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Economic and Enterprise Impacts from Public Investment in R&D in Ireland

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A Report by the Strategic Policy Division, Department of Jobs, Enterprise and Innovation

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Executive Summary

ES 1. Public Investment in R&D in Support of Innovation-Led Growth in Ireland

Much of Ireland's success in the 1980s and 1990s can be attributed to providing a manufacturing base for intellectual property that was developed elsewhere by multinational companies (MNCs). During this period, Ireland's cost base increased towards that of other advanced economies. This increased cost base can be linked to relocation of high production manufacturing activities by MNCs to lower cost locations and a corresponding decline in employment in Irish manufacturing from the peak it experienced in the late 1990s. From this time, there was an acceptance that the factors which contributed to Ireland's economic success in the past in terms of low cost environment and attractive fiscal regime would not be sufficient to maintain success into the future and Ireland needed to find a new way to compete globally so as to ensure greater resilience in the enterprise base.

Research indicated that to sustain high levels of quality employment and the ability to generate wealth, we would increasingly depend on our ability to innovate and sell differentiated, high-value products and services to global markets. International evidence, including for Ireland, relates innovation to increased productivity, economic growth and new job creation. To realise the transformation of the enterprise base towards one based on knowledge activities, it was considered that Ireland needed to: strengthen the national R&D skills base; strengthen the innovation performance of enterprises in Ireland; and be able to develop and commercially exploit our own intellectual property and new knowledge from around the world.

Government has a pivotal role in driving this structural change. This stems from the need to address market failures related to knowledge spill-overs from private investment in research and development (R&D), risks associated with imperfect information and costs associated with R&D activity. However, it also stems from the role of Government in incentivising and supporting the enterprise base to develop its capacity and capability in R&D. In particular Government plays a key role in the supply side for enterprise R&D through supporting: the development of the researchers required by the enterprise base to undertake R&D; the development of new knowledge within the publicly performing research system; and the transfer and diffusion of economically and socially useful knowledge and outputs arising from R&D.

International evidence points to enhanced private sector R&D activity from public investment in private R&D, and clear private and social returns emanating from the firm-level R&D. However, the economic impact arising from publicly performed R&D has been universally more difficult to determine - though some studies have looked at elements of the public investment such as the impact of investments from specific public R&D funding bodies or programmes, and reported positive economic returns.

Overall, however, the international evidence acknowledges that due to: the multiple investments in R&D across multiple R&D performing entities; the non-linear nature of innovation systems; and the time-lag that exists between the investments in R&D activity and the commercial

benefits, that it is difficult to determine a single, econometrically based numerical estimate for return on public investment in R&D.

To date, the return on public investment in R&D has been examined across a number of R&D funding programmes in Ireland. However, there has been no consolidated evidence base that reviews the returns from public investment in R&D for Ireland in a collective manner. This study aims to address this insofar as is possible, though it is noted that a wide range of methodological approaches have been employed to date to assess impact and some of these methodologies are more robust than others. The study focuses on the public R&D investments that are aimed at achieving enterprise impacts: this relates to investments by Department of Jobs, Enterprise and Innovation, Enterprise Ireland, IDA, Science Foundation Ireland, The Higher Education Authority, The Irish Research Council, and InterTrade Ireland. While it is acknowledged that there are broader economic and social impacts arising from public investment in R&D this report does not try to capture those, focusing exclusively on enterprise impacts. Overall, this report sets out:

- The evolution of public research, development and innovation (RD&I) policy and the focus of public investment in R&D in Ireland specifically towards realising enterprise impacts between 2000 and 2015.
- The economic and enterprise impacts of R&D active firms in Ireland.
- The evidence base demonstrating the economic and enterprise impacts of the public investments in R&D in Ireland.

ES 2. Evolution of National RD&I Policy and Public Investment in R&D in Support of Economic and Enterprise Impacts: 2000-2015

There has been a clear and deliberate evolution of research and development and innovation (RD&I) policy in Ireland since 2000. This policy agenda has focused on building a national innovation system that supports economic and social goals and public investment in R&D has been shaped by 4 interrelated elements:

- Capacity and capability of the publicly performing research system: the objective has been 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.
- Enterprise RD&I Base: the objective has been to broaden and deepen the enterprise R&D base, its absorptive capacity and its ability to develop and commercialise intellectual property.
- Knowledge Exchange System: the objective has been to strengthen the system of knowledge exchange through three main channels: formal collaborations, human capital mobility and knowledge transfer infrastructure.
- Public sector research: the objective has been to invest in Government research organisations and funding programmes to underpin public policy.

Ireland's RD&I policy has been strategically evolved since 2000 across three key phases:

- Phase 1 (2000 – 2006): Technology Foresight Exercise and the National Development Plan
- Phase 2 (2006-2015): SSTI 2006-2013 and Research Prioritisation Exercise
- Phase 3 (2016 – 2020): Innovation 2020

Having come from a low base, Ireland has made very significant progress over the past fifteen years in building a research infrastructure that in some instances is amongst the best in Europe; in retaining and attracting top level researchers; and in achieving closer synchronisation between research endeavour in HEIs, Government agencies, and industry.

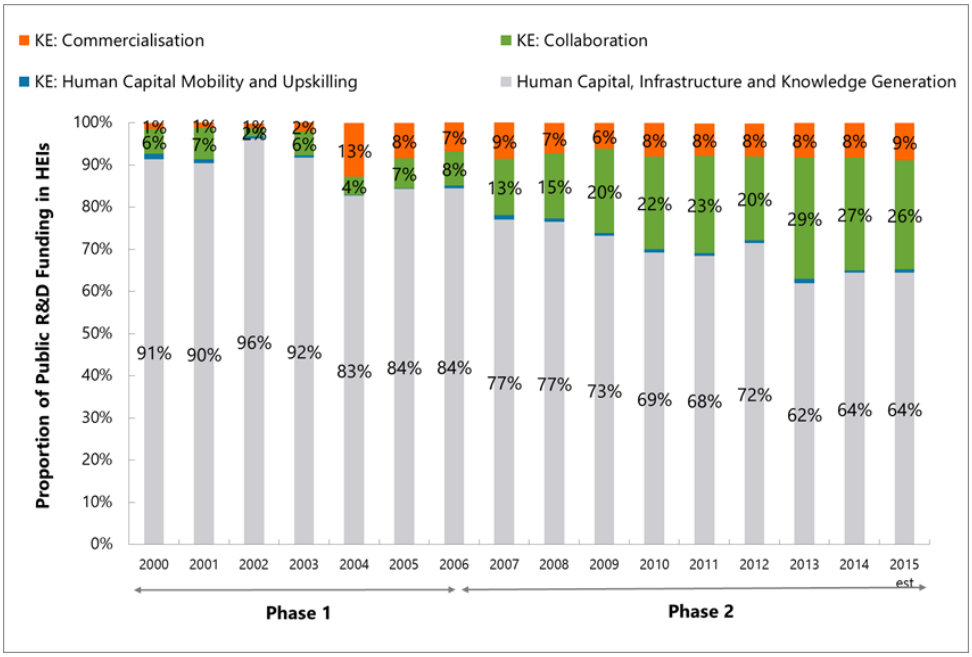
In tandem with the policy evolution, there has been an evolution of the levels and orientation of public investment on R&D across three elements of the innovation system that are targeted at enterprise impacts, namely: the Public Research System; the Enterprise R&D Base; and the Knowledge Exchange System. Funding allocations in the first phase reflected the key policy objective to develop the capacity and capability of the publicly performing R&D system from a low base. Year on year increases in public investment in R&D to both HEIs and firms were recorded, but with a higher proportion of public investment directed towards HEIs.

Funding allocations in phase two reflected the policy ambition to build on the evolving capacity and capability in the HEI R&D system towards strengthening the innovation system across its other elements, and the impact of the recession and research prioritisation. During this period there was a decline in the overall level of public funding for R&D to HEIs (from 2009) and an increased proportion of public investment directed to firms. The increased focus on achieving economic and enterprise impacts was further emphasised during this period by the shifting emphasis of funding in HEIs towards knowledge exchange activities[1], as is demonstrated in Figure ES1.

Innovation 2020 marks the third phase of Ireland's RD&I policy evolution and it sets out Irelands 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. It also 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 in other areas. While setting out ambitious targets for growth, Innovation 2020 also seeks to address the legacy of relative underinvestment on the public side across all elements of the system: the ambition 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.

[1] Here, knowledge exchange activities relate to activities associated with transferring of knowledge (including knowledge embedded in people) generated in the public performing research system to support economic growth. Key mechanisms include: human capital mobility and training; HEI-enterprise collaborations; and commercialisation of public R&D.

Figure ES1 Proportion of public investment for R&D in HEIs between 2000 and 2015 according to investment in: human capital, infrastructure and knowledge generation, knowledge exchange: human capital mobility and upskilling, knowledge exchange: collaboration, and knowledge exchange: commercialisation.



ES 3. Economic and Enterprise Performance of R&D Active Firms in Ireland

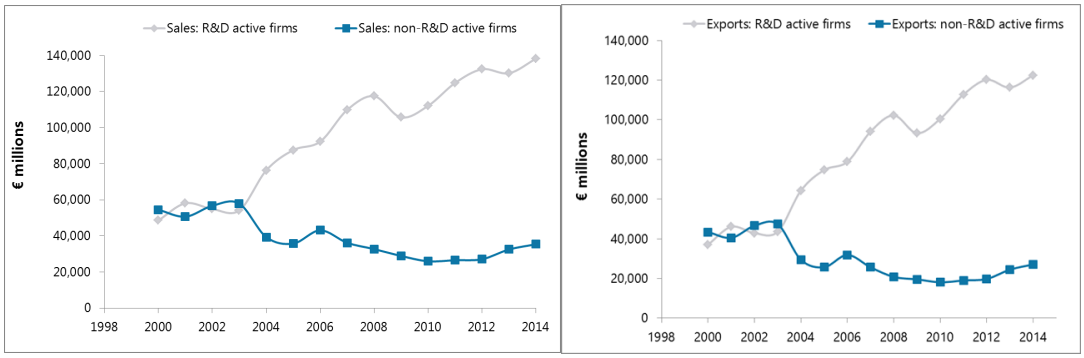
In this study, evidence is presented which indicates a clear correlation between firm engagement in R&D and stronger sales, exports, value added and employment performance for both Irish-owned and foreign-owned agency firms. The conclusions drawn from the data analysis also supports a picture of an enterprise base which is in the process of transforming towards one increasingly based on knowledge activities.

The sales and export performance of R&D active and non-R&D active agency firms (with 10 or more persons engaged) are presented in Figure ES2. The data clearly shows the higher level of sales and exports by cohorts of R&D active agency firms between 2003 and 2014: sales and exports increased from €54.1 bn and €43.6 bn in 2003 to €138.2 bn and €122 bn respectively in 2014 and remained higher than sales and exports by non-R&D active agency firms throughout this period. This relates to growth of 155% and 181% for sales and exports over the 2003-2014 period for R&D active agency firms, in comparison to losses of -39% and -42% respectively for non-R&D active agency firms. Overall, the performance of the two cohorts of firms led to an increasing contribution by R&D active agency firms to total sales and exports of agency firms: from 48% and 48% in 2003 to 80% and 82% respectively in 2014.

The value added performance of R&D active agency firms was also found to be stronger than for non-R&D active firms. R&D active firms exhibited growth in value added from €19.3 bn in

2003 to €45.3 bn, in 2014 and this related to 134% growth in value added for R&D active firms. In comparison an overall decline in value added of -44% was measured for non-R&D active agency firms during the same period. Such performance has led to an increasing contribution by R&D active agency firms to total value added of agency firms: from 44% in 2003 to 76% in 2014.

Figure ES2 Sales and exports in each year by all agency firms for cohorts of R&D active and non-R&D active firms.



Thus, the data supports the conclusions that:

- **Amongst agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in sales, exports and value added from 2003-2014.**
- **The sales and export performance of R&D active agency firms (with 10 or more persons engaged) have masked the poorer performance of sales, exports and value added from the cohorts of non-R&D active agency firms over the 2003-2014 period.**

Additional analysis also reveals that similar conclusions can be drawn separately for both Irish and foreign-owned firms.

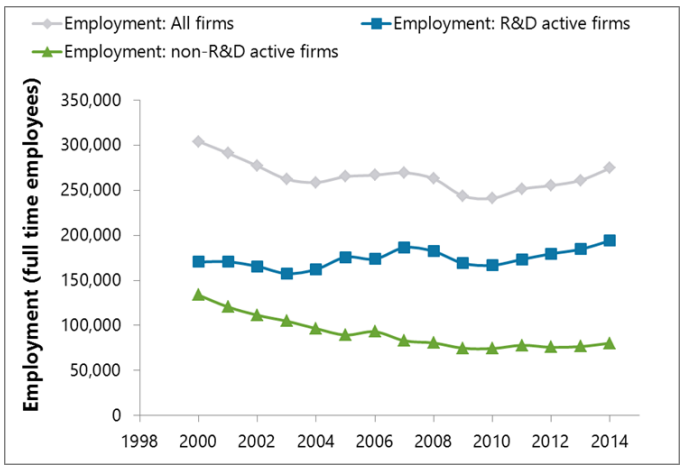
Employment characteristics of agency firms operating within the services and manufacturing sectors of the economy (and with 10 or more persons engaged)[2] are shown in Figure ES3. It can be seen that the employment behaviour of R&D active and non-R&D active firms has been distinctly different over the 2000-2014 time frame.

The overall downward trend in total employment up until 2009 was driven by the declining employment in non-R&D active firms, and the upswing in employment from 2009 was driven by the R&D active firms. Overall, the data demonstrates that there was greater sustainability of employment in R&D active agency firms: employment grew between 2000 and 2014 by 14% as compared to the decline of 40 % of non-R&D active firms during this time period. This more

[2] The data does not represent the totality of employment for agency firms, but rather the employment in the manufacturing and services sectors for agency firms with 10 or more persons engaged.

sustained employment by R&D active agency firms led to an increase in the contribution to employment by agency firms from 56% of employment by R&D active agency firms in 2000 to 71% in 2014.

Figure ES3 Employment in the manufacturing and services sectors in agency firms with 10 or more persons engaged: total employment[3] and employment in R&D Active and non-R&D active firms.



Thus, it can be concluded that:

- **Amongst agency firms (with 10 or more persons engaged) in the manufacturing and services sectors, R&D activity is a characteristic of firms that contribute most to employment between 2000 and 2014.**
- **The employment performance of R&D active firms (with 10 or more persons engaged) in the manufacturing and services sectors has masked the poorer performance in employment amongst the non-R&D active firms between 2000 and 2014.**

Within the services sector, R&D activity has been found to be a characteristic of firms that drove employment growth in the services sector in both Irish and foreign-owned agency firms, as indicated in Table ES1. Within the manufacturing sector, employment decreased overall between 2000-2014 in both Irish and foreign-owned agency firms, however, the evidence indicates that R&D activity is a characteristic of both Irish and foreign-owned agency firms for which employment declined less as indicated in the data presented in Table ES1.

Thus, the evidence also supports the conclusion that **R&D activity is a characteristic of firms that have significantly limited the employment losses in the manufacturing sector since 2000 and have been driving growth in employment in the services sector.**

[3] Employment in Primary Production and Construction Sectors are not included here in the total employment figure.

Table ES1 Percentage change in employment in R&D active and non-R&D active firms, for foreign and Irish-owned agency firms in the manufacturing sector and services sector, between 2000 and 2014.

Sector	Measure	R&D Active Firms	Non-R&D Active Firms
Manufacturing Sector	% change in employment in foreign-owned firms in the manufacturing sector between 2000-2014	-7%	-72%
	% change in employment in Irish-owned firms in the manufacturing sector between 2000-2014	-10%	-52%
Services Sector	% change in employment in foreign-owned firms in the services sector between 2000-2014	150%	-9%
	% change in employment in Irish-owned firms in the services sector between 2000-2014	101%	39%

Furthermore, employment of R&D personnel in agency firms increased by 96% across the manufacturing and services sector between 2000 and 2014 indicating that employment of R&D personnel plays a role in the more resilient employment performance of R&D active firms. For both Irish and foreign-owned agency cohorts of firms it was determined that:

1. Growth in R&D personnel in the services sector followed the overall trend in employment in R&D active firms in the services sector between 2000 and 2014.
2. There was overall positive growth in R&D personnel employment in R&D active agency firms in the manufacturing sector between 2000-2014 in comparison to a decline overall in employment in this cohort of firms, thus supporting the conclusion that **employment in R&D roles has been more resilient than employment in other roles in the manufacturing sector between 2000 and 2014.**

Employment in R&D roles also leads to employment in higher value jobs: the average annual labour costs per full time equivalent (FTE) employee engaged in R&D in firms in Ireland has been estimated at €72,500 in 2013, much higher than the estimate of average annual labour cost per FTE employee in Ireland in 2013 of €47,121. However, the higher value jobs are not limited to the R&D personnel. Rather the evidence indicates that higher average wages across all employees is a characteristic of firms that are R&D active: average payroll per employee in R&D active agency firms was estimated at €59,385, in comparison to €53,783 for average payroll

per employee in non-R&D active agency firms and average yearly earnings of €35,768 in the wider economy. Thus, it is concluded that **employment in both R&D roles and non-R&D roles in R&D active firms is related to employment in higher value jobs.**

Estimates of the wider economic impacts of R&D active firms have also been made and indicate the importance of these firms to the Irish economy. Based on data for 2013 for example, it was estimated that R&D active firms supported:

- In the region of between 352,000 and 384,000 full time employees, and this related to between 24% and 26.5% of full time employees across the total economy in this year.
- A wider value added impact of €76.1bn, accounting for in the region of 44% of GDP (at constant prices) and 54% of GNP (at constant prices) in 2013.

ES 4. Economic and Enterprise Impacts from Public Investment in R&D

In this report, evidence of the economic and enterprise impacts arising from this public investment in R&D are set out in three distinct sections:

- The economic and enterprise impacts from public investment in R&D which is directly focused towards firms to stimulate increased R&D activity.
- The economic and enterprise impacts from public investment in R&D directed towards the HEIs (and DJEI and IDA funded R&D facilities).
- The economic and enterprise impacts from public investment in R&D aimed at promoting international engagement in R&D.

ES 4.1 Impacts from Public Investment in R&D Directed to Firms

IDA and Enterprise Ireland operate funding schemes aimed at providing financial support directly to foreign-owned and Irish-owned firms to support engagement in R&D, and the R&D tax credit scheme is administered through the Revenue Commissioners.

The evidence presented in this study supports the conclusions that **public investment in grant-aid and R&D tax credits stimulates firms to undertake R&D to a greater extent or more immediately than they would do in the absence of such financial support.** The stimulation effect of grant-aid has been quantified in an emerging econometric analysis which estimates that a €1 increase in grant paid leads to a €1.64 increase in R&D carried out by firms when based on 'similar' firm analysis. Empirical analysis of the R&D tax credit points to positive economic impacts of this policy tool also. Using a treatment and control group econometric approach, the evaluation concluded that firms conducted significantly more R&D in the presence of the scheme than they would have done in its absence. It estimated that of the R&D carried out by firms over 2009-2014, 60% was additional R&D (meaning carried out as a direct result of the R&D tax credit). When considering the additional R&D in relation to the costs of the scheme, the evaluation found that for each €1 of foregone tax revenue by the State, €2.40 of additional R&D was carried out by the typical firm. Enterprise feedback also supports the findings of increased R&D as a consequence of grant-aid funding and the R&D tax credit scheme.

The **direct grant-aid support to firms to undertake R&D realises positive returns to the firm and on the State investment through additional economic value added (EVA) produced by firms**. Through econometric analysis, the grant-aid funding has been shown to lead to increased net EVA for both foreign-owned and Irish-owned firms. For IDA funded firms, this was measured at €1.366 billion from State funding of €273 million. It was estimated that a return of €5.00 was achieved in the short term for every €1 of grant approved by IDA and a projected return of €1:€25.5 in the longer term was also estimated. EI grant-aid funding to firms for R&D also shows a positive return on State investment at €1.82 in net EVA in the short term for every €1 of State support provided: noting that this is a conservative estimate, and does not fully account for the lapsed time period generally required before the full economic impact of an R&D programme can be determined.

The evidence also points to **R&D grant-aid as a characteristic of firms that achieve greater levels of employment growth and demonstrate greater resilience in employment**: employment was found to grow faster in both EI and IDA grant funded firms and employment was less impacted by the recession in these firms than companies that were not grant-aid funded.

Finally, feedback from enterprise strongly supports the evidence that access to R&D grant-aid and the R&D tax credit is key to the endeavours of the business base to transform their operations towards more knowledge-based activities and higher value jobs which in turn is helping to sustain and embed existing FDI firms in Ireland.

ES 4.2 Impacts from Public Investment in R&D Directed to HEIs

Impact from Public Investment in Knowledge Based Human Capital Development

The public investment in R&D directed towards HEIs is heavily focused on developing a supply of knowledge based human capital as indicated in Figure ES1. This study concludes that this **investment in human capital is a necessary requirement in supporting the evolution towards a knowledge economy in Ireland**, and **the knowledge based human capital output from Irish HEIs is feeding a growing demand by the R&D active enterprise base in Ireland for knowledge workers**. Such statements are underpinned by a suite of evidence brought forward in this study including:

- The increase in the level of research personnel employed by the enterprise base from 6,937 in 2001 to 13,750 in 2013: a 98% increase.
- The increase in the employment of PhD qualified personnel increased from 1,179 in 2007 to 2,181 in 2013 (16 % of all researchers and 9% of all R&D staff in 2013): an increase of 85%.
- The continued increase in employment of research personnel throughout the period (2007-2011) of decline in employment in the broader economy: employment of researchers increased by 29% between 2007 and 2011, while employment in the total economy declined by 15.5%.
- 30% of PhD graduates from Irish HEIs in 2014 that were employed in the Republic of Ireland within 9 months of graduation were employed in industry.

