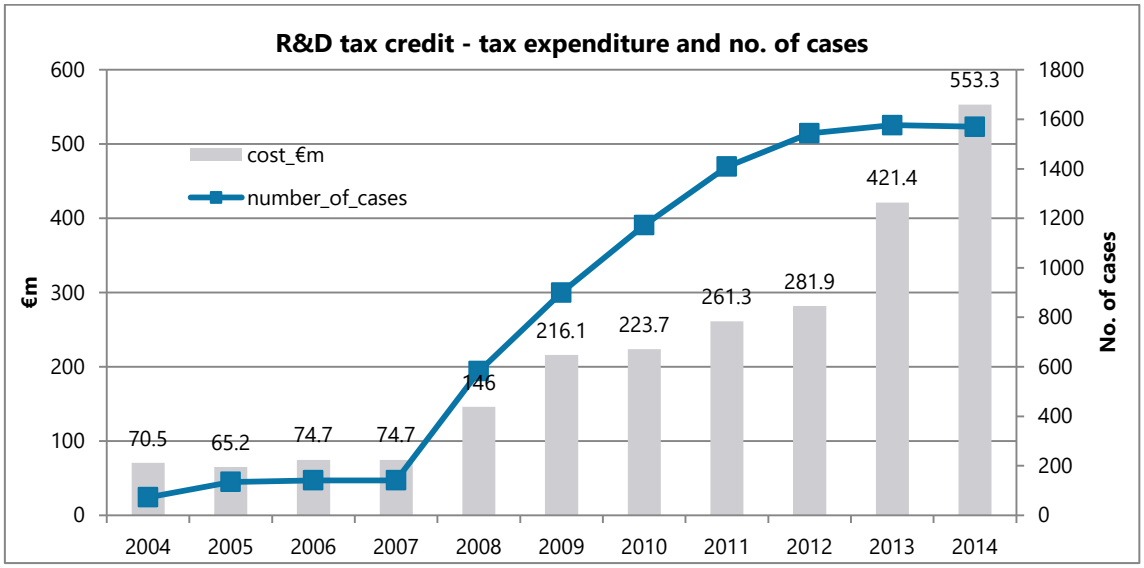
Source: Department of Public Expenditure and Reform: Estimates of Public Expenditure

Over time, RDI expenditure has accounted for an increasing proportion of total DJEI capital spend, increasing from 22 percent in 2001 to an average of 70 percent from 2006 onwards. This reflects both increased policy emphasis in RDI, along with a general move away from grants for capital and employment in line with changes to State Aid rules and Regional Aid Guidelines. It also underlines how recent RDI capital investment is relative to other areas of capital spend.

4.3. R&D Tax Credit

The R&D tax credit must also be considered in assessing the environment of enterprise investment in RDI. The R&D tax credit has become a substantial incentive for expenditure by firms on RDI. A 25 percent tax credit for qualifying Research and Development expenditure exists for companies engaged in in-house qualifying research and development undertaken within the European Economic Area. This credit may be set against Corporation Tax liability. [14]

Figure 4.2 Research and Development Tax Credit (2004-2014)



Source: Revenue Commissioners Statistics http://www.revenue.ie/en/about/statistics/tax-expenditures.html

Data from Revenue shows a significant increase in the number of companies availing of the credit in recent years, from less than 150 in the years 2004 to 2007 to over 1,500 in the years 2012 to 2014. The cost of the credit has increased from less than €100m in the same period to €553m in 2014. In the period 2012 to 2014, the number of companies claiming the credit has generally remained between 1,540 and 1,570 while the cost has increased from €281.9m to €553.3m, indicating significant increased scale of R&D investment within enterprise base. An evaluation of the R&D tax credit by Department of Finance in 2016 found that that of the R&D

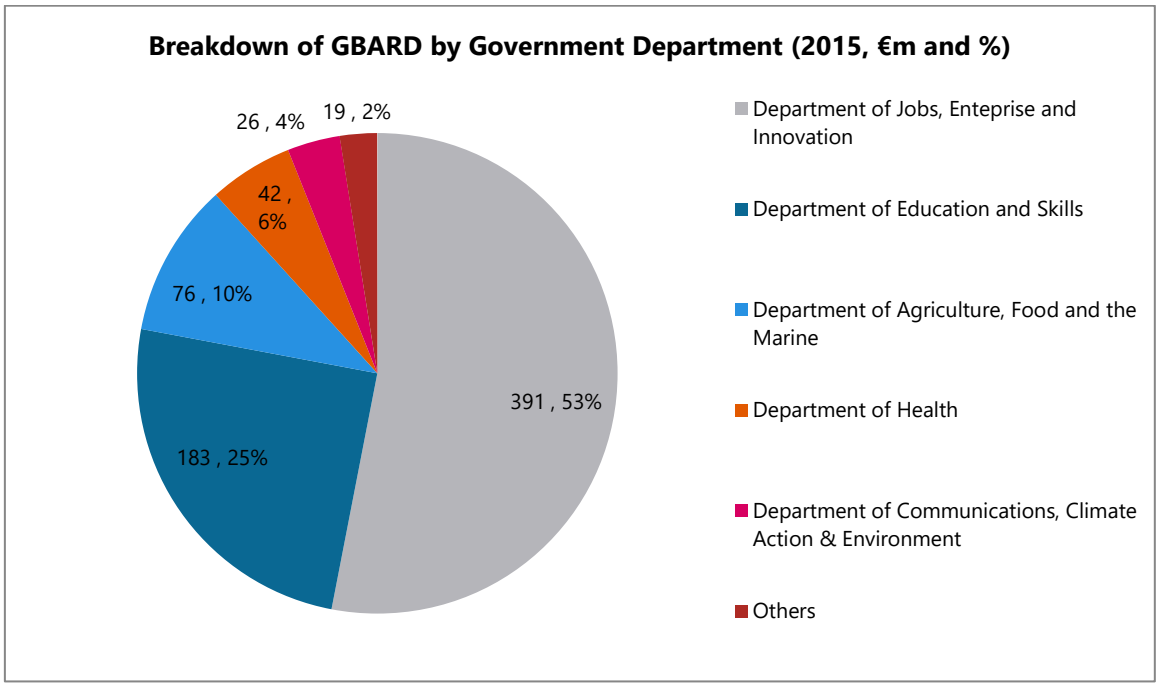
[14] Department of Finance (2016) Economic Evaluation of the R&D Tax Credit http://www.finance.gov.ie/sites/default/files/170214%20R-and-D-Credit-Evaluation-2016.pdf . Note, there was a significant change to the scope of the R&D tax credit in 2009 which allowed, subject to limits, firms with insufficient taxable income to avail of the full value of the credit in a given year to apply to make a claim for one third of the unused credit to be paid in cash. The outstanding amount is either used to reduce future tax liability or is paid out as a payable credit over the next two years.

conducted by firms since 2009, 60% is additional R&D i.e. the tax credit incentivises firms to perform R&D that would not have occurred in the absence of the tax credit policy. For each euro in tax expenditure, the R&D tax credit yields an additional 2.4 euro in R&D expenditure.

4.4. DJEI's contribution to National and Public Expenditure

In looking at the context of DJEI expenditure on RDI, it is important to look at its role and contribution to total public expenditure on RDI and in relation to total economy investment in RDI (Government Budget Allocations for R&D, GBARD).[15] According to the Research and Development Budget (2016) DJEI accounted for 53 percent of total Government Budget Allocation for R&D (GBARD).[16]

Figure 4.3 Government Budget Allocations for R&D by Department (2015)



Source: DJEI (2016) Research and Development Budget (outturn figures).

According to the Research and Development Budget, total direct Government Funding accounted for approximately 27 percent of total estimate spend on Research and Development in the Economy (2014, €798m out of an estimated €2,921m). The remainder is comprised of Enterprises (€1,542m, 53 percent); Funds from Abroad (€544m, 19 percent) and the non-Profit sector (€38m, 1 percent).

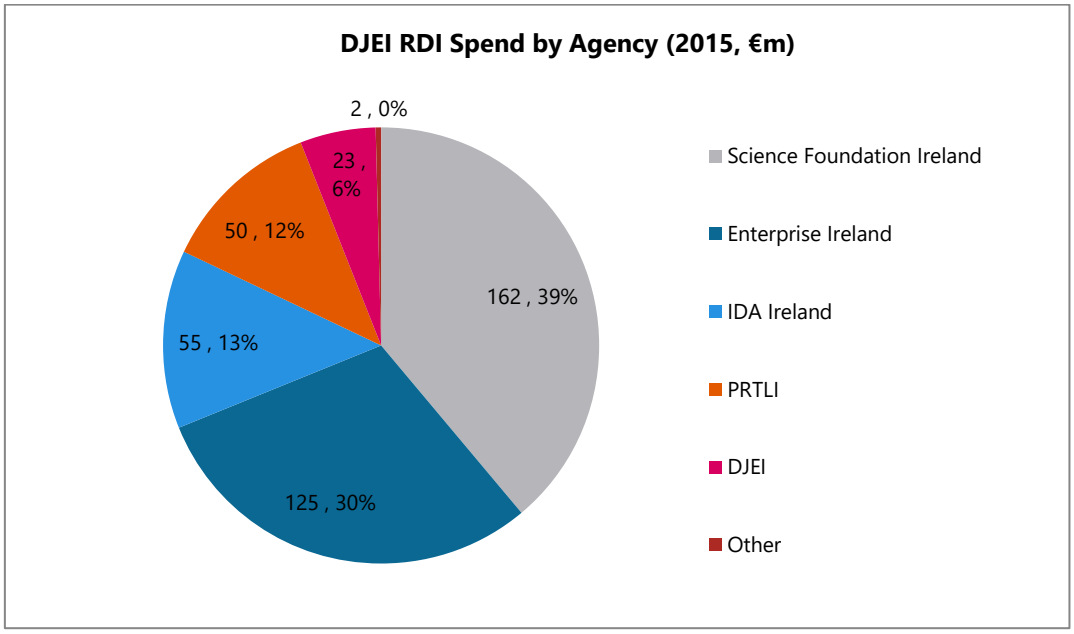
[15] Note, GBARD has only been collected since 2004.

[16] Most of the €183m allocated by the Department of Education and Skills relates to the research component of the HEA "Block Grant" to HEIs. The research component is imputed based on the share of time that academics devote to research. While the research activity of HEIs is taken into account explicitly in the HEA allocation model, the actual allocation of funds within an individual HEI is a matter for that institution.

4.5. DJEI's agencies and funds

DJEI's funding of RDI supports is primarily delivered through its agencies. The following graph shows the distribution of the investment according to agency. The agencies work collaboratively to identify areas of mutual interest, for example, Enterprise Ireland and IDA Ireland client companies may participate in SFI Research Centres. Appendix II provides detailed information on the agency functions and main programmes provided.

Figure 4.4 Distribution of DJEI Expenditure by Agencies (2015)



Source: DJEI (2016) Research and Development Budget; Enterprise Agencies (outturn figures).

Science Foundation Ireland invests in academic researchers and research teams who are most likely to generate new knowledge, leading edge technologies and competitive enterprises. SFI programmes form a key element of the drive to boost Ireland's international competitiveness and attract foreign direct investment. The expansion of SFI's new remit under the Industrial Development (Science Foundation Ireland) Act 2013 has allowed SFI to fund activities in the applied research arena, as well as continuing to provide key supports for oriented basic research. SFI makes grants through its centres and programmes based upon the merit review of distinguished scientists.

Enterprise Ireland is the government organisation responsible for the development and growth of Irish enterprises in world markets. Enterprise Ireland works in partnership with Irish enterprises to help them start, grow, innovate, scale and win export sales in global markets. Enterprise Ireland's RDI competencies are broad with supports for both companies and researchers in Higher Education Institutes to develop new technologies and processes that will lead to job creation and increased exports. Broadly, supports include direct funding to firms (Irish and foreign-owned) and funding for commercialisation and collaboration between enterprises and the research system. Enterprise Ireland also houses the National Support Office for EU Framework Programme funding, Knowledge Transfer Ireland and national support for engagement with the European Space Agency.

IDA Ireland is the inward investment promotion agency focused on promoting Foreign Direct Investment into Ireland through a range of services. IDA Ireland partners with potential and existing investors to help them establish or expand their operations in Ireland. IDA Ireland plays an important role in RDI development by providing funding support to suitable projects in the form of direct grants to industry and referral of client companies to relevant supports provided by other innovation agencies.

The **Programme for Research in Third-Level Institutions** (PRTLI) provides integrated financial support for institutional strategies, programmes and infrastructure in key areas of research spread across all disciplines. The programme supports research in humanities, science, technology and the social sciences, including business and law. It is administered by the Higher Education Authority (HEA). Note, PTRLI was transferred to DJEI in 2010.

Other DJEI funding provided relates to participation in international programmes and specialist research organisations/programmes. See Appendix II for further information. DJEI is responsible for developing and co-ordinating Ireland's input to EU research policies and programmes. DJEI is also responsible for the funding of, and is represented on, the Government Council of the European Space Agency and the policy formulation committees of the following five Inter-Governmental S&T Organisations: European Molecular Biology Conference (EMBC); Co-operation in Science and Technology Programmes (COST); EUREKA; European Molecular Biology Laboratory (EMBL).

4.6. Expenditure by Funding Objective

As presented in the introduction, to simplify the approach for the purposes of this analysis, the expenditure and programmes have been grouped into five major funding categories that reflect major policy objectives. This is to allow for tracking through the logic model from inputs to outputs and outcomes with associated analysis of efficiency and effectiveness.[17] These five broad categories are:

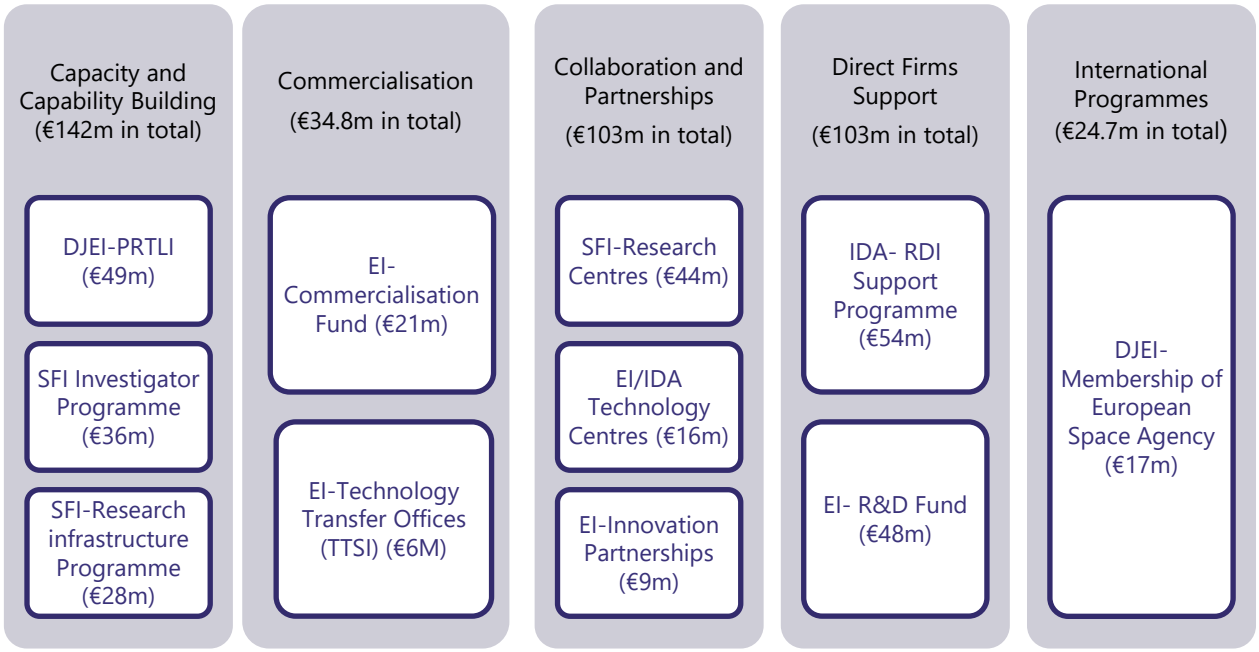
- **Capacity and Capability Building Supports** – i.e. supports that develop human capital and infrastructure;
- Supports for **Commercialisation and Collaboration**;
- **Direct Enterprise Supports**; and
- **International Programmes.**

The major programmes are presented below by broad theme. Together, the programmes account for approximately 78 percent of total outturns by DJEI in 2015. Only programmes with

[17] Note, where more detailed programme or agency data is relied upon when looking at DJEI expenditure by theme, these are based on a combination of sources, including the Science Budget, Annual Reports and Agency Data. In this context, there may be some differences between annual totals as the outturn figures may differ slightly from the estimates figures presented in the above sections.

funding greater than €5m are included. The full list of programmes and expenditure is in provided in the Appendix III for Information. In volume terms, it is worth highlighting that Innovation Vouchers (€4.2m in 2015) account for over 500 academic-industry collaborations a year, which provide an important entry point for many previously non-active companies for innovation. Enterprise Ireland Technology Gateways (€4.1m in 2015) had over 370 collaborations in 2016.

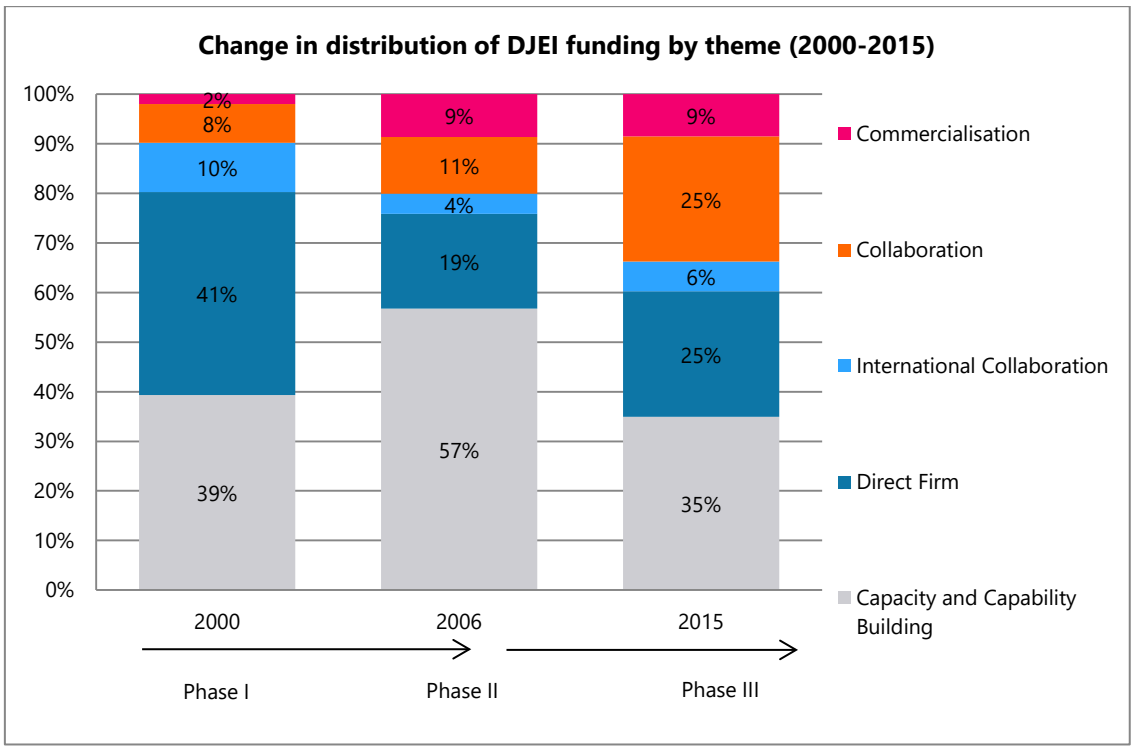
Figure 4.5 Main DJEI Programmes by Theme and Expenditure 2015



Source: DJEI/Agency Data (Enterprise Ireland R&D fund includes equity funding for Innovative High Potential Start Ups)

The graph below shows the relative contributions of the different themes to total funding over the three main phases of the review period as presented in section 3. Overall, there has been significant change in the nature of funding delivered by DJEI over the review period as the policy mix has broadened from capacity and capability building and direct firm supports to additional emphasis on collaboration and commercialisation.