- The increasing move of Irish trained PhD graduates into industry over time as their careers evolve: with 63% of PhD graduates in their fifth employment role employed in industry.

The **public investment in knowledge based human capital is also supporting employment in higher value jobs**, with research graduates from Irish HEIs in 2014 typically gaining employment in higher paid jobs than graduates with bachelors degrees. In particular, more than 90% of PhD qualified graduates in 2014 achieved salaries of more than €25,000. 31% of PhD graduates achieved a salary of more than €45,000 - significantly higher than the average earnings per employee across the total economy in Ireland (€35,768 in 2014). Furthermore, analysis of PhD graduates from Irish Universities (graduating between 1995 and 2014) indicates that PhD graduates take on more senior positions when they move into industry than those with bachelors degrees.

Impact from Public Investment in Knowledge Exchange Activities

As the capacity and capability of the HEI system has evolved there has been an increased emphasis on achieving enterprise impacts from the public investment by focusing on transferring the knowledge and skills generated in the HEIs to the enterprise base.

Research findings in this study show that **the increased focus of public policy and funding for HEI-enterprise collaborations in R&D has been met by a fast growing demand by enterprise to engage with HEIs on R&D** with the number of publicly supported formal HEI-enterprise collaborations dramatically increased from 86 in 2006 to 1,371 in 2014[4].

The increasing value that firms are attributing to such collaborations is also demonstrated by the increase in the amount of cash contributions that firms are committing to these engagements with the HEIs.

Further analysis undertaken shows that **engagement in publicly supported collaboration with HEIs is a characteristic of foreign-owned agency firms (with 10 or more persons engaged) that contribute significantly to the economy**. Based on analysis of actual firm responses to the ABSEI survey, it was indicated that that collaborating foreign-owned firms contributed an estimated average of 39% to exports by foreign-owned firms (responding to the survey) per year between 2009 and 2014; they accounted for in the region of 46% of total value added by foreign-owned agency firms (responding to the survey) between 2009 and 2014; they accounted for of the order of 20% of employment in 2009 by foreign-owned firms (for firms with more than 10 persons engaged and responding to the survey) and this had increased to an estimated 31% in 2014, as indicated in Figure ES4.

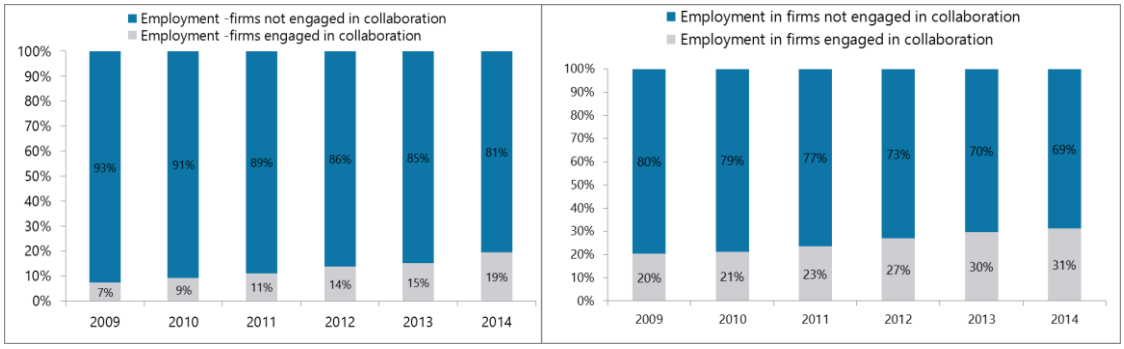
The analysis also identifies that **engagement in publicly supported collaboration with HEIs is a characteristic of Irish-owned agency firms that are increasingly contributing more to the**

[4] The data represents the number of collaborations by firms with HEIs. In programmes where a project approval relates to a single approval of funding to the HEI to engage with multiple partners – for example Technology Centres and Technology Gateways, the number of HEI-enterprise collaborations relates to the number of firms that have engaged with the HEI under the approved Centre/project approval.

economy. Based on an analysis of actual firm responses to the ABSEI survey, it was indicated that collaborating Irish-owned firms increased their contribution to total exports of Irish-owned firms (responding to the survey), from approximately 7% in 2009 to approximately 17% in 2014, as illustrated in Figure ES4; their contribution to total value added by Irish-owned agency firms increased from the order of 4% of total value added in 2009 to the order of 16% in 2014 (based on survey response values); their estimated indicative contribution to employment in Irish-owned agency firms (based on firms responding to the survey and firms with 10 or more persons engaged) increased from 7% of employment in 2009 to 19% in 2014, also illustrated in Figure ES4.

Direct enterprise feedback further supports these findings, indicating that public investment in HEI-enterprise engagements is: supporting firms to transform the nature of their operations through enabling them to access and develop knowledge, expertise and capability; and stimulating firms to engage in R&D activities and/or access Intellectual Property which in turn supports the development of new goods, services and process innovations by these firms.

Figure ES4 Indicative proportion of employment in each year (based on survey responses) for cohorts of (a) Irish-owned agency firms (b) foreign-owned-owned agency firms, engaged and not engaged in publicly supported HEI-enterprise collaborations.



(a) (b)

Furthermore, econometric analysis indicates that public investment in HEI-enterprise R&D collaboration programmes leads to net turnover growth in firms and net value added (EVA), which has positive implications for enterprise growth and the economy and which results in net returns from public investment in R&D collaboration programmes. Evaluations of a number of State programmes indicates that in the short term a €1 investment in the specific programme reviewed HEI-enterprise programme leads to between €2-€3 return in terms of net EVA, and in the longer term, this return on investment is expected to rise to between €4.5 and €11 per €1 investment by the State.

Public investment in knowledge exchange has also focused on seeking to commercialise knowledge generated in the publicly performing R&D system, and the data shows that the commercialisation activities have been continually strengthening over the past decade:

- The number of spin-out firms increased from 8 in 2006 to 31 p.a. in 2015.
- The number of Licences, Options and Assignments being issued increased from 55 in 2007 to 200 p.a. in 2015.

- The number of Licences, Options and Assignments, and spin-out firms has increased to levels that are comparable to some internationally renowned HEIs (when normalised according to the level of underpinning R&D investment).

Impacts from the commercialisation of publicly developed knowledge are being achieved through the development of new to market goods and service innovations which are based on licences from Irish HEIs and research performing organisations and through the population of a pipeline of innovative high potential start-up firms (HPSUs) in Ireland which have been found to achieve higher turnover than HPSUs born outside the publicly performing R&D system.

Furthermore, the combined public investment in R&D in HEIs, in technology transfer infrastructure and in the company incubation infrastructure in HEIs has realised impacts through:

- Strong growth in firm turnover from firms that utilise the campus incubation facilities: net turnover increases in firms, as a direct result of the campus incubation programme were measured as €310 million over the 2009-2013 period, which represents an increase in turnover of €3.61 for every €1 invested in the campus incubation facilities by the State.
- Driving enterprise impacts at a regional level by: attracting firms in the HEI incubation facilities to remain in the location of the HEI; retaining firms that spin-out from the HEIs to remain in the location of its foundation HEI.

Thus it can be concluded that public investment aimed at supporting **commercialisation of publicly performed R&D in Ireland is growing in terms of activity levels and is driving enterprise impacts at a regional level.**

ES 4.3 Impact from Public Investment in R&D in Support of International Engagement

Public investment in support of international engagement in R&D is primarily through Ireland's contribution to EC budgets, and in turn the eligibility of Irish-based researchers – in HEIs and firms- to apply for funding from the European RD&I Funding Programmes. Additional investment by Ireland in support of internationalisation of R&D is through payment of membership fees to a series of International Research Organisations (IROs), providing Irish-based researchers with the eligibility to engage with these organisations.

Irish researchers competed well in the seventh RD&I European Framework Programme (FP7-2007-2013), making Ireland a net beneficiary of the programme: **drawdown by Irish entities from FP7 was 1.4% of the total FP7 budget at €625 million, exceeding the national target of €600 million (1.2%). This represented a net gain for Ireland based on a contribution of 1.2% towards the EC budget.**

FP7 drawdown represented 4.8% of Gross expenditure on R&D (GERD) in Ireland in 2014 and enterprise and HEI feedback indicated that:

- 96% of successful firm applicants indicated that they would have abandoned the project (53%) or would have progressed the project at a reduced scale (45%) in the absence of

the FP7 funding. Unsuccessful firm applicants responding to the survey reinforced that this is what had happened in their case.

- 49% of successful HEI applicants would have abandoned the project, while a further 48% indicated that the project would have been undertaken, but at a reduced scale. This sentiment was reinforced by the response of unsuccessful applicants from HEIs with a majority of these respondents indicating that failure in securing FP7 funding led them to either abandon the project, or undertake the project at a reduced scale.

Thus, it can be concluded that **participation in FP7 has signified a sizeable contribution to Ireland's pool of resources available for R&D in HEIs in Ireland, which complements the funding provided through national public R&D funding programmes**.

Furthermore, companies that participated in the FP7 programme report that the engagement had a positive impact on turnover, employment and productivity and analysis indicates that firms that won financial public supports via FP7 are characterised, on average, by higher levels of: R&D expenditure; employment; productivity; sales; exports; and export intensity.

It is broadly estimated that stemming from Ireland's FP7 activity, **Irish public investment in FP7 has supported the addition of 2,000 jobs per year and an annual contribution of €300 million to GDP**, with the projection that this annual economic impact will be felt for many years after the end of the FP7 programme (2013).

HEI feedback also confirms that **national public funding in support of R&D in HEIs by way of membership fees to International Research Organisations complements the national public funding provided directly to HEIs.** In particular, membership of the European Space Agency (which accounts for 96% of public investment in IROs) supports: enterprise growth - predominantly in Irish-owned firms-through eligibility to engage in ESA contracts which drive increased company employment, sales, and exports; and existing Irish-owned firms and start-up high-value adding companies in developing and building R&D capability though eligibility to engage in ESA contracts. Furthermore, **there is a strong return on Investment to the State from public investment in membership of ESA**: comparing Ireland's ESA budget (2010) with the estimate for total additional economic income of €110 million, a return on investment of approximately 7:1 was calculated.

ES 5. Study Conclusions

In summary, the findings in this study show that:

- Firm engagement in R&D is correlated with the growth in sales, exports and value added from firms in Ireland, and sustainment and growth in employment of high value jobs that have been underpinning the Irish economy for more than a decade.
- Public investment in R&D in firms stimulates increased R&D activity in firms.
- Established and new R&D performing firms rely on the public R&D system to support their engagement in R&D activity.

Overall, from the evidence base set out in this report, it is concluded that **public investment in R&D has been instrumental in driving the transition of the Irish enterprise base towards one based on knowledge activities.**

Chapter 1: Public Investment in R&D in support of Innovation-Led Growth

1.1 Introduction

This chapter sets out the international and Irish evidence relating innovation to increased productivity, economic growth and new job creation. A conceptual framework is also presented which links the types of business investments in innovation to economic growth, with the evidence highlighting the increasing importance that firms in Ireland are attributing to investing in Knowledge Based Capital (KBC)[5] (including research and development - R&D) over physical capital. Finally, the rates of private and social returns from business investment in R&D are reviewed across countries, including for Ireland; the rationale for public investment in R&D in support of economic growth is developed; and the international evidence on the returns from public investment in R&D is presented.

1.2 Productivity and Innovation and Economic Growth

Most models that seek to understand the process of economic growth stress that long-run sustainable growth stems from an economy's ability to produce increased value from a given amount of resources, i.e. increased productivity. Productivity is measured by relating a set of inputs to output through a production function, and, growth in productivity is shown to be driven by inputs of labour and capital[6].

Growth in output that cannot be attributed to the relative contributions of labour and capital is termed Multi Factor Productivity (MFP) or Total Factor Productivity (TFP) growth. An increase in MFP means that more output is obtained from the same set of inputs or equivalently that fewer inputs can be used to make the same amount of output: new technology is adopted or inputs are utilized more efficiently. As highlighted in Figure 1, while MFP was poor for Ireland in earlier periods, since 2010 Ireland is one of the few countries to demonstrate positive MFP and was ranked 5th of 32 OECD countries in terms of MFP growth between 2010 and 2013.

While increased labour inputs and investment in physical capital have historically been drivers of productivity growth, stagnating, aging and declining populations and diminishing returns from investments in physical capital have led OECD[7] countries to seek new sources of productivity growth and this is centred around driving innovation[8,9].

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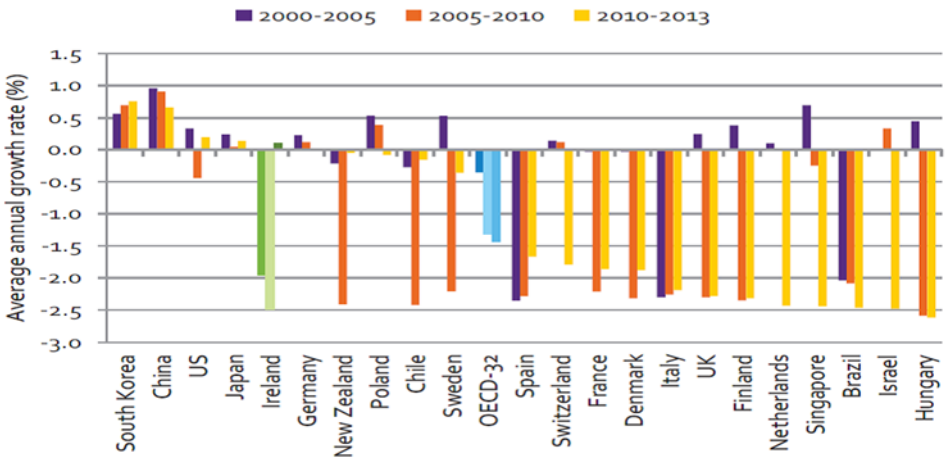
[5] Knowledge Based Capital (KBC) refers to a range of assets that are based on investment in knowledge, including R&D, software and data, intellectual property, firm specific skills, and organisational know-how.

[6] Capital describes both the ideas needed for production (intangibles) and the actual equipment and machines used in production (tangibles).

[7] The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental economic organisation with 35 member countries, founded to stimulate economic progress and world trade. It is a forum of countries describing themselves as committed to democracy and the market economy, providing a platform to compare policy

Figure 1 Average annual growth in total factor productivity[10] (%), 2000-2013.



Source: Reproduced from 'Irelands Competitiveness Scoreboard 2015, National Competitiveness Council'.

A large theoretical and empirical literature has emerged relating innovation[11] to productivity growth[12] - though there are many innovations that have little to do with productivity[13] - and the link appears to be robust to different data sets, model specifications, and econometric

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experiences, seeking answers to common problems, identify good practices and coordinate domestic and international policies of its members.

[8] Developing Human Capital in support of innovation activities, driving firm level investments aimed at innovation, developing environmental policies that supports innovation to flourish etc..

[9] New Sources of Growth: Knowledge-Based Capital Key Analyses and Policy Conclusions, Synthesis Report, OECD 2013

[10] Total-factor productivity (TFP), also called multi-factor productivity, accounts for effects in total output not caused by traditionally measured inputs of labour and capital.

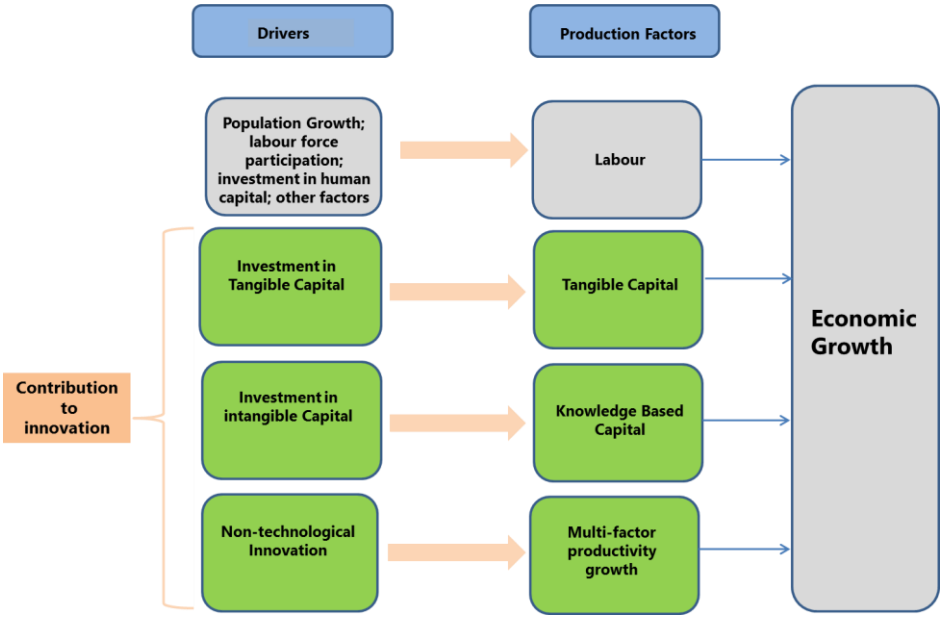
[11] The OECD OSLO Manual defines innovation as: the introduction of a new or significantly improved product, process or method.

[12] See for example: Crépon B., E. Duguet and J. Mairesse (1998), Research, Innovation and Productivity: An Econometric Analysis at the Firm Level, Economics of Innovation and New Technology, 7(2), 115-158; Griffith R., E. Huergo, B. Peters and J. Mairesse (2006), Innovation and Productivity across Four European Countries, Oxford Review of Economic Policy, 22(4), 483-498.

[13] There are many innovations that have little to do with productivity or competitiveness. For example, the innovation of the smart electric grid will help boost electric utility productivity, but will do little to boost competitiveness as electric utility services are not typically internationally traded (though, reduced energy costs to firms due to improved productivity will support firm growth and attraction of foreign direct investment). Likewise, while the development of a new technology to enable better weather prediction would boost quality of life, it would also not directly affect productivity. In contrast, the creation of a new drug, a new kind of airplane or a faster computer chip would not only enhance traded sector industry competitiveness, it would also improve quality of life and/or productivity. So while innovation can increase productivity and competitiveness, it is not synonymous with either. 'Innovation and Productivity: Clearing up the Confusion', - Robert D. Atkinson, August 2013, The Information Technology & Innovation Foundation.

methods[14]. Indeed, based on econometric analysis using firm level-innovation data reported in the Irish Community Innovation Survey (CIS)[15], innovation active firms[16] in Ireland have been shown to have a higher productivity over non-innovation active firms[17,18]: the analysis confirming innovation as a key characteristic over and above other firm characteristics such as international activities and size[19]. The analysis also indicates that firms based in Ireland that are engaged in exporting activities invest more in innovation and have higher innovation outputs and higher productivity relative to those firms only serving the Irish markets. With the emergence of this type of evidence across countries, many OECD countries now consider that future growth must increasingly come from innovation.

Figure 2 A simplified framework to analyse economic growth and the contribution from innovation.



Source: Adapted from the OECD – The Innovation Imperative: Contributing to Productivity ,Growth and Wellbeing, OECD 2015

[14] Boosting Innovation and Productivity in Enterprises: What Works? Frances Ruane, Iulia Siedschlag, Renewal Series, Paper 3, November 2011

[15] CIS 2006 and CIS 2008

[16] Innovation active implies that a firm is engaged in new product, new process, marketing or organisational innovation: new product and new process can be new to firm as well as new to market and so product and process innovations can be underpinned by own R&D activity, but also can be a result of adoption of technology developed elsewhere.

[17] Iulia Siedschlag & Xiaoheng Zhang, Economics of Innovation and New Technology, Vol 24, No. 3, 183-203, 2015

[18] B. Peters, R. Riley, I. Siedschlag, P. Vahter and J. McQuinn, Innovation and Productivity in Services: Evidence from Germany, Ireland and the United Kingdom, JRC Technical Reports: IPTS Working Papers on Corporate R&D and Innovation- No. 04/2014

[19] This innovation-labour productivity relationship was found for all innovation types except product innovation and product combined with process innovation.

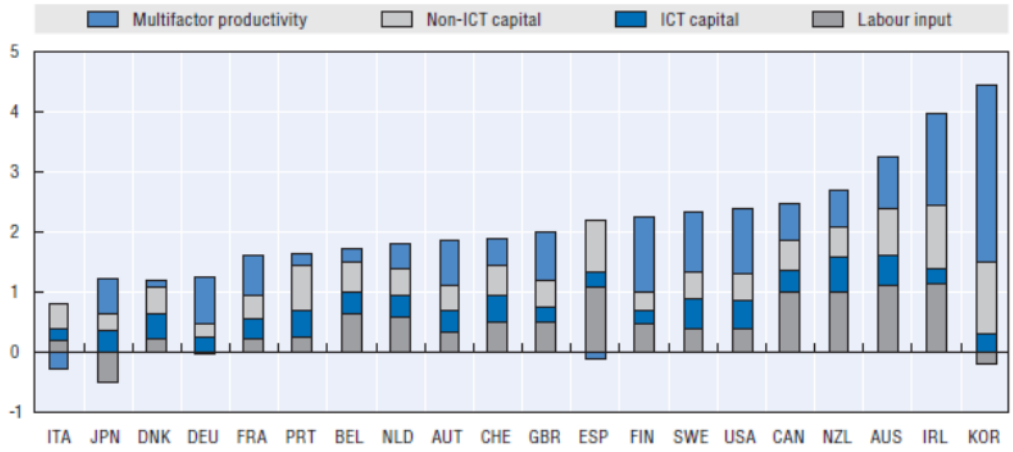
Innovation is not a simple linear process and so it is not feasible to develop straightforward links between investments in innovations and economic returns. The contribution of innovation to economic growth can however be conceptually considered by looking at the relationship between innovation and economic growth through a production function, where growth results from the input of labour and capital (both tangible and intangible) and from increases in MFP[20]. A simplified framework for analysis of economic growth, as adapted from the OECD, is set out in Figure 2.

The contribution to growth from innovation can be considered as:

1. **Contribution from innovation** resulting from **technological progress embodied** in **tangible capital**: for example, investment in more advanced machinery or in new computers.

The OECD found that between 0.2 and 0.4 percentage points of gross domestic product (GDP) growth between 1985 and 2000 was linked to such embodied technological progress[21]. More recent OECD estimates show that about 0.35 percentage points of GDP growth between 1995 and 2013 can be attributed to investment in information and communications technology (ICT) capital alone as can be seen in Figure 3, and for Ireland this was reported as 0.27 percentage points of national GDP growth for the period covered.

Figure 3 Contribution of Labour, MFP and ICT and Non-ICT Capital to GDP Growth across OECD countries: annual percentage point contribution, 1995-2013.



Source: Reproduced from 'The Innovation Imperative: Contributing to Productivity ,Growth and Wellbeing, OECD 2015': Source Data: OECD 2015, Compendium of Productivity Indicators

[20] The Innovation Imperative: Contributing to Productivity , Growth and Wellbeing, OECD 2015

[21] The Innovation Imperative: Contributing to Productivity ,Growth and Wellbeing, OECD 2015

2. **Contribution from innovation** resulting **from business investment in Knowledge Based Capital (KBC).**

As the industrial structure of advanced economies has shifted away from manufacturing and towards services, it is becoming increasingly recognised that concepts like "technical change" and "R&D" only describe some of the sources of increased productivity in the economy and that scientific R&D is only one of a set of wider 'intangible investments' in knowledge which help to drive innovation and generate economic returns[22,23,24]. Firms are increasingly investing in a range of intangible assets[25], and those intangibles that are specifically related to knowledge are collectively termed Knowledge Based Capital (KBC)[26]. Investment in KBC includes investment in firm-specific employee training, databases, organisational capital, software, and R&D and this investment drives innovation in firms[27]. Unlike tangible assets such as machinery and equipment, knowledge based intangible assets are non-rival: this means that they can be simultaneously employed by multiple users without diminishing their basic usefulness. Thus, the initial cost incurred does not get re-incurred as the latter are combined with other inputs in the production process. Hence, in economies where KBC is important, growth is less likely to be constrained by scarcity than in an economy dominated by tangible capital.

Indeed, the investment in KBC has risen steadily across the OECD[28] and recent analysis by Corrado et al.[29] (2012) found it accounted for around 0.5 percentage points of GDP growth in European Union (EU) countries from 1995 to 2007, and 0.9 percentage points in the United States. However, the contribution to GDP from KBC has not yet been incorporated in the OECD estimates and so contributions to GDP stemming from KBC investment are not captured within the MFP estimate in Figure 3. It is noted that some investments in innovation-related spending are capitalised in National Accounts[30] and therefore included in national estimates of GDP and productivity growth e.g. software and mineral exploration. However, for investments in other forms of KBC, the spending is often treated as an intermediate - though there has been a move

[22] UK Innovation Index: Productivity and Growth in UK Industries, Peter Goodridge, Jonathan Haskel, Gavin Wallis, Nesta Working Paper No. 12/09, 2012

[23] Innovation and productivity, Bronwyn H. Hall, Paper prepared for the Nordic Economic Policy Conference on productivity and competitiveness, 29 April 2011, Helsinki, Finland

[24] New Sources of Growth: Knowledge-Based Capital Key Analyses and Policy Conclusions, Synthesis Report, OECD 2013

[25] An intangible asset is an asset that lacks physical substance (unlike physical assets such as machinery and buildings) and usually is very hard to evaluate. It includes patents, copyrights, franchises, goodwill, trademarks, trade names, the general interpretation also includes software and other intangible computer based assets.

[26] There are other intangible assets such as goodwill that are not related to knowledge.

[27] OECD accounting studies and macroeconomic and microeconomic studies offer evidence that business investment in KBC can promote growth and productivity: New Sources of Growth: Knowledge-Based Capital Key Analyses and Policy Conclusions, Synthesis Report, OECD 2013

[28] New Sources of Growth: Knowledge-Based Capital Key Analyses and Policy Conclusions, Synthesis Report, OECD 2013

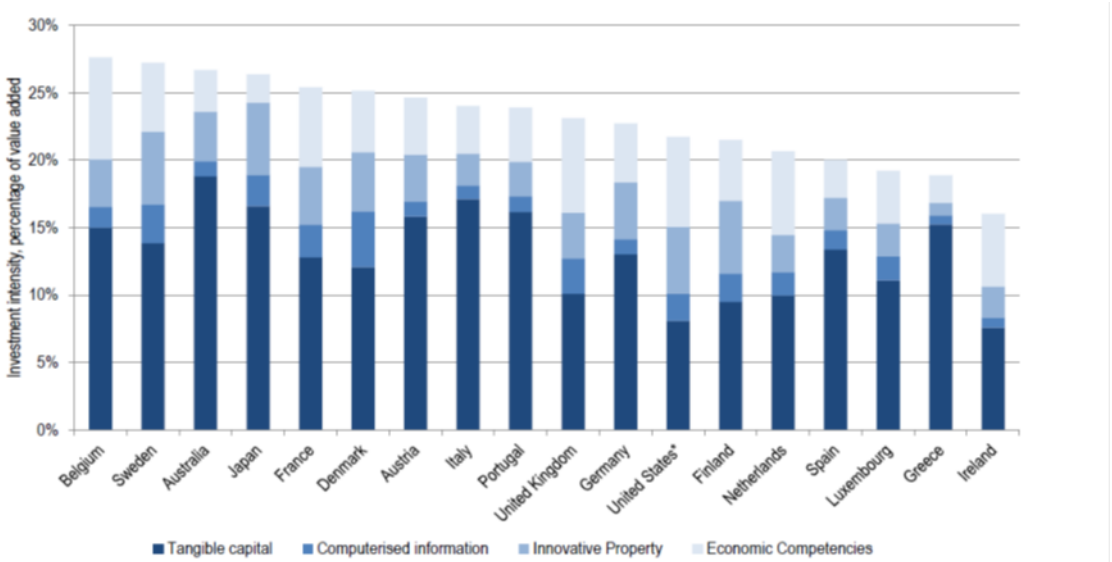
[29] C. Corrado, J. Haskel, C. Jona-Lasinio, M. Iommi, IZA Discussion Paper No. 6733, 2012

[30] National accounts or national account systems (NAS) are the implementation of complete and consistent accounting techniques for measuring the economic activity of a nation.

towards capitalising R&D in National Accounts in many countries[31], including Ireland, which will result in more direct attribution of R&D to economic growth in future analysis. By not including the full range of innovation-related spending as investments, then innovation gets relegated to inclusion in MFP thus limiting the ability to link investments in innovation to economic growth.

In some countries firms now invest more in KBC than they do in physical capital such as machinery equipment or buildings[32]. The data in Figure 4 demonstrates quite clearly this to be the case for the US, Finland, and the UK. The data for Sweden, France, Denmark, The Netherlands, and Ireland indicates that the investment in physical and knowledge based capital is split approximately evenly between tangible and knowledge capital in each of these countries, while for the remaining countries investment in tangible capital dominates over KBC.

Figure 4 Business investment in KBC and tangible capital across OECD Countries, 2010 (% of value added).



Source: New Sources of Growth: Knowledge-Based Capital Key Analyses and Policy Conclusions, Synthesis Report, OECD 2013

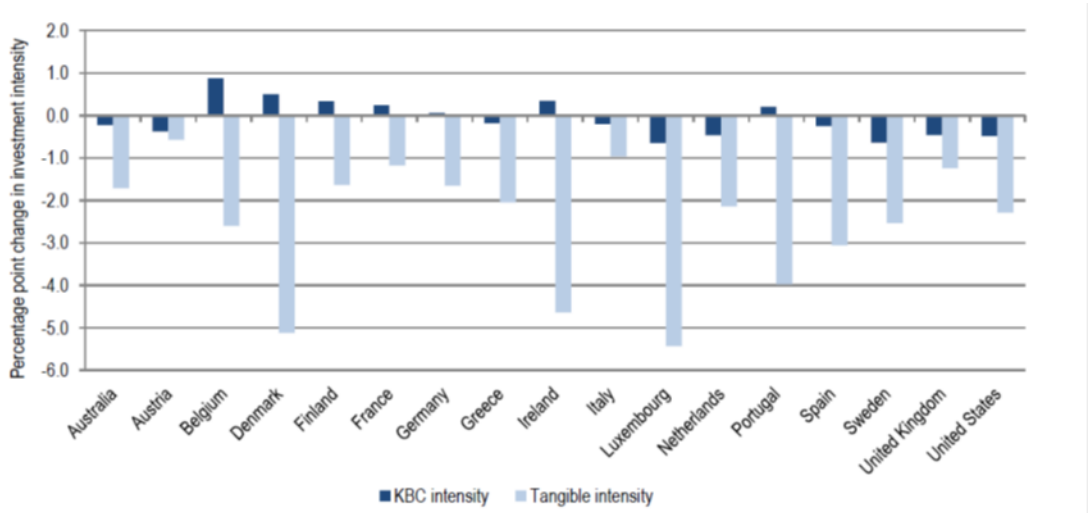
While the investment intensity in total capital (both tangible and KBC) is lowest for Ireland amongst the countries reviewed, the proportion of investment in KBC is higher for Ireland than

[31] Many of the outputs associated with R&D activities are intangible, and can take a variety of forms, including the stock of knowledge that firms accumulate concerning production techniques, along with their ability to acquire, assimilate, and apply new knowledge for competitive advantage. R&D outputs are often safeguarded via copyrights, trademarks, patents, and other forms of intellectual property protection. Like tangible capital assets such as machinery and equipment, R&D outputs can be used repeatedly, and can generate income flows over a long period. Therefore it is considered that R&D expenditures have more in common with investment expenditures than with the intermediate expenditures that firms make to support their production processes.

[32] Meeting of the OECD Council at Ministerial Level, June 2015 3-4 2015: OECD Innovation Strategy 2015 - An Agenda for Policy Action

Australia, Belgium, Greece, Spain, Italy, Portugal and Luxembourg. The low business investment intensity for capital in Ireland in 2010 relative to the other countries reviewed stems in part at least from the significant decline in business investment in total capital during the period 2008-2010 - which was more significant in Ireland than in many other countries as can be seen in Figure 5. Business investment in KBC as a percentage of value added increased for Ireland during this time, while business investment in physical capital declined significantly, thus indicating the importance that firms in Ireland are attributing to investment in KBC. This pattern of change in investment in capital was found to be true across most countries (KBC investment increased or declined less than investment in physical capital), but was particularly marked for Denmark, Ireland and Luxembourg. Thus, despite overall decreases in capital investment, the evidence points to the growing importance of investment in KBC for firms in Ireland over investment in physical capital.

Figure 5 Change in intensity by type of business investment from 2008 to 2010 across OECD Countries (percentage points of value added).



Source: New Sources of Growth: Knowledge-Based Capital Key Analyses and Policy Conclusions, Synthesis Report, OECD 2013

3. **Contribution from innovation** which results **in increased efficiency in the use of labour and capital** and which results **in increased MFP growth**[33].

A substantial part of increases in MFP can be attributed to non-technological innovation, for example through social, marketing and organisational innovations as well as the spillover effects of investments in technology or KBC (as discussed in points 1 and 2 above).

MFP accounted for over 0.7 percentage points of GDP growth between 1995 and 2013 in the countries shown in Figure 3, or about one-third of total GDP growth[34] (it is noted that in this data the MFP figure also includes growth derived from innovation stemming from investment in KBC as growth from this production factor is not captured elsewhere in the estimates). By comparison, during this period MFP accounted for 40% of GDP growth for Ireland.

The dynamic nature of innovation also needs to be taken into account in considering how innovation supports economic growth. Innovating firms are likely to grow more than others and new entrants with better products to offer are likely to displace existing inefficient firms with a concomitant increase in aggregate productivity levels[35].

Intensive growth is powered by the discovery of better ways to use workers and resources, thus the allocation of economic resources to their most productive uses is a critical determinant of growth[36,37]. The efficiency of resource allocation varies considerably from country to country, however; OECD data indicates that countries that are more successful at channelling resources to the most productive firms also invest more in KBC[38].

Furthermore, recent analysis of the exporting behaviour of firms in the manufacturing sector in Ireland[39] highlights that, in the short and medium term, export volumes are largely explained by

[33] MFP reflects the efficiency with which inputs are used, via improvements in the management of production processes, organisational change or R&D and innovation. An increase in MFP means that more output is obtained from the same set of inputs or equivalently that fewer inputs can be used to make the same amount of output: new technology is adopted or inputs are utilized more efficiently. In turn, this may represent the availability of new knowledge or greater effort to take advantage of existing knowledge. Thus, MFP corresponds to the growth of output that is not explained by the relative contributions of capital and labor, and innovation and adoptions of new technologies are key elements of MFP.

[34] OECD 2015, Compendium of Productivity Indicators 2015

[35] Innovation and productivity, Bronwyn H. Hall, Paper prepared for the Nordic Economic Policy Conference on productivity and competitiveness, 29 April 2011, Helsinki, Finland

[36] OECD (2013), "Raising the Returns to Innovation: Structural Policies for a Knowledge-based Economy", OECD Economics Department Policy Notes, No. 17 May 2013.

[37] The principal reallocation mechanisms are firm turnover (entry and exit), shifts in resources across firms and reallocation within firms.

[38] OECD (2013), Supporting Investment in Knowledge Capital, Growth and Innovation, OECD Publishing. http://dx.doi.org/10.1787/9789264193307-en

[39] Expanding and Diversifying the Manufactured Exports of Irish-Owned Enterprises, Research carried out by the ESRI as part of a research programme on " Enterprise, Exporting, Innovation and Productivity" jointly funded by Enterprise Ireland and the Department of Jobs, Enterprise and Innovation, 2016.

export sales related to existing products in existing markets. However, it was determined that in the long run, export growth is underpinned by extensive growth[40], indicating that the churning of products and markets is a crucial element of economic growth strategies focused on exports. Thus, indicating the requirement for continual product innovation, for successful exporters, in order to sustain their position in dynamic global markets.

1.3 Innovation and Job Creation

The relationship between economic growth and employment is complex[41]. The emergence and diffusion of new ideas, products and production techniques throughout the economy entails a process of "creative destruction". At the macro level, new technologies destroy jobs in some industries, especially among the low-skilled, while creating jobs which are often in different industries and require different skills. Historical evidence[42] indicates that this process has led to net job creation in the economy, as new industries replace old ones and workers adapt their skills to changing and expanding demand[43]. The efficient reallocation of resources to more productive use is an important part of the process in terms of realising net job creation from innovation.

The evidence points towards productivity growth associated with product innovation as leading to the creation of new jobs in firms[44]. While process innovation can lead to displacement of employment, the extent to which this occurs is dependent on the compensation effects arising from the process innovation[45]. Process innovations leading to labour saving activities may mean increased availability of resources to be applied to new/other activities elsewhere in a firm, or to the reduced cost of a product or service leading to enhanced demand and competitiveness of a product or service thus leading to increased firm sustainability. Thus, within-firm reallocation of resources to more productive means, on the back of process innovations, may lead to retention

[40] Introduction of new products and entering new markets.

[41] Faridah Djellal and Faïz Gallouj, The relationship between innovation and employment in Services: A review of the literature and an agenda for research. Institute of Innovation Research (IoIR) / ASEAT Conference 2006 on "Innovation in Services", Jun 2006, Manchester, United Kingdom. 2006

[42] Rupert Harrison, Jordi Jaumandreu, Jacques Mairesse, Bettina Peters Does innovation stimulate employment? A firm-level analysis using comparable micro data from four European countries: 2005, http://crei.cat/conferences/RandD_and_Innovation_in_the_Development_Process/activities/sc_conferences/23/papers/mairesse.pdf

[43] To realise the full potential of technological change in improving economy-wide productivity, growth and job creation, Governments need to make innovation and technology diffusion policies an integral part of overall economic policy.

[44] Product innovation is proxied by R&D expenditure, while process innovation is mainly incorporated in the new vintages of fixed capital, i.e. investment in new advanced machinery and equipment can be related to process innovation: Francesco Bogliacino, Marco Vivarelli, The Job Creation Effect of R&D expenditures, JRC Technical Notes: IPTS WORKING PAPER on CORPORATE R&D AND INNOVATION - No. 04/2010

[45] Rupert Harrison, Jordi Jaumandreu, Jacques Mairesse, Bettina Peters Does innovation stimulate employment? A firm-level analysis using comparable micro data from four European countries: 2005, http://crei.cat/conferences/RandD_and_Innovation_in_the_Development_Process/activities/sc_conferences/23/papers/mairesse.pdf

and growth of employment at firm level. Thus, the intention and strategies of a firm for engaging in process innovation, as well as the market forces, will have a significant impact on the consequences to employment from process innovations.

Overall however, the evidence suggests that, on average, innovative firms are more likely to survive and grow than firms that do not innovate[46,47]. Productivity improvements determine the robustness and future prospects of a firm/sector: therefore enhancing productivity through innovation is vital for both job retention and for growth in employment.

For agency firms in Ireland it has been shown that a small proportion of firms are key contributors to new job creation in the Irish economy. These firms, termed 'High Growth Firms' (HGFs), are identified as firms that grew employment levels at a fast pace over a three year period[48], and a key characteristic of HGFs is that they tend to be driven be innovative.

Analysis revealed that agency HGFs in Ireland accounted for[49]:

- 6.3% of active agency firms[50] in 2005, and contributed 40% of the new jobs created by agency firms in the 2002-2005 period;
- 4.9% of active agency firms in 2008, and contributed 45% of the new jobs created by agency firms in the 2005-2008 period;
- 4.5% of active agency firms in 2011, and contributed 33% of the new jobs created by agency firms in the 2008-2011 period.

This relationship is further illustrated in Figure 6. This performance by agency firms in Ireland is within international norms: across OECD nations, HGFs typically account for between 3% and 10% of the business firm stock in an economy or sector[51], with variation explained by differences in the operating conditions of the economies or sectors being compared. Furthermore, HGFs

[46] ibid

[47] Elena Cefisa, Orietta Marsili, Research Policy, Volume 35, Issue 5, June 2006, pg 626–641

[48] The OECD defines a high growth enterprise as: An enterprise with average annualized growth greater than twenty percent per annum, over a three-year period, and with ten or more employees at the beginning of the observation period. Growth is thus measured by the number of employees or by turnover.

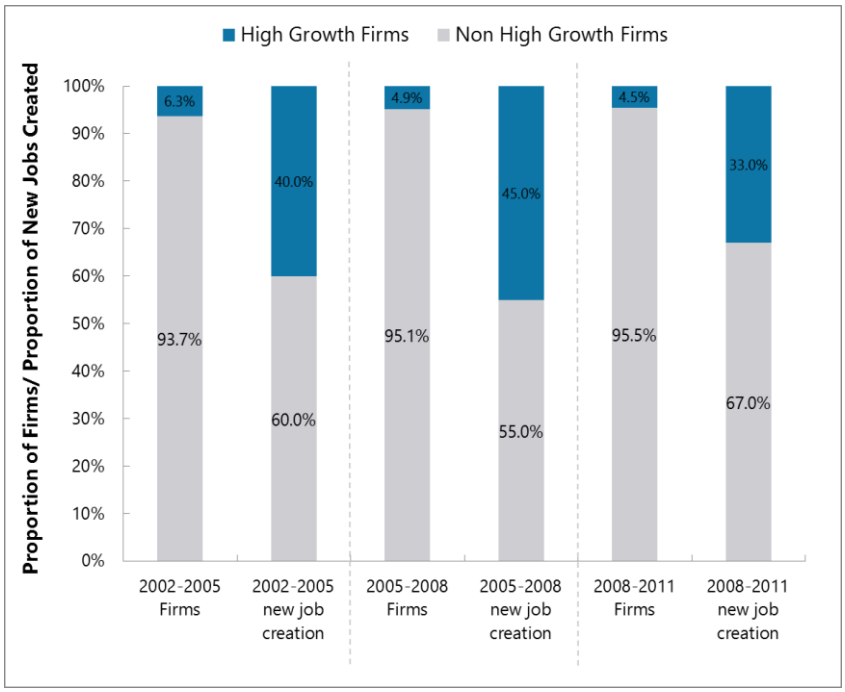
[49] Innovation in Agency-Supported High Growth Firms in Ireland, Forfás, 2014

[50] Agency firms are firms that have received support from one of the enterprise agencies - either ongoing, or at some point in time over the analysis time frame. Active agency firms are those agency firms that are in business within the given year specified.

[51] At the upper end of the scale, HGF activity tends to be associated with emerging economies, where innovation strategies are not the driver for the emergence of HGFs. For example, new EU member states that are further away from the technological frontier modify available blueprints and base their competitive edge on other comparative advantages such as low-cost labour rather than on innovation. Holzl W. and Friesenbichler K., Economics Bulletin, 30, 2, pg1016-1024, 2010

have accounted for between approximately 25% and 60% of new job creation in other countries[52].

Figure 6 Proportion of agency firms in Ireland identified as HGFs and their contribution to new job creation in the periods: 2002-2005; 2005-2008; and 2008-2011.