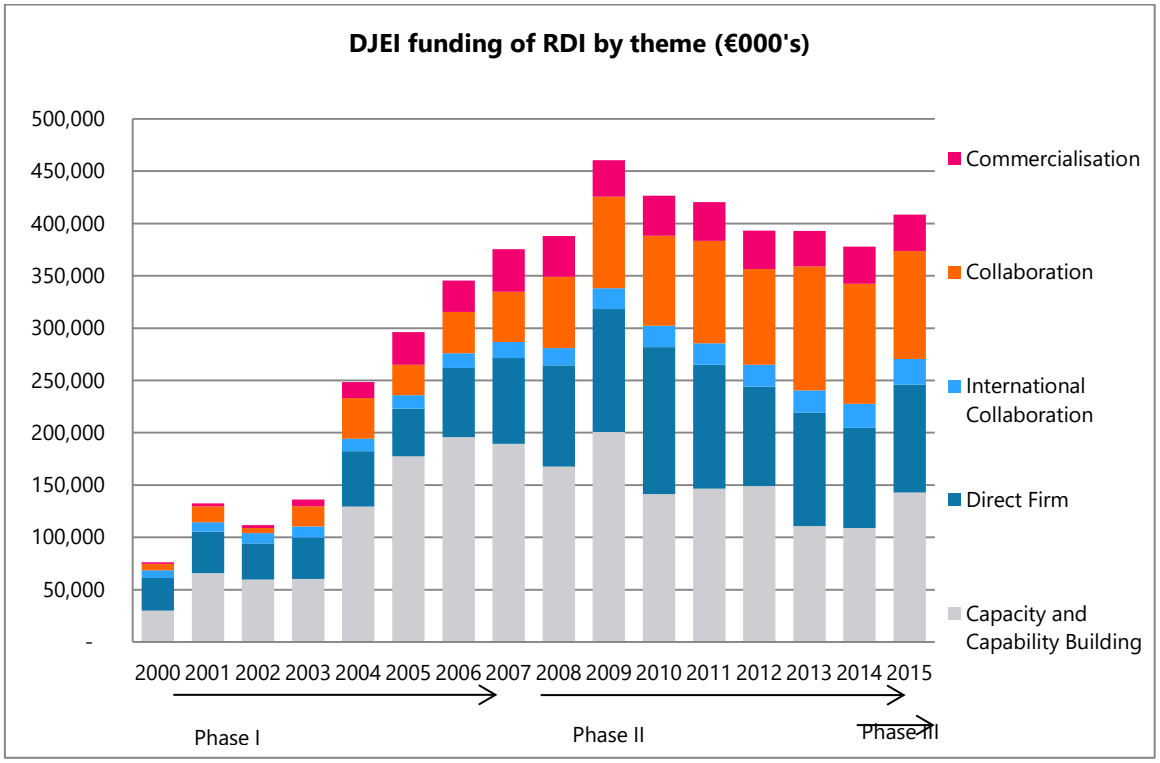
Figure 4.6 DJEI distribution of funding by theme



Source: DJEI (2016) Science Budget and Agency Data

The following graph shows how the nature of DJEI funding of RDI has changed over time reflecting changes in policy focus outlined in Chapter 3. The main trends are:

Figure 4.7 DJEI Funding by Theme (€000's)



Source: DJEI (2016) Science Budget and Agency Data

- In Phase I, annual expenditure increased by 4.5 times between 2000 and 2006 from €76.1m to €345.4m;
- Expenditure increased across all themes, however, the increase was primarily driven by an increase of €166m in Capability and Capacity Building from €30m in 2000 to €195.9m reflecting the policy focus in the Technology Foresight exercise on the need for a significant increase human capital and research infrastructure in order to widen and strengthen the base. In practice, this was mainly delivered through the expansion of the PRTLI in Higher Education Institutes and the establishment of Science Foundation Ireland (Investigator Programme); and
- The other major change in this period is the very significant increase in Commercialisation and Collaboration activities. Commercialisation funding increased from €1.5m in 2000 to €29.7m in 2006 with Collaboration funding increasing from €5.9m to €39.4m in 2000. This activity is primarily driven by SFI and Enterprise Ireland.

The funding in **Phase I** can therefore mainly be described as building up all aspects of the national innovation system, with the main emphasis on building capabilities and capacities. Phase II covers both the increased ambition for Ireland to further develop its research base set out in the first Strategy for Science Technology and Innovation (2006-2013) and the reduction in funding that occurred across Government capital expenditure in the period from 2009 onwards. The data indicates:

- There was a significant ramp up in funding from 2006 to 2009 (€+115.2m), mainly driven by further increases in Collaboration activities (€+48m) but also significant increases in Direct Funding to forms (€+51.3m);
- The increase in collaboration activities reflects increased funding in programmes such as the Enterprise Ireland Innovation Partnerships, Technology Centres and Technology Gateways, SFI Centres for Science and Technology and Strategic Research Clusters;
- In line with increasing Collaboration funding, DJEI's support for International activities also increased, with funding increasing over from €7.5m in 2000 to €24.5m in 2015. This is mainly driven by Ireland's participation in the European Space Agency (ESA) (€17.3m in 2015), which enables and supports Irish companies to bid for ESA contracts;
- The increase of direct funding of firms is reflective of the SSTI policy ambition to increase the number of firms with R&D investment at particular scale and is mainly driven by IDA grants for RDI and Enterprise Ireland's R&D fund;
- This reflects IDA Ireland's increasing focus on RDI activities as a means to move the client base up the value chain and enhance firm embeddedness. It also reflects Enterprise Ireland's broadening mandate in RDI and enhanced strategic focus on increasing the scale and breadth of companies investing and performing R&D activities in this period.

Outturn expenditure declined by 18 percent between 2009 and 2014 in line with tightening capital budgets across Government before increasing by 8 percent to approximately €408m in 2015. The major areas of change in 2015 relative to the 2009 are:

- Capacity and Capability expenditure decreased by €58.1m (-29 percent), primarily due to reduction in the PRTLI funding.
- Direct firm funding decreased by €14.2m (-12 percent), shared roughly equally between IDA Ireland and Enterprise Ireland.
- Collaboration activities have further increased by €15.6m (18 percent), mainly as a result of increased activity in areas such as SFI research centres; IDA Ireland/Enterprise Ireland Technology Centres and Enterprise Ireland Innovation Partnerships and Innovation Vouchers.[18]

4.7. Conclusions

- DJEI capital expenditure on innovation targets a number of aspects of the innovation system through its agencies and programmes.
- Each agency and programme seeks to support different but complementary aspects of the national innovation system.
- Expenditure trends reflect the various policy objectives and changing emphasis over the years.

[18] It is important to note that not all programmes run in all years. For example, the SFI Research Infrastructure Programme (€34.9m in 2012 and €28.8 in 2015) did not run in 2013 and 2014 due to the long run nature.

5. Outputs

Review questions

- What are the outputs? How many are produced? Are output targets met?
- How long does it take to produce an output? Are time targets met?
- How complete and accurate are outputs?
- What are the key indicators for measuring the operational efficiency of the programme?
- To what extent have output and result indicators been specified for the programme?

5.1. Introduction

This section provides indicators of the outputs from DJEI investment. Note, as some research activity draws funding from a range of different sources, nationally and internationally, not all outputs relate entirely to DJEI funding. Outputs have been separated into the main investment themes:

- Capacity and Capability Building – Outputs from Academic Funding;
- Commercialisation and Collaboration Outputs; and
- Firm level Outputs.

Outputs have been collected from 2006 to 2016 where possible. This is to provide some accommodation for the lag effects of investment in RDI taking place and some outputs taking years to emerge. Summary data on outputs from engagement in the European Space Agency is provided in Appendix IV.

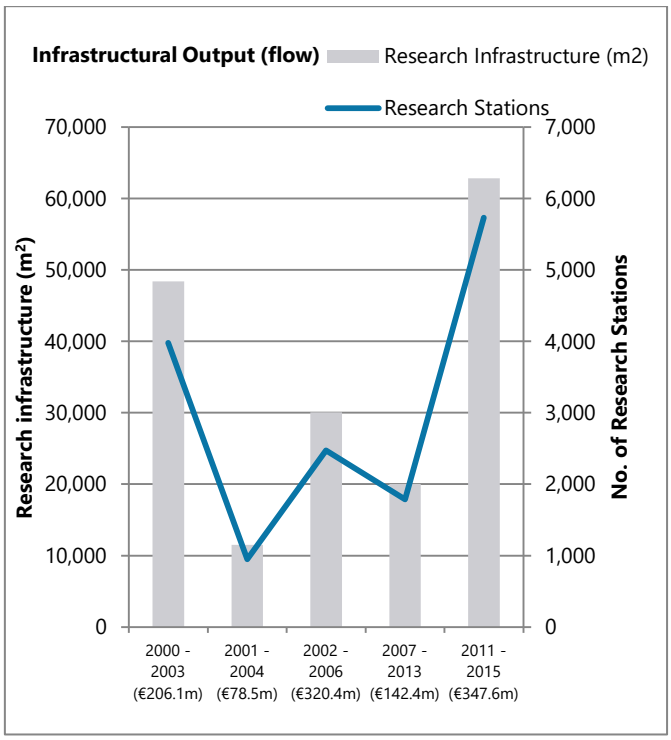
5.2. Academic Outputs (Capacity and Capability Building)

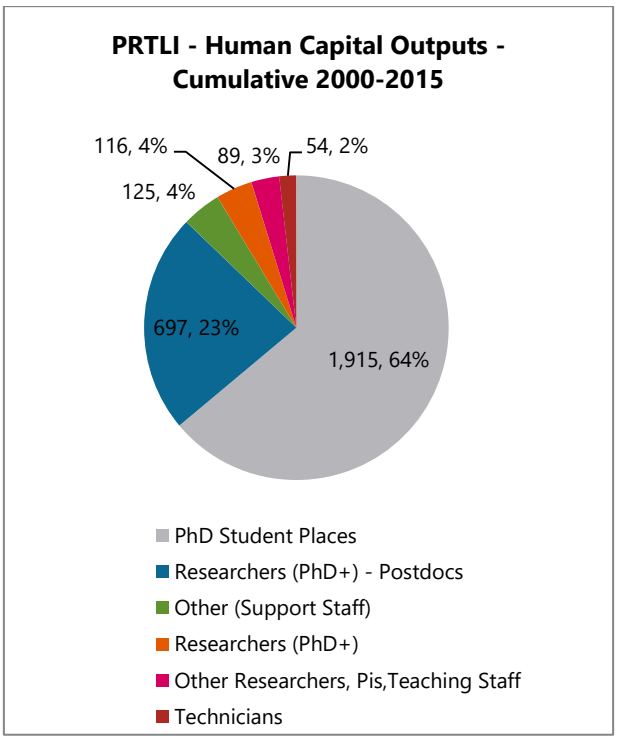
The PRTLI provides an important supporting role for other aspects of the research base as demonstrated in the framework in Appendix V. As evident, the PRTLI provider a foundation for research activities carried out by SFI investigators or through the Irish Research Council to develop by facilitating research infrastructure and capability development. Enterprise Ireland supports the commercial potential research through providing platforms for commercialisation within Higher Education institutes and collaborations between industry and the research base. Ultimately, this feeds through to economic activity in the form of human capital, commercialisation of research and efficiency savings.

The outputs from investment are infrastructure and human capital which have the objective of building capacity and capabilities in the system. Outputs from the Programme for Research in Third Level Institutes are presented below for the period 2000 to 2015. PRTLI funding has transferred from Department of Education and Skills to DJEI since 2010, however, it remains administered by the Higher Education Authority. Cumulatively, the programme has produced:

- Over 172,000m^2 in research infrastructure and over 14,900 research stations; and
- 3,000 researchers, of which approximately two thirds (1,915) are PhD student places.

Figure 5.1 Outputs from Programme for Research in Third Level Institutions

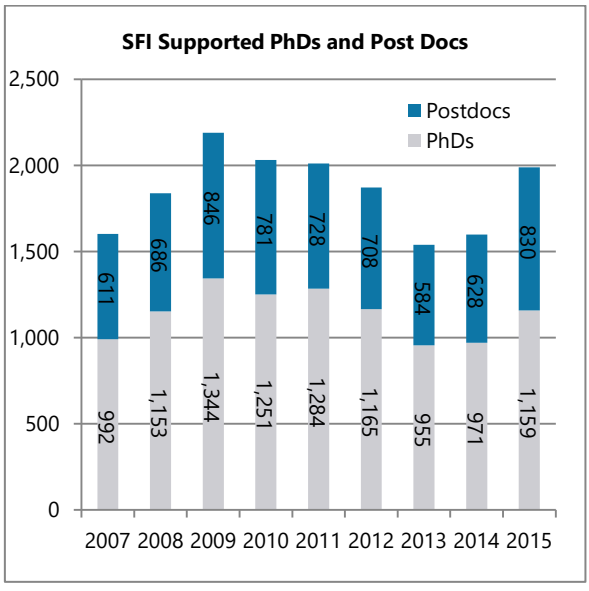


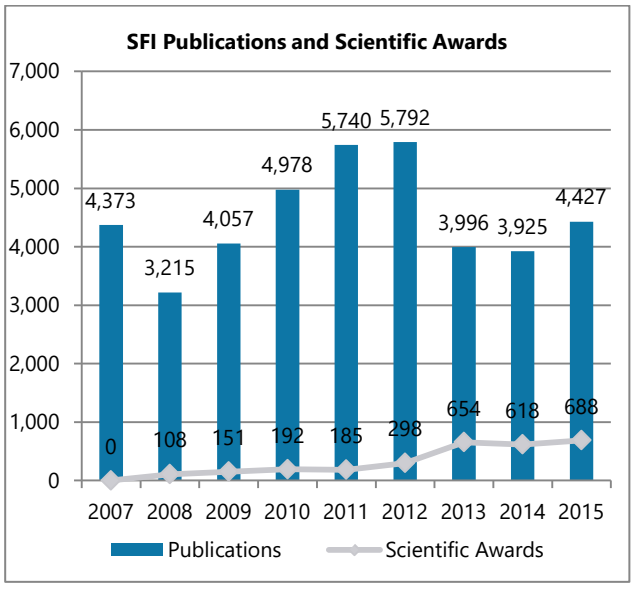


Source: Higher Education Authority

The following graphs shows the major SFI academic outputs which support capability building within the National Innovation System. SFI academic outputs reflect a range of policy objectives, including the need to develop the talent base (PhDs and Post) and enhanced quality in the research base (Publications, Awards). In context, it is also important to consider that the outputs here also have a critical impact on the data presented in the next section on Commercialisation and Collaboration by providing a foundation for this activity.

Figure 5.2 Science Foundation Ireland - Main Academic Outputs





Source: Science Foundation Ireland – note PhDs refers to no. supported in a given year (not graduates)

- The number of SFI supported PhDs and post-docs declined by 30 percent between 2009 and 2013, but have since recovered to just under 2,000 by 2015;
- Publications are another key output of research funding by SFI. On average, SFI funded research yields 4,500 publications per year on average. In total, there have been over 40,500 publications supported by SFI research in the period; and
- There has been a major increase the in the number of scientific awards secured by SFI funded research, increasing 6 fold from 108 in 2008 to 688 in 2015, which is an indicator of increasing quality in the research base.

In interpreting the data, it is important to consider that output measures such as the number of Scientific Awards and Publications do not have a strong relationship with trends in the annual investment. This is because these types of outputs are the result of investment in capability and capacity over many years. In addition, some outputs may be the result of joint funding between SFI and other institutes and/or international funding.

In this context, there should be caution taken in attempting to create cost-efficiency (cost per output) measures as the relationships between inputs and outputs are not linear. Rather they are the result of sustained investment and are a reflection of increasing quality in the system. It is more appropriate to treat the investment as yielding a number of types of output which together build capability and capacity in the system, either quantitatively (through numbers of researchers) and from a quality perspective (through awards and publications), both of which are important for the National Innovation System to grow and develop.

Furthermore, these outputs then provide an important supporting base for commercialisation and collaboration outputs which are presented in the section below, and therefore have important downstream implications beyond counting the outputs alone. This reinforces the view set out in the introduction of the need to consider DJEI's investment as providing a portfolio of measures which contribute in different but complementary ways to wider National Innovation System.

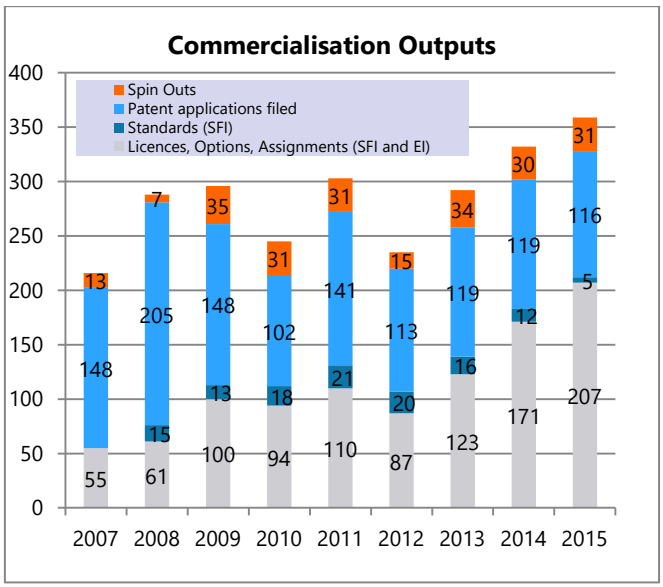
5.3. Commercialisation and Collaboration Outputs

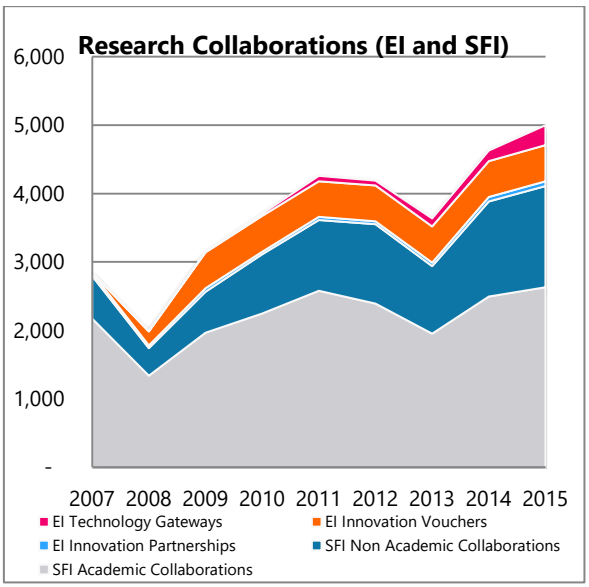
Commercialisation and Collaboration activities are not only important for enhancing commercial capabilities and relevance within the research system, they are crucial for broadening the base of firms that may not have the internal capabilities to conduct the research independently. They therefore represent important levers for incentivising RDI activity and investment in the enterprise base additional to research that may be undertaken in-house by firms or within the public research system. The main outputs from commercialisation of public research activity are:

- Licenses, Options and Assignments;
- Patents;
- Spin out companies; and
- Standards approved/ratified by standardisation bodies.

In addition, collaboration activity represents an important indicator of the degree of engagement between enterprise and the public research base.

Figure 5.3 Commercialisation and Collaboration Outputs





Source: Enterprise Ireland; Science Foundation Ireland

As presented in section 4, funding in the areas of commercialisation and collaboration has increased significantly over the years from an average of €28m per annum in the years 2000-2005 to €121m in the years 2006-2015 and increased outputs of this investment are now materialising. In broad terms, from a relatively low base in 2006 there have been significant relative increases in the volume of commercialisation and collaborative activity, which is a reflection of both the increased funding and broadening national policy objectives to increase activity in these areas. Since 2012, commercialisation outputs have increased driven primarily by spin-outs and licences, options and assignments, while collaborations have increased from an average of 2,900 per annum in the period 2007-2010 to 4,350 per annum for the period 2011-2014. This represents significant progress from a low base.

Enterprise Ireland estimates that its commercialisation and collaboration activities support approximately 1,200 researchers per annum on industry-focused projects, which enhances the commercial capabilities within the public system. In addition, SFI analysis of its core basis research scheme (Investigators Programme) has found that 31 percent of Investigators Programme awards produced a scientific article that was later cited in a patent. This indicates that basic research programmes deliver economically relevant outputs further downstream, alongside the other impacts that arise from the projects.

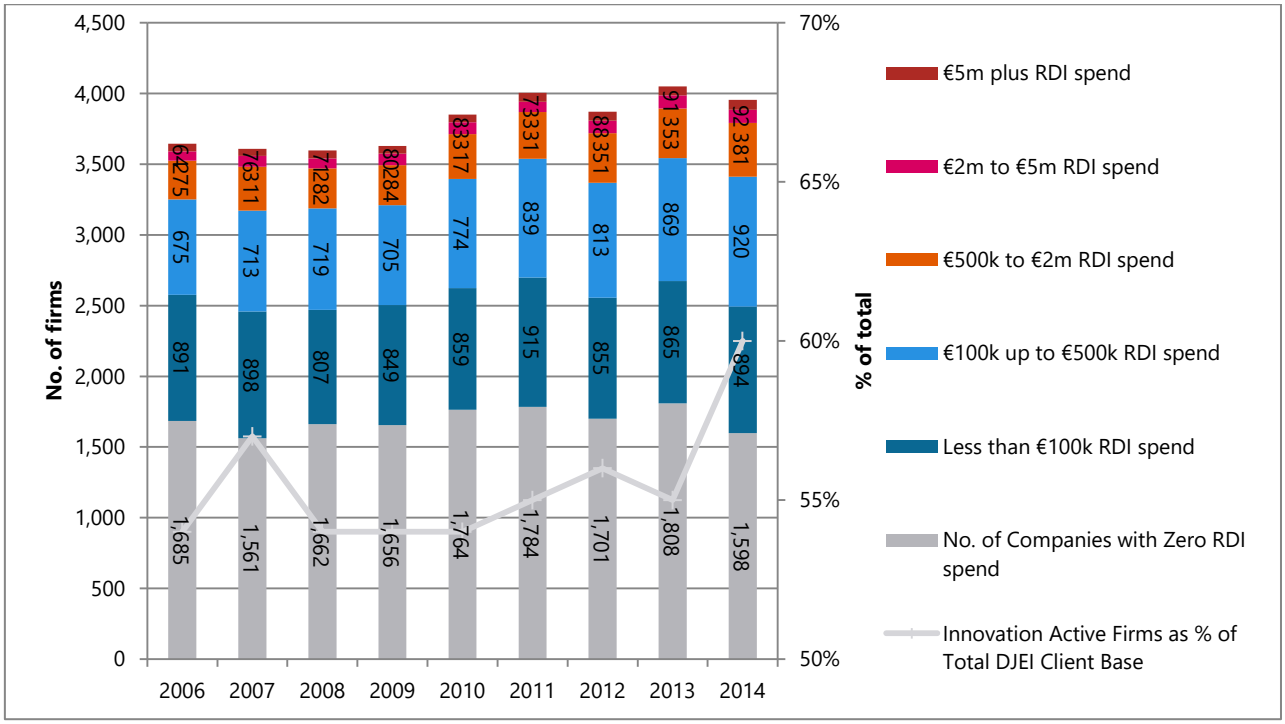
Again, there is caution required in interpreting the results relative to the investment. It is clear the outputs can differ year to year. This is due to the fact that outputs do not materialise at an equal pace or scale and therefore cost-per-output metrics would not deliver an accurate assessment of efficiency in the system, nor would they take into account any measures of quality (for example, in terms of the commercial value of one licence or patent versus another).

5.4. Firm Level Output

The main firm level indicator from DJEI's perspective is related to the policy objective for broadening of the base of firms engaged in RDI and the scale of investment they are making.

The number of firms engaged in RDI is a reflection of the direct supports to enterprise but also the wider impact of investments made in human capital, infrastructure, collaboration and commercialisation. The following graph assesses the number of companies in the DJEI client base and the level of investment they are making in RDI according to various scales.[19]

Figure 5.4 No. of Firms by Level of RDI Expenditure (2006-2014)



Source: DJEI Annual Business Survey of Economic Impact

Overall, the number of innovation active firms within the DJEI client base has increased by 398 companies (20 percent) in 2014 relative to 2006. Within this trend:

- The number of companies with zero expenditure on RDI has declined by 5 percent;
- The number of companies with less than €100k annual expenditure has remained broadly the same;
- Companies with annual spend of €100k to €500k has increased by 245 (36 percent);
- Companies with annual spend of €500k to €2m has increased by 28 (44 percent);
- Companies with annual spend of €5m plus has increased from 54 to 71 (31 percent); and
- In total, the proportion of DJEI firms that have RDI expenditure has increased from 54 percent of the total base to 60 percent of the base.

[19]Data is from the DJEI Annual Business Survey of Economic Impact, a survey of 4200 client companies of Enterprise Ireland, IDA Ireland and Údarás na Gaeltachta employing ten or more employees in Ireland. It also includes a small number of High-Potential Start-Up (HPSU) companies with employment of less than 10 where there is an expectation that their employment will exceed 10 in the following survey. The data therefore excludes non-HPSU agency clients with less than 10 employees.

It is important to reiterate that this upward trend is not just a result of direct supports for firms but of investment in the wider innovation system, for example, the investment in human capital which has widened the skills pool available to enterprise to engage in RDI, which supports commercialisation and collaboration activity, which in turn facilitates knowledge transfer and mobility of researchers between the research and enterprise bases. It also reflects the significant increase in collaborative activity presented under the outputs in 6.3 in addition to wider effects that must also be considered such as the R&D tax credit or the increasing engagement by Irish enterprises in European Framework programmes for research.

Furthermore, notwithstanding the improvement in performance, it is clear that there remains a large cohort of companies that either not innovation active or engaged in substantial RDI. Out of the total base of 3,956 companies in 2014 (with 10 employees or more) 2,340 (63 percent) of companies have either no expenditure or less than €100k expenditure on RDI. This represents a significant scope to both broaden the number of companies engaged in RDI and increase the scale of investment within companies that are already active.

5.5. Conclusions

- In broad terms, the key trends are there have been overall increases in activities and outputs relative to the investment. Investments in infrastructure and human capital have provided the subsequent foundation for downstream RDI activities in terms of commercialisation, collaboration and in-house innovation;
- Overall, the proportion of innovation active firms has increased from 55 percent of the total base to 60 percent in the period 2014. Notwithstanding this increase, 63 percent of companies have either no expenditure or less than €100k expenditure on RDI. This represents a significant scope to both broaden the number of companies engaged in RDI and increase the scale of investment within companies that are already active;
- Outputs such as scientific awards, spin outs, licences, publications, collaborations, publications or firms engaged in RDI, do not have a strictly linear relationship to funding and are dependent on years of sustained investment in building capacities and capabilities in the system, for example, in the form of developing human capital and providing access to appropriate research infrastructure and specialist equipment;
- Therefore, it is necessary to emphasise that investment in innovation has multiple and often interrelated outputs that can take years to materialise;
- Furthermore, as stated earlier, DJEI funding only accounts for just over half of total public investment in RDI. Other public and international funding (e.g. European Framework) also contributes significantly to the outputs, directly and indirectly and therefore direct attribution of outputs relative to inputs is not always possible by taking a macro approach such as in this review. This provides additional impetus for mapping how the national innovation system is comprised and operates.

6. Outcomes and Impacts

Review Questions

- *What are the medium to long term impacts on the targeted beneficiaries?*
- *What are the wider socio-economic effects of the programme?*
- *Is it possible to isolate the programme contribution to wider impact?*
- *Are there impact indicators to measure the socio-economic effects?*
- *Can impact indicators, or proxy indicators, be specified for this?*

6.1. Introduction

This section presents the main indicators of impacts from DJEI investment in RDI activity. Previous DJEI evaluation of RDI programmes have dealt with the challenges around determining causality, deadweight and additionality of supports. This is explored further in section 8.

It is important to emphasise the interdependencies between the outputs and impacts. For example, the quality of the research base depends on the investment in infrastructure and flow of researchers from the higher education system. The number of researchers working in enterprise requires long term investment in industry relevant researchers. New firms engaged in RDI depend on building the infrastructure for commercialisation and collaboration, in addition to the stock and flow of human capital. The quality of publications impacts on Ireland's citation ranking, which also feeds through to Ireland's attractiveness internationally as a base for RDI activity. In this context, impacts do not simply connect to one output but are often the result of the portfolio of complementary measures. As referred to at the beginning (and similar to the analysis of outputs), the RDI landscape is by necessity busy and complex, with impacts materialising in various ways and generated for many years. Finally, it is important to highlight again that DJEI accounts for approximately half of total Government expenditure on RDI. The impacts presented here also result from investment outside of DJEI (other exchequer, international, private) that is beyond the scope of this review.

6.2. Review of Academic and Empirical Evidence – International and Ireland

An extensive body of evidence links innovation to productivity and economic growth. A recent European Commission report points to empirical evidence in a number of studies:[20]

- Two-thirds of economic growth in Europe from 1995 to 2007 derives from research, development and innovation;
- Research and innovation accounted for 15 percent of all productivity gains in Europe in the period 2000 to 2013. For Ireland it is estimated to be 30 percent;
- An increase in 10 percent of investment in R&D is associated with productivity gains of between 1.1 and 1.4 percent and estimated impact of 0.2 percent in GDP;

[20] DG Research and Innovation (2017) The Economic Rationale for Public R&I Funding and its Impact

- During the global economic crisis, employment in knowledge intensive areas in the EU grew from 28.9 million in 2008 to 29.3 million in 2013;
- The private rates of return for enterprise from investment in RDI is estimated to be 10 to 30 percent. Rates of return are estimated to be higher for those companies that proportionately invest more in R&D; and
- The impacts of RDI vary across countries with factors such as macroeconomic stability, functioning markets, financial conditions, human capital, openness to trade and distance from technological frontier playing significant roles in returns from RDI investment.

Specifically with regard to the impacts of **public investment** in RDI, the report estimates:

- Public R&D drives productivity growth. An increase of 10 percent in public R&D results in an estimated increase of 1.7 percent in total factor productivity. However, not all studies have been able to find such a positive link;
- Some studies have calculated the economic returns to public R&D to be around 20 percent i.e. for every 100 euros of public R&D invested, the economy expands by 120 euro; and
- An evaluation of the Seventh European Framework programme estimated it will contribute to an increase of €50 billion euros to GDP and 160,000 additional jobs over a 25 year period.

In the Irish context, recent research by ESRI estimates that on average, a 10 per cent increase in investment in knowledge-based capital per employee is found to increase firm productivity by 2 per cent. Knowledge Based Capital comprises a broad range of intangible assets such as: computerised information (computer software, and data sets); research and development (R&D); intellectual property assets (designs, copyrights, patents, licences); branding; organisational know-how; and employees' skills. The research results indicate that the size of the impact is larger for Irish-owned firms, increasing productivity by 3.6 per cent in comparison to 2.4 per cent for foreign-owned firms.[21]

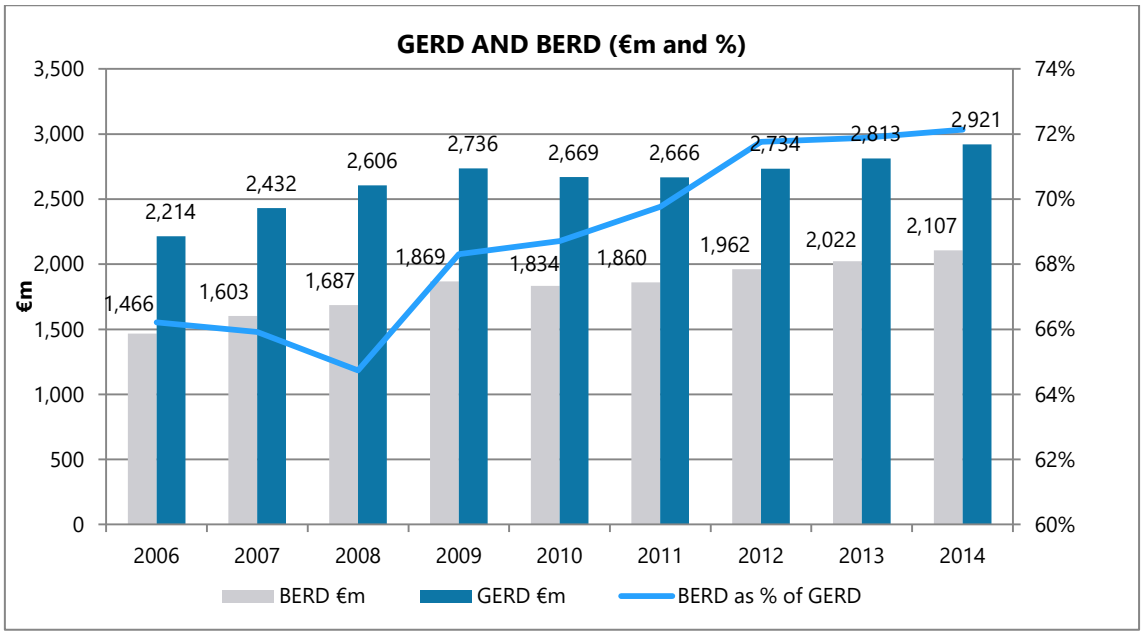
6.3. Investment by Firms in Research and Development

The most relevant indicator of DJEI investment is the overall investment activity by firms in Research and Development (Business Expenditure on Research and Development, BERD). This is related to DJEI's overarching objective to support enterprise oriented research through a number of complementary channels as outlined in previous chapters, with the ultimate aim of enhancing RDI activity in enterprise. The table below shows that BERD has increased by 44 percent from €1,466m in 2006 to €2,107m in 2014. This has increased at a rate ahead of Gross

[21] ESRI (2017) Investment in knowledge-based capital and its impact on productivity http://www.esri.ie/publications/investment-in-knowledge-based-capital-and-its-impact-on-productivity/

Expenditure on Research and Development (comprised of business (BERD), higher education (HERD) and government expenditure on research and development (GOVERD).

Figure 6.1 Trends in Business Expenditure on Research and Development (BERD) and Gross Expenditure on Research and Development 2006-2014



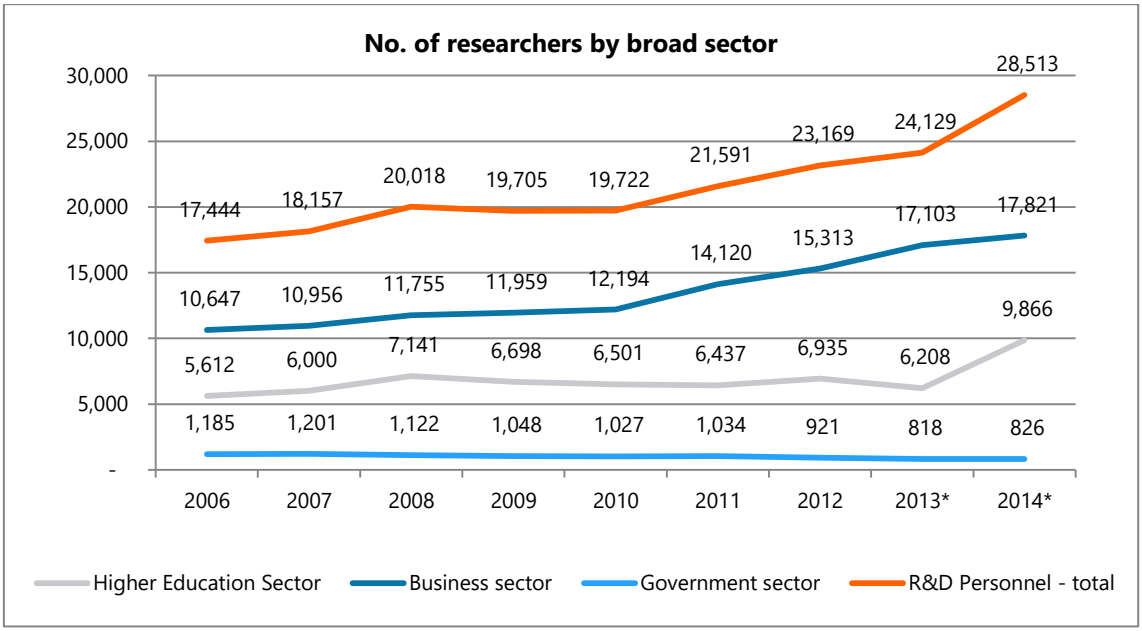
Source: DJEI Research and Development Budget (2016)

Overall, BERD has increased from 66 percent of total GERD in 2006 to 72 percent in 2014. In turn, this means that BERD has been the primary driver of the overall increase in investment in R&D in the economy in the period. This is primarily due to relatively low increases or decreases in public expenditure on R&D over the same period. It also likely reflects changes to the R&D tax credit to firms in 2009 which considerably widened the base of firms eligible for the relief.

6.4. Number of Researchers Working in Enterprise

Another main impact indicator related to DJEI investment is the number of researchers working in enterprise. This reflects policy objectives such as developing the human capital base and knowledge transfer from the research base to enterprise. The long term nature of this type of investment and activity must be recognised as researcher careers develop over many years with mobility between public and private research systems.

Figure 6.2 No. of Researchers by Broad Sector



Source: DJEI Research and Development Budget (2016). Note, from 2014 on, there is a break in the data series due to the inclusion of doctoral students in the numbers for the first time in 2014.[22]

- Overall, the number of researchers working in the economy grew by over 11,000 (63 percent) from 2006-2014. Within Higher Education Institutes the growth was 4,254 (76 percent), the majority of which is primarily due to the inclusion of doctoral students within the researcher numbers from 2014. Otherwise, the researcher population within Higher Education has held broadly constant.
- The general increase in the researcher population in the economy overall represents a potential enhanced pool available to the enterprise base in future years. The number of researchers working within enterprise has increased from almost 10,700 in 2006 to over 17,800 in 2014 (67 percent). This indicates a major increase in the level of knowledge transfer to the enterprise base in the time period and enhanced linkages between the research and enterprise base. SFI analysis finds that 53 percent of team-members are in the private sector 6-8 years after the end of the SFI award.
- The corollary of this trend is that a significant decrease in PhD enrolments in the higher education system is likely to have a knock on impact for skills base available to the enterprise sector in the coming years and therefore the capability for enterprises to invest and engage in RDI. HEA statistics show the number of PhD researcher enrolments has decreased by 11.5 percent from a peak of 7,684 in 2012 to 6,800 in 2015, which represents a significant reduction in future skills supply.

[22] The inclusion of doctoral students is in line with the guidelines set out for collecting and reporting data in the Frascati Manual 2015

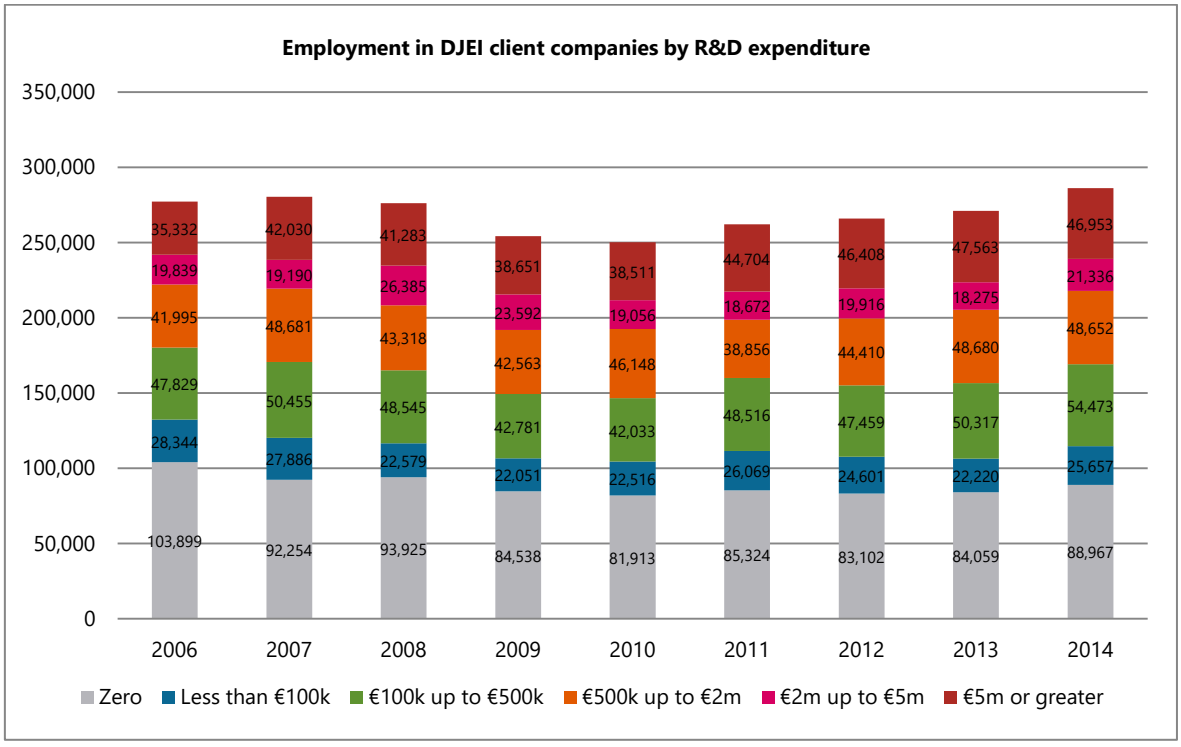
6.5. Relative Performance of RDI Active Firms vs Non RDI Active Firms

A further interest of impact of RDI from a DJEI perspective is whether or not there are disproportionately higher economic returns from RDI firms compared to firm that are not engaged in RDI. The key indicators are employment, exports and value-added per employee.

Employment

The following graph shows that there were significant employment declines across the DJEI client base from 2007 to 2010 in line with the domestic and global recessions, with a loss of approximately 30,000 jobs. Since 2010, employment has recovered by 36,000 jobs. The main drivers of the increase are firms with R&D expenditure greater than €100k. Average annual growth for these firms ranged between 2 and 3.9 percent in the period 2006 to 2014, compared to -1.7 percent for firms with no R&D expenditure.

Figure 6.3 Employment in DJEI agency companies by RDI expenditure levels

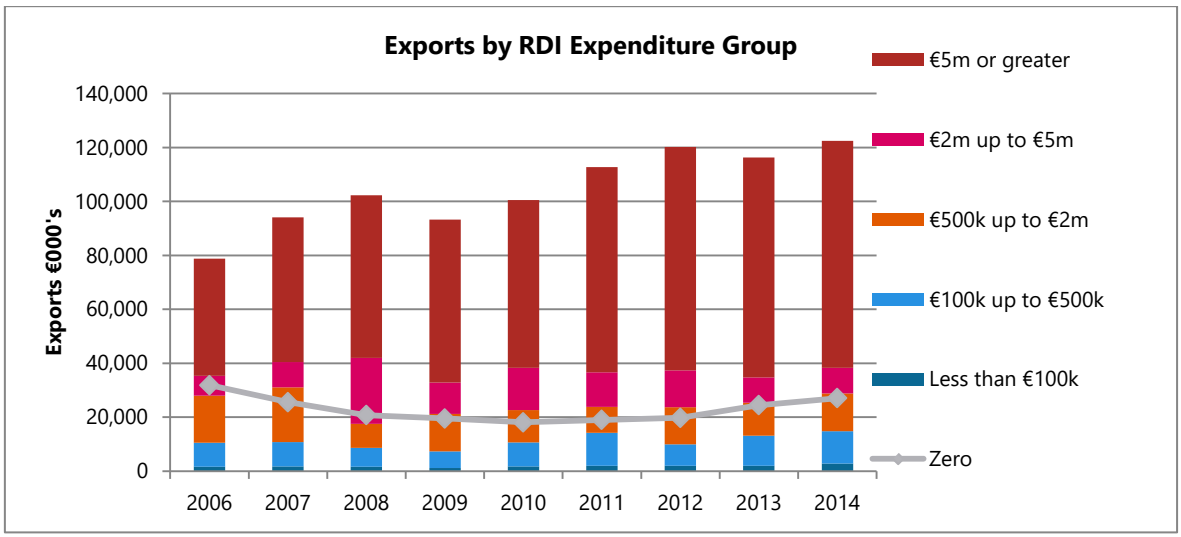


Source: DJEI Annual Business Survey of Economic Impact

Exports

A similar trend is evident with regard to exports. Overall, exports grew by €38.8 billion over the period. Companies with zero annual expenditure on RDI experienced average annual growth in exports of -1 percent in the period 2006 to 2014. This compares to 4 percent average annual growth in exports for the period in total and average annual growth rates of between 3.6 percent and 16.3 percent for companies with RDI expenditure. Employment in non-RDI active firms is split relatively evenly between Irish-owned firms (49 percent) and foreign owned (51 percent), although foreign owned firms account for 26 percent of total number of non-RDI active firms, with a relatively small number of firms accounting for a large portion of employment.