Source: Forfás analysis of Annual Business Survey of Economic Impact 2013

1.4 Returns from Firm-level Investment in R&D

Historically business investments underpinning innovation have been proxied by spending on R&D[53,54]. While it is increasingly recognised that investment in R&D activities may not be the only ingredient in the recipe for successful innovation[55], nor the only type of innovation investment opportunity for firms, it is the engine for the creation of new knowledge, techniques and technologies. As technology changes, people can produce more with either the same amount or fewer resources, thereby increasing productivity. Furthermore, while the industrial structure of advanced economies has moved more towards services in recent years, the changes underpinning growth in the services sectors have largely been enabled by the technological advancements emerging from R&D activities: for example the development of electronic goods

[52] Bravo-Biosca A.,Crisculo C. and Menon C., 'What Drives the Dynamics of Business Growth?', Science, Technology and Industry Policy Papers, No. 1, OECD 2013

[53] Innovation and productivity, Bronwyn H. Hall, Paper prepared for the Nordic Economic Policy Conference on productivity and competitiveness, 29 April 2011, Helsinki, Finland

[54] Including spending on in-house R&D activity, purchase of equipment and machinery for R&D, spending on R&D done externally, and purchasing of licences and know-how.

[55] Successful R&D leads to invention, which then needs to be adopted internally or commercialised and adopted more widely to realise the innovation.

and software products has led to the emergence and evolution of many services companies and has changed the traditional modes of interaction between firms and the consumer and the products offerings that firms can provide to their customers. Thus, economic growth can stem from industries using the products of the R&D as well as the industries conducting the R&D.

Business investment in R&D is one of the riskier forms of investment for firms as the desired outputs are not guaranteed and knowledge generated from the investment is also likely to spill-over to other companies and to society as a whole, both of whom will also benefit as a result. Despite the uncertainty for firms in engaging in R&D, the econometric evidence speaks in favour of positive and substantial impacts of R&D on productivity and economic growth at firm, industry and country levels. An OECD review[56] of the literature on impact of private investment in R&D indicates that returns from investment in business R&D (gross of depreciation) usually outmatch those found for ordinary capital investments. At the same time, review of the evidence base highlights variation in the magnitude of estimated R&D impacts which can be considered a reflection of the size of R&D impacts across different groups of firms, industries and countries. An OECD analysis of gross rates of return to own R&D, based on firm and industry data, indicate returns lie in the range of 0.20-0.30, while estimates based on economy-wide data tend to exceed the former, both in terms of size and the variability. Another review of the literature on the relationships between R&D expenditure and economic growth indicates that the positive relationship is more evident in more modern countries[57].

Analysis was also carried out by the OECD of the social rates[58] of return to R&D, which were found to be significantly larger than private rates of return to R&D, the average (median) social return to R&D amounting to roughly 1.2 (0.8).

Heretofore, there has been no econometric analysis undertaken to estimate the rate of private return from the R&D investment by the enterprise base in Ireland. However, an exercise to address this gap is currently underway[59], and emerging findings from an analysis of agency firms indicate a return of €3.60 in increased profits after 3 years for an initial €10 increase in R&D: this relates to a private return of 0.36 by the end of the third year after investment in R&D- in line with international norms. In addition, evidence of the impact to Irish-based firms from investment in R&D has been reported in terms of impact on firm innovation. Econometric analysis of the Irish CIS[60] data indicates positive effects on the likelihood of innovation from

[56] OECD 2015, The Impact of R&D Investment on Economic Performance: A review of the Econometric evidence. OECD: DSTI/EAS/STP/NESTI (2015)8

[57] Erdil Şahin, Paper prepared for the EY International Congress on Economics II "GROWTH, INEQUALITY AND POVERTY" Ankara, November 5-6, 2015, The Relationship Between R&D Expenditures and Economic Growth: Panel Data Analysis 1990-2013

[58] Social returns encompass both increases in profits for firms who can make use of the innovations created by other firms or in the public sector, as well as harder-to-measure returns to wider society such as gains to health, well-being, security, etc..

[59] 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

[60] CIS 2004 and 2006

firms that invest in R&D and this varies according to firm ownership (Irish-owned and foreign-owned firms) and type of R&D spending: intramural R&D; extramural R&D; acquisition of advanced machinery, equipment, and computer hardware or software; and acquisition of new knowledge[61].

1.5 Role of Public Investment in Supporting R&D

As indicated previously, international evidence points to a high rate of social return stemming from private investment in R&D. This stems from knowledge spill-over effects i.e. the firms that invest in R&D do not capture all the benefits from the R&D as knowledge generated by one company's R&D is likely to spill-over to other companies and to society as a whole, both of whom will also benefit as a result. From the national economic and social perspective, knowledge spill-overs are a positive outcome from firm investment in R&D. However, from the firm perspective it is a more negative outcome - others are benefiting from the risks[62] they take - and this limits the level at which firms are willing to invest in R&D. Other factors that limit private investment in R&D include:

- **Imperfect Information:** The less certain nature of the required inputs, capability and timelines associated with R&D and the uncertainty of achieving a commercially viable outcome makes undertaking R&D a more risky venture for firms. Imperfect information can also limit the level of industry and academic collaboration: often businesses are unaware of what research is underway in the Higher Education Institutes (HEIs) and HEI researchers are unaware of the commercial applications of their research.
- **Financial:** This is of particular significance for start-ups and small firms investing in R&D, who may be limited in raising finance to undertake this higher risk activity, or may not be in a financial position to await the returns from the R&D activity: the economic returns to R&D are typically delivered over 7 years or more.

Thus, in terms of market failure, it is the higher rate of social returns from firm R&D due to knowledge spill-overs, coupled with imperfect information and financial issues that can result in companies investing in R&D at levels that are less than optimal for the economy and society more generally[63]. This underinvestment (market failure) provides a strong rationale for government support of R&D, and OECD research finds that the strongest evidence for private under-investment exists for R&D-related spending – suggesting a continued important role for

[61] J. Doran, D. Jordan and Eoin O'Leary, Journal of the Statistical and Social Inquiry Society of Ireland Vol XLII, p.15, 2015

[62] The risk associated in particular with longer term R&D activities discourages many companies from conducting R&D that has longer lead times to commercialisation. The risk aversion applying in particular to small firms which may also have difficulties in accessing funding for their R&D activities –even when the R&D activities are nearer to market activities.

[63] Sharon Pells, Ministry of Business, Innovation & Employment, Occasional Paper 'How can we lift BERD', 2014

public investment[64]. Government intervention can assist in offsetting higher risks and addressing opportunity costs for firms thus stimulating firms to engage in more optimal levels of R&D as the State pursues policy goals such as stimulating entrepreneurship, job creation and R&D and innovation activity and multiplier or other secondary impacts such as spill-overs. Government funding of R&D in the publicly performing research system also supports the development of new stocks of knowledge in further from market research. The subsequent desire for knowledge spill-overs from this publicly performed research then also underpins the rationale for investing in fostering HEI–enterprise linkages.

In Ireland, as in other countries, the rationale for State support to firms has thus broadened considerably beyond the market failure concept to also include a wider view of the State: with a role for the State as an investor in R&D both in firms and in the publicly performing research system, but also as a co-ordinator, networker, promoter and informer.

It is acknowledged that any government funding provided should focus on supporting R&D that would not otherwise be carried out, that is where spill-overs are extensive and where the difference between private and social return is considerable. The recognition that there are varying degrees of market failure in different types of research and innovation related activity underpins the fact that there is a 'slope' in the degree to which governments subsidise them[65]. In particular, government plays an important role in supporting basic research and this leads to the rationale for State funding of basic research in HEIs being more fully funded, while work intended to lead more directly to industrial applications is typically funded privately or may be cost-shared between the State and industry where risks and potential spill-overs are high. Implicit in the public funding of R&D is the expectation that the research will lead to intellectual advances, and that, over the long term, these advances, either directly or indirectly, will benefit citizens and the economy. Basic research may well lead to a variety of benefits, including training, social, environmental or economic impacts, etc., in the longer or shorter term, even if these are not the primary objectives of the research. State funding of R&D in the HEIs (and public research institutes where such institutions form a part of the landscape in a country) is thus a key requirement in the development of a national innovation system. This support is essential to support the creation of new knowledge and also very importantly for the enterprise base, the development of knowledge-based human capital that can be accessed (or offered for access) by all actors in the economy.

The systemic failures that can undermine the development of an innovation eco-system and hence reduce the level of innovation below its optimal level and/or undermine its potential efficiency include:

- **Coordination Failures**

  The successful operation of national innovation systems rely on knowledge exchange across firms, publicly performing research organisations and the public sector. Indeed, to

[64] OECD 2012, New Sources of Growth: Knowledge-Based Capital Driving Investment and Productivity in the 21st Century

[65] Sharon Pells, Ministry of Business, Innovation & Employment, Occasional Paper 'How can we lift BERD', 2014

realise a return for some investments in R&D requires that many public and private sector actors are co-ordinated to invest or take specific actions. In some cases, businesses may be unwilling or unable to collaborate to jointly invest in commercialisation and R&D assets that would benefit a wider group of firms.

The State has a role in addressing co-ordination failures by providing mechanisms to support the collaboration of enterprises (with each other and other R&D performing entities), and through promoting these mechanisms to the enterprise base.

- **Capability failures**

  Inadequate 'absorptive capacity' – i.e. the ability to understand and make use of external knowledge, often through doing R&D – is a key capability failure[66]. However, enterprises and individuals do not always invest in developing R&D capability for a number of reasons such as: lack of awareness of the benefits of R&D, the lack of understanding as to how to engage in R&D, prohibitive financial costs and time pressures.

  The State has a clear interest in addressing these barriers as the benefits from R&D accrue more widely than individual or firm level to the economy and society.

- **Infrastructural Failures**

  These failures relate to inadequate policy response to another kind of failure. For example, under-investment in basic research would be an infrastructural failure that hampers innovation not only by producing too little new knowledge but also by failing to generate research-trained people able to absorb and use new knowledge generated by others.

Throughout the OECD economies, these market and systemic failures for R&D are collectively seen as providing the rationale for governments to develop policies designed to support innovation and higher productivity levels within enterprises[67]: international findings supports the view that government intervention in R&D is required to address market and systemic failures to ensure the development, diffusion and use[68] of economically and socially useful knowledge and outputs stemming from R&D.

The success of State support for R&D should not only be measured in terms of monetary benefit but also in wider economic impacts (e.g. multiplier effects such as indirect or induced employment or clustering impacts) and behavioural change. Government intervention can play a key role in incentivising behavioural change that can have a transformative effect on industry structure, productivity and growth potential. The incentive effect is evident when the aid changes the behaviour of a company to engage in additional activity which it would not have

[66] The Case for Public Support of Innovation- At the Sector, technology and challenge area levels, Produced by Technopolis Ltd, for the Department for Business Innovation and Skills, 2014

[67] Boosting Innovation and Productivity in Enterprises: What Works? Frances Ruane, Iulia Siedschlag, Renewal Series, Paper 3, November 2011

[68] Investment in R&D also relates to activities associated with commercialisation of R&D.

engaged in without the aid or would only have engaged in such activity in a restricted or different manner or in another location.

Innovation is a central pillar of *Ireland's National Enterprise Policy 2015-2025*[69] which is aimed at ensuring the on-going contribution of a competitive, sustainable enterprise base to Ireland's future economic growth. It is thus imperative that the Irish Government invests in the appropriate types and levels of support for R&D to deliver on Ireland's innovation strategy- *Innovation 2020*[70].

1.6 The Returns from Public investment in R&D: International Evidence

The international literature on investment in R&D shows[71,72,73]:

- Clear returns from private sector R&D: both private and social returns.
- Enhanced private sector R&D activity from public investment in private R&D (via tax credits and grants): at national aggregate level, research generally concludes that direct public funding of R&D to the private sector has a positive effect on private R&D[74,75]. This applies whether the funding is in the form of tax incentives or direct allocations[76].
- Evidence of enhanced private sector R&D activity from public investment in publicly performed R&D: a study of 20 OECD countries shows clear complementarity between publicly performed R&D and business sector R&D, with publicly performed R&D influencing business R&D at the level of the economy[77,78]. Specifically it was found that "an increase of one standard deviation in the share of non-business R&D in GDP (an increase of 0.06 percentage points for the average economy) raises business sector R&D by over 7% and patenting levels by close to 4%."

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[69] Enterprise 2025: Ireland's National Enterprise Policy 2015-2025

[70] Innovation 2020: Excellence, Talent, Impact, Ireland's strategy for research and development, science and technology, 2015

[71] The Relationship Between Publicly Funded Basic Research and Economic Performance, Report prepared by Science Policy Research Unit of Sussex for HM Treasury, UK 1996

[72] Growth through Research and Development – what does the Research Literature say?, VINNOVA, Sweden, 2008

[73] Public Support for Science and Innovation, Productivity Commission Research Report, Australian Government, 2007

[74] Crowding out or Stimulus: The Effect of Public R&D Subsidies on Firm's R&D expenditure-DRAFT Version http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.194.9505&rep=rep1&type=pdf

[75] Heshmati, Almas Loof, Hans, The Impact of Public Funds on Private R&D Investment: New Evidence from a Firm Level Innovation Study

[76] Guellec, D. and van Pottelsberghe de la Potterie, B., The Impact of Public R&D Expenditure on Business R&D

[77] F. Jaumotte and N. Pain, 'From Ideas to Development: The Determinants of R&D Patenting', OECD Economics Department Working Paper,2005

[78] F. Jaumotte and N. Pain, 2005. 'Innovation in the Business Sector,' OECD Economics Department Working Papers 459, OECD Publishing, 2005

- Public investment in research conducted within HEIs gives rise to significant spill-over effects outside of HEIs: a UK analysis estimates that an extra £1 of public expenditure on HEI research leads to £0.29 of private funding of HEI research[79].
- Public investment in publicly performed and private R&D also acts to attract internationally mobile R&D, thus realising a 'crowding-in' effect. While there are a number of factors that support locational investment decisions of internationally mobile R&D, including proximity to markets, business and regulatory environment etc., studies indicate that factors such as the prospect of high quality collaborators, availability of knowledge-based human capital and technology transfer infrastructure also support attraction of R&D foreign direct investment (FDI)[80]. Thus, a high quality publicly performing research base will attract international R&D and encourage existing companies in the enterprise base to expand their R&D investments.
- Some evidence of economic returns from public investment in R&D:
  - A major study in 2004 of aggregated data of 15 OECD economies found that the responsiveness of economic productivity to publicly performed R&D is positive[81].
  - Other studies have looked at elements of the public investment: such as the impact of investments from specific public R&D funding bodies[82] or programmes[83,84] and reported positive economic returns.

  Though, measuring the economic returns from public investment in the publicly performing system is substantially more difficult than measuring the economic returns from public investment in R&D in firms. The main reasons for this are:
  - The type of research carried out in the publicly performing system is much more likely to be basic research, with outputs that are further from market than the R&D conducted by firms themselves and with large lag times between investment and any economic impacts arising.

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[79] 'What is the relationship between public and private investment in science, research and innovation?', Economic Insight, A report commissioned by the Department for Business, Innovation and Skills, 2015

[80] 'Value of Research', Policy Paper by the Research, Innovation and Science Policy Experts (RISE), Luke Georgiou, 2015

[81] Guellec, D. and Van Pottelsberghe de la Potterie, B. (2004) 'From R&D to Productivity Growth: Do the institutional settings and the source of funds of R&D matter?' Oxford Bulletin of Economics and Statistics, 66 (3): 353-378

[82] Haskel and Wallis (2010, 2013) explored how social returns to public sector R&D vary according to whether the investments are made through government departments, research councils or higher education. Haskel, J. and Wallis, G. (2013), "Public support for innovation, intangible investment and productivity growth in the UK market sector", Economics Letters, 119(2), 195-98. Haskel, J., A. Hughes and E. Bascavusoglu-Moreau (2014), The Economic Significance of the UK Science Base, Campaign for Science and Engineering (http://www.sciencecampaign.org.uk/UKScienceBase.pdf) B

[83] Ten Years On: Confirming Impacts from Research Investment: A case study focusing on the direct commercial and economic impacts from exchequer investment into centres and initiatives supported by the Programme for Research in Third Level Institutions (PRTLI) 2000-2006. An independent report to the Higher Education Authority (HEA) by PA Consulting, 2011

[84] Evaluation of Enterprise Supports for Research and Development, Forfás, 2013

- The outputs from research in the publicly performing system are more multifaceted than the outputs of research conducted by firms. Many of the outputs from research in HEIs, such as human capital, publications, new instrumentation and processes etc. are often the inputs to the innovation activities of firms.
- Public investment in the publicly performing system has objectives that are not solely focused on economic impact, but some proportion of the funding is also directed towards public good activities: though funding focused on public good activities can give rise to positive economic impacts and conversely funding geared towards economic impact through enterprise support can result in public good impacts also.
- Public investment in the publicly performing system is only one source of funding for the activities: the publicly performing system attracts funding from other sources such as industry; not-for-profit organisations; philanthropists; foundations and individuals. Furthermore, public funding is constituted by national funding and European funding. As the various types of funding may all contribute, to a greater or lesser extent, to the research that results in economic impact, it is difficult to attribute one single source of funding to resulting economic impacts.

Overall the literature acknowledges that due to: the multiple investments in R&D across multiple R&D performing entities; the non-linear nature of innovation systems; and the time-lag that exists between the investments in R&D activity and the commercial benefits, that it is difficult to determine the output of the total public investment in the publicly performing research in a country through a single production function.

1.7 This Study: The Economic and Enterprise Impacts from Public Investment in R&D in Ireland

Given the difficulties outlined with regards to measuring the economic impact from publicly performed R&D, it is concluded that it is not feasible to produce a single, econometrically based numerical estimate for Ireland's return on public investment in R&D. Furthermore, international considerations point towards taking a wider perspective on estimating the returns from public investment in R&D, as aspects such as initiating behavioural changes can have important long-term implications in the economy but may not be reflected in results from economic models.

While the return on public investment has been examined across a number of individual R&D funding programmes in Ireland, there is no consolidated evidence base that attempts to review the total returns or enterprise impacts from public investment in R&D for Ireland. This study aims to address this insofar as is possible, though it is noted that a wide range of methodological approaches have been employed to date to assess impact and some of these methodologies are more robust than others. The study focuses on the public R&D investments that are aimed at achieving enterprise impacts: this relates to investments by Department of Jobs, Enterprise and Innovation (DJEI), Enterprise Ireland (EI), IDA, Science Foundation Ireland (SFI), The Higher Education Authority (HEA), The Irish Research Council (IRC), and InterTrade Ireland. While it is acknowledged that there are broader economic and social impacts arising

from public investment in R&D this report does not try to capture those, focusing exclusively on enterprise impacts.

In the next chapters this report sets out for Ireland:

- The evolution of public research, development and innovation (RD&I) policy and the focus of public investment in R&D in Ireland specifically towards realising enterprise impacts between 2000 and 2015.
- The economic and enterprise impacts of R&D active firms in Ireland.
- The evidence base demonstrating the economic and enterprise impacts of the public investments in R&D in Ireland.

This work was guided by an Advisory Group of representatives from DJEI, EI, IDA, SFI, HEA, IRC and chaired by DJEI.

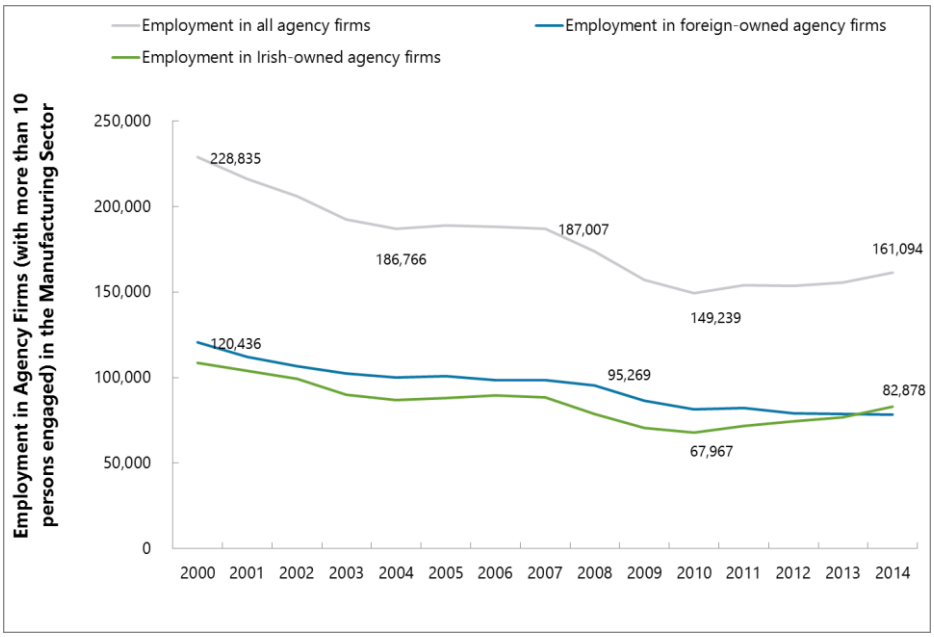
Chapter 2 Evolution of National RD&I Policy and Public Investment in R&D in Support of Economic and Enterprise Impacts: 2000-2015

2.1 Enterprise Policy in Ireland

The primary rationale for government investment in R&D is to maintain our economic success by enabling Ireland to compete as a knowledge economy. The period since 2000 covers a period of structural and disruptive change globally, where activities within and across sectors have evolved significantly due to factors such as technological advances, sectoral convergence, emerging markets, economic and political uncertainty, shifting demographic and consumer patterns with ongoing disruption in business models and global markets. Innovation has increasingly been seen as critical to Ireland's competitiveness over that period.

Enterprise policy in Ireland is based on an acceptance that the factors which contributed to Ireland's economic success in the past in terms of low cost environment and attractive fiscal regime would not be sufficient to maintain success into the future. Ireland is now a higher income economy with a cost base comparable to that of other rich economies and therefore needs to compete in the future on the basis of knowledge and high-skills with an enterprise base characterised by high-productivity, innovation-intensive firms.

Figure 7 Employment in manufacturing agency firms, 2000-2014: for all firms (with 10 or more persons engaged) and for foreign-owned and Irish-owned firms separately.