Figure 6.4 Exports in DJEI agency companies by RDI expenditure levels

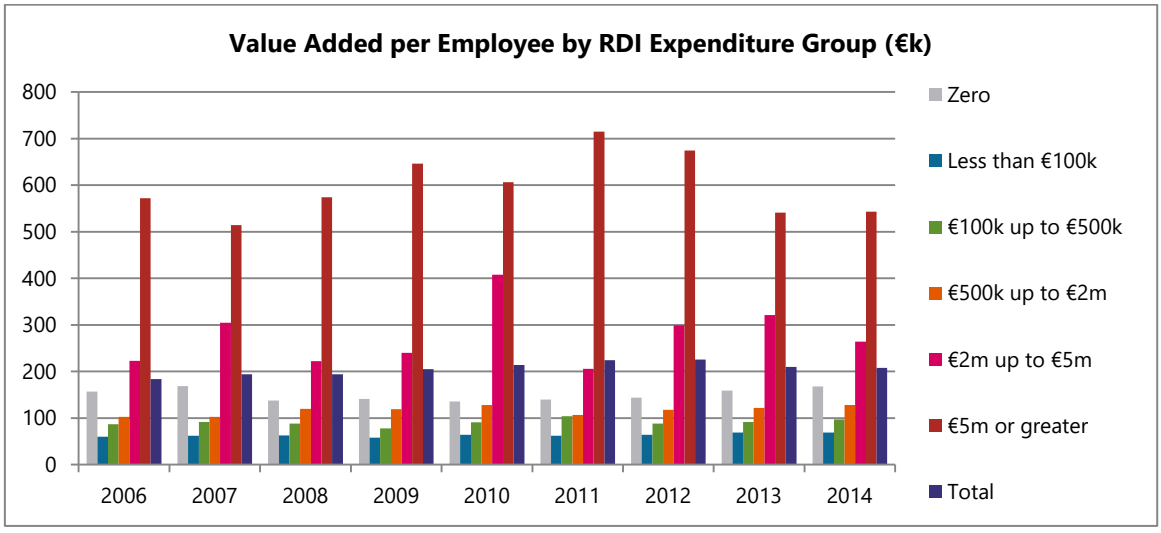


Source: DJEI Annual Business Survey of Economic Impact

Value-Added

Finally, value-added is perhaps the most important indicator of innovation impacts as it is a primary proxy for productivity, which is ultimately the only source of sustainably increasing wealth in the economy. Value-added per employee has increased across all cohorts within the time period, on average by €23k for the entire DJEI base. At a high level, companies with expenditure of €2m and above on RDI are the primary drivers of productivity performance. There are significant differences across cohorts by RDI with Value-added per Employee increasing by 1 percent on an annual average basis for companies with zero RDI expenditure during the period 2006 to 2014, while for companies spending less than €100k and up to €5m per annum had growth in Value-added per employee of between 2 to 9 percent on an average annual basis. Value Added per employee actually decreased slightly in the cohort with RDI expenditure of greater than €5m, however, due to the small population and high concentration of RDI activity, this is likely by a small number of firms.

Figure 6.5 Value Added in DJEI Agency Firms by RDI Expenditure Levels

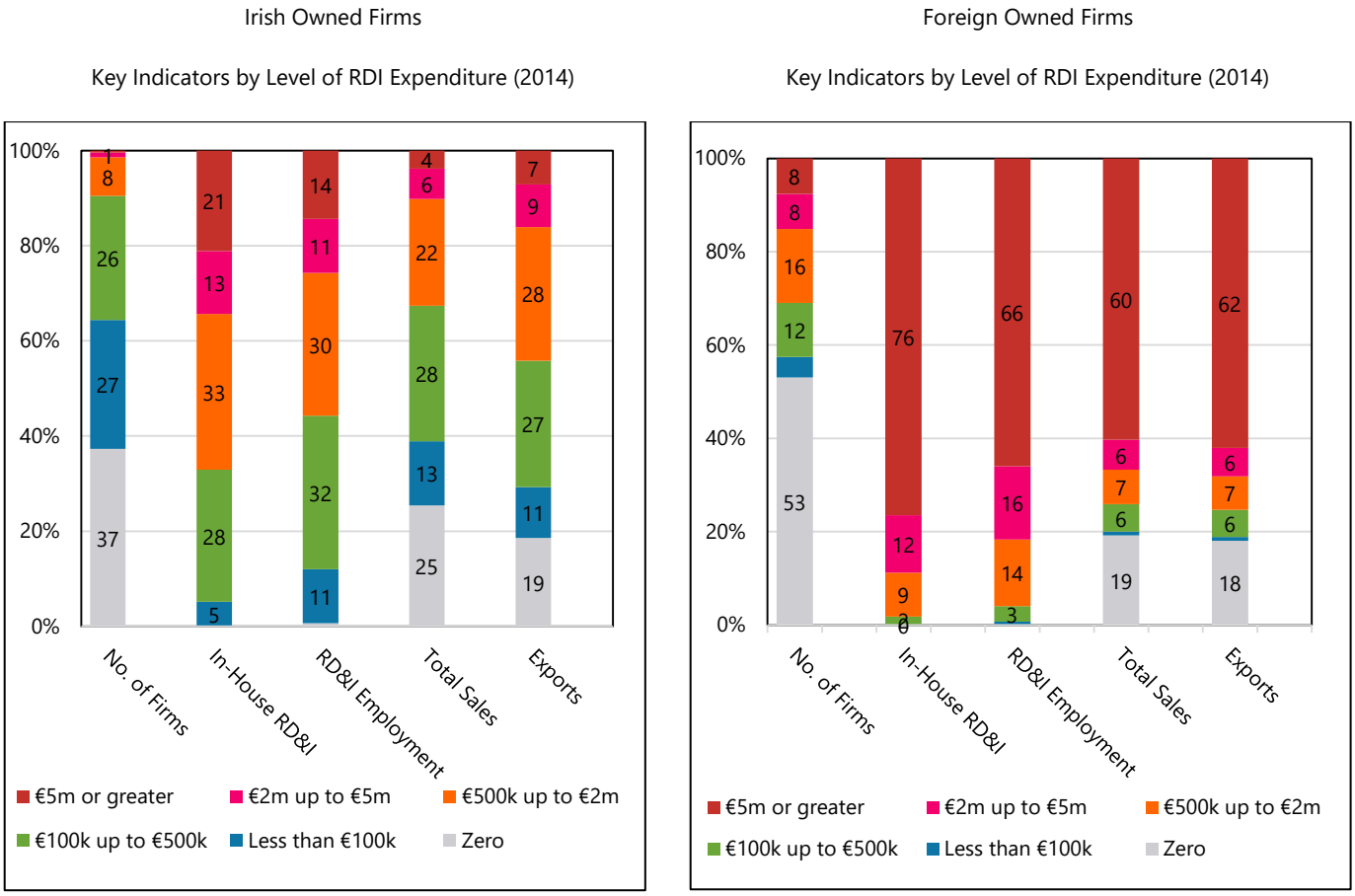


Source: DJEI Annual Business Survey of Economic Impact

6.6. Concentration of Activity

The graphs below provides indicators of the disproportionate effect RDI active firms have on the key performance indicators for the DJEI client base. The analysis is split between Irish owned firms and foreign owned firms as there are significant different profiles between these cohorts in terms of size and sector.

Figure 6.6 Irish and Foreign Owned Firms – Relative Shares of RDI and Economic Indicators



Source: DJEI Annual Business Survey of Economic Impact

Within the Irish owned base:

- RDI active firms account for 63 percent of total firms, 75 percent of total sales and 81 percent of exports.
- Overall, 37 percent of Irish owned firms within the DJEI client base have zero expenditure on RDI. These firms account for just 25 percent of total sales and 19 percent of exports.

Within the Foreign Owned FDI base:

- Concentration is higher within this population, with a relatively small number of firms accounting for the majority of activity.
- 47 percent of Foreign Owned firms have expenditure on RDI. These firms account for 81 percent of total sales and 82 percent of total exports.

- 16 percent of Foreign Owned companies have expenditure of €2m and above. These companies account for 88 percent of in house RDI expenditure; 82 percent of RDI employment; 66 percent of sales and 68 percent of total exports.

Notwithstanding the disproportionate effects, the data also highlights that:

- 37 percent of Irish owned firms (with 10 employees or more) have no R&D expenditure and a further 27 percent have expenditure under €100k. This means that just one third of Irish owned firms have substantial expenditure on R&D (over €100k).
- Similarly, 53 percent of foreign owned firms have no R&D expenditure with a further 4 percent with expenditure of €100k or less This represents a sizable cohort of multinationals that are could be deeper embedded with RDI activity.

The scale of firm investment is ultimately reflected in Ireland's performance gap relative to other countries in terms of private investment in RDI (see section 7.8). In this context, there is scope for both broadening the base of firms and but also deepening the investment levels within the RDI active base in line with policy ambitions to be among the top innovation performers.

6.7. Synergies, Leverage and Crowding-in Effects

Another key measure of impact is the extent to which State support leverages additional funding from private or international sources.

Empirical Analysis

Specifically with regard to DJEI supports, recent empirical analysis of EI and IDA R&D grant-aid data to firms over the 2000-2012 period and ABSEI data from 2000-2013 indicates that providing grant aid support for R&D activity in firms leads to increased R&D expenditure in agency firms.[2324:] The study indicates that grant winners experience a 19.8% higher R&D growth rate than 'similar' non-grant winners in the year after winning. The return per Euro invested is about 12 Euro relative to the average non-grant winning firm, but declines to 1.64 when benchmarked against 'similar' non-grant winners, suggesting grants help stimulate additional private investment.

Evaluations

Various evaluations have made estimates of leverage impacts of programmes. The table below shows that public funding is complemented with significant additional private or international funding across a range of schemes, which have varying objectives. At an overall level, Enterprise Ireland estimates the private contributions account for 60 percent of total RDI project investments with the average EI contribution of 40 percent.

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[23] Using a novel proprietary dataset of 1,806 R&D grants awarded to Irish domiciled firms for the period 2003-2012, and the ABSEI data for 2000-2013

[24] Measuring the returns to investment in innovation: Do R&D grants influence corporate innovation, performance and employment? Teresa Hogan, Mark Humphrey Jenner, Huong Tran Thi Lan and Ronan Powell, http://ssrn.com/abstract=2647500

Table 6.1 Programme Leverage Estimates

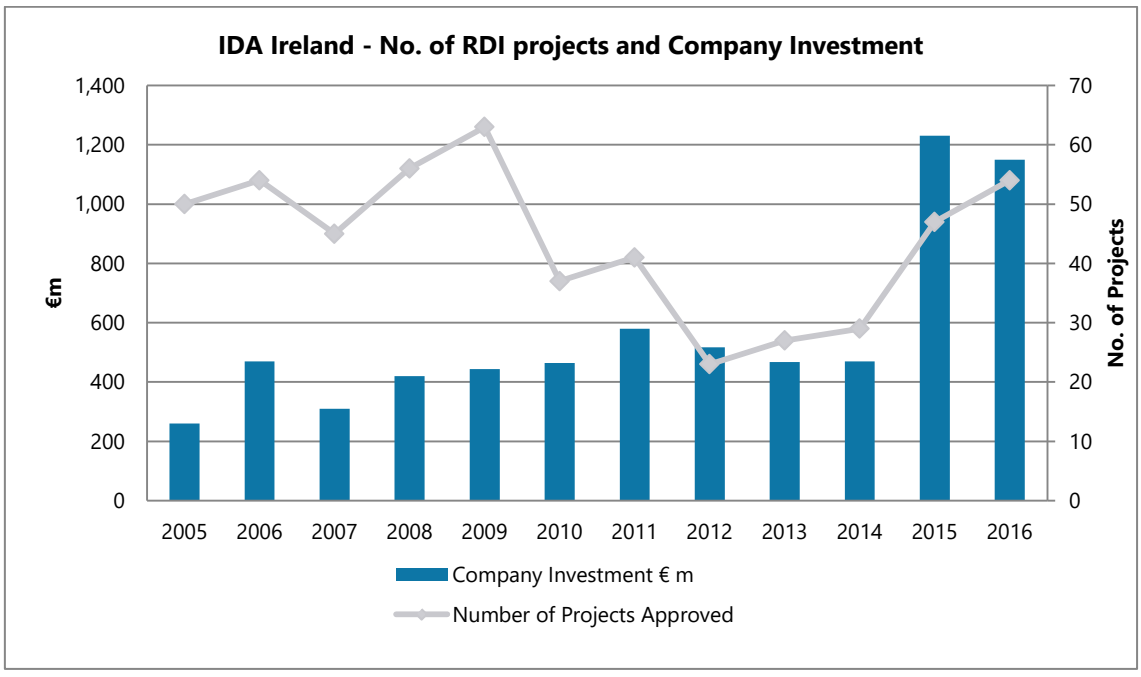
Evaluation	Input	Leverage
SFI Centres for Science, Engineering and Technology (CSETS) 2003-2012	€225m in direct costs	€77m in industry funding, the scheme also decreased exchequer funding dependence by 47%
SFI Strategic Research Clusters (SRCs) 2007-2012	€95m in direct costs	For every €1 invested leads to €.15 in private spending, €.52 in non-Irish Public Sector spend & €.62 in Irish public bodies: business in kind contributions
EI Innovation Partnerships 2004-2006	€17.8m	€8.9m Average 40% Industrial Contribution
EI Technology Gateways (ex-ante) 2012	€22.8m over 4-5 years	Industry expected approx. 40%
IDA R&D Fund 2003-2009	€582m	€1,541m (company contribution).
EI RTI Scheme 2002-2006	€113.9m	Industry contribution depends on project type and company size (currently 50 to 75 percent).
Program for Research at Third Level Institutions Cycles 2000-2006	€1.173bn	€478.9m philanthropic, private and international

Source: DJEI (2014) Evaluations of Enterprise Supports for RDI; Higher Education Authority/PA Consulting Group (2011) Ten Years On – Confirming Impacts from Research Investment

IDA Ireland

In the period 2005 to 2015, IDA Ireland attracted 526 R&D projects. Total company investment in these projects was €6.7billion. It is notable that since 2010, the average investment approval has increased notably, ranging from €5.2m to €8.7m in the period 2005 to 2009 to between €12.5 to €26m in the period 2010-2015, particularly driven by approvals of over €1billion in the years 2015 and 2016. This indicates that R&D projects are increasing in scale and reflect Ireland's growing value proposition as a location for RDI mobile investment.

Figure 6.7 IDA Ireland: RDI Projects and Value of Company Investment

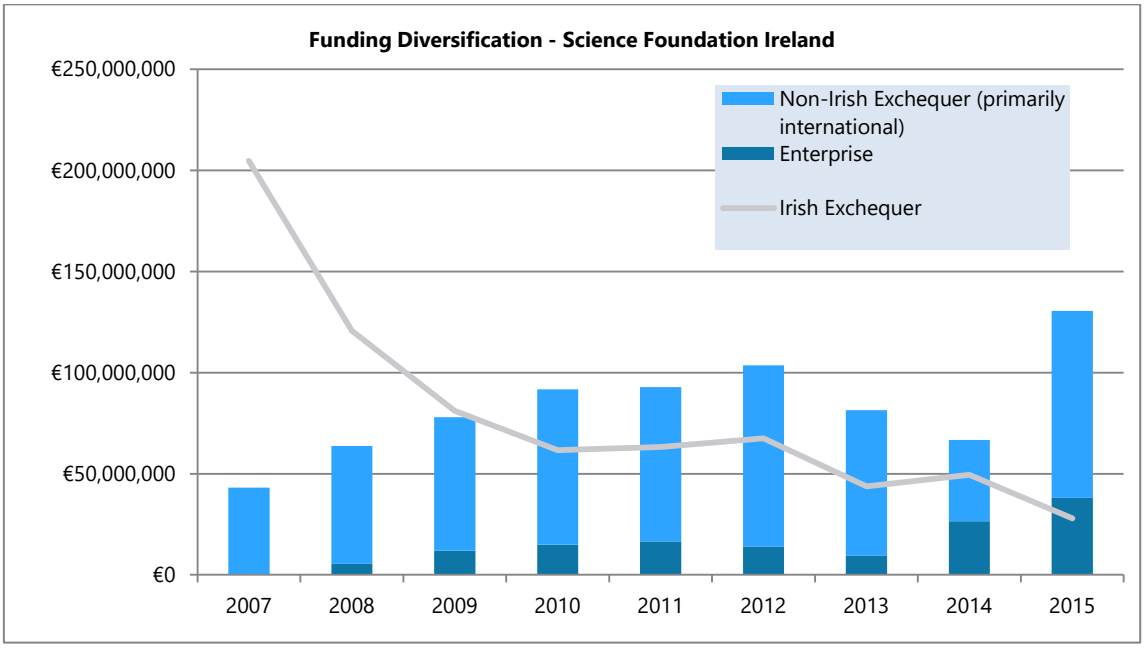


Source IDA Ireland

Science Foundation Ireland – Diversified Funding

Diversified funding is a key metric for Science Foundation Ireland. It measures all non-SFI funding received by the SFI award holders. In particular, it includes funding from industry (cash and in-kind), philanthropy, European Framework Programmes, other international sources (Welcome Trust, European Union non-H2020), other national funders (e.g. Enterprise Ireland, Irish Research Council, Health Research Board). The data shows that SFI award holders attract on average €163.5m per year from non-SFI resources, broadly equivalent to currently funding provided through DJEI (€162m in 2015). Notably non-Exchequer (primarily international) funding and funding by enterprise have increased to account for 82 percent of total SFI's diversified funding in 2015, indicating reduced reliance on Exchequer sources.

Figure 6.8 SFI Funding Diversification



Source: Science Foundation Ireland

According to SFI, the step change that has taken place regarding private cash contributions to research funding reflects deepening engagement in the system. For example, the SFI Research Centres, Spokes, and Partnerships programmes have (since 2012) been requesting significantly increased levels of mandatory industry (cash) cost share. The SFI Research Outputs 2016 reported €20.4m of cash from industry. Given that industry has continued to participate in these schemes, despite the increased requirements, suggests that excellent research acts as a strong attractant for private investment.

EU Framework Programmes and International Funding

Ireland has been a participant the EU Framework Programmes for research since they began in 1984. The Framework Programme has historically been an important driver in the internationalisation and excellence within the Irish research base. Funding is competitive with an emphasis on excellent science, industrial leadership and tackling societal challenges. In the past 15 years, Ireland has succeeded in attracting significantly more funding from Framework Programmes, thereby providing additional funding to the national research base in Ireland. In FP7, Irish participants succeeded in securing €625m of funding. In turn, it is estimated that FP7

funding leveraged an additional €460m of investment through 'crowding in' effects from public and private organisations.

Table 6.2: Irish Participation in the Fifth to Eighth Framework Programmes

	FP5 1998-02	FP6 2002-2006	FP7 2007-2013	Horizon 2020 (2014 to February 2017)
Total Drawdown (€)	€148m	€188m	€625m	€386m
% of Total FP Budget	0.98%	1.12%	1.68%	1.70%
Drawdown by private sector	€28m	€21m	€164m	€126m
% of Irish total by private sector	19	11	26	33
Number of Participants	1,042	816	1,960	922
Number of Projects	865	661	1,465	708

Ireland's current target for Horizon 2020 is to secure €1.25 billion in competitive funding from 2014 to 2020. Based on current performance to date, Ireland is on course to achieve its drawdown target, however, it is contingent on sustaining current success rate throughout the remainder of programme. This is particularly important given the majority of funding is released towards the latter years of the programme lifecycle. It is particularly notable that the private sector is accounting for an increasingly higher proportion of funding drawdown (33 percent).

DJEI has undertaken an ex-post evaluation of the 7th Framework Programme and an interim evaluation of Horizon 2020.[25] The evaluations indicate significant additionality from engagement in the Framework Programme. The majority of participants surveyed (and successful applicants) indicated that they would have abandoned the project had their project not received FP7 funding (53 percent). Furthermore, 43 percent of respondents indicated that they would have still progressed the project, but at a reduced scale. 48 percent of unsuccessful applicants stated that they actually abandoned their project, while 36 percent stated that they progressed their project at a reduced scale. Appendix VI shows how SFI research centres have secured funding from various strands of the current European Framework Programme (Horizon 2020). Overall, €101.4m of EU funding has been allocated to SFI researchers to 2016. According to SFI, this is only possible due to national investment in the research centres.

In a wider context, according to the Research and Development Budget,[26] total international funds from abroad (funds invested in R&D in this country but sourced outside the state) have grown from approximately €146m in 2004 to an estimated €544m in 2014. This funding now represents approximately 19 percent of Gross Expenditure on Research and Development (€2,921m) in 2014, which reflects Ireland's increasing attractiveness as a research location.

[25] https://www.djei.ie/en/Publications/Evaluations-of-Irelands-participation-in-FP7-and-Horizon-2020.html

[26] DJEI Research and Development Budget (2016) https://www.djei.ie/en/Publications/Research-and-Development-Budget-2015-16.html

6.8. Other economic impact indicators

Payroll

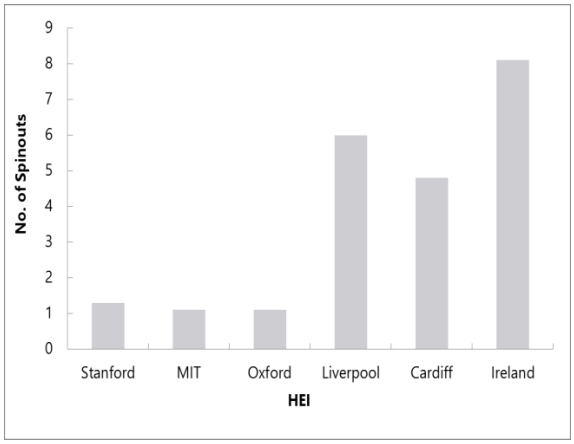
Recent analysis of payroll data of DJEI RDI active client firms shows that average payroll per employee of RDI active firms is was €59,385 (€5,600 or 10 percent higher) compared to non RDI active firms (€53,783). Relative to average earnings, payroll per employee in RDI active firms is 66 percent higher than for the economy overall in 2014 (€35,768, CSO Earnings Data).

Spin-Outs

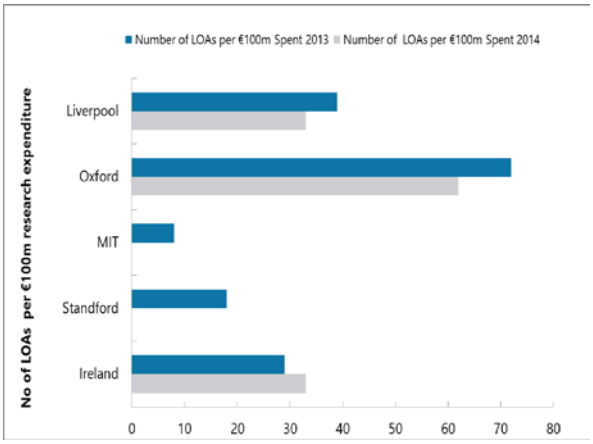
Between 2011 and 2014, 46 high potential start-up firm (HPSU) spin-outs were established: by 2014 only 3 were no longer trading and 1 had been acquired. According to ABSEI Data, spinout HPSUs achieved 18% more turnover (€877k) than average non-spinout HPSUs (€740k). Furthermore, average employment in Spin Out HPSUs is 8 compared to 10 employees in non-spin out HPSU's, indicating higher sales per employee levels. The commercialisation performance of the Irish publicly performing R&D system compares well to internationally renowned HEIs when outputs are compared and normalised based on the level of R&D expenditure. This is true when comparing numbers of spin-out firms in Ireland across all comparator HEIs reviewed, and for the number of Licences, Options and Assignment s (LOAs) generated in Irish HEIs when compared with the US HEIs, as demonstrated in the data below. It is acknowledged however, that higher volume output does not necessarily translate to higher impact - the quality of the spin-outs and LOAs is paramount in achieving positive enterprise and economic impacts.

Figure: 6.9 Spin Out Activity in Ireland and Internationally

No. of spin-outs per €100 million R&D expenditure for the Irish publicly performing R&D system and a number of internationally renowned HEIs per €100 million R&D expenditure[27].



The number of LOAs per €100 million R&D expenditure for the Irish publicly performing R&D system and a number of internationally renowned HEIs per €100 million R&D expenditure[28].



Source: Knowledge Transfer Ireland

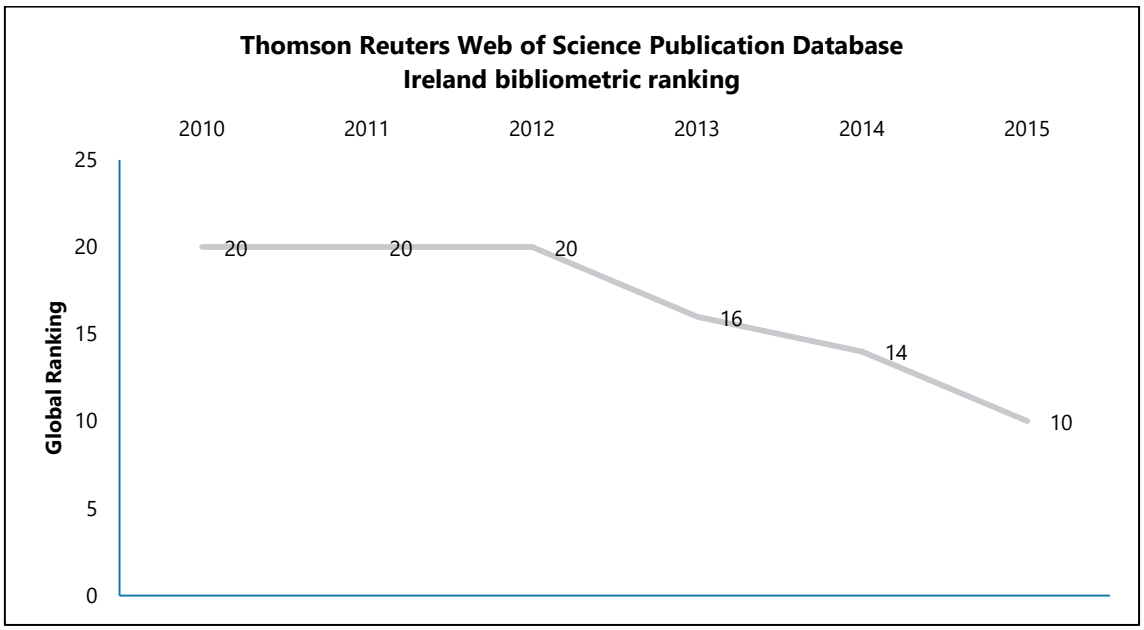
[27] Knowledge Transfer Ireland analysis. It is noted that the UK data collection is for the academic year e.g. 2012-13. The UK data is used here as 2013 data.

[28] Knowledge Transfer Ireland analysis

6.9. Scientific Impacts – Quality Indicators

Bibliometric rankings are a primary indicator of the developing quality of the science base.[29]

Figure 6.10 Ireland bibliometric ranking



Source: Thomson Reuters Web of Science publication database

Ireland is consistently improving in global rankings, to a position of 10th in terms of overall scientific quality. Notably, the ranking is influenced by specific fields where Ireland is ranked globally;

- 1st for Nanotechnology;
- 3rd for Chemistry
- 3rd for Immunology
- 3rd for Materials Sciences
- 3rd for Agricultural Sciences
- 4th for Mathematics

Looking more closely at citations, analysis by SFI shows that from 1980-2002, for any funder, the percentage of publications in the top 1 percent is 1.02% for Ireland as a whole. For the period 2003-2016 (see table below), the percentage of publications in the top 1 percent is 1.54 percent for Ireland and 2.41 percent in the case of SFI publications. Therefore the overall system has improved with a disproportionate impact from SFI-funded publications. According to SFI, this is

[29] Citations are recognised as the pre-eminent quantitative measure of research quality. They constitute a large component of international university rankings such as the Times Higher Education World University Rankings. Research has found that good citations are much more common than bad citations. The Clarivate Analytics/Thomson Reuters InCites rankings used in the Review are normalised to remove the disadvantage of Ireland's small scale and permit a useful comparison of quality to be made.

a reflection of the benefit of funding schemes where the selections are made by international peer review.

Table 6.3 Citations by Country and Top Citations

Country	Funder	# Documents in Web of Science	Documents in the Top 1%
USA	All	7,628,277	1.74%
UK	All	2,079,720	1.75%
New Zealand	All	134,292	1.70%
Singapore	All	171,345	2.03%
Israel	All	227,063	1.50%
Finland	All	187,873	1.63%
Denmark	All	232,099	2.38%
Ireland	**All**	**133,713**	**1.54%**
China	All	2,729,495	0.9%
Ireland	**SFI**	**11,852**	**2.41%**
All	European Research Council (ERC)	37,475	4.82%
All	National Science Foundation (NSF)	365,378	2.7%
All	National Institutes of Health (NIH)	596,566	2.9%

Source: Incites, Thomson Reuters 2003-2016; Science Foundation Ireland

6.10. Behavioural Impacts

Evaluations of Enterprise Agency R&D programmes also indicate a range of behavioural impacts arising from DJEI supports.[30] This is important to understand from the perspective of how and why the supports generate impact for the firms. Behavioural impacts include:

- Upgrading technical capabilities enabling and enhancing strategic importance to parent company (IDA firms).
- Transitioning to higher value operations had raised skills levels (IDA firms)
- Enterprise Ireland firms reported 4 products per firm were either introduced or improved as a result of RTI funding. Recent research by ESRI shows that Irish manufacturing firms with a greater mix of products and markets have much higher survival rates.[31]

[30] https://djei.ie/en/Publications/Evaluation-of-Enterprise-Supports-for-Research-Development-and-Innovation.html

[31] ESRI (2017) Expanding and Diversifying the Manufactured Exports of Irish Owned Enterprises http://www.esri.ie/pubs/BKMNEXT335.pdf

- 61 percent of Enterprise Ireland companies in receipt of Innovation Vouchers had no pre-existing relationship with a Higher Education Institute and 69 percent of companies developed new or improved processes and products.
- Companies engaged in Innovation partnerships also reported enhanced strategic ambitions to internationalise as a result of the partnership.
- The Innovation Partnership schemed increased mobility of researchers to industry with over 60 percent of research teams reporting that members had moved on to the private sector, meeting an important knowledge transfer function.
- DJEI Evaluations of Enterprise Ireland Commercialisation Fund and SFI programmes (CSETs and SRCs) also found significant behavioural impacts in terms of increased academic linkages and the relevance of research undertaken.

6.11. Conclusions

A range of impacts are indicated from DJEI investment in RDI programmes:

- Innovation has been empirically linked as a key driver to productivity and economic growth, both internationally and in Ireland.
- Overall, enterprise expenditure on R&D has increased from 66 percent of total economy RDI expenditure in 2006 to 72 percent in 2014. In turn, this means that BERD has been the primary driver of the overall increase in investment in R&D in the economy in the period.
- The number of researchers working in enterprise has increased by 67 percent from 10,700 in 2006 to 17,800 in 2014, indicating a major increase in the level of knowledge transfer from the research system to the enterprise base. SFI analysis finds that 53% of team-members are in the private sector 6-8 years after the end of the SFI award.
- Companies with no R&D expenditure accounted for the majority of job losses during the recession and on average had lower rates of employment, value added and export growth than RDI active companies. RDI active firms account for a disproportionately higher amount of sales and exports relative to non-RDI active firms. RDI active companies have on average higher levels of pay than non-active RDI companies in the DJEI base and significantly higher than the average for the economy.
- Notwithstanding the disproportionate effects, the data also highlights that:
    - 37 percent of Irish owned firms (with 10 employees or more) have no R&D expenditure and a further 27 percent have expenditure under €100k. This means that just one third of Irish owned firms have substantial expenditure on R&D (over €100k).
    - Similarly, 53 percent of foreign owned firms have no R&D expenditure with a further 4 percent with expenditure of €100k.
- Public investment is RDI is important for leveraging further activity.
    - Empirical analysis of DJEI R&D grants in shows that a €1 increase in grant aid leads to a €12 increase in R&D carried out by agency firms that receive grant aid. This declines to €1.64 when benchmarked against 'similar' non-grant winners

- Private contributions account for an estimated 60 percent of Enterprise Ireland RDI investments.
- Total FDI investment in RDI projects secured by IDA Ireland has amounted to €6.7 billion from 2005-2016. Notably, the scale of RDI investments approved by IDA Ireland has increased to an average of €26m in the period 2010 to 2015.
- Science Foundation Ireland Award holders attract on average €163.5m annually in additional funding per year from non-SFI sources.
- Ireland's €625m funding secured in the 7th European Framework programme stimulated an additional €430m through crowding in effects.

- Ireland compares well internationally for its commercialisation activity and outputs.
- Sustained investment in the research base is yielding scientific quality impacts with Ireland consistently improving in global world rankings for bibliometric, to a position of 10th in terms of overall quality. This is important for Ireland's reputation internationally as a location for research activity and investment.
- A range of behavioural impacts are also evident from evaluations, including knowledge transfer, raised strategic ambitions, increased relevance of research, enhanced industry-academic linkages and the transformation and further embedding within the multinational base.

7. Efficiency and Effectiveness

Review Questions

- What methods are used to assess effectiveness?
- Is the achievement measured against a valid baseline?
- Can the indicators relating to the assessment of effectiveness be improved?
- What is the performance gap? (i.e. the difference between actual and expected outputs and results)
- What are the contributing factors to the performance gap?

7.1. Introduction

This section provides an overview of main processes and measures in place within DJEI and the Agencies for monitoring performance and effectiveness of investment provided.

7.2. DJEI Key Measures for Performance Monitoring

At a broad strategic level, DJEI has placed an increased emphasis within the Innovation 2020 strategy on quantitative metrics and processes for monitoring performance and progress. Innovation 2020 sets out 2020 targets relating to:

- Gross Expenditure on Research and Development (GERD);
- Private sector RDI investment;
- Research personnel employed in enterprise; no. of active RDI firms;
- Commercialisation outputs;
- Leverage of European Framework funding;
- Innovation Union Scoreboard;
- Public engagement with R&D.

The Strategy also sets out actions for reporting to Government on implementation progress and evaluation of the strategy including mid-term and retrospective evaluation. An implementation group has been established to oversee implementation of the strategy. The targets and baseline performance measures are provided in the table below. Progress relative to the targets is monitored by the Innovation 2020 implementation Group, which is chaired by DJEI.

Table 7.1 Innovation 2020 – Metrics and Targets

	Metric	Baseline[32]	Target 2020	Data Source
1	GERD	€2.9bn	2.5% of GNP	DJEI
2	Increase private funding of R&D performed in HE sector	€24m per annum	€48m per annum	HERD survey (DJEI)
3	Increase research masters and Ph.D. enrolments	1,750 (2015)	2,250	
4	Research Personnel[33] in Enterprise	24,785 (2013)	40,000	BERD survey (CSO)
5	Increase number of firms that are[34]: a. Innovation active b. Significant R&D performers c. Large R&D performers	a. 58% b. 1,040 c. 170	a. 73% b. 1,200 c. 200	*Innovation in Irish Enterprises* survey (CSO)
6	Commercialisation Targets a. Commercially relevant technologies (Licences, Options, Assignments) b. Spinouts c. High Potential Start-Ups (HPSUs) from Spinouts d. Collaborative research projects between enterprise and PRS[35]	a. 124 b. 29 c. 11 d. 878	a. 175 b. 40 c. 16 d. 920	EI/Knowledge Transfer Ireland
7	Drawdown Horizon 2020	€620m under FP7	€1.25bn	European Commission
8	Innovation Union Scoreboard: performance relative to EU average	+13% (2015)	+20%	European Commission
9	How informed the public feel about R&D in STEM	49% (2015)	60%	Barometer survey (SFI, biennial)

Source: DJEI (2015) Innovation 2020

Annually, DJEI collates the Research and Development Budget, which tracks Government budget allocations for Research and Development (GBARD) over time and across 31 different Departments and Agencies. It also tracks total expenditure on R&D in the economy (GERD) and personnel engaged on R&D in the country by all sectors of the economy. Collectively, this represents the expenditure and personnel in the government, business and the higher education sectors. This indicator includes all expenditure from all sources spent on R&D performed in these sectors.

[32] Baseline year is 2014, unless otherwise indicated.

[33] Includes researchers, technicians and support staff.

[34] Using CSO definitions.

[35] Public Research System.

7.3. Research Prioritisation

The main DJEI instrument adopted for ensuring efficiency at a funding level is Research Prioritisation. As pointed to previously, the Research Prioritisation Exercise identified a number of priority areas around which future investment in publicly-performed research should be based. These priority areas should deliver sustainable economic return through their contribution to enterprise development, employment growth, job retention and tangible improvements in quality of life. Distinct criteria were established for selecting the priority areas:

- The priority area is associated with a large global market or **markets in which Irish based enterprises already compete** or can realistically compete;
- Publicly performed R&D in Ireland is required to exploit the priority area and will **complement private sector research** and innovation in Ireland;
- Ireland has built or is **building (objectively measured) strengths in research disciplines** relevant to the priority area;
- The priority area represents an appropriate approach to a **recognised national challenge and/or a global challenge** to which Ireland should respond.

Innovation 2020 committed to maintaining the Research Prioritisation approach as the central pillar of Government strategy to support the enterprise sector. To enhance accessibility, it has grouped the 14 priorities under six themes: ICT, Manufacturing & Materials, Health and Medical, Food, Energy, and Services & Business Processes. Innovation 2020 also commits to reviewing the Priority areas, taking into consideration, inter alia, recent and likely future advances in science and technology, as well as the dynamics of international markets and global supply chains and policy developments.

7.4. DJEI Enterprise Programmes and Policies Evaluations Unit

DJEI has a dedicated unit for evaluation of agency expenditure. An evaluation framework was developed in 2012 that takes a programme logic model approach, evaluating the objectives of expenditure and associated inputs, activities, outputs, outcomes and impacts. Conclusions are drawn with regard to appropriateness, efficiency and effectiveness and recommendations are aimed at enhancing the additionality of the programmes and minimising deadweight. Since 2012, DJEI has completed 30 evaluations of approximately 50 supports provided across the agencies. Supports were grouped on a thematic basis (Start Up and Entrepreneurship; Research, Development and Innovation; and Business Development Programmes).

The evaluations are focused on both quantitative and qualitative findings. Quantitative findings are mainly expressed in terms of additional jobs or exports that can be directly attributed to participation in the programme. Cost-Benefit analysis is undertaken where data permits. Qualitative findings are also considered important, as they can explain much of the how and why programmes help generate additionality. In particular, evidence of behavioural additionality is explored within the evaluations. Behavioural additionality is about assessing, and where possible, quantifying the behavioural impact of a programme on a firm, for example, in relation to capability building, leadership, increased collaboration, ambition, resilience, improved working environments etc.

In general, the individual RDI programmes evaluated were found to be appropriate, efficient and effective.[36] The DJEI evaluations of RDI programmes found that the programmes each play a role as part of the National Innovation System (NIS) and, by and large, are performing well in terms of meeting their stated objectives. From a policy perspective, it is important that the various roles that are fulfilled are recognised. The programmes evaluated span the technology push and market pull aspects. Metrics are different depending on the objectives (e.g. scientific excellence (citations); capability development (enhanced skills); new products developed/sold (turnover); economic growth (EVA, employment). Therefore, direct comparison is not always possible or advisable. It is about assessing the performance of the programme against their objectives, relevance, and in terms of their role within the National Innovation System.

7.5. Cost Benefit Analysis and Deadweight

Cost Benefit Analysis

Through the evaluations, DJEI and the Agencies have undertaken Cost Benefit Analysis on its major programmes where possible. The results are net of estimated programme deadweight. Note, due to differences in methodologies applied as a result of variances in data availability, programme objectives, years in operation and programme size, CBA results are not directly comparable. Cost Benefit Analysis undertaken on Enterprise Ireland's RTI scheme and IDA Ireland R&D fund indicates a return of €1.82 to 1 for EI companies and €5.00 to 1 for IDA companies in terms of value added.

Table 7.2 Summary of Cost-Benefit Analysis results in DJEI Evaluations

Programme	Cost-Benefit Results
IDA Ireland R&D Fund 2003-2009	€5.00 Value Added per annum for every €1 invested by 2009
Enterprise Ireland RTI Scheme 2002-2006	€1.82 Value Added for every €1 Invested by 2010

Source: DJEI (2014) Evaluation of Enterprise Supports for RDI. Note, due to differences in methodologies applied as a result of variances in data availability, years in operation and programme size, CBA results are not directly comparable.

Table 7.3 below sets out the return on investment in terms of the estimated net value added[37] (EVA) from State funding of a number of programmes through evaluations undertaken by Enterprise Ireland. The data here highlights that in the short term a €1 investment in the specific programme reviewed leads to between €2-€3 return in terms of net EVA. In the longer term, this ROI is expected to rise to between €4.5 and €11 per €1 investment by the State.

[36] DJEI (2014) Evaluation of Enterprise Supports for Research, Development and Innovation https://djei.ie/en/Publications/Evaluation-of-Enterprise-Supports-for-Research-Development-and-Innovation.html

[37] Value Added was estimated using the ABSEI data and the calculation of sales revenue minus the expenditure on materials and services.

Table 7.3 Estimates of Net EVA impact from State investment in HEI-Industry collaboration programmes.

Programme	Net EVA impact-experienced	Net EVA impact-projected
Commercialisation fund		€2.04
Advanced Research Enhancement Centres	€2.12	€4.47
Innovation Partnerships	€2.38	€9.38
Innovation Vouchers	€3.1	€11.26
Technology Centres		€8.20

Source: Enterprise Ireland

Programme Deadweight

In determining net additionality, DJEI and the Agencies also seek to undertake analysis of programme deadweight where possible. The gold standard measure of deadweight and additionality calculation would be to undertake an econometric counterfactual impact assessment, comparing a 'treated' group of firms with a matched control group of firms with similar characteristics, and track their progress against each other relative to the main programme objective (e.g. productivity, turnover, employment, R&D spend). The difference in the performance provides an empirical measure of the additionality of the support in addition to estimating through the control group what would have happened anyway (deadweight). DJEI's evaluations have sought to employ this as the primary method of estimating additionality and deadweight; however, this has not been possible except in a small number of evaluations for the following reasons:

- Empirical analysis requires comprehensive data at firm level over a number of years – this is not always available due to varying response rates year to year in the DJEI Annual Business Survey of Economic Impact. This is a particular issue with smaller firms.
- Many agency companies are in receipt of more than one type of support, which also needs to be considered in interpreting the results.
- Some R&D supports targeted a small cohort of companies, or start-ups, spin outs or research within the public system. Detailed profile data is not always available for these actors or it is too early to measure impact. Nevertheless it is important that these supports are evaluated.

When these challenges arise in some evaluations, estimates of deadweight are undertaken via other methods, primarily through surveys, inviting companies to estimate what their turnover or employment levels would be in the absence of the support. This is supplemented where possible with international evaluation evidence from similar supports. Partial deadweight is also

investigated where possible or appropriate through trying to establish if projects would have proceeded on smaller scale or a delayed basis. This is based on a best practice approach.[38] Where good population sizes are available, control group analysis is undertaken to try and assess the difference between the reported deadweight and actual performance relative to companies with similar characteristics. Appendix VII provides the CBA and deadweight estimates for each programme evaluated and methodological approach to its measures. A number of caveats are important for analysing the figures:

- Due to different parameters to what is actually being measured in terms of deadweight and additionality (e.g. turnover, employment, project decision), methodologies, population sizes and timeframes allocated to measuring impact, there is no basis for comparing deadweight measures between programmes i.e. comparing one programme to another on the basis of deadweight alone is not an accurate determinant of the effectiveness of the programme relative to another.
- The programme objectives are also relevant when assessing the level of deadweight. For example, qualitative measures rather than quantitative may be the more desired outcome for some programmes e.g. commercialisation, research excellence and relevance, patents.
- In addition, high levels of deadweight may only be evident because the intervention is small in terms of cost (e.g. innovation vouchers or partnerships) and therefore the intervention does not have huge immediate quantitative impact on, for example, total turnover. In this context, deadweight needs to be considered relative to both the cost and the additionality that the support delivers.
- The long term returns to innovation mean that the level of deadweight and additionality may well change if estimated over longer timeframes.

Due to these issues, DJEI attempts to ensure that its evaluations are accompanied with appropriate context and explanation regarding methodologies. Data quality and availability are the primary determinants in the methodologies employed and their associated advantages and limits. DJEI is continually seeking to improve the firm level data set available so more empirical techniques can be applied to measuring additionality and deadweight.