Source: Annual Business Survey of Economic Impact 2015

The Enterprise Strategy's Group (ESG) Report *Ahead of the Curve* in 2004 attributed much of our success in the 1980s and 1990s to providing a manufacturing base for intellectual property that was developed elsewhere by multinational companies. From the early 2000s, however, employment in Irish manufacturing began a decline from the peak it experienced in the late 1990s. This decline is evident in Figure 7, which presents the employment levels in agency manufacturing firms (with 10 or more persons engaged) over the 2000-2014 period. Between 2000 and 2010 employment in these firms declined by 79,000 before recovering some ground in the years to 2014. As can be seen in Figure 7, employment levels in foreign-owned and Irish-owned manufacturing firms exhibited similar trends throughout the 2000-2010 period. Since 2010, there has been some growth in employment in Irish-owned firms (with 10 or more persons engaged), with employment in foreign-owned firms (with 10 or more persons engaged) remaining approximately constant over this time frame.

The ESG noted some of the factors driving this decline: that competition for production activity had increased globally, and while Ireland had strengths in manufacturing and operations, it identified significant weaknesses in both the early stages of the product life cycle – in R&D and technology development – and at the later stages – in international sales and marketing. Therefore, the report concluded, if Ireland was to sustain high levels of quality employment our national skills base needed to be strengthened; and the innovation performance of enterprises in Ireland and the ability to be able to develop and commercially exploit our own intellectual property and new knowledge from around the world needed to be significantly enhanced.

This has been a consistent theme in enterprise policy and the changing global economy has only reinforced Ireland's need to adapt. Increasingly, our international competitiveness performance, and ultimately our ability to generate wealth, depends on our ability to sell differentiated, high-value products and services to global markets. The knowledge content of the goods and services produced here has, over time, increased significantly.

The most recent articulation of enterprise policy, Enterprise 2025, has identified innovation as one of four of Ireland's differentiators to build competitive advantage. Enterprise 2025 recognises that in order to compete internationally, particularly in light of external uncertainties, greater resilience is required in the enterprise base and it calls for a step-change in enterprise performance to achieve a significant uplift in enterprises investing in R&D –with more enterprises and greater levels of investment – delivering innovative products and services and higher levels of productivity. In responding to these challenges enterprise policy must continue to evolve towards a 'systems' approach with Government taking on the role of facilitator, coordinator and market creator in addition to investor.

2.2 RD&I Policy and the Focus of Public Investment in R&D

The evolution in Ireland's enterprise base towards such knowledge based activities has also largely determined research, development and innovation (RD&I) policy in Ireland. This paper sets out three distinct phases which show a clear and deliberate evolution of policy since 2000 focused on building a national innovation system that supports economic and social goals.

There has been broad consistency in what has been regarded as the core activities or *elements* of that 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[85] since 2000 are:

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

Having come from a low base, Ireland has made very significant progress over the past decade in building a research infrastructure that in some instances is amongst the best in Europe; in retaining and attracting top level researchers; and in achieving closer synchronisation between research endeavour in HEIs, Government agencies, and industry.

The quality of research output as measured by citation impact has improved and Ireland's citation impact is now 25% above the world average. The transfer of research knowledge and capacity from the HEIs to the wider economy has increased through research graduates finding employment in industry and through industry-academic collaboration.

The increased public investment in R&D is impacting positively on the commitment to research and innovation in the business sector - approximately three quarters of Ireland's gross R&D expenditure is privately funded and one quarter is publicly funded.

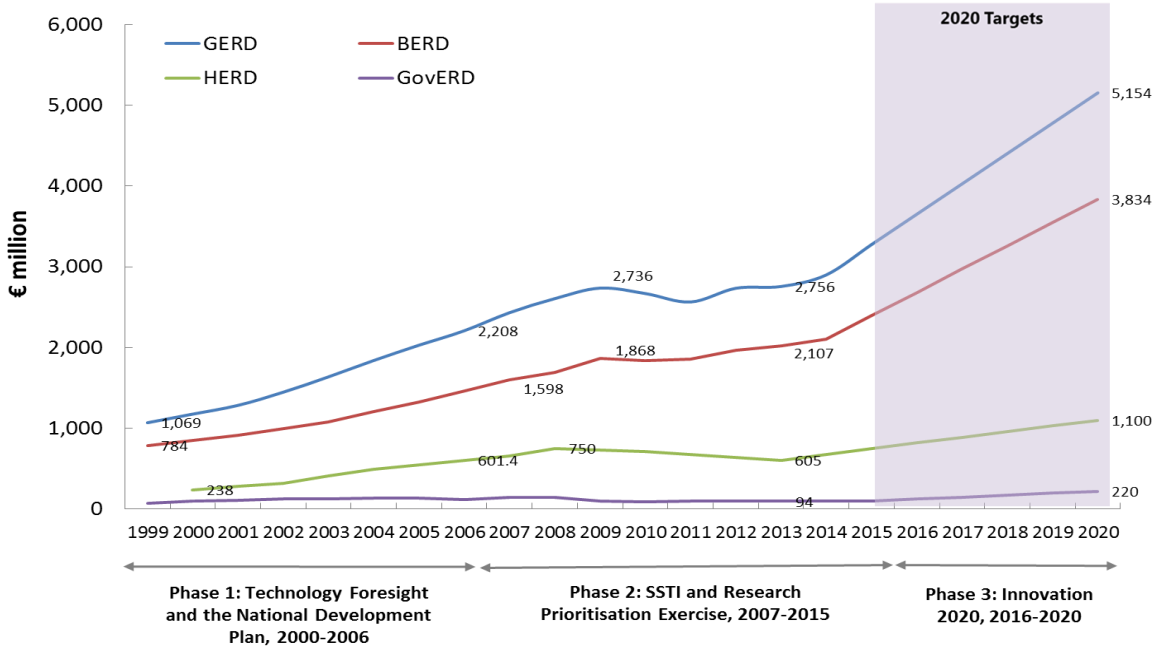
This success arises from the period of sustained investment across the four main elements of the innovation system. The following section sets out the specific objectives under those elements as articulated at the different phases of RD&I policy:

- 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 graph in Figure 8 plots the total levels of public and private investment in the R&D system since 2000 and the next section describes the main policy initiatives shaping that investment and the corresponding focus of the public investments directed towards achieving economic and enterprise impacts.

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

Figure 8 Gross Expenditure on Research and Development (GERD), Business Expenditure on Research and Development (BERD), Higher Education Expenditure on Research and Development (HERD) and Government Expenditure on Research and Development (GovERD), 2000-2020 (incorporating Innovation 2020 targets) (€ million, current prices)[86].



[86] Yearly figures are given in constant prices. For BERD, HERD and GovERD, where possible the figure for a particular year is taken from the BERD, HERD or Science Budget/State Expenditure reports of that year. For GERD figures, a combination of figures provided in Science Budget 2014-2015, and Research and Development Statistics at a Glance (2006) have been used. Given the bi-annual reporting of BERD (2001, 2003, 2005…) and HERD (2000, 2002, 2004…) , the gap was made up by a halfway graduated step from one year to the next until the next reported year. For projections to 2020, missing figures between 2014 and 2020 were covered by an even graduated step to the 2020 figures demanded for each expenditure category.

2.2.1 Phase 1: Technology Foresight Exercise 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[87] 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 (elements 1 and 2). At the same time, the EU Structural Funds provided co-financing opportunities for Member States to additionally target and accelerate the development of the R&D base.

From a public investment of €0.5bn in 1994-1999, the NDP 2000-2006 set out a five-fold increase in budget for industry related science and technology expenditure with 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.
- Increasing the quantity and quality of the R&D between institutions and companies[88].

During this phase, the public investment was focused on broad areas that were appropriate for building a base of expertise in fundamental, underpinning science and technology and to strengthening the national R&D capacity and capability in the HEIs. The investment was aimed at 'investing in human knowledge and people in niche areas with the view to driving economic development'[89].

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.

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[87] Technology Foresight Report 1999

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

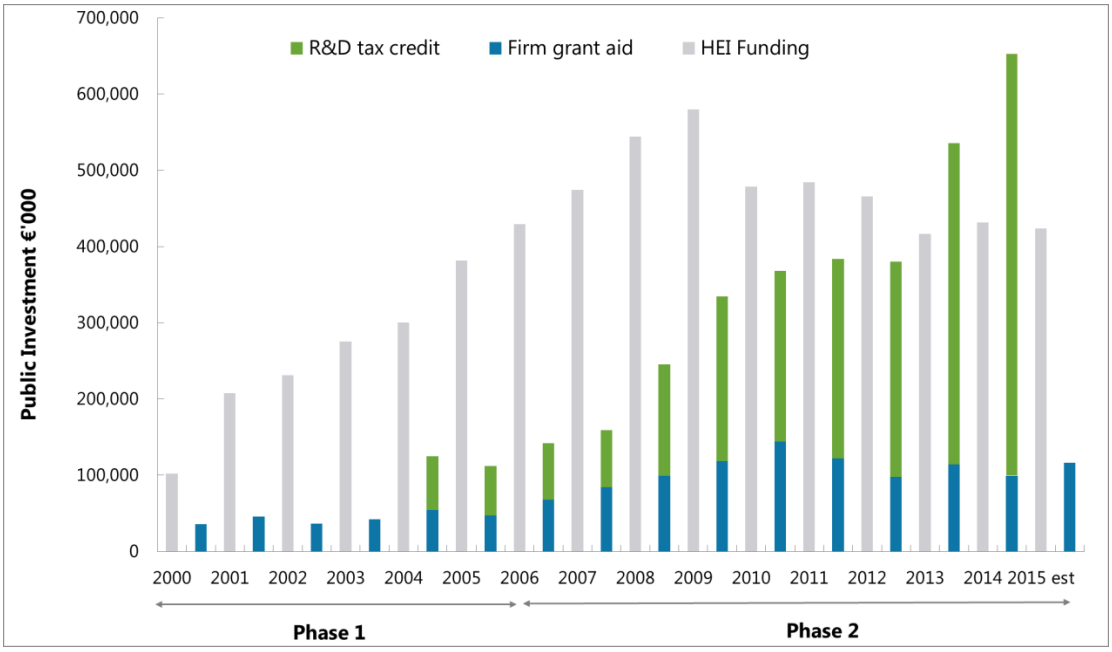
[89] The NDP explained that the 'availability of highly qualified people will help to attract high technology enterprises to Ireland… encourage existing enterprises to undertake more sophisticated innovation and… lead to the establishment of new enterprises based on research findings, thereby supporting social and economic progress and improving living standards'.

- Establishment of SFI 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.
- Establishment of the Research Councils to fund research excellence across a wider range of disciplines.

Additional sources of funding also supported the R&D capacity and capability building in the HEIs, including: the HEA block grant for R&D; increased resources for Marine, Agricultural and Health research; European funding; and other sources of funding leveraged by the HEIs.

In parallel, funding was available to firms via the enterprise agencies by way of grant-aid and in 2004 a tax credit regime for R&D was introduced in Ireland, in the Finance Act 2004.

Figure 9 Public investment in R&D 2000-2015 directed towards achieving enterprise impacts: public funding to HEIs; public funding for grant-aid funding to firms; and public funding to firms through the R&D tax credit (note: no R&D tax credit data was available for 2015).



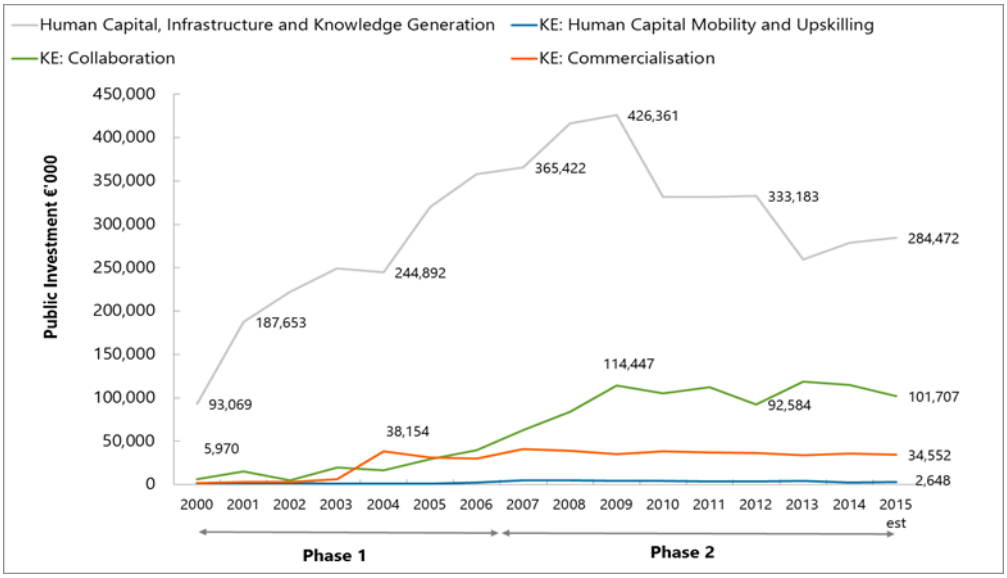
Source: DJEI

Figure 9 provides an overview of the trend of the public investments for R&D since 2000 that were particularly focused towards achieving enterprise impacts[90]. A distinction is made between HEI focused and firm-focused public investments (firm grant-aid and R&D tax credits). For phase

[90] Funding from DJEI , SFI, IDA,EI, IRC, and the HEA (including the block grant for R&D) is included as well as public investment associated with the R&D tax credit. This distinguishes these investments from GBAORD more generally (Government Budget Appropriations on Research and Development). Funding for R&D for sectoral objectives to underpin public policy are not included, although it is recognised that R&D activity in these areas can also give rise to economic benefits.

one of RD&I policy, public investment in R&D to both HEIs and by way of grant-aid to firms increased year on year: public investment in HEIs rose from €102m to €429m, an increase of 321%, and firm grant-aid investment from €36m to €67m, an 86% increase. If the R&D tax credit is included, the total firm-focused investment total was €142m in 2006. With or without the R&D tax credit, however, the rise in HEI investment was proportionately far greater- its share of total public investment in R&D vis-à-vis firm focused investment (exclusive of the R&D tax credit) increased from 74% in 2000 to 86% in 2006. Its share was 75% in 2006, inclusive of the R&D tax credit investment. This funding allocation reflects the key policy objective during the phase one period to develop the HEI R&D system from a low base.

Figure 10 Public Investment for R&D in HEIs according to investment in human capital, infrastructure and knowledge generation, knowledge exchange: human capital mobility and upskilling, knowledge exchange: collaboration, and knowledge exchange: commercialisation, 2000-2015.



Source: DJEI

Figure 10 examines trends in the focus of public funding for R&D to HEIs across 4 main categories:

- Human Capital, Infrastructure and Knowledge Generation
- Knowledge Exchange: Human Capital Mobility and Upskilling
- Knowledge Exchange: Formal Collaboration
- Knowledge Exchange: Commercialisation

The funding to HEIs was mapped in to one of these four categories in accordance with the primary objective of each of the funding programmes: though it is understood that programmes may have sub-objectives that overlap with other categories.

The graph in Figure 10 shows that the scale of the increase in total public investment up to 2006 was largely driven by funding for 'Human Capital, Infrastructure and Knowledge Generation',

which increased from €93m to €358m in 2000-2006, a 284% increase. This €264m increase accounted for 81% of the increase in HEI focused investment, and 73% of the overall increase in public R&D investment. This demonstrates that the core focus of investment in phase one of RD&I policy was in human capital development and knowledge generation. It is notable, however, that there was also a step change in investment in commercialisation activity from 2000 to 2004, which increased from €1.5m to €38m.

2.2.2 Phase 2: Strategy for Science Technology and Innovation and Research Prioritisation Exercise, 2006 – 2015

The vision for RD&I 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.

The key objectives were to strengthen Ireland's enterprise base, to move Ireland towards a knowledge economy through human capital investment, and to maximise the return on R&D investment to Ireland's economic and social development.

The scale of the challenge was recognised - 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 number of researchers in the enterprise sector, and the returns firms were achieving from their innovation performance.

The SSTI had an ambition to move Ireland to an acknowledged leader position by providing the ideas, people and capacity needed for the existing enterprise base, to continue to increase its innovation performance and to attract additional mobile investment to Ireland in the future.

The strategy recognised the need to continue to sustain the State investment in developing Ireland's R&D infrastructures and capabilities by way of funding world class basic research activity and thus continuing to develop knowledge-based human capital and a stock of knowledge within the HEIs. However, in a further evolution of policy, the strategy also recognised the need to build on the public investment in HEI R&D capability and capacity towards achieving enterprise impacts by way of: increasing the R&D absorptive capacity in firms; stimulating increased levels of R&D in the enterprise base; and strengthening knowledge exchange channels, in particular commercialisation of publicly performed R&D.

Thus, the strategy aimed to strengthen the innovation system across its other activities or elements, particularly with regard to the linkages between them: forging more effective linkages and interactions among the different parts of the system to support increased absorptive capacity in firms and increased in-house R&D in firms. Overall the SSTI agenda was acted on through:

- Ambitious 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 beginning of the phase two period this included the SFI funding of Centres of Science, Engineering and Technology (CSETs) and Strategic Research Clusters (SRCs) and the establishment of Competence Centres by EI/IDA. Towards the end of the second phase, the Research Centre landscape had been transformed to support the evolving enterprise needs; to support the development of entities of critical mass which were built on the capability and capacity developed in the HEI in the previous decade; to allow more flexible arrangements for enterprise to engage with centres; and to align the activities in the centres to the national areas of opportunity identified for Ireland through the Research Prioritisation Exercise (RPE)[91]. At the end of the phase two period, the key State-funded centre programmes focused on supporting enterprise to collaborate on R&D with HEIs are the SFI Research Centres, and the EI/IDA Technology Centres.
- Development of a Technology Transfer Office (TTO) Infrastructure[92]. 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.
- 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).

However, the implementation of SSTI was deeply impacted by the deep and prolonged recession 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 that 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, and it marked a further evolution in RD&I policy. Government investment in R&D was likely to remain under severe pressure in the years ahead but it was acknowledged that RD&I needed to stay centre stage in the Government's economic strategy in order to ensure sustainable enterprise

[91] Report of the Research Prioritisation Steering Group, 2012

[92] 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

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.

The broad areas around which budgets were oriented since Technology Foresight (e.g. ICT, biotechnology etc.) were appropriate for building a broad base of expertise in fundamental, underpinning science and technology (S&T). Ireland also now had a greater focus on building on those emerging strengths and targeting investment in areas where we could build critical mass and that link more precisely to current and likely future societal and economic needs.

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[93].

This time frame also marked a significant period of reform in the higher education system and the priorities for higher education are reflected in the *National Strategy for Higher Education to 2030* through which the reforms are being progressed. The landscape of institutions is evolving with the introduction of Technological Universities and the development of higher education regional clusters. Through the Strategic Dialogue process between the Higher Education Authority and the institutions, the *Higher Education System Performance Framework 2014-16* is driving the coherence of the higher education system, while at the same time encouraging diversity in keeping with institutional strategic strengths.

The ambition to build on the evolving capacity and capability in the HEI R&D system towards strengthening the innovation system across its other activities and elements, as well as the impact of the recession and research prioritisation, was reflected in the investment trends during phase two of RD&I policy, as charted in Figures 9 and 10. Figure 9 points to how investment in R&D in HEIs and firm grant-aid R&D investment continued after 2006, hitting a peak in 2009/10. HEI investment reached €580m in 2009, and firm grant-aid reached €144m in 2010. Both, however, experienced declines in the period to 2015. This decline was proportionately larger in the case of HEI funding, which fell to €423m in 2015, a 27% drop, while firm grant-aid investment fell to €116m, a 19% drop over 2010. These declines were concentrated in the 2009-2013 period, after which there was relative stability in investment levels for both HEI and firm grant-aid[94] for R&D.

[93] 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 RD&I capabilities internationally.

[94] Overall, the share of public investment in R&D as a percentage of GBAORD (Government Budget Appropriations on Research and Development) rose from 59% in 2000, when GBAORD totalled €234m, to between 72% and 78% between 2009 and 2015: this is during a time when GBAORD has declined from €890m to €735m. Much of the remainder of GBAORD over this time has been accounted for by Teagasc, the Health Research Board, and the

The focus on stimulating R&D investment in the enterprise base during this phase is emphasised when the R&D tax credit is included in the analysis. The value of claims under the R&D tax credit increased 685% from its introduction in 2004 to 2014, the latest year for which official statistics are available, from €70.5m to €553m. The consequence of this upward trend was that total investments directed towards firms accounted for a larger share of total public investment in R&D in more recent years; in 2013 total public investments towards firms surpassed HEI investment in its share of total public investment in R&D.