7.6. Agency Evaluation and Performance Measures

In action 210 of the 2016 Action Plan for Jobs required Science Foundation Ireland, Enterprise Ireland and IDA Ireland to outline actions undertaken to embed an evaluation culture. The following material is based on the responses of the agencies in fulfilment of implementation of the action.

[38] The two-stage question follows the distinction between "full" and "partial" deadweight used by e.g. H. Lenihan, *Evaluating Irish Industrial Policy in Terms of Deadweight and Displacement: A Quantitative Methodological Approach,* Applied Economics, 36:3, PP 229-252, 2007

Science Foundation Ireland

Science Foundation Ireland has undertaken a number of actions to embed an evaluation culture for support programmes. At an organizational level, independent evaluations are carried out regularly, approximately one per year. Independent evaluations are published and implementation plans responding to the recommendations are agreed by the Executive Committee. These evaluations provide critical inputs to the regular evolution and improvement of SFI's individual programmes, and the updating of SFI's portfolio of programmes. Evaluations are being built into the ex-ante process of program design and project appraisal processes are evolving due to independent evaluation in 2015 review of the peer review process.

New or updated programmes are subject to appropriate ex-ante evaluation outlined in a framework ensuring ex-ante evaluation promotion. An SFI impact framework has been established for all programmes which outline activities, outputs, outcomes and impacts in evaluation. All programmes are evaluated at the ex-ante stage for programme rationale, alignment with SFI and national policy goals, objectives, and metrics.

Improvements have been made by SFI to ensure performance metrics are readily available and Management Information Systems (MIS) are up to date. Monitoring and evaluation of progress against SFI's Agenda 2020 strategy and its metrics are taking place twice yearly while consideration is being given to reviewing Agenda 2020 in light of Innovation 2020. The ongoing evolution of the SFI MIS will enable improved ex-post evaluations.

SFI evaluations maintain independence using independent consultants and internationally renowned scientists in peer review processes. Internal oversight processes are made through the Executive Committee, SFI Board Grant Approval Committee and SFI Board. Evaluations are also overseen by the Performance Improvement Division in the Strategy Directorate rather than programme managers in the Programmes Directorate, which ensures the programme manager is not directly responsible for the evaluation itself.

Enterprise Ireland

Enterprise Ireland has undertaken a number of actions recently to enhance its evaluation culture. Enterprise Ireland now has a requirement that significant new funding programmes complete an ex-ante evaluation. This evaluation is submitted to a sub-committee of the Executive for review and sign off. In addition, Enterprise Ireland is adapting its programmes in line with client demand. For example, a new small project initiative under the Innovation Partnership scheme was introduced to address a perceived client and market need.

At organisational level, all new major funding programmes have identified evaluation timetables. A major focus in the approval decision of all approved programmes is value for money and impact analysis. All approved programmes have specific metrics and review periods built in to their work programmes.

Enterprise Ireland ensures that performance metrics are applied to its funding programmes. These are regularly reviewed with Enterprise Ireland's internal committees and Board to ensure that they are focused on impact. For example the Technology Centre program has developed an Economic Value Added (EVA) performance metric. A new Management Information System for reporting has been tested that will facilitate more timely access to relevant management information for evaluation.

Enterprise Ireland evaluations maintain independence using independent consultants in conjunction with staff that is independent of the management and operation of the significant programmes being evaluated. Enterprise Ireland also updates DJEI regularly through the liaison meeting mechanism which affords an opportunity to input into the Terms of Reference before being finalised ensuring DJEI are in consultation prior to evaluations.

All projects that come to Enterprise Ireland for grant approval must also go through the Economic Appraisal Model/System. This is an ex-ante cost benefit analysis in which the projected net benefits of the project are compared to the current costs of the grant. The benefits and costs are adjusted for a number of parameters underpinned by economic evidence. The model serves an advisory role and is one aspect of an overall system of appraisal.

IDA Ireland

Since the DJEI programme evaluations (2012-2015), IDA Ireland has updated its internal Intranet to reflect the rationale for State Intervention of its grant programmes. IDA has developed formal Programme Logic Model for all grant programmes.

At organisational level, IDA has ex-ante and ex-post project appraisal processes in place. A standard application process is in place for each type of grant. IDA Ireland uses an economic appraisal system prior to the approval of Regional Aid grants (Capital & Employment) to assess their suitability for grant receipt.

Financial appraisal, in terms of eligibility of expenditure, is carried out as part of the technical assessment of Training, Environmental and RDI grants. IDA Ireland uses a Financial Analysis & Company Evaluation (FACE) Model to facilitate the analysis of grantee company's financial statements. Ex post appraisal is carried out by a standalone unit in IDA and IDA's Training and R&D grant programmes are independently assessed by a third party.

To ensure that new programs are evaluated a system was developed by the EU to publicise grants under the Transparency Directive. From July 2016, all approvals greater than €500,000 are recorded on the EU website and IDA has implemented as required.

7.7. Review of Economic Appraisal Model

In 2017, DJEI has commissioned a review of the Enterprise Agency Economic Appraisal Model. It is a cost benefit model that assesses the economic return from DJEI investments in firms. One of the main questions for the review is to ascertain if benefits and spill-overs from RDI investments can be better quantified in project appraisal.

7.8. Performance Gap

The performance gap is measured in terms of Ireland's innovation performance benchmarked internationally against key innovation indicators. Section 9 proposes some areas for policy focus that can assist in enhancing impact and effectiveness in the National Innovation System and close the gap relative to Ireland's main competitors.

The first measure looks at investment in RDI in Ireland across the main sectors and number of researchers in the economy.

- GERD (Gross Expenditure on Research and Development)
- BERD (Business Expenditure on Research and Development)
- HERD (Higher Education Expenditure on Research and Development)
- GOVERD (Expenditure on Research and Development carried out by Government Organisations)
- GBARD (Government Budget Outlay on Research and Development)
- Researchers per Thousand Labour Force

Table 7.5 Main R&D Expenditure Indicators

Key Indicators	***Ireland***	***EU-28***	***OECD***	***Leader***
GERD 2015 (% of GDP)	1.51% (1.79% GNP)	1.95%	2.40%	Korea 4.25%
BERD 2015 (% of GDP)	1.09%	1.23%	1.65%	Israel 3.63%
HERD 2015 (% of GDP)	0.28%	0.45%	0.43%	Denmark .99%
GovERD 2015 (% of GDP)	0.05%	0.24%	0.27%	Korea .50%
GBARD 2015 (% of GDP)	0.29% (0.36% GNP)	0.62%	0.54%	Denmark 1.01%
Researchers Per Thousand Labour Force (2015)	9.61	7.4	7.61 (2014)	Denmark 14.33

Source: OECD STI Indicators https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB. Note, data does not capture RDI tax credits that may differ between countries.

The data shows that Ireland remains behind the EU and OECD across all major measures of RDI investment relative to the economy and significantly behind the leading countries. Notably, Ireland is ahead of the EU and OECD average in terms of researchers per 1,000 population, which indicates success in terms of growing the researcher base domestically and attracting researchers internationally notwithstanding relatively low levels of investment historically compared to competitors.

The European Innovation Scoreboard 2016 measures innovation performance using a composite indicator – the Summary Innovation Index – which summarizes the performance of a range of different indicators. The EIS has eight innovation dimensions, capturing in total 25 indicators.[39] It is one Ireland's key metrics for Innovation 2020, with the ambition that Ireland's score would be 20 percent higher than the European Average by 2020. In addition to the summary index, the scoreboard captures a number of sub indicators which are composite based. These are:

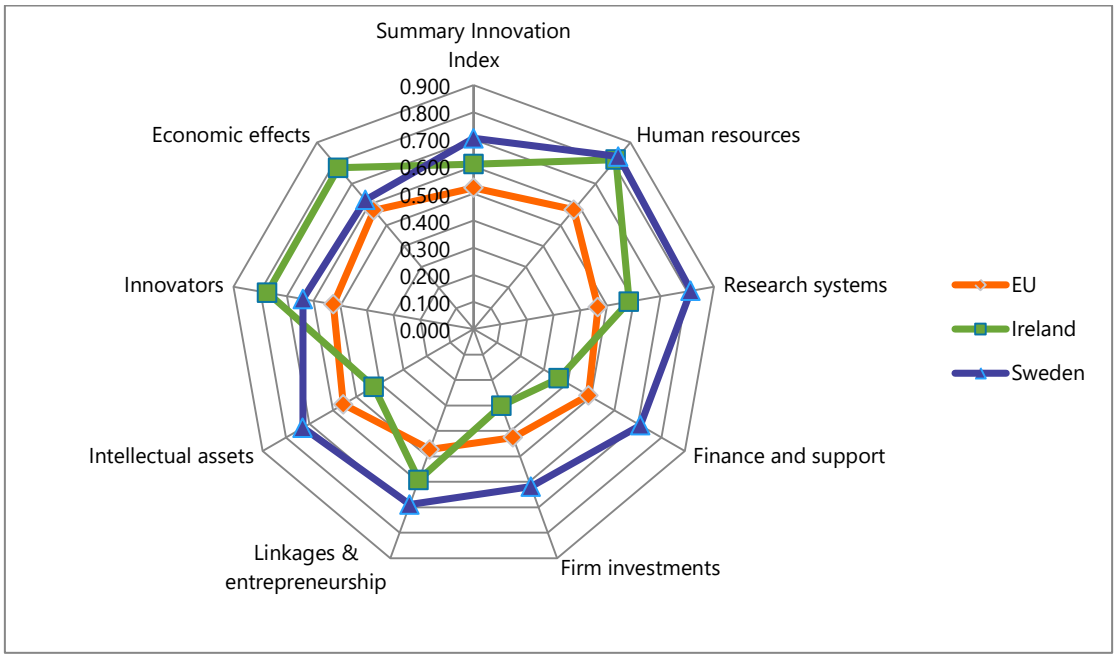
- **Human resources** (includes indicators such as new PhD graduates; education levels in population);
- Openness, excellence and attractiveness of the **research systems** (based on measures such as scientific co-publications, citations and non-EU doctoral students);
- **Finance and support** (includes venture capital and government investment in research organisations);
- **Firm investments** include two indicators of both R&D and Non-R&D investments that firms make in order to generate innovations.;

[39] European Commission DG Internal Market (2016) European Innovation Scoreboard 2016

- **Human resources** captures New doctorate graduates, Population aged 30-34 with
- **Linkages & entrepreneurship** includes three indicators measuring innovation capabilities by looking at SMEs that innovate in-house, collaboration efforts between innovating firms, and research collaboration between the private and public sector;
- **Intellectual assets** captures Intellectual Property Rights (IPR) generated in the innovation process, including Patent Cooperation Treaty (PCT) patent applications, Community trademarks and Community designs;
- **Innovators** include measuring the share of firms that have introduced innovations, covering both technological and non-technological innovations, and employment in fast-growing firms in innovative sectors;
- **Economic effects** includes economic impact of innovation in employment in knowledge-intensive activities, exports of medium and high tech products, exports of knowledge-intensive services, sales due to innovation activities, and License and patent revenues from selling technologies abroad.

Ireland's scores on the composite indicators are presented below relative to the EU and Sweden, which has the highest score in the EU for 2016. Ireland's overall score (summary innovation index) is 0.609, which is 6th in the EU overall and 17 percent higher than the composite EU score of 0.521.

Figure 7.1 EU, Ireland and Sweden – Innovation Scoreboard



Source: European Commission (2016) European Union Innovation Scoreboard 2016

Relative to the leading EU country, Sweden is 35 percent higher than the EU score and 16 percent higher than Ireland. Ireland is ahead of the EU on all indicators except Finance and Support, Firm Investments and Intellectual Assets. This is reflective of the underinvestment in RDI in Ireland relative to the EU average as presented above. Ireland is behind Sweden on all indicators except for Linkages and Entrepreneurship, Innovators and Economic Effects, which

likely reflects Ireland's high tech export base and increasing employment overall in RDI active firms. The 'Intellectual Assets' dimension of the EIS is broken down into PCT Patent Applications, Trademark Applications and Design Applications (per billion GDP). Ireland is below the EU average on each of these indicators. The measure is particularly affected by GDP being used as the denominator instead of population size. The GDP ratio is not a stable indicator from an Irish point of view relative to GNP or GNI. In addition, there is a large economic impact from multinationals in the economy, and their applications for Intellectual Property protection e.g. patents, trademarks and designs may be filed in their home country.

7.9. Conclusions

DJEI has a number of measures in place to monitor performance and effectiveness.

- Baseline metrics and targets have been established for Innovation 2020 which are tracked through the Innovation 2020 implementation group;
- Government expenditure on R&D is collated and monitored annually by DJEI through the Research and Development Budget and benchmarked internationally;
- DJEI Evaluations Unit carries out evaluations on major areas of agency expenditure on a regular basis. These are overseen by a steering group with independent expertise appointed;
- Across all evaluations, DJEI attempts to quantify the cost-benefit, deadweight and additionality of the support. Where possible, counterfactual impact assessment with control groups are undertaken. However, DJEI has highlighted a number of issues that present practical challenges in measuring deadweight and additionality in RDI supports. These need to be taken into account before comparisons of effectiveness are made between programmes;
- The Agencies have developed ex-ante and ex-post evaluation processes internally for programmes. Ex-ante appraisal is made for all Enterprise Ireland and IDA Ireland investments and cost-benefit is undertaken where possible. SFI funding is linked significantly to research priority areas. A primary issue for DJEI in its review of the Agency Appraisal Model is how to better capture and quantify the benefits of RDI investments if possible; and
- In terms of the performance gap, Ireland benchmarks well against the European Union across most innovation indicators, however, Ireland still ranks substantially behind innovation leaders with which Ireland has a policy objective to match. Internationally the fact that Ireland performs relatively well with comparatively low levels of investment is an indicator of general efficiency and productivity in the system,.

8. Continued Relevance

Review Questions

- What is the justification for the continued allocation of public money to the programme?

Introduction

This section outlines the justification for continuing public investment in RDI on the basis of evidence provided in this review. The major challenges to be addressed for DJEI in the future are outlined in Section 9: Policy Considerations.

Economic returns to Innovation

Productivity growth is widely accepted as the main sustainable driver of wealth and living standards. Innovation is empirically linked as a primary driver of productivity and economic growth, both nationally and internationally. The effectiveness of the National Innovation System is therefore a central platform for generating sustainable sources of economic growth.

Innovative firms contribute proportionately more in an economic sense. Within the DJEI client-base, companies with no R&D expenditure accounted for the majority of job losses during the recession and on average had lower rates of employment growth, value added and export growth than RDI active companies. RDI active firms account for a disproportionately higher amount of sales and exports relative to non-RDI active firms. RDI active companies have on average higher levels of pay than non-active RDI companies in the DJEI base and significantly higher than the average for the economy.

While the proportion of innovation firms within the DJEI base has increased, 63 percent of client firms have either no RDI expenditure or less than €100k. Recent research by the ESRI has been demonstrated that firms with greater varieties of products and markets have much better survival rates and ability to withstand shocks.[40] Innovation is central to developing the both the product or service mix and the organisational capabilities to internationalise. The corollary is that the least innovative firms will be most vulnerable to technological, market and geo-political forces.

Innovation supports restructuring of the enterprise base and competitiveness

Innovation is linked intrinsically to Ireland's competiveness. The need to both broaden the base of firms engaged in RDI and deepen the scale of investment within the existing base is fundamental to the ability of enterprises in Ireland to compete in international markets. The imperative for restructuring of the economy to sustainable export-led growth is also well recognised given previous overreliance on exposed sectors.

[40] ESRI (2017) Expanding and Diversifying the Manufactured Exports of Irish Owned Enterprises http://www.esri.ie/pubs/BKMNEXT335.pdf

Ireland's export economy depends on a mix of high value goods and services exports. Ireland's strong export performance is in part due to targeting RDI intensive sectors where RDI investment results in high value goods and services. GDP growth has and will continue to be strongly supported by exports of high margin products and services, which have a high level of embedded intellectual property (in terms of patent protection, trade secrets, know-how or brand value). Investment in RDI is central to ensuring Ireland can continue to grow the base of exports of high value products and services.

Recently, the European Commission Country-Specific Recommendations for Ireland pointed to the gap in performance between the Irish owned and multinational exporters with a particular focus on the role of innovation.

The recommendation states: "The Irish economy presents a division between the mostly small and medium-sized Irish-owned firms and large multinational companies operating in Ireland. Linkages between multinational companies and Irish-owned firms remain limited. Their export performances and profiles are significantly different, while the productivity gap between them is growing wider. Irish-owned firms present a weaker exporting profile than multinationals established in Ireland. Their exports are heavily concentrated by sector and destination, making them more vulnerable to shocks. Investing in innovation would foster the productivity and exporting potential of Irish firms at a time when diversifying exports and export destinations could help stabilise the performance of Irish firms. Public research and development expenditure remains low. Fully implementing measures to increase public research and development, in particular measures to support the innovation capacity of SMEs, depends on the return to a trend of sustained investment".

From a policy perspective, it is worth emphasising that the Irish Government's 2.5 percent target (R&D investment to GNP) by 2020 is routed firmly in the European competitiveness agenda dating back to the Lisbon Strategy in 2000 (which set a 3% GERD/GDP target for Europe generally). The overall goal of balanced investment in R&D across the public and private sectors in order to compete at a global level remains relevant today for Ireland and Europe.

DJEI funding is targeted at market potential and maximising economic return

DJEI's primary goal is to increase enterprise oriented research activity throughout the public and private research bases with the aim of ensuring alignment between investment and areas of market potential. Through policy advances such as Research Prioritisation, DJEI funding of research provides alignment with market potential and leverages our existing capabilities.

Enterprises that do not have the internal resources to conduct RDI need a supporting infrastructure that incentivises collaboration, which also enhances the commercial relevance of the research undertaken through public funding. Without this infrastructure and support, a significant volume of research activity with market potential that depends on collaboration would simply not occur. Similarly, without supports for commercialising research in the public system, the commercial potential of research would unlikely materialise to the same extent.

There is evidence of increasing quality and effectiveness in the system:

- In terms of "scientific excellence", this is demonstrated through, for example, global rankings based on citations which show Ireland out-performing peers in a number of economically relevant "fields of science" with SFI-funded research teams far exceeding the national average;
- An indicator of increasing absorptive capacity in the system is increasing agency reserve lists. For the past few years only, SFI have had lists of fundable excellent proposals at the end of the year with insufficient budget to fund them. The most recent Research Centres call for example resulted in eight fundable proposals, with only budget for four of them. This further reflects the capacity and capability building made in previous years.
- In terms of the commercialisation of research, Ireland is producing a level of output that matches international research-intensive institutions;
- European Commission analysis shows that, in aggregate terms, Ireland is one of the best innovation output performers despite its comparatively low levels of expenditure, making it one of the most efficient performers overall in terms of outputs relative to investment.[41]

DJEI investment leverages significant additional funding

The review has shown that DJEI investment leverages significant external sources of investment from enterprises and internationally. Ireland's increasing ability to attract international funding (for example, through European Framework Programmes or engagement in the European Space Agency) depends foremost on quality of the research base domestically. The impact is also circular – increased international engagement based on excellence of research in turn improves the quality of the research base in Ireland, which in turn enhances Ireland's attractiveness as a location for researchers and investment.

[41] DG Research and Innovation (2014) Research and Innovation Performance in the EU http://ec.europa.eu/research/innovation-union/pdf/state-of-the-union/2014/iuc_progress_report_2014.pdf

9. Policy Considerations

Introduction

Notwithstanding the progress made to date in developing the National Innovation System from a low base, there are some significant challenges to be addressed in order to further enhance impact and effectiveness of funding throughout the system.

Imperative to broaden the base and deepen scale of in-company innovation

In broad terms, the Irish economy and enterprise base in being significantly impacted by the pace of technological change. Technological and market forces such as the development of the data economy, which is impacting on all sectors, the exceptionally strong growth in e-commerce and online trade, and the impact of digitisation in manufacturing and services sectors are having profound effects on business models and the basis for competition in international markets.

Technological trends will have implications for the world of work in the future. The development of augmented reality/virtual reality, artificial intelligence and robotics are likely to have increased applications in a wide range of sectors from obvious ones such as manufacturing to less obvious ones such as tourism. An aging workforce will mean a comprehensive approach is required to lifelong learning and skills training. These changes will have far reaching implications for the type and amount of jobs available in the future. While this will result in job losses in some areas, ensuring the economy is at the technological frontier will mean we can compete for and win the new wave of work. Responding to the challenges that these new technologies will present requires a flexible and adaptable approach to skills development and lifelong learning at the regional as well as the national level.

Ireland remains behind its competitors internationally in terms of total economy RDI investment levels. The need to both broaden the base of firms engaged in RDI and deepen the scale of investment within the existing base is fundamental to the ability of Irish enterprises to compete in international markets. Deepening innovation activity within the existing base can also provide the pivot for enterprises to drive productivity growth. The need for sustainable export-led growth supported by a focus on continuing productivity is well recognised given previous overreliance on exposed and more labour intensive sectors.

Notwithstanding recent employment and export performance in the overall economy, job churn within the DJEI base remains elevated, with losses of approximately 5-6 percent annually. There remains a sizable cohort within the DJEI client base that is not meaningfully engaged or investing in innovation and are most vulnerable to structural change brought about by external forces. Sustaining productivity growth and employment levels demands a continuing strengthening of innovation performance in the firm client base, in particular through a continued flow of qualified graduates, a broader base of innovative enterprises and an appropriate mix of supports that facilitates and incentivises innovation throughout enterprise activities (from product and service design, to new or improved processes, to organisational innovations).

More balanced and targeted policy mixes and funding approaches are required

Enterprise focused funding through DJEI and its agencies helped to ensure relevance and a strong alignment between R&D investment and the needs of the enterprise sector. However, there remain challenges in the overall balance and mix of supports available. Most of DJEI's RDI resources are being channelled through the higher education system and most of the Government's financial support for in-company R&D is coming through the (generally applicable) R&D tax credit.