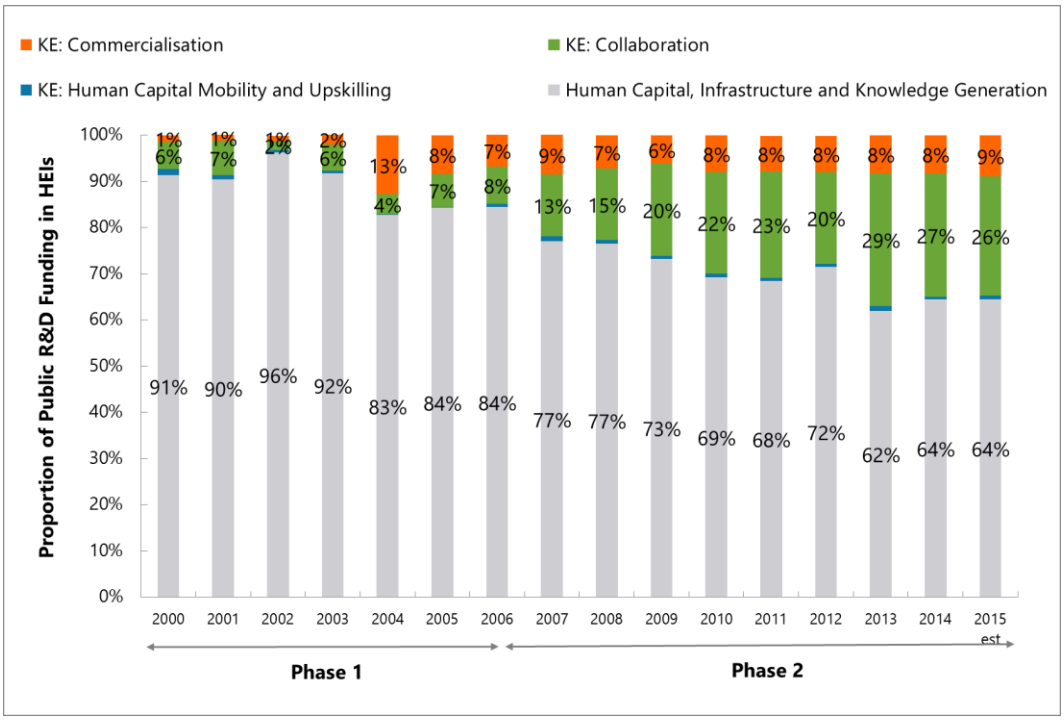
Figure 10 provides an overview of trends of R&D investment in the HEIs in the second phase. Investment in 'human capital, infrastructure, and knowledge generation' drove the rise in total public investment in R&D in phase one, but this category accounted for the majority of the decline in HEI funding after 2009. Having reached a peak of €426m in 2009, it fell by 33% to €284m by 2015[95]. This decline was partly offset by increases in investment in the Knowledge Exchange categories, particularly for HEI-Industry Formal Collaboration. Funding for collaboration rose from €39m in 2006 to €114m in 2009, and the 2009 level of investment was largely sustained up to 2015 at just over €100m. Furthermore, the funding for commercialisation was largely maintained at 2006 levels throughout the second phase, fluctuating between €30 million and €40 million.

This shift in emphasis of investment in R&D in HEIs towards an enhanced focus on achieving enterprise impacts is clearly demonstrated in Figure 11, which shows the proportion of public investment in HEIs across the four funding categories for the 2000-2015 period. The graph illustrates the decline in the share of public investment in HEIs for human capital, infrastructure and knowledge generation (from 91% at the beginning of phase one to 64% at the end of phase two) and the corresponding rise in the share of public investment in HEIs directed towards Knowledge Exchange activities. This was particularly driven by increases in investments in HEI-industry collaborations (which increased its share of investments from 8% in 2006 to 26% by 2015) in particular through the SFI funding to centres and by the sustained investment levels in commercialisation over the phase two period. While the data as presented in Figures 10 and 11 may imply a shift away from investment in human capital development and knowledge generation, this is not the case. Rather, investments in industry-HEI collaborations places an emphasis on human capital development and knowledge generation within the context of a stronger enterprise agenda than is typical in purely academic driven R&D activity.

Department of Agriculture, Food and the Marine. In 2014/15 funding to these Departments/agencies represented 17-18% of GBAORD.

[95] Much of the decline in public funding to HEIs over 2009-2015 resulted from: gradually smaller yearly allocations as cycles 4 and 5 of the Programme for Research in Third Level Institutions (PRTLI) progressed to completion in 2013 and 2015 (from a yearly allocation of €90m in 2009 to €26m in the 2015 estimate); declines in the HEA core grant, from €188m in 2009 to €141m in the 2015 estimate, although this was a recovery from €130m in 2013; and an overall drop in SFI's yearly budget during this period.

Figure 11 Proportion of public investment for R&D in HEIs between 2000 and 2015 according to investment in: human capital, infrastructure and knowledge generation, knowledge exchange: human capital mobility and upskilling, knowledge exchange: collaboration, and knowledge exchange: commercialisation.



Source: DJEI

2.2.3 Phase 3: Innovation 2020, 2016 - 2020

The development of Innovation 2020 comes at a critical juncture in Ireland's transformation from an economy recovering from the most severe recession to a competitive, innovative, highly productive economy providing sustainable full employment for its people. Innovation 2020, which marks the third phase of Ireland's RD&I policy evolution sets out Irelands 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. While setting out ambitious targets for growth, Innovation 2020 also seeks to address the legacy of relative underinvestment on the public side across all elements of the system.

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.
- An internationally competitive research system that acts as a magnet and catalyst for talent and industry.

Thus, the Innovation 2020 Strategy retains a focus on the key aspects of research excellence, nurturing talent, supporting firms to carry out R&DI and international engagement in R&D. However, it also signals a clear message with regards to the commitment to maintain a focus on the impact and relevance of the R&D supported. While the balance of funding has evolved to reflect the overall economic and social objectives of the RD&I 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 in other areas.

While setting out ambitious targets for growth, Innovation 2020 also seeks to address the legacy of relative underinvestment on the public side across all elements of the system: the ambition 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.

Chapter 3: Economic and Enterprise Performance of R&D Active Firms in Ireland

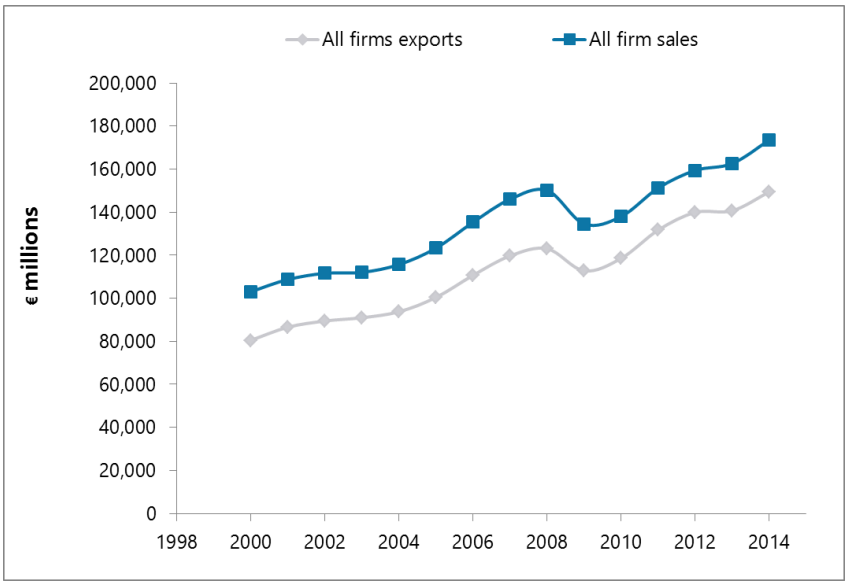
3.1. Introduction

This chapter presents data based evidence that supports the hypothesis that 'within the Irish enterprise base, firm investment in R&D leads to benefits to enterprise and the economy'. The analysis demonstrates that R&D is a characteristic of firms in the Irish enterprise base that are key contributors to sales, exports, value added and employment and that employment in R&D active firms is associated with higher value jobs in the economy. In contrast, for the cohort of firms not engaging in R&D, the evidence points to: declining or more static sales, exports, value added and employment, and, employment in lower value jobs relative to those in R&D active firms. While a causal relationship between R&D activity in agency firms (with 10 or more persons engaged) and sales, export, value added and employment growth is not proposed, there is clear correlation between firm engagement in R&D and more robust performance across these measures for both Irish-owned and foreign-owned agency firms, and this has positive implications for the Irish economy.

3.2 Firm R&D Activity and Sales and Export Performance

3.2.1 All Agency Firms

Figure 12 Sales and exports in each year by all agency firms (with 10 or more persons engaged).



Source: Annual Business Survey of Economic Impact 2015

Sales and exports by all agency firms (with 10 or more persons engaged) in the manufacturing, services, construction and primary production sectors of the economy are plotted in Figure 12. It

can be seen that sales and exports by all-agency firms have grown between 2000 and 2014. Sales by agency firms are predominantly export sales: exports accounted for 81% of total sales by agency firms in 2003 and this had increased to 86% by 2014. Sales and exports by agency firms have grown by 55% and 64% respectively between 2003 and 2014 as indicated in Table 1.

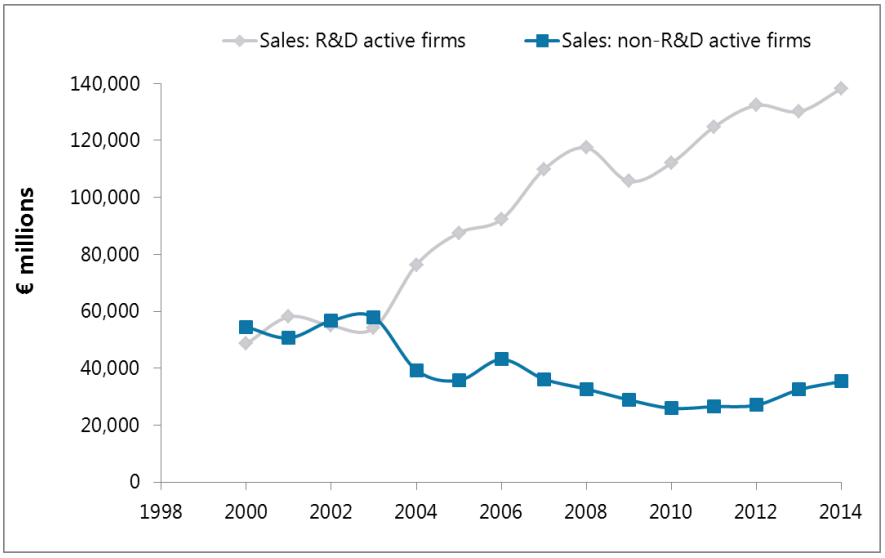
Since 2003 it is the R&D active companies[96] that have been contributing more to sales and exports than the non-R&D active firms, as can be seen in Figures 13 and 14[97]. Sales and exports by R&D active agency firms have grown by 155% and 181% respectively between 2003 and 2014 as indicated in Table 1. In comparison, sales and exports of non-R&D active agency firms declined by 39% and 42% respectively during this time frame, as also indicated in Table 1.

Table 1 Sales and exports growth across all agency firms (with 10 or more persons engaged) between 2003 and 2014, and in each category of R&D expenditure..

All agency-owned Firms	% Growth 2003-2014	
	Sales	**Exports**
All firms	55%	64%
R&D Active	155%	181%
Non-R&D Active	-39%	-42%

Source: Annual Business Survey of Economic Impact 2015

Figure 13 Sales in each year by all agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active firms.

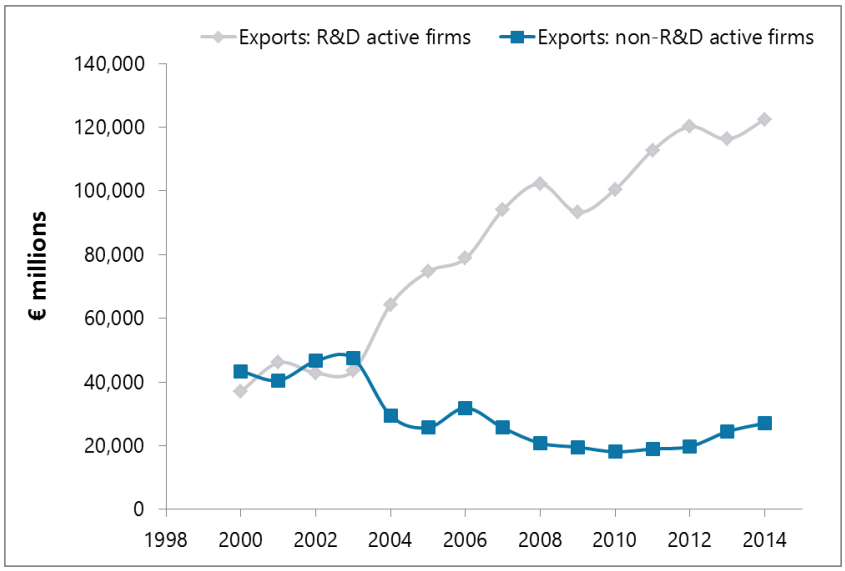


Source: Annual Business Survey of Economic Impact 2015

[96] R&D active firms are the agency firms that indicate an expenditure on R&D in the ABSEI.

[97] Agency client firms account for ~100 % of total BERD expenditure.

Figure 14 Exports in each year by all agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.



Source: Annual Business Survey of Economic Impact 2015

A number of conclusions can be drawn with regards to the role of R&D active and non-R&D active agency firms in terms of sales and exports:

- **Amongst agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in sales and exports between 2003 and 2014.**
- **The sales and export performance of R&D active agency firms (with 10 or more persons engaged) have masked the poorer performance of sales and exports from the cohorts of non-R&D active agency firms over the 2003-2014 period.**

The conclusions are underpinned by the data which shows:

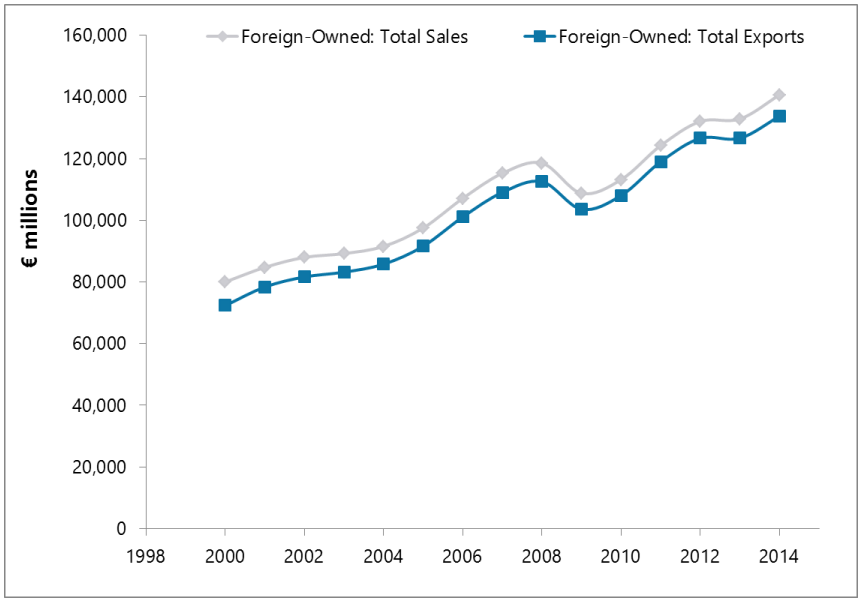
- Higher level of sales and exports by cohorts of R&D active agency firms between 2003 and 2014: sales and exports increased from €54.1 bn and €43.6 bn in 2003 to €138.2 bn and €122 bn respectively in 2014 and remained higher than sales and exports by non-R&D active agency firms throughout this period.
- Cohorts of R&D active agency firms exhibited growth of 155% and 181% for sales and exports over the 2003-2014 period, in comparison to growth of -39% and -42% respectively for non-R&D active agency firms. This led to an increasing contribution by R&D active agency firms to total sales and exports of agency firms: from 48% and 48% in 2003 to 80% and 82% respectively in 2014.
- The short lived (2008-2009) decline in sales and exports for R&D active firms during the recessionary period and the continued growth thereafter - with R&D active agency firms exceeding the 2008 peak sales and export levels in 2011. This is in comparison to the

performance of non-R&D active firms that exhibited a low rate of rebound for sales and exports which were still below 2006 peak levels in 2014.

3.2.2 Foreign-owned Firms

Sales and exports by foreign-owned firms (with 10 or more persons engaged) grew between 2000 and 2014 as can be seen in Figure 15. Sales by foreign-owned agency firms are predominantly export sales: exports accounted for 93% of total sales by agency foreign-owned firms in 2003 and this had increased to 95% by 2014. Sales and exports by foreign-owned agency firms have grown by 55% and 64% respectively as indicated in Table 2.

Figure 15 Total Sales and Exports in each year by foreign-owned agency firms (with 10 or more persons engaged).



Source: Annual Business Survey of Economic Impact 2015

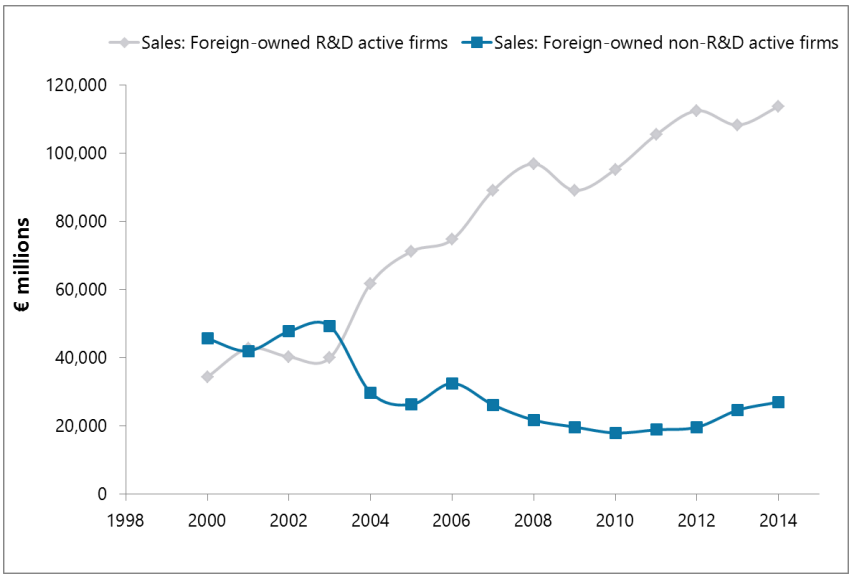
Table 2 Sales and exports growth across all foreign-owned agency firms (with 10 or more persons engaged) in each category of R&D expenditure between 2003 and 2014.

Foreign-owned Firms	% Growth 2003-2014	
	Sales	**Exports**
All firms	55%	64%
R&D Active	184%	190%
Non-R&D Active	-45%	-47%

Source: Annual Business Survey of Economic Impact 2015

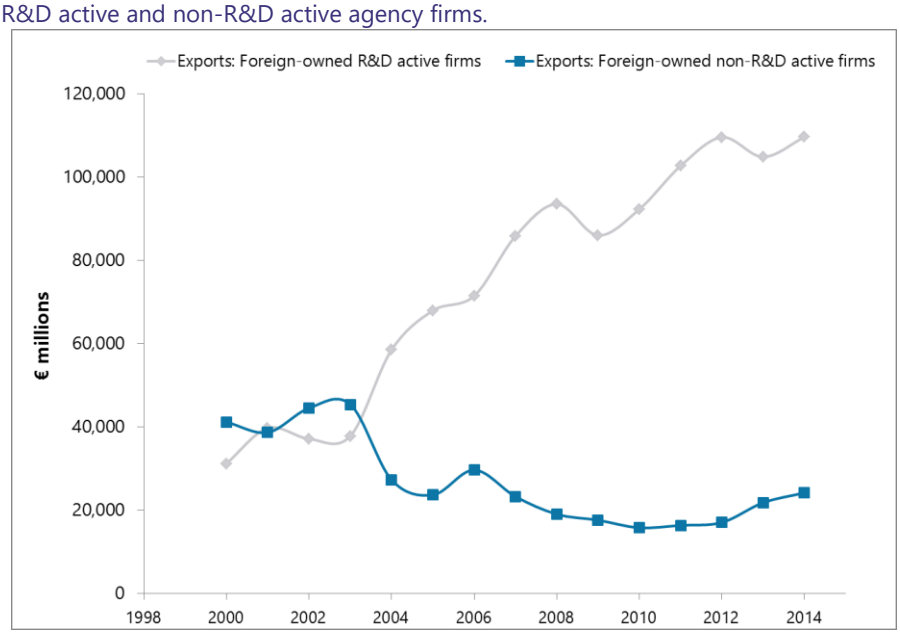
Since 2003 it is the R&D active companies that have been contributing more to sales and exports than the non-R&D active firms, as can be seen in Figure 16 and 17.

Figure 16 Sales in each year by foreign-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active firms.



Source: Annual Business Survey of Economic Impact 2015

Figure 17 Exports in each year by foreign-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.



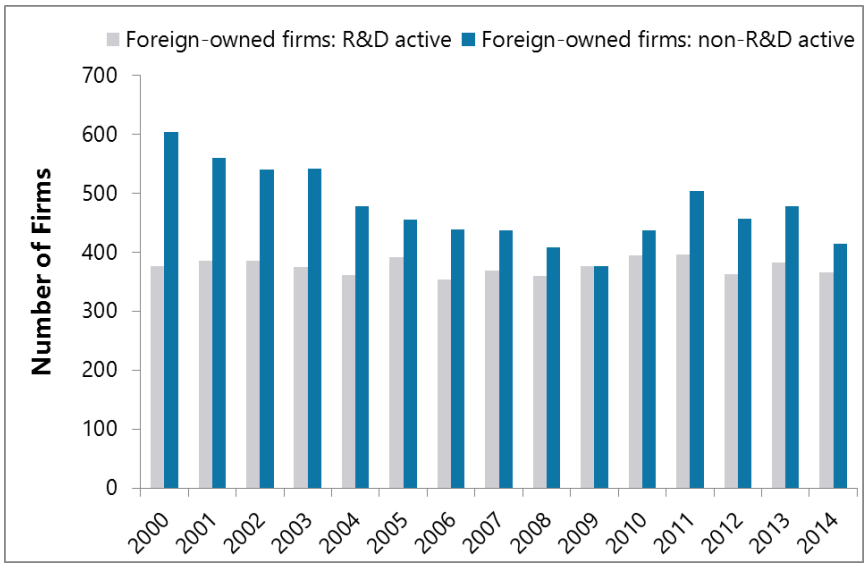
Source: Annual Business Survey of Economic Impact 2015

During the 2003-2014 time frame, the proportion of sales and exports related to the cohorts of R&D active foreign-owned agency firms has been increasing.