The recent European Commission Country-Specific Recommendation for Ireland has specifically pointed to increased reliance on the R&D tax credit in recent years and the need to rebalance towards a better policy support mix and direct funding, particularly for SMEs. The recommendation advises: "to stimulate innovation by SMEs, innovation policies could be rebalanced towards more direct forms of funding. Support from the government for business research and development has increasingly relied on research and development tax credits. More targeted policy mixes with more direct funding may better address the needs of Irish young innovative firms and exploit opportunities from the strong investing power of multinational companies. This would serve to facilitate access to global value chains and accelerate knowledge spillovers". [42]

Prioritising Investment to support enterprise engagement

In terms of funding for science, particularly through Science Foundation Ireland, the approach has evolved from relatively broad-based funding in the areas of ICT and Biotechnology which was appropriate for the early years of the investment programme to a portfolio approach which focuses most investment on priority areas of research and programmes with a high level of enterprise engagement. At the same time, funding continues to be available for smaller scale, investigator-led programmes with less of a requirement for direct enterprise engagement but which is also required to continually develop the human capital base.

Regarding enterprise R&D, funding instruments have been adapted, in line with changes to State Aid rules, with greater recognition of the importance of innovation in business services and new business models. Compared to some other countries, however, the supports available in Ireland have tended to focus on a traditional approach of grant subsidy for R&D performed in-company and/or in collaboration with HEIs. The suite of programmes has only recently been adapted to move towards more "demand-led" approaches such as Innovative Procurement, Small Business Innovation Research (SBIR), or the Health Innovation Hub. This builds on progress made to date on industry led collaborations in Innovation Partnerships or Technology Gateways. There is scope to re-balance the portfolio of enterprise supports further in this direction. As well as renewed focus on, and increased investment in, in-company RDI supports offered by EI and IDA, the current DJEI Review of Innovation Supports will inform the design of any new targeted initiatives that are required.

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[42] European Commission (2017) Recommendation for a Council Recommendation on the 2017 National Reform Programme of Ireland https://ec.europa.eu/info/sites/info/files/2017-european-semester-country-specific-recommendations-commission-recommendations-ireland.pdf

Innovation 2020 identifies the Research and Technology Organisation (RTO) model as an effective mechanism for delivering R&D outputs to industry based on identified market needs. The typical funding model in RTOs (such as Fraunhofer in Germany) requires one third of funding to come directly from industry and this is key to ensuring ongoing market relevance and adoption of industry-led agendas. Other characteristics of RTOs include working across the spectrum from research into development and having close links to - but a degree of separation from - the Higher Education sector. Within DJEI's remit, Tyndall National Institute (ICT) and the National Institute for Bioprocessing Research and Training (NIBRT) are identified as entities that are close to being Ireland's RTOs in terms of their scale, spread of activity and other characteristics. The area of advanced manufacturing is another area where a RTO would help to meet a critical enterprise need. There is a good base on which to build through one of the EI/IDA Technology Centres (Irish Manufacturing Research). The RTO model could be further explored to complement the work of SFI Research Centres and, in combination, this could be an effective platform to drive greater economic impact from public investment in research and development.

Responding to Brexit

DJEI's investments in RDI have become all the more critical as a result of the UK decision to leave the European Union. The challenges associated with Brexit underscore the importance of product and process innovation across the enterprise sector and particularly Irish-owned SMEs. Recent Enterprise Ireland data shows that export growth to the UK has slowed from 12 per cent in 2015 to 2 per cent in 2016 indicating Brexit is already impacting on companies exporting to that market.[43]

Key responses to the challenges associated with Brexit include the need to diversify Irish exports (both sectorally and geographically) and the need to ensure that Irish exports to the UK are as competitively priced as possible. For both reasons, it is imperative that RDI supports be mobilised to ensure that Irish companies can respond to the challenge of Brexit. In terms of academic research, there is an opportunity associated with Brexit to attract world leading researchers to Ireland and to strengthen further participation in EU research programmes (Horizon 2020) from Ireland. Brexit challenges and opportunities underscore the need for both an appropriate level of funding and the need to ensure that the funding instruments are fine-tuned to address these challenges and take advantage of the opportunities.

DJEI Innovation Activity in a European Context

As well as accounting for the largest share of Government investment in RDI, DJEI leads the whole-of-Government effort to facilitate and encourage participation by researchers and companies in EU research programmes and is currently overseeing Ireland's strategy to drawdown €1.25bn from Horizon 2020. The alignment of national policy and programmes for

[43] https://www.enterprise-ireland.com/en/News/PressReleases/2017-Press-Releases/Enterprise-Ireland-Client-company-exports-increase-by-6-globally-to-%E2%82%AC21-6bn.html

research and innovation with European policies and programmes is a critically important consideration and will be particularly important as preparations for the next round of EU funding ("FP9") get underway. This will be particularly important in the context of the refresh of research prioritisation which provides an opportunity to reassess the alignment of Irish and European research priorities. There is a link also to national funding – it is clear that strong performance in European research programmes depends on the level of investment and activity taking place nationally. Strong performance in EU research programmes cannot be achieved from a weak base and therefore continued focus is required ensure Ireland maximises opportunities to leverage international funding.

Need for whole-of-Government strategy

DJEI's investment in RDI has to be considered in the context of wider public (and private) investment. Approximately two thirds of DJEI's RDI capital funding (€250m of €380m in 2017) will be invested through Ireland's higher education system. Continuing to deliver impact from DJEI's RDI programme also depends on the health and sustainable financing of the higher education system. For this reason, deliberations around the future funding of the HE sector (e.g. Allocation Model for HEA "Block Grant", Cassell's Report on Future Funding of HE Sector, consultation on possible changes to the National Training Fund etc.) are all relevant. Innovation 2020 implementation provides a mechanism to ensure a fully joined-up whole-of-Government approach to research funding. It will be important to monitor developments in this area to ensure that the funding provided through different departments continues to be well aligned. In addition, DJEI's current review of its RDI programmes can assist in identifying areas of overlap and duplication.

Supporting Inter-company Research and Innovation Collaboration

While there is a wide range of supports that facilitate industry-academic collaboration, the DJEI "policy mix" does not currently include instruments that are targeted at facilitating one-to-one RDI collaboration between companies. While a certain level of collaboration and/or sub-contracting is allowed under existing in-company RDI supports, this is not the same as having instruments that actively target and drive such activity. A particular form of one-to-one collaboration, of special relevance in the Irish context, is RDI collaboration between foreign-owned multinationals and Irish-owned SMEs. Programmes exist in other countries that specifically target such activity (for example, Israel Binational Industrial Research and Development (BIRD) programme). A programme such as this could be considered in the Irish context and this could be taken forward in the context of the DJEI Review of Innovation Supports.

Addressing Enterprise Skills Needs through DJEI RDI Programmes

While there is evidence that DJEI's RDI investments produce human capital outputs that feed through to the needs of the enterprise sector, the numbers being produced and the length of time taken before they transition to industry are issues that need to be addressed. The review shows that PhD enrolments have declined by 11.5 percent in 2015 from a peak in 2012,

representing a significant contraction in future skills supply of researchers. A re-focusing on the quantity and quality of skilled researchers being produced at Masters level and at PhD level could help to address identified skills needs in enterprise and would accord strongly with Innovation 2020 and Enterprise 2025 goals.

There is a risk that SFI's focus on driving industry-academic collaboration, particular through its Research Centres, has the unintended consequence of shifting emphasis away from PhDs trained for industry in favour of post-doctoral researchers. These post-docs are more likely to remain employed within SFI-funded teams in order to work on collaborative projects and less likely to transition quickly to industry. In the context of increased investment required, some re-balancing of SFI funded activity to support training of Research Masters and PhD level researchers, who would move directly to industry, is warranted. At the more applied end, Enterprise Ireland should look at mechanisms to target the introduction of engineering and technology management capacity into firms in Ireland.

Sustainable Research Infrastructure Funding to Underpin World Class Research

The PRTLI programme has been a critically important component of the research funding system from its introduction in 1998 up to around 2014. The last injection of new funding under PRTLI was in 2010 and a new cycle of funding should have been announced around 2014. The programme has been key to providing the foundation investment in world class buildings, equipment and key personnel on which SFI and other funded research teams undertake their work. The decision in 2010 to integrate PRTLI within the DJEI suite of RDI programmes was designed to ensure even tighter integration of research infrastructure investment with the funding delivered through SFI. The reduction in funding from 2014 is the key gap that currently exists in the Higher Education research funding system. SFI has tried to plug the gap through occasional, targeted calls for new equipment through its own budget. However, this is not a sustainable long term solution. The restoration of a funding line (of approx. €50m to €75m per annum) for sustainable, planned investment in research infrastructure (buildings, equipment and key personnel) is a priority for DJEI programmes on the Higher Education side and needs to be urgently addressed.

Future Analysis and Evaluation

As documented in DJEI's Evaluations Synthesis Report, it is clear that ex-ante and ex-post evaluation methodologies need to evolve to reflect the 'systems' approach to supporting companies, in order to ensure that the most appropriate mix of supports is continually provided. It is also important to further understand the longer term impacts of supports in the more foundational aspects of the system such as human capital and infrastructure, and their role in driving performance downstream in commercialisation and collaboration activities. The role of policy measures such as Research Prioritisation in enhancing the focus of funding and its connection to growth also needs to be continually assessed. Together, this assists in developing a better understanding of the National Innovation System as it matures.

In this context, it is important to continually explore a range of quantitative and qualitative evaluation techniques that can tackle the complexities of the innovation system and provide the

evidence base for most effective targeting of supports. Some future areas for areas for further analysis and evaluation identified in consultation with Department of Public Expenditure and Reform could include:

- Impact of Research Prioritisation: understanding how redirecting funding towards areas of greatest market potential for Ireland translates down the line to economic opportunity and growth.
- Growth and Resilience of Innovation Active SMEs: building on ESRI empirical evidence and DJEI evaluations, analyse how starting on the innovation pathway by non-active firms connects through to capability and capacity to withstand shocks and achieve higher growth rates. Following on from this, assess how a continued strategic focus on building in-house innovation capabilities translate through to scaling and success in international markets.
- Knowledge transfer of PhDs: given the significant ramping up of PhDs since the early 2000's trace the extent of mobility of PhD researchers post-graduation from the public system to the private sector and the degree of application of their skills gained in an enterprise setting.
- Sectoral and size dynamics: Identify sectoral and size dynamics underpinning innovation performance and what they could mean for tailoring supports.
- Data Collection: Actively engage with the agencies to review ex-ante data variables that can be used to evaluate supports in future.
- Enterprise Ireland Client Engagement Model: Ensure data is collected on Enterprise Ireland clients engaged in the new client engagement model with a view to a future evaluation of the impact and objectives of the CEM in delivering more targeted supports.

Glossary

ABSEI – Annual Business Survey of Economic Impact

BERD – Business Expenditure on Research and Development

BIRD – Binational Industrial Research and Development

CBA – Cost Benefit Analysis

COST – Co-operative in Science and Technology Programmes

CSETS – Centres for Science, Engineering and Technology

DJEI - Department of Jobs, Enterprise & Innovation

DPER – Department of Public Expenditure and Reform

EI – Enterprise Ireland

EMBC – European Molecular Biology Conference

EMBL – European Molecular Biology Laboratory

ESA – European Space Agency

ESRI – Economic and Social Research Institute

EVA – Estimated Net Value Added

FACE Model – Financial Analysis & Company Evaluation Model

FP – Framework Programme

GBARD – Government Budget Allocations for Research and Development

GERD - Gross Expenditure on Research and Development

GOVERD – Government Expenditure on Research and Development

HEA – Higher Education Authority

HEIs – Higher Education Institutes

HERD – Higher Education Expenditure on Research and Development

HPSU – High Potential Start UP

IDA Ireland – Industrial Development Agency Ireland

IGEES – Irish Government Economic Evaluation Service

IPR – Intellectual Property Rights

LOAs – Licences, Options and Assignments

MIS – Management Innovation Systems

NIBRT – National Institute for Bioprocessing Research and Training

NIS - National Innovation System

OECD - Organisation for Economic Co-operation and Development

PCT – Patent Cooperation Treaty

PLM – Programme Logic Model

PRS – Public Research System

PRTLI – Programme for Research at Third Level Institutions

RDI – Research, Development & Innovation

ROI – Return on Investment

RTD – Research & Technical Development

RTOs - Research and Technology Organisations

SBIR – Small Business Innovation Research

SFI – Science Foundation Ireland

SME's – Small to Medium Enterprises

SRCs – Strategic Research Clusters

SSTI – Strategy for Science Technology and Innovation

TTSI - Technology Transfer Strengthening Initiative

Appendix I – Evolution of RDI Policy

Phase 1: Technology Foresight and the National Development Plan (2000-2006)

The first phase of the activity was activated with a decisive shift in public policy stemming from the conclusions of the Irish Council for Science Technology and Innovation (ICSTI) **Technology Foresight Exercise**[44] and initiated under the National Development Plan (NDP) 2000-2006, through its Technology Foresight Fund. The Foresight exercise concluded that for Ireland to remain competitive and provide well paid employment, it needed a transformation of the R&D performance of the enterprise base and an upgrading of the scientific and research skills of the public research system. From a public investment of €0.5bn in the period 1994 to 1999, the NDP 2000-2006 set out a five-fold increase in budget for industry related science and technology expenditure. This had the goal of investing in R&D in key areas of technology that could best assist in the upgrading the future competitiveness of the traded goods and services sector in Ireland. This strategy involved:

- Significantly scaling up the R&D capacity and science and technology infrastructure in Ireland's HEIs and other public research organisations;
- Strengthening the supports available to research students and researchers in third-level and state research institutes;
- Directly supporting R&D capacity within the enterprise sector; and
- Increasing the quantity and quality of the R&D between institutions and companies[45].

Key public investments during this phase included:

- Expansion of the funding through the Higher Education Authority (HEA) **Programme for Research in Third Level Institutions** (PRTLI) towards supporting the development of basic research in the HEIs through investment in human capital and physical infrastructure;
- Establishment of **Science Foundation Ireland** in 2000 to fund the development of world class research capability in the HEI system and the building of research excellence in biotechnology and ICT; and
- Establishment of the **Research Councils** to fund research excellence across a wider range of disciplines.

Phase 2: Strategy for Science, Technology and Innovation and Research Prioritisation Exercise, 2006-2016

Phase 2 recognised that Ireland's innovation system was still relatively underdeveloped in terms of the comparative strength of the public and private research bases and their inter-linkages, the

[44] Technology Foresight Report 1999

[45] Ireland- National Development Plan, 2000-2006, p.129

number of researchers in the enterprise sector, and the returns firms were achieving from their innovation performance. The vision for RDI in Ireland, as articulated in the **Government's Strategy for Science Technology and Innovation 2006-2013 (SSTI)** and in the NDP was that, by 2013, Ireland would be internationally renowned for the excellence of its research, and would be to the forefront in generating and using new knowledge for economic and social progress, within an innovation driven culture. Overall the SSTI agenda was acted on through:

- Targets to **increase the number of enterprises with minimum scale** R&D to 1,570 and significant R&D to 250;
- Setting a target of an **increase in the number of science, technology, engineering and maths (STEM), and Arts, Humanities and Social Sciences (AHSS) PhDs** by 2013 (with a 2005 baseline), from 543 to 997, and 187 to 315 respectively;
- Increased focus on public investments within the HEI system that were geared towards **increased collaboration of firms with the HEI R&D system** and engagement with other firms in enterprise-led agendas. At the end of this phase, the key State-funded centre programmes focused on supporting enterprise to collaborate on R&D with HEIs are the SFI Research Centres, and the Enterprise Ireland/IDA Ireland Technology Centres;
- Development of a **Technology Transfer Office** (TTO) Infrastructure[46]. This later evolved into Knowledge Transfer Ireland (KTI) which supports 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 economy;
- Continued funding of campus incubation facilities in the HEIs in support of **commercialisation of HEI** performed R&D activity; and
- Changes to legislation in 2013 to allow SFI to fund applied research, thus increasing the opportunity for public funding to stream to nearer to market R&D activity in the HEIs - a particularly attractive proposition for small and medium enterprises (SMEs).

As occurred across Government spending, the implementation of SSTI was impacted by the financial crisis which required significant adjustments to the projected investment planned under SSTI. As well as reductions in levels of public investment there was a much sharper policy focus on leveraging the investment than had been made to date by targeting investment on public research that could deliver an economic return particularly in the form of jobs. This was the underpinning rationale for the **Research Prioritisation Exercise** (RPE) in 2012. It was acknowledged that RDI needed to remain central in the Government's economic strategy in order to drive sustainable enterprise growth. This combination of limited resources and crucial need led to a decision to focus investment in those areas that were most likely to give demonstrable returns in the medium term while at the same time, sustaining an innovation system that could underpin longer term national prosperity and wellbeing.

[46] Since 2007, the State has invested in boosting the knowledge transfer capability and capacity in Ireland's research base. A total of €52 million has been invested (2012-2016) through two rounds of the Enterprise Ireland Technology Transfer Strengthening Initiative (TTSI) programme. - See more at: http://www.knowledgetransferireland.com/How-to/Technology-Transfer-Offices/#sthash.T46XDzQr.dpuf

Government, in partnership with enterprise, identified **14 Priority Areas** that presented particular market opportunities for Ireland. The RPE also identified the need to support relevant key enabling technologies to underpin the priority areas and, equally importantly, provide the foundation on which to develop capacity in new, emerging areas of opportunity. In tandem the SFI research centre portfolio was consolidated into a smaller number of larger centres that are broadly aligned with the research priority areas[47].

Phase 3: Innovation 2020

Launched in December 2015, *Innovation 2020,* which marks the third phase of Ireland's RDI policy evolution and sets out Ireland's five year strategy for research and development, science and technology, including a roadmap to deliver on the vision for Ireland to become a global innovation leader by focusing on excellence, talent and impact. The vision set out for this strategy is for Ireland to become a Global Innovation Leader driving a strong sustainable economy and a better society underpinned by:

- Excellent **research in strategically important areas** that has relevance and impact for the economy and society;
- A strong innovative and **internationally competitive enterprise base**, growing employment, sales and exports;
- A **renowned pool of talent both** in Ireland's public research system and in industry that maximises exchange of talent and knowledge;
- A coherent **joined-up innovation ecosystem**, responsive to emerging opportunities, delivering enhanced impact through the creation and application of knowledge; and
- An **internationally competitive research system** that acts as a magnet and catalyst for talent and industry.

While the balance of funding has evolved to reflect the overall economic and social objectives of the RDI policy, *Innovation 2020* continues to recognise the interdependencies of the different activities within the innovation system and the requirement therefore to sustain all activities at an optimum level to ensure that weaknesses in one area of activity does not constrain performance others. Innovation 2020 also seeks ensure value for money through targeting investment at economic return and to address the legacy of relative underinvestment on the public side across all elements of the system. The ambition of *Innovation 2020* is to **increase overall expenditure on R&D to 2.5% of GNP**, while retaining the three quarters to one quarter balance between private and public funding. This is aligned with Ireland's *Europe 2020* target for Gross Investment in Research and Development. Increased investment will be targeted at:

- Increasing the number of **research personnel** in enterprise to 40,000;
- **Researchers**: increase annual research masters and PhD enrolments by 500 to 2,250;

[47] Their objective was to accelerate advances in research through the advantage of scale and to acts as flagships in terms of critical mass, strategic focus and visibility for Irish RDI capabilities internationally.

- Supports for enterprise: **Doubling private investment in R&D** within the public research system;
- **Research Centres**: Further developing the network of Centres, building critical mass and addressing enterprise needs;
- Infrastructure: Introducing a **successor to the Programme for Research in Third Level Institutions** to provide investment in new facilities and equipment, and the maintenance and upgrading of existing ones; and
- Expanding Ireland's participation in **International Research Organisations**.

Appendix II Agency Roles and Programme Activities

Agencies

Science Foundation Ireland invests in academic researchers and research teams who are most likely to generate new knowledge, leading edge technologies and competitive enterprises. SFI programmes form a key element of the drive to boost Ireland's international competitiveness and attract foreign direct investment. The expansion of SFI's new remit under the Industrial Development (Science Foundation Ireland) Act 2013 has allowed SFI to fund activities in the applied research arena, as well as continuing to provide key supports for oriented basic research. SFI makes grants through its centres and programmes based upon the merit review of distinguished scientists.

Enterprise Ireland is the government organisation responsible for the development and growth of Irish enterprises in world markets. Enterprise Ireland works in partnership with Irish enterprises to help them start, grow, innovate and win export sales in global markets. Enterprise Ireland's RDI competencies are broad with supports for both companies and researchers in Higher Education Institutes to develop new technologies and processes that will lead to job creation and increased exports. Broadly, supports include direct funding to firms and funding for commercialisation and collaboration between enterprises and the research system. Enterprise Ireland also houses the National Support Office for EU Framework Programme funding.

IDA Ireland is the inward investment promotion agency focused on promoting Foreign Direct Investment into Ireland through a range of services. IDA Ireland partners with potential and existing investors to help them establish or expand their operations in Ireland. IDA Ireland plays an important role in RDI development by providing funding support to suitable projects in the form of direct grants to industry and referral of client companies to relevant supports provided by other innovation agencies.

The **Programme for Research in Third-Level Institutions** (PRTLI) provides integrated financial support for institutional strategies, programmes and infrastructure in key areas of research spread across all disciplines. The programme supports research in humanities, science, technology and the social sciences, including business and law. It is administered by the Higher Education Authority (HEA). Note, PTRLI was transferred to DJEI in 2010.