Overall, sales and exports in R&D active foreign-owned agency firms increased by 184% and 190% respectively between 2003 and 2014 as indicated in Table 2. While there was a decline in the value of sales and exports in 2008-2009, sales and export levels recovered by 2010 followed by further growth to 2014. In comparison, sales and exports for non-R&D active foreign-owned agency firms declined over the 2003-2014 time period.

The increased exports and sales performance of foreign-owned agency firms has occurred against a backdrop of declining numbers of foreign-owned agency firms (with 10 or more persons engaged) in Ireland over the 2000-2014 period. While the details of firm churn are difficult to account for precisely in moving across years, it is noted that the number of R&D active foreign-owned agency firms in a given year has stayed reasonably steady over this time frame, whereas the number of non-R&D active foreign-owned agency firms in each year declined up to 2010, after which there was growth in the number of these firms, as can be seen in Figure 18.

Figure 18 Number of foreign-owned agency firms (with 10 or more persons engaged) in each year according to R&D status.



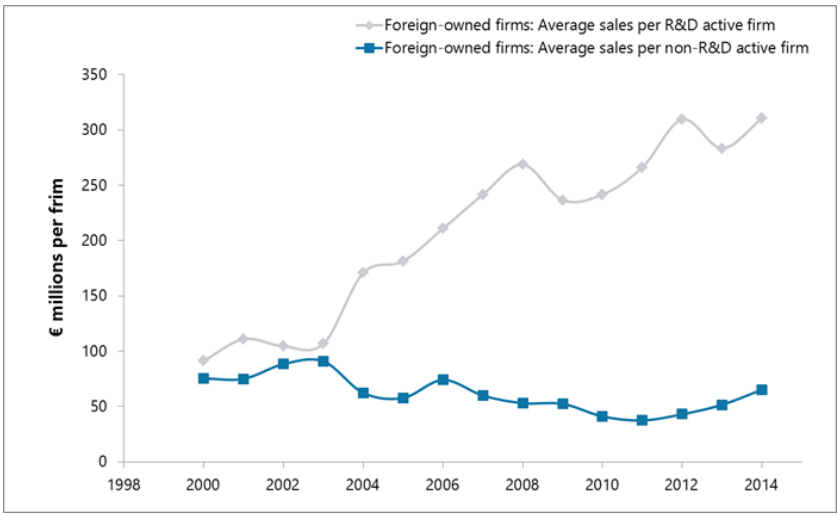
Source: Annual Business Survey of Economic Impact 2015

It is also noted that despite the relatively constant number of R&D active firms over this time period, R&D expenditure by foreign-owned agency firms has increased considerably (from €808 million to €1.5 bn) and this is related to a greater number of firms with larger R&D expenditures[98].

[98] The number of firms spending between €2 million and €5 million per year on in-house R&D increased from 24 to 59 and the number of firms spending more than €5 million per year increased from 29 to 59 firms.

Figures 19 and 20 show that the average sales and exports per firm for R&D active and non-R&D active foreign-owned agency firms demonstrate similar trends to the absolute values of sales and exports by these cohorts over the 2000-2014 time frame. Furthermore, the average sales and exports for R&D active firms was consistently higher than for non-R&D active firms and grew over the time period in comparison to the declining and more static levels recorded for non R&D-active firms.

Figure 19 Average sales per firm in each year for foreign-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.



Source: Annual Business Survey of Economic Impact 2015

Figure 20 Average exports per firm in each year for foreign-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.

Source: Annual Business Survey of Economic Impact 2015

A number of conclusions can be drawn from the analysis:

- **Amongst foreign-owned agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in sales and exports between 2003-2014.**
- **The sales and export performance of R&D active foreign-owned agency firms (with 10 or more persons engaged) have masked the decline in the value of sales and exports from the cohorts of non-R&D active foreign-owned agency firms over the 2003-2014 period.**

The conclusions are underpinned by the data which shows:

- Higher level of sales and exports by cohorts of R&D active foreign-owned agency firms between 2003 and 2014: sales and exports increased from €40 bn and €38 bn in 2003 to €114 bn and €110 bn respectively in 2014 and remained higher than sales and exports by non-R&D active foreign-owned agency firms throughout this period.
- That the cohorts of R&D active foreign-owned agency firms exhibited growth of 184% and 190% for sales and exports over the 2003-2014 period, in comparison to growth of -45% and -47% respectively for non R&D active foreign-owned agency firms. This led to an increasing contribution by R&D active foreign-owned agency firms to total sales and exports of foreign-owned agency firms: from 45% and 45% in 2003 to 81% and 82% respectively in 2014.
- The short lived (2008-2009) decline in sales and exports for R&D active foreign-owned firms during the recessionary period and the continued growth thereafter with R&D active foreign-owned agency firms reaching 2008 sales and export levels by 2011). This is in comparison to the low rate of rebound for sales and exports for non-R&D active firms, which were still below 2006 peak levels in 2014.

3.2.3 Irish-owned Firms

Sales and exports by Irish-owned agency firms (with 10 or more persons engaged) have also grown over the 2003-2014 time period as can be seen in Figure 21, with 42% and 102% growth respectively, as indicated in Table 3. Cohorts of R&D active Irish-owned agency firms however demonstrate higher levels and greater growth in sales and exports than non-R&D active Irish-owned agency firms, as can be seen in Figures 22 and 23. As indicated in Table 3, sales by Irish-owned agency firms that were R&D active increased by 74% between 2003 and 2014 while exports by these firms grew by 122%. Sales by Irish-owned agency firms that were not R&D active declined over the period by 4%: the decline was initiated at the start of the recessionary period (2008) and little recovery has been made in sales by this cohort of firms since then. However, exports by non-R&D active Irish-owned firms did demonstrate a return to growth following a decline between 2007-2008, with an overall growth in export sales of 46% being measured between 2003 and 2014.

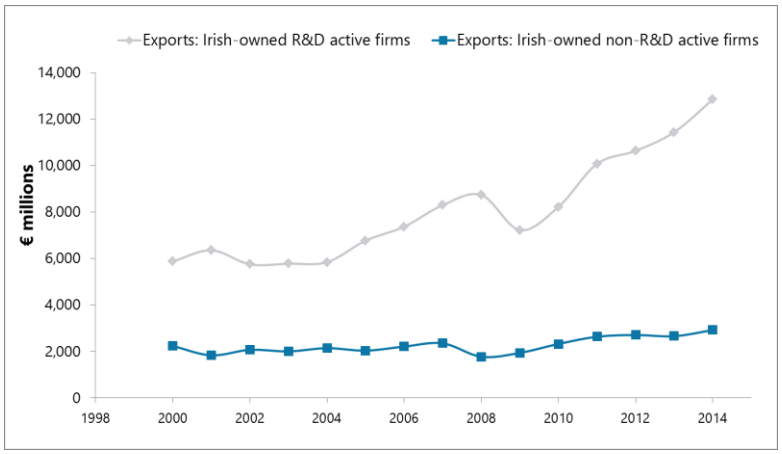
Figure 21 Total sales and exports in each year by Irish-owned agency firms (with 10 or more persons engaged).

Source: Annual Business Survey of Economic Impact 2015

Figure 22 Sales in each year by Irish-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.

Source: Annual Business Survey of Economic Impact 2015

Figure 23 Exports in each year by Irish-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.



Source: Annual Business Survey of Economic Impact 2015

Table 3 Sales and exports growth across Irish-owned firms (with 10 or more persons engaged) in each category of R&D expenditure between 2003 and 2014.

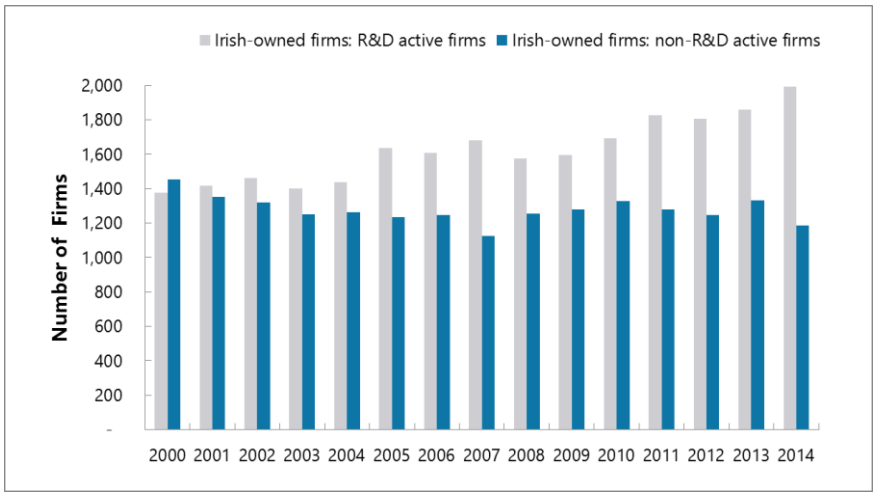
Irish-owned Firms	% Growth 2003-2014	
	Sales	**Exports**
All firms	42%	102%
R&D Active	74%	122%
Non-R&D Active	-4%	46%

Source: Annual Business Survey of Economic Impact 2015

The exports and sales performance of Irish-owned agency firms (with 10 or more persons engaged) has been against a backdrop of an increased number of Irish-owned agency firms in Ireland over the 2000-2014 period. While the details of firm churn are difficult to account for precisely in moving across years, it is noted that in this case, the number of Irish-owned R&D active agency firms has grown over the time period[99] while the number of non-R&D active Irish-owned agency firms have remained at a more static level (as can be seen in Figure 24).

[99] With a related increase in R&D expenditure by firms from €323 million in 2003 to €686 million in 2014.

Figure 24 Number of Irish-owned agency firms (with 10 or more persons engaged) in each year according to R&D status.



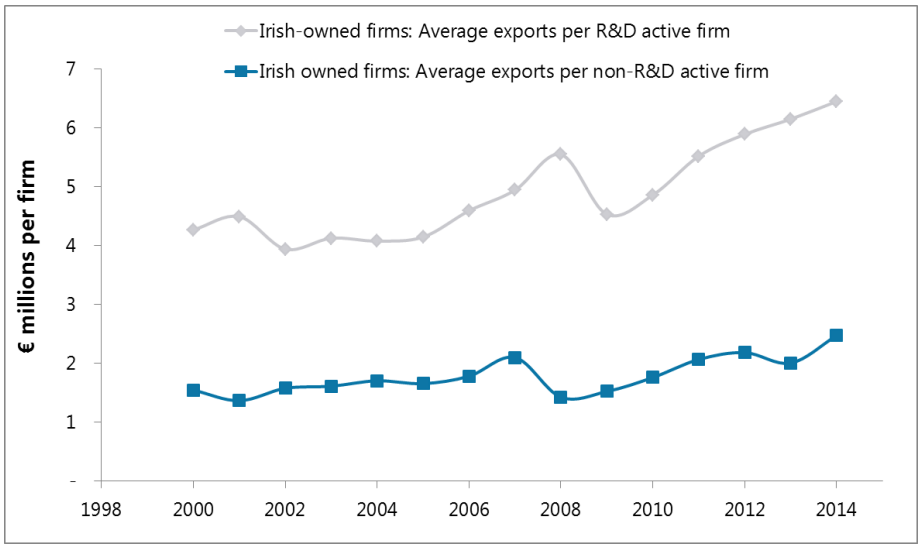
Source: Annual Business Survey of Economic Impact 2015

An examination of the trends of average sales and exports per firm by R&D active and non-R&D active Irish-owned agency firms (Figures 25 and 26) finds them to be similar to those for absolute value of sales and exports by the respective cohorts (Figures 22 and 23). This indicates that growth in sales and exports in the R&D active cohort of firms is not simply due to an increasing number of R&D active firms, but is also due to improving performance across the cohort of R&D active firms.

Figure 25 Average sales per firm in each year by Irish-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.

Source: Annual Business Survey of Economic Impact 2015

Figure 26 Average exports per firm in each year by Irish-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms**.**



Source: Annual Business Survey of Economic Impact 2015

Furthermore, the average sales and exports for R&D active firms were higher than for non-R&D active firms throughout the 2003-2014 period. Following a decline in average sales per firm from 2008-2010, R&D active firms recovered to 2008 values by 2012 and subsequently exceeded these levels. In comparison, average sales per firm for non-R&D active firms declined between 2007 and 2010 and have remained largely static since then.

Average exports per firm for R&D active firms declined between 2008 and 2009, and for non-R&D active firms between 2007-2008. While both cohorts have subsequently shown growth in average exports per firm, R&D active firms demonstrated a greater growth and returned to the previous peak level of 2008 in 2011 and subsequently exceeded this level in 2012. In comparison, while non-R&D active firms returned to the previous peak level of 2007 this was not until 2012, and this level was marginally exceeded in 2014.

A number of conclusions can be drawn with regards to the role of R&D active and non-R&D active Irish-owned agency firms in terms of sales and exports.

- **Amongst Irish-owned agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in sales and exports between 2003 and 2014.**
- **The sales and export performance of R&D active Irish-owned agency firms (with 10 or more persons engaged) have masked the poorer performance of sales and the lower level of export growth from the cohorts of non-R&D active Irish-owned agency firms over the 2003-2014 period.**

The conclusions are underpinned by the data which shows:

- Higher level of sales and exports by cohorts of R&D active Irish-owned agency firms between 2003 and 2014: sales and exports increased from €14.2 bn and €5.8 bn in 2003 to €24.5 bn and €12.8 bn respectively in 2014 and remained higher than sales and exports by non-R&D active Irish-owned agency firms throughout this period.
- Cohorts of R&D active Irish-owned agency firms exhibited growth of 74% and 122% for sales and exports over the 2003-2014 period, in comparison to growth of -4% and 46% respectively for non-R&D active Irish-owned agency firms. This led to an increasing contribution by R&D active Irish-owned agency firms to total sales and exports of Irish-owned agency firms: from 62% and 74% in 2003 to 75% and 81% respectively in 2014.
- The short lived (2008-2009) decline in sales and exports for Irish-owned firms during the recessionary period and the continued growth thereafter - with R&D active Irish-owned agency firms exceeding the 2008 peak sales and export levels in 2013 and 2011 respectively. This is in comparison to the performance of non-R&D active firms that exhibited a low rate of rebound for sales, which were still below 2008 peak levels in 2014, and exports, which returned to 2007 levels in 2011, but have been static since then.
- The increase in exports by R&D active firms supported a rise in total exports by Irish-owned agency firms from 34% of total sales by Irish-owned agency firms in 2003 to 48% of total sales in 2014.

While a causal relationship between R&D activity in agency firms and sales and export growth is not proposed, **there is clear correlation between engagement in R&D and enhanced sales and export performance for both Irish-owned and foreign-owned agency firms and this has positive implications for the Irish economy**.

3.3 Firm R&D Activity and Value Added

3.3.1 All Agency Firms

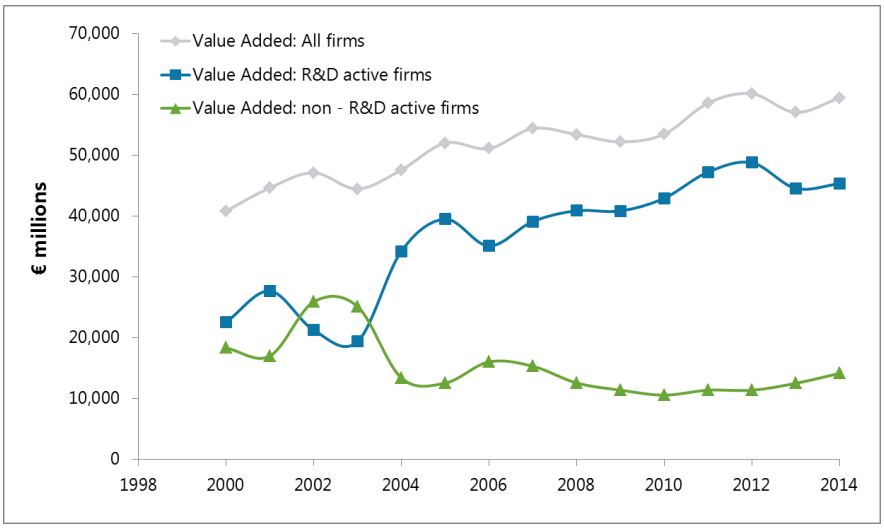
Value added by all agency firms (with 10 or more persons engaged) in the manufacturing, services, construction and primary production sectors of the economy are plotted in Figure 27. It can be seen that value added[100] by all-agency firms (with 10 or more persons engaged) have grown between 2000 and 2014: with growth of 46% over this time frame.

Since 2003, it is the R&D active agency firms that have been contributing more to value added than non-R&D active agency firms, as can be seen in Figure 27. Following a decline in value added since 2003, value added of non-R&D active firms has essentially plateaued since 2009, resulting in an overall decrease in value added of 44% between 2003 and 2014. In comparison,

[100] Value added estimates are based on sales revenue minus the cost of materials and services.

value added of R&D active firms has increased by 134% over this time frame, as indicated in Table 4.

Figure 27 Value added in each year by all agency firms (with 10 or more persons engaged) and for cohorts of R&D active and non-R&D active agency firms.



Source: Annual Business Survey of Economic Impact 2015

Table 4 Percentage growth in value added across agency firms (with 10 or more persons engaged) in each category of R&D expenditure between 2003 and 2014.

Agency Firms	% Growth in Value Added 2003-2014
All firms	34%
R&D Active	134%
Non-R&D Active	-44%

Source: Annual Business Survey of Economic Impact 2015

A number of conclusions can be drawn with regards to the role of R&D active and non-R&D active agency firms in terms of value added:

- **Amongst agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in value added between 2003 and 2014.**
- **The value added performance of R&D active agency firms (with 10 or more persons engaged) has masked the poorer performance of value added from the cohorts of non-R&D active agency firms over the 2003-2014 period.**

The conclusions are underpinned by the data which shows:

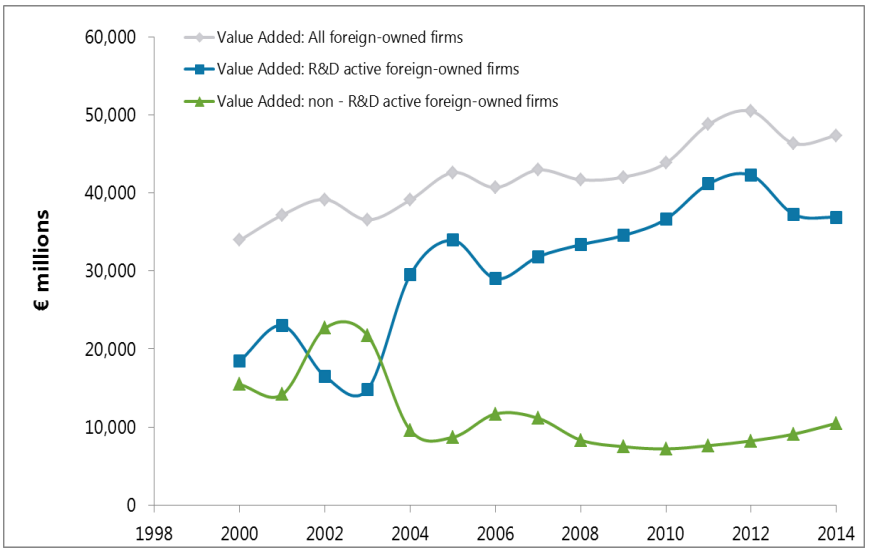
- Higher levels of value added by cohorts of R&D active agency firms since 2003: value added increased from €19.3 bn in 2003 to €45.3 bn respectively in 2014 and remained higher than value added by non-R&D active agency firms since 2003.
- Cohorts of R&D active agency firms exhibited growth of 134% for value added over the 2003-2014 period, in comparison to an overall decline in value added of -44% for non-R&D active agency firms. This led to an increasing contribution by R&D active agency firms to total value added of agency firms: from 44% in 2003 to 76% in 2014.
- The continued growth in value added for R&D active firms during the recessionary period.

3.3.2 Foreign-owned Firms

Total value added by foreign-owned agency firms (with 10 or more persons engaged) grew between 2000 and 2014 as can be seen in Figure 28. However since 2003, R&D active foreign-owned agency firms have been contributing more to value added than non-R&D active firms. The proportion of value added contributed by the cohorts of R&D active foreign-owned agency firms has also been increasing over the 2003-2014 time frame.

Overall, value added by foreign-owned agency firms increased by 30% between 2003 and 2014 as indicated in Table 5. This was supported by an increase of 149% in value added by R&D active foreign-owned agency firms. Despite growth of 45% between 2010 and 2014 there was an overall decline of 52% in value added between 2003 and 2014 for non-R&D active foreign-owned firms.

Figure 28 Value added in each year by foreign-owned agency firms (with 10 or more persons engaged) and for cohorts of R&D active and non-R&D active foreign-owned agency firms.



Source: Annual Business Survey of Economic Impact 2015

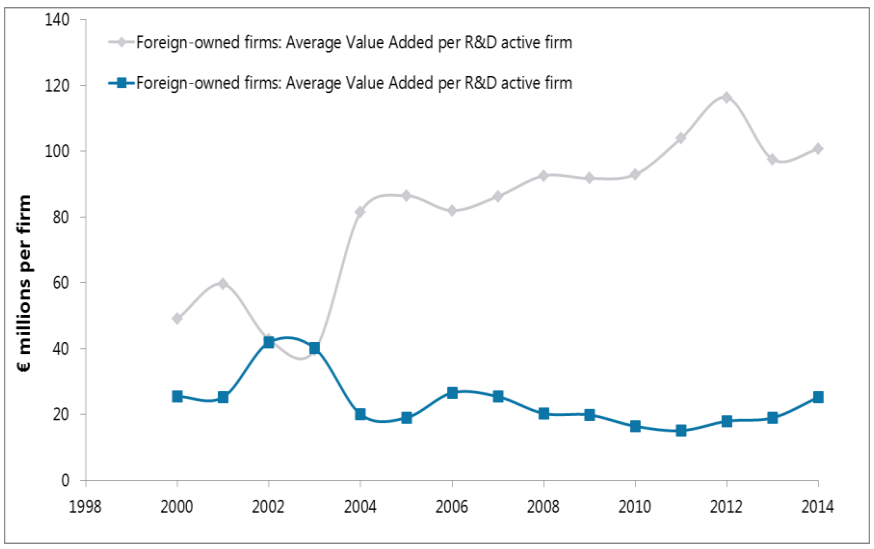
Table 5 Percentage growth in value added across foreign-owned agency firms (with 10 or more persons engaged) in each category of R&D expenditure between 2003 and 2014.