Other DJEI funding provided relates to participation in international programmes and specialist research organisations/programmes. DJEI is responsible for developing and co-ordinating Ireland's input to EU research policies and programmes. DJEI is also responsible for the funding of, and is represented on, the Governing Council of the European Space Agency (ESA) and the policy formulation committees of the following four Inter-Governmental S&T Organisations: European Molecular Biology Conference (EMBC); Co-operation in Science and Technology Programmes (COST); EUREKA; European Molecular Biology Laboratory (EMBL)

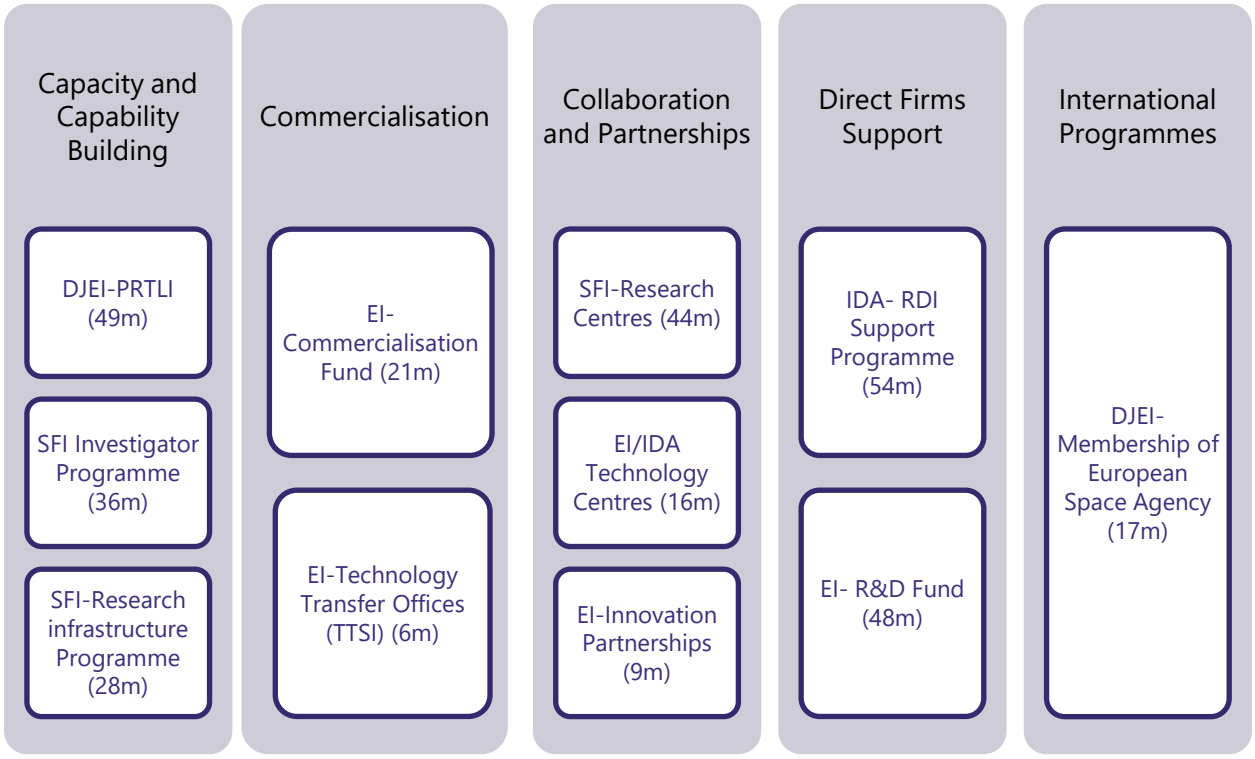
DJEI is also responsible for funding and providing administrative support to ELIXIR – A distributed infrastructure for life-science information and for CECAM-IRL an organization devoted to the promotion of fundamental research on advanced computational methods and to their application. DJEI funds the Tyndall National Institute, UCC is one of Europe's leading centres for Information, Communications and Technology research and development aimed at

providing a critical mass of researchers that would support the growth and development of a smart knowledge based economy in Ireland. In addition, DJEI co-funds the The Irish Centre for High-End Computing (ICHEC). Its mission is to provide High-Performance Computing (HPC) resources, support, education and training for researchers in third-level institutions and through technology transfer and enablement to support Irish industries large and small to contribute to the development of the Irish economy.

Main Programmes

This section provides a brief overview of the main programmes that are funded by DJEI and their key objectives and outputs. Together, the programmes account for approximately XX percent of total funding by DJEI in 2015. The programmes are set out below according to the funding themes presented in the inputs section. Only programmes with funding greater than €5m are included. The full list of programmes and expenditure is in provided in the Appendix for Information.

Figure 5.1 Main Programmes by Theme and Expenditure



Source: DJEI/Agency Data

Capability and Capacity Building

DJEI-Programme for Research at Third Level Institutes (€49m): This programme's main objective is to enhance Ireland's competitive offering in terms of research capability and capacity. The activities of the programme promote research at 3rd level institutes through government funding in areas of scientific interest as well as the development of new research infrastructure. The outputs of the programme include research infrastructure, research stations PhD's graduates and research posts.

SFI Investigator Programme (€36m): The SFI Investigators Programme supports the development of world-class research capability and human capital in areas of science, technology, engineering and mathematics (STEM) that demonstrably support and underpin enterprise competitiveness and societal development in Ireland. To this end, the Investigators Programme funds outstanding people with innovative ideas and strategic partnerships, recognising that excellence remains a paramount criterion. For this Programme, scientific excellence is both necessary and paramount but is not sufficient in isolation; applications must also be able to clearly articulate the potential for economic and societal impact.

SFI-Research infrastructure Programme (€28m): The objectives of this programme include enhancing activities and outputs of SFI researchers and other research groups, promote future sustainability through the development of access charge plans and encourage strategic infrastructural planning by research bodies. The objectives are achieved by funding key research Infrastructures that will enable Irish researchers to compete for Horizon 2020 research funding calls in particular the EU Framework Programmes for Integrated Research Infrastructures, Societal Challenges and Leadership in Enabling and Industrial Technologies (LEIT). The outputs include, key research infrastructure improving the capacity and capability of R&D investment in Ireland.

Commercialisation

EI-Commercialisation Fund (€21m): The programme objectives include transforming innovative ideas to new Products and assisting HEI's to develop commercially valuable outputs. The activities include the development of proof of concept projects, tech development projects and commercialisation projects. The outputs of the programme include increasing the number of Spin-outs/IP academic research and increasing competitiveness between companies and of Irish firms on a global scale.

EI-Technology Transfer Offices (TTSI) (€6m): Technology Transfer offices help researchers to explore the commercial potential of their technology. The objective of the transfer offices is to help fund and support researchers wishing to develop, protect and commercialise technologies. This includes a number of soft supports, such as advice and area knowledge and expertise. The outputs of the programme include the number of companies that are aided in commercialising technologies and increased Spin-outs.

Collaboration and Partnerships

SFI-Research Centres (€44m): The project aims to develop a set of world-leading, large-scale research centres that will provide major economic impact for Ireland improving overall capacity to undertake research in the long run. The centres are established to promote linkages in research between academia and industry. Following the course of the programme a number of outputs have been produced including infrastructure, research collaboration and high quality research.

EI/IDA Technology Centres (€16m): There are 15 industry-led research centres in the Technology Centres Programme. The centres are collaborative entities established and led by industry. They are resourced by researchers associated with research institutions who are empowered to undertake market focussed strategic R&D for the benefit of industry. This is a

joint initiative between Enterprise Ireland and IDA Ireland allowing Irish companies and multinationals to work together in these centres.

EI-Innovation Partnerships (€9m): The Innovation Partnership Programme provides up to 80% of the cost of research work to develop new and improved products, processes or services, or generate new knowledge. Outputs of the programme include research, collaborations between smaller industry members and academia.

Direct Funding of Firms

IDA- RDI Support Programme (€54m): IDA Ireland plays a role in RDI development by providing funding support for suitable projects. The aim of the R&D support programme is to Increase R&D Capability and Capacity and moving subsidiaries of multinational companies up the value chain in Ireland. IDA Ireland also identifies support opportunities from partner organisations, such as Enterprise Ireland, Science Foundation Ireland and Sustainable Energy Authority Ireland.

EI- RDI Fund (€48m): The Research, Development & Innovation (RDI) Fund supports the development of new or substantially improved products, services or processes which will have a competitive advantage in their target market. This aims to enable companies increase employment through sustainable and substantially increased sales. Projects must be non-routine and represent a 'step-up' for the company in terms of the level of RDI capability.

International Programmes

DJEI- Membership of European Space Agency (€18m): Ireland's membership of ESA permits Irish companies (60) and research teams (13) to bid for ESA contract development work in a range of space programmes. ESA promotes co-operation among European States in space research, technology and applications. Enterprise Ireland's role in relation to ESA is to assist Irish companies to successfully bid for ESA contracts. Enterprise Ireland provides support for Irish companies in developing and executing space strategies, as well as being a point of reference for the international space industry when they want to identify relevant sources of space-related expertise within Ireland. ESA provides a platform for the development of innovative space technologies and their export on world markets valued at over €80 million p.a.

European Framework Programmes represents a significant proportion of international funding of research into Ireland. The Framework Programme has historically been an important element in the internationalisation of Irish research and driver of excellence within the research base. Funding is competitive with an emphasis on excellent science, industrial leadership and tackling societal challenges. Horizon 2020 is the 8th EU framework programme for research and innovation. With a budget of €75 billion, Horizon 2020 runs over seven years from 2014 – 2020. Horizon 2020 is the successor programme to FP7 (Framework Programme 7) and is the largest ever research and innovation programme in the EU. DJEI chairs the Horizon 2020 High Level Group whose core role is to oversee the development and implementation of the Horizon 2020 national strategy. The Horizon 2020 HLG consists of members from across Departments and Agencies.

Summary and Conclusions

DJEI activities support a portfolio of different measures which aim to enhance and increase activity in complementary ways across the National Innovation System.

Appendix III – Full List of Programmes by Theme and Agency

Detailed Breakdown of Programme Expenditures	2015 (€000's)
Capacity and Capability Building	**€142,783**
DJEI	**€51,214**
DJEI-ICHEC	€1,400
DJEI-PRTLI	€49,814
Enterprise Ireland	**€4,463**
EI- Innovation Management	€24
EI- New Frontiers	€4,439
IDA Ireland	**€600**
IDA-NIBRT	€600
Intertrade Ireland	**€1,539**
InterTrade- Fusion Programme	€1,539
Science Foundation Ireland	**€84,967**
SFI- Career Development Award	€1,722
SFI- Centres (National Access Programme)	€2,808
SFI- Charles Parsons Energy Research Awards	-€2
SFI- Engineering- Professorship and Lectureship Programme	€6
SFI- ERC Development Award	€2,586
SFI- ETS Walton Visitor Award	€16
SFI- Research Frontiers Programme	€735
SFI- STOKES- Professorship and Lectureship Programme	€31
SFI- Translational Research Award	€222
SFI/Irish Research Council- Postgraduate Scholarship Scheme	€522
SFI-ERC Support: starting, consolidator, advanced	€2,325
SFI-HRB-Welcome Trust Awards	€111
SFI-Industry Fellowship Programme	€509
SFI-Investigator Programme	€36,146
SFI-President of Ireland Young Researcher Award(PIYRA)	€1,455
SFI-Research infrastructure Programme	€28,766
SFI-Research Professorship (including 'SFI Fellow' programme, active 2002 to 2006)	€3,091
SFI-Starting Investigator Research Grant (SIRG)	€3,918
Direct Firm	**€103,145**
Enterprise Ireland	**€48,465**
EI- R&D Fund	€48,465
IDA Ireland	**€54,564**
IDA- RDI Support Programme	€54,564
Intertrade Ireland	**€116**
InterTrade-INNOVA	€116
International Collaboration	**€24,575**
DJEI	**€18,611**
DJEI - EUREKA	€26
DJEI - European Molecular Biology Conference	€190
DJEI- Membership of European Space Agency	€17,279
DJEI-European Molecular Biology Laboratory	€1,116
Enterprise Ireland	**€3,574**

EI International Collaboration Activities	€3,574
Science Foundation Ireland	**€2,390**
SFI- US-Ireland partnership	€2,390
Knowledge Exchange: Collaboration	**€103,092**
DJEI	**€3,400**
DJEI-Tyndall	€3,400
Enterprise Ireland	**€34,030**
EI/IDA Technology Centres	€16,034
EI-Industry Led Networks	€62
EI-Innovation Partnerships	€9,605
EI-Innovation Vouchers	€4,216
EI-Technology Gateways	€4,113
Science Foundation Ireland	**€65,662**
SFI- Spokes	€3,392
SFI-CSET	€9,228
SFI-Pfizer Biotherapeutics Innovation Award Programme	€896
SFI-Research Centres	€44,909
SFI-SRC	€4,563
SFI-Strategic Partnerships	€2,674
Knowledge Exchange: Commercialisation	**€34,801**
Enterprise Ireland	**€30,334**
EI-Campus Incubation Facilities	€2,222
EI-Commercialisation Fund	€21,865
EI-IP Assistance Scheme	€93
EI-Technology Transfer Offices (TTSI)	€6,154
Science Foundation Ireland	**€4,467**
SFI/EI TIDA	€4,467
Grand Total	**€408,396**

Appendix IV European Space Agency Outputs

Outputs from International Engagement (European Space Agency)

Ireland's investment in the European Space Agency represents approximately 70 percent of total DJEI funding for participation in international programmes. The remainder of activity is across smaller niche research areas (approximately €1m-€3.5m per annum). The main output/outcome metrics from ESA are below relative to funding. Note, funding by DJEI gives Ireland membership of the ESA and enables companies and institutes to bid for ESA contracts. The output/outcome indicators are an indicator of the quality of the innovative technologies in the Irish space sector developed over the last 10 years.

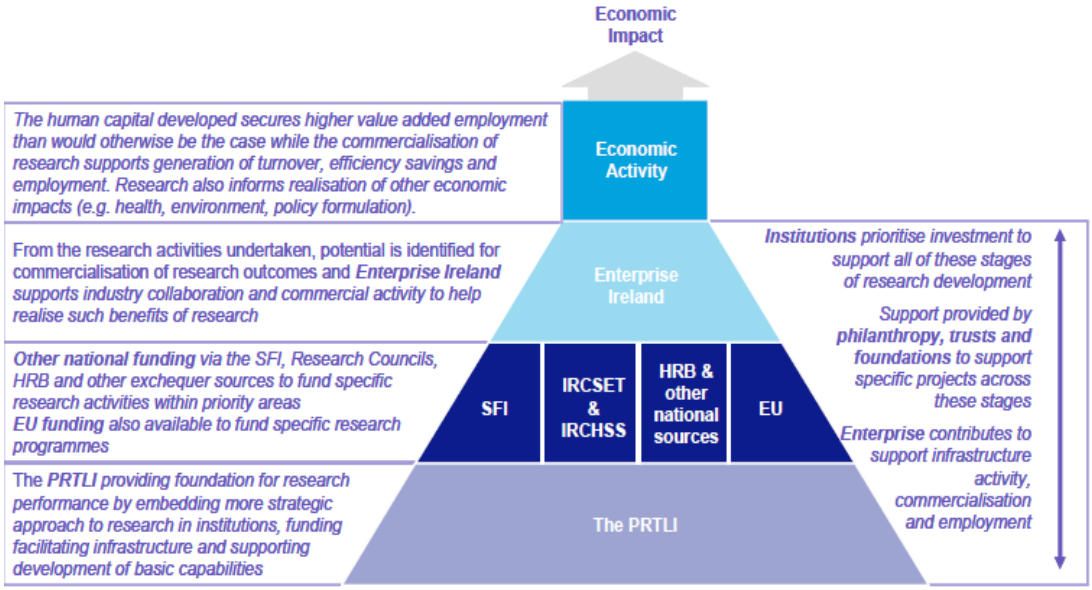
Key metrics	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Change 2006-2016	% change	Average Annual Growth
Investment in ESA (€m)	12.3	13.2	13.5	14.5	14.4	14	14.8	17.3	17.3	17.3	19.3	7	57%	5%
Number of Contracts placed with industry in Ireland	25	13	22	20	23	27	29	23	25	29	24	-1	-4%	4%
Number of Contracts placed with HEIs/Other in Ireland	5	5	5	7	6	7	8	9	7	10	11	6	120%	10%
Value of Contracts placed in Ireland (Industry & HEIs) (€m)	6	6	8	9	9	9	10	11	12	13	13	7	117%	8%
Number of companies active under contract	30	30	35	35	35	35	40	45	50	55	60	30	100%	7%
Direct Sales/Exports	14	16	18	25	30	35	40	43	55	77	80	66	471%	20%

Source: DJEI. Note, €19.3m in 2016 reflects a non-recurring additional payment of €2m in 2016.

The figures show that there has been increase in activity across the different metrics, generally in excess of the rate of increase in funding.

- The number of contracts with industry and higher education institutes has grown by 4 percent and 10 percent on average per annum.
- The value of contracts has increased from €6m to €13m
- The number of active companies has doubled from 30 to 60.
- Exports within the client cohort have increased from €14m to €80m or 20 percent per annum.

Appendix V – Programme for Research in Third Level – Economic Value Framework

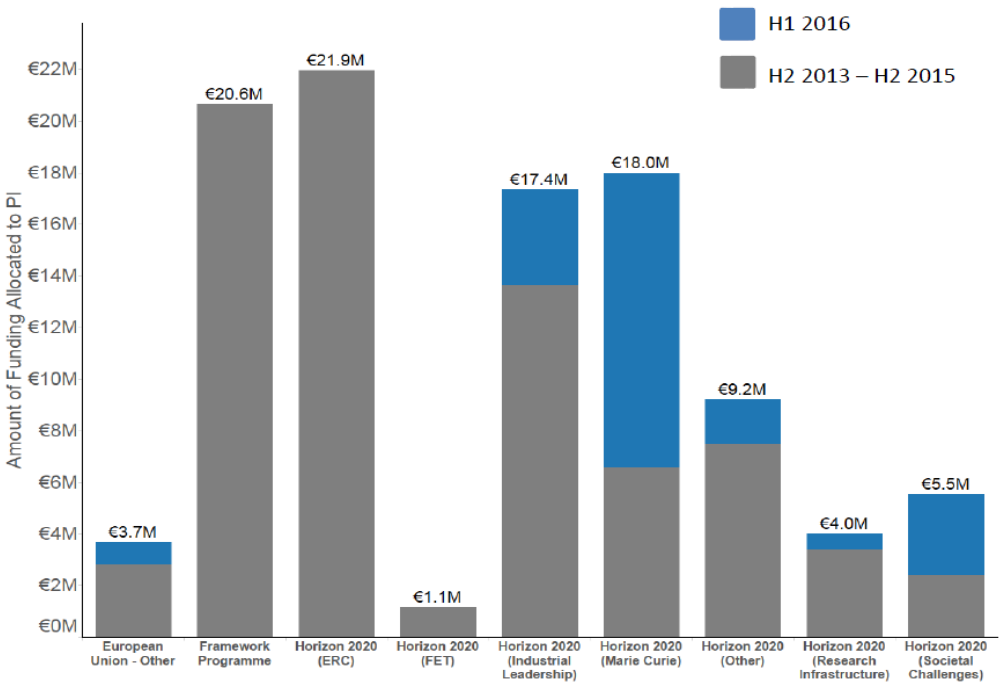


Source: Higher Education Authority/PA Consulting Group (2011) Ten Years On – Confirming Impacts from Research Investment MOVE TO APPENDIX

Appendix VI – SFI leverage of European Funding

The following graph shows how SFI principal investigators have secured funding from various strands of the current European Framework Programme (Horizon 2020). Overall, €101.4m of EU funding has been allocated to SFI principal investigators to 2016. According to SFI, this is only possible due to national investment in the research centres.

Figure 7.9 EU Funding secured by SFI Research Centres by Funding Stream



Source: Science Foundation Ireland

Appendix VII DJEI Evaluations – Deadweight and CBA Estimates

Estimates of CBA and Deadweight – DJEI Evaluations

Programme	CBA	Deadweight	Approach
Commercialisation			
Enterprise Ireland Commercialisation Fund 2003-2009	2.04:1 to 2015 Discounted Deadweight Leakage Displacement Substitution Multiplier	62 percent turnover, 64 percent employment	Scottish 75 percent Survey
Enterprise Ireland Intellectual Property Assistance Scheme 2005-2009	No formal CBA – estimate of future income from licencing	66 percent – quality of application is central to decision	Survey
Business Partners 2009	Not undertaken	Not undertaken	Rely on international approaches New metrics developed
Campus Incubation 2005-2007	Not undertaken (too early to assess)	Not undertaken (to early to assess)	Rely on international approaches Sign posting
Collaboration			
SFI Centres for Science, Technology and Innovation 2003-2012	General measures of additionality – linkages, industry relevance	Qualitative – would not have had opportunity	Survey
SFI Strategic Research Clusters 2007-2012	Not undertaken	1/3 of companies said they would not have developed the technology at all without the SRC support	Survey
Enterprise Ireland Innovation partnerships 2004-2006	2.13:1 to date Discounted Deadweight Leakage Displacement Substitution Multiplier	93 percent for turnover 95 percent employment	Survey
Enterprise Ireland Innovation Vouchers 2007-2012	2.95:1 to date Discounted Deadweight Leakage Displacement Substitution Multiplier	90 percent Partial Deadweight (turnover) A lot lower Moderately lower About the same	Survey
Enterprise Ireland Technology Gateways 2012	N/A	Partial Deadweight – (project basis) would have gone ahead, delayed, smaller, cancelled	Survey
Enterprise R&D Support			
IDA R&D Fund 2003-2009	€5.07 to 1 €25 to 1 Future Value Deadweight Displacement Leakage Multiplier	63 percent deadweight (turnover basis)	Survey – a lot lower moderately lower, about the same.

Programme	CBA	Deadweight	Approach
	Control Group Analysis – Counterfactual R&D Fund Companies, Non R&D Fund Companies, Total		
Enterprise Ireland RTI Scheme 2002-2006	CBA 1.82 Control group analysis EI RTI companies, Non RTI and All EI companies	35 percent deadweight (project decision basis). Abandoned, reduced, unchanged, delayed,	Survey + Control Group Analysis
Enterprise Ireland R&D Advocates 2006-2011	NA	58 predicted turnover would be lower, 43 percent that employment would be lower	Survey + Control Group Analysis

Source: DJEI (2014) Evaluation of Enterprise Supports for RDI

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