Foreign-owned Agency Firms	% Growth in Value Added 2003-2014
All firms	30%
R&D Active	149%
Non-R&D Active	-52%

Source: Annual Business Survey of Economic Impact 2015

The increasing value added recorded for the cohorts of R&D active foreign-owned agency firms has occurred against a backdrop of an approximately constant level of foreign-owned R&D active agency firms (as indicated in Figure 18). Figure 29 indicates that the average value added per firm for R&D active and non-R&D active foreign-owned agency firms demonstrate similar trends to the absolute values for value added by these cohorts over the 2000 to 2014 time frame: with the average value added for R&D active foreign-owned firms remaining consistently higher since 2003.

Figure 29 Average value added per firm in each year by foreign-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.



Source: Annual Business Survey of Economic Impact 2015

A number of conclusions can be drawn with regards to the role of R&D active and non-R&D active foreign-owned agency firms in terms of value added:

- **Amongst foreign-owned agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in value added between 2003 and 2014.**

- **The value added performance of foreign-owned R&D active agency firms (with 10 or more persons engaged) has masked the poorer performance of value added from the cohorts of foreign-owned non-R&D active agency firms over the 2003-2014 period.**

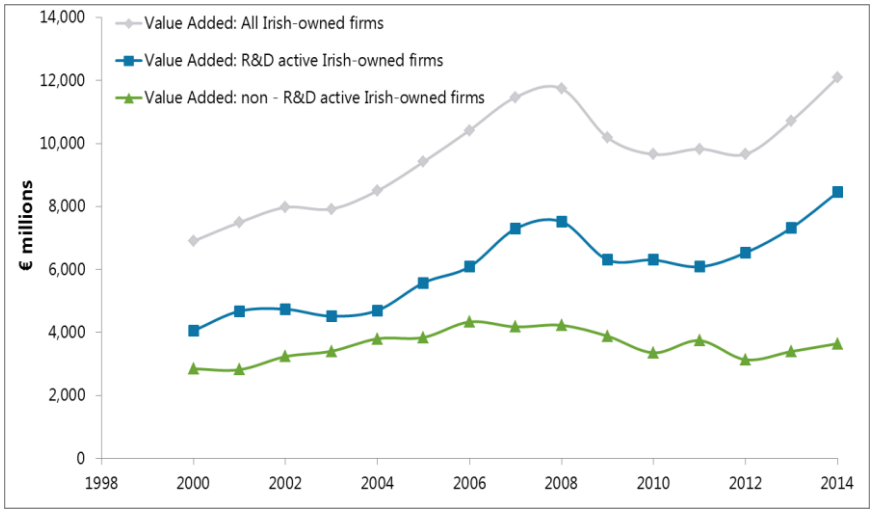
The conclusions are underpinned by the data which shows:

- Higher levels of value added by cohorts of foreign-owned R&D active agency firms since 2003: value added increased from €14.8 bn in 2003 to €36.9 bn respectively in 2014 and remained higher than value added by non-R&D active agency firms since 2003.
- Cohorts of foreign-owned R&D active agency firms exhibited growth of 149% for value added over the 2003-2014 period, in comparison to an overall decline in value added of 52% for foreign-owned non-R&D active agency firms. This led to an increasing contribution by foreign-owned R&D active agency firms to total value added of foreign-owned agency firms: from 40% in 2003 to 78% in 2014.
- The continued growth in value added for foreign-owned R&D active firms during the recessionary period.

3.3.3 Irish-owned Firms

Total value added by Irish-owned agency firms (with 10 or more persons engaged) grew between 2000 and 2014 as can be seen in Figure 30. Throughout this time period, R&D active Irish-owned agency firms have been contributing more to value added than non-R&D active firms. Furthermore, the proportion of value added contributed by the cohorts of R&D active Irish-owned agency firms has also been increasing over the 2003-2014 time frame.

Figure 30 Value added in each year by Irish-owned agency firms (with 10 or more persons engaged) and for cohorts of R&D active and non-R&D active Irish-owned agency firms.



Source: Annual Business Survey of Economic Impact 2015

While value added of Irish-owned R&D active firms declined between 2008 and 2009, strong growth since 2011 has resulted in value added levels in 2014 surpassing the previous peak recorded in 2008. In comparison value added for Irish-owned non-R&D active declined from 2006 and have not yet recovered to this level of performance.

Overall, value added by Irish-owned agency firms increased by 75% between 2000 and 2014 as indicated in Table 6. This was supported by an increase of 108% in value added by R&D active foreign-owned agency firms and an increase of 28% in value added by Irish-owned non-R&D active firms over this time. However, when viewed over the 2006-2014 time frame, value added for Irish owned firms increased by 17%, with value added of R&D active Irish owned firms increasing by 38% and value added of non-R&D active Irish-owned firms declining by 16%.

Table 6 Percentage growth in value added across Irish-owned agency firms (with 10 or more persons engaged) in each category of R&D expenditure between 2000 and 2014.

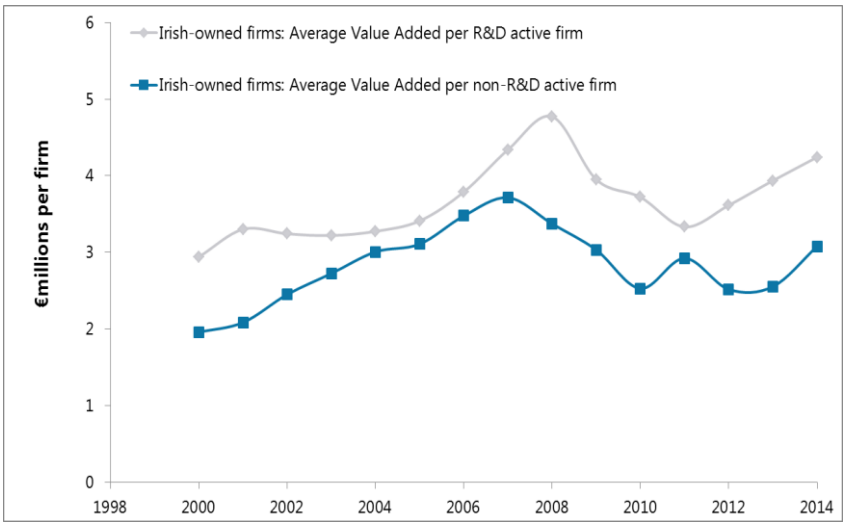
Irish-owned Agency Firms	% Growth in Value Added 2000-2014
All firms	75%
R&D Active	108%
Non-R&D Active	28%

Source: Annual Business Survey of Economic Impact 2015

The changes in value added recorded for Irish-owned agency firms between 2000 and 2014 has occurred against a backdrop of an increasing number of R&D active agency firms and an approximately static number of non-R&D active Irish-owned agency firms (Figure 24).

Figure 31 indicates that the average value added per firm for R&D active and non-R&D active Irish-owned agency firms deviate somewhat from the trends for absolute values of value added. However, the data indicates that average value added per firm remained higher for R&D active Irish-owned agency firms than for non-R&D active Irish-owned agency firms throughout the 2000 to 2014 period.

Figure 31 Average value added per firm in each year by Irish-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms.



Source: Annual Business Survey of Economic Impact 2015

A number of conclusions can be drawn with regards to the role of R&D active and non-R&D active Irish-owned agency firms in terms of value added:

- **Amongst Irish-owned agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in value added between 2000 and 2014.**
- **The value added performance of Irish-owned R&D active agency firms (with 10 or more persons engaged) has masked the poorer performance of value added from the cohorts of Irish-owned non-R&D active agency firms over the 2000-2014 period.**

The conclusions are underpinned by the data which shows:

- Higher levels of value added by cohorts of Irish-owned R&D active agency firms since 2000: value added increased from €4 bn in 2000 to €8..45 bn respectively in 2014 and remained higher than value added by non-R&D active agency firms since 2000.
- Cohorts of Irish-owned R&D active agency firms exhibited growth of 108% for value added over the 2000-2014 period, in comparison to a 28% increase in value added for Irish-owned non-R&D active agency firms. This led to an increasing contribution by Irish-owned R&D active agency firms to total value added of foreign-owned agency firms: from 59% in 2000 to 70% in 2014.
- The continued growth in value added for Irish-owned R&D active firms since 2012.

While a causal relationship between R&D activity in agency firms and value added growth is not proposed, **there is clear correlation between engagement in R&D and enhanced value added performance for both Irish-owned and foreign-owned agency firms and this has positive implications for the Irish economy**.

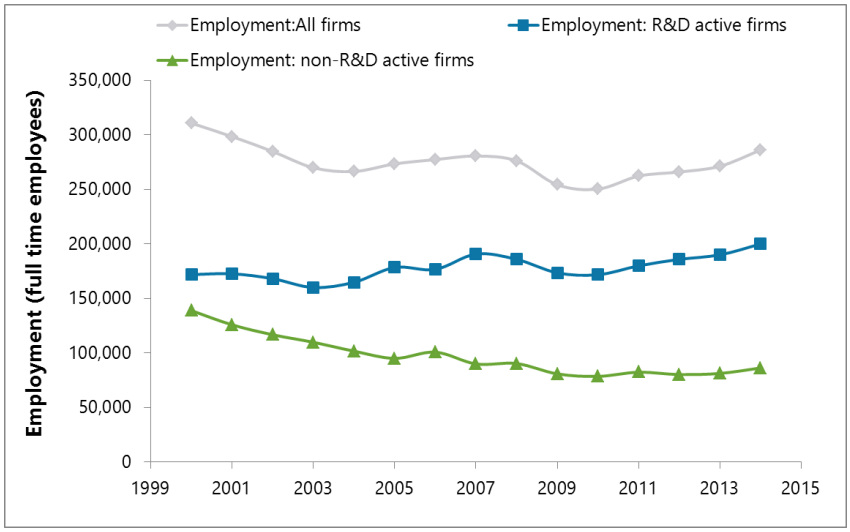
3.4 Firm R&D Activity and Employment Performance in Agency Firms

3.4.1 All Agency Firms

It is noted that for exports, sales and value added the analysis relates to analysis of data from agency firms in the manufacturing, services, construction and primary production sectors of the economy. For the analysis of employment in agency firms, the analysis is restricted to the manufacturing and services sector specifically, although additional analysis on employment of R&D personnel across all firms in the economy is also presented.

Employment amongst agency firms (with 10 or more persons engaged)[101] in the manufacturing and services sectors has declined over the 2000-2014 time frame by 29,600. This decline is associated with decreasing employment in the non-R&D active firms, as is indicated in the data presented in Figure 32. Employment declined by 53,300 amongst non-R&D active agency firms which related to a 40% decline in employment over the 2000-2014 time frame. In tandem employment in the R&D active agency firms grew up until 2007 and then there was a decline in employment between 2007-2009 after which employment continued to grow again, surpassing the 2007 peak level of employment in 2014.

Figure 32 Employment in the manufacturing and services sectors in agency firms (with 10 or more persons engaged): total employment[102] and employment in R&D active and non-R&D active firms.



Source: Annual Business Survey of Economic Impact 2015

[101] ABSEI firms represent 70-78% of employment in Irish owned-agency firms between 2005 and 2014 and between 80-88% of employment in foreign-owned agency firms- based on comparison of data reported in the ABSEI and the Annual Employment Survey (AES).

[102] Employment in Primary Production and Construction Sectors are not included here in the total employment figure.

The decline in firm employment in non-R&D active firms is against a backdrop of a declining number of non-R&D active firms up until 2007, after which the number of non- R&D active firms started to increase up to 2013. In comparison, the number of R&D active firms has been trending upwards since 2004.

The evidence thus points us towards a number of conclusions:

- **Amongst agency firms (with 10 or more persons engaged) in the manufacturing and services sectors, R&D activity is a characteristic of firms that contribute most to employment between 2000 and 2014.**
- **The employment performance of R&D active firms (with 10 or more persons engaged) in the manufacturing and services sectors has masked the poorer performance in employment amongst the non-R&D active firms between 2000 and 2014.**

The conclusions are underpinned by the data which shows:

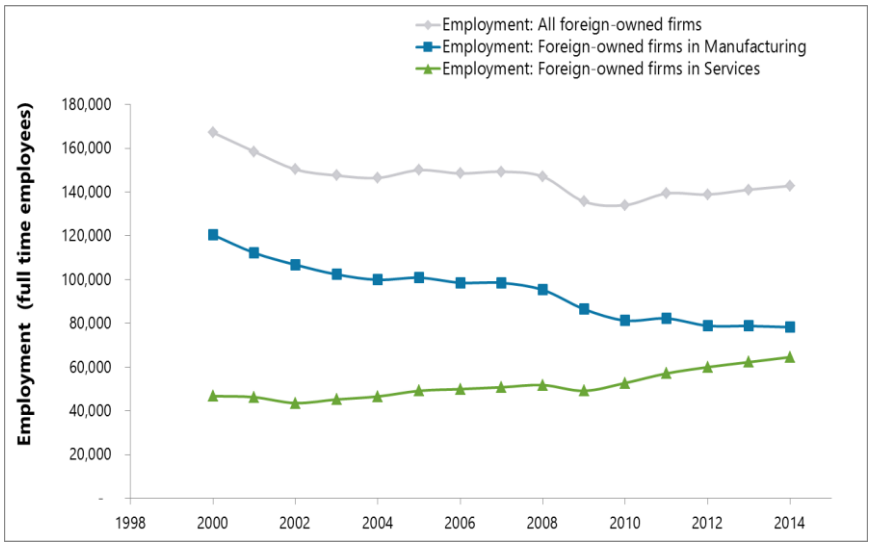
- Greater overall sustainability of employment in R&D active agency firms: employment grew between 2000 and 2014 by 14% as compared to the decline of 40% of non-R&D active firms during this time period.
- More sustained employment by R&D active agency firms which lead to an increase in the contribution to employment from 56% of employment by agency firms across all sectors in 2000 to 71% in 2014.

3.4.2 Foreign-owned Firms

Employment in the manufacturing and services sectors amongst agency foreign-owned firms (with 10 or more persons engaged[103]) has declined over the 2000-2014 time frame by 24,400. This decline is associated with decreasing employment in the manufacturing sector, as is indicated in the data presented in Figure 33. In tandem the foreign-owned agency firms in the services sector have exhibited growth in employment over this same time period.

[103] ABSEI firms represented 70-78% of employment in Irish owned-agency firms between 2005 and 2014 and between 80-88% of employment in foreign-owned agency firms- based on comparison of data reported in the ABSEI and the Annual Employment Survey (AES).

Figure 33 Employment in foreign-owned agency firms (with 10 or more persons engaged): combined employment in the manufacturing and services sectors[104] and employment separately in the manufacturing and services sectors.



Source: Annual Business Survey of Economic Impact 2015

The employment performance of foreign-owned agency firms has occurred against a backdrop of declining numbers of foreign-owned agency firms in the manufacturing sector over the 2000-2014 period and an increase in the number of foreign-owned agency firms in the services sector between 2009 and 2013 (as can be seen in Figures 35 and 37)[105].
Disaggregation of yearly employment levels in the manufacturing and services sectors, according to employment contribution by R&D active and non-R&D active cohorts of foreign-owned agency firms, reveals a more nuanced picture as can be seen in Figure 34.

Employment levels in R&D active foreign-owned agency firms in the manufacturing sector remained essentially static from 2000 (69,000) to 2003 (68,000) and then grew to 2007 (80,000) before declining during the recessionary period, and appears to have plateaued since 2010 (63,900 in 2014). In contrast, for the cohorts of foreign-owned agency firms in the manufacturing sector that were not R&D active, employment decreased from 51,000 in 2000 to 14,000 in 2009, and employment has remained at this low level since then.

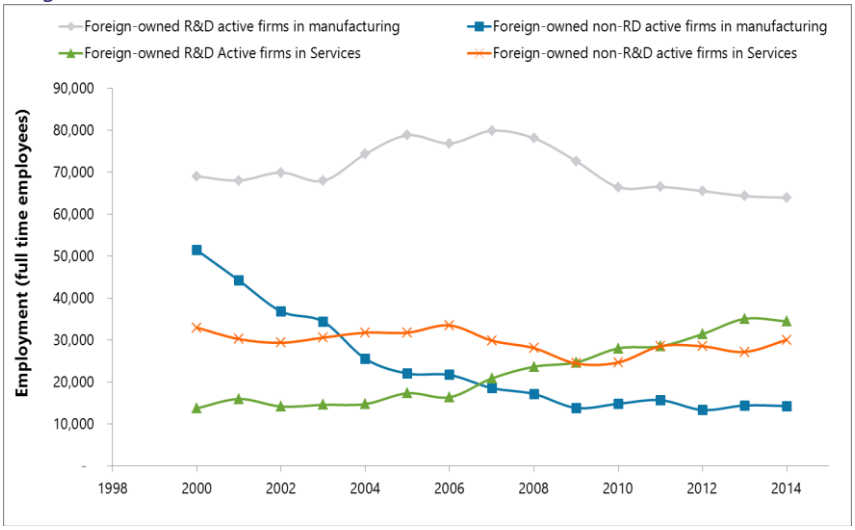
In the manufacturing sector, the numbers of R&D active firms in a given year remained reasonably constant up to 2011 - at an average of 290 firms (standard deviation 11) - followed by a decline between 2011 and 2012, after which the number of firms has remained constant to 2014- the average number of R&D active foreign-owned agency firms in the manufacturing sector between 2012 and 2014 was 233. In contrast, the number of non-R&D active foreign-

[104] Employment in Primary Production and Construction Sectors are not included.

[105] It is noted that the operating activities and business objectives of foreign-owned firms are becoming increasingly multifaceted as technology and business processes and opportunities evolve and this leads to increased difficulty in designating some firms as manufacturing or services firms.

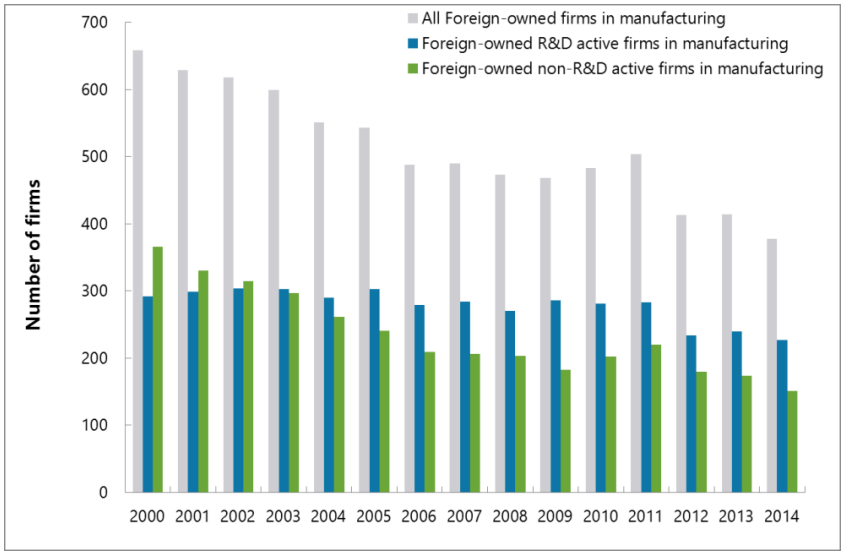
owned agency firms in the manufacturing sector has been declining since 2000 (from 365 to 150 in 2014) as can be seen in Figure 35.

Figure 34 Employment in foreign-owned agency firms (with 10 or more persons engaged): employment in the manufacturing and services sectors for R&D active and non-R&D active firms.



Source: Annual Business Survey of Economic Impact 2015

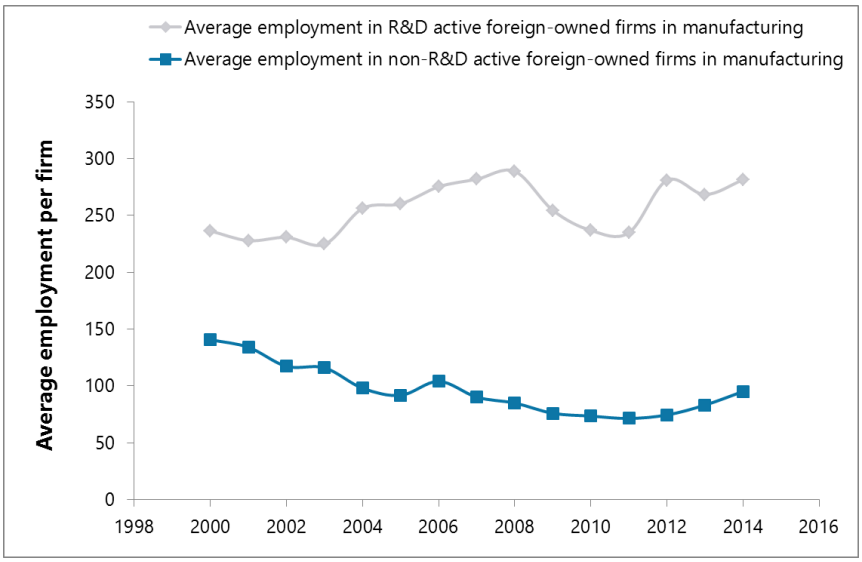
Figure 35 Number of foreign-owned agency firms (with 10 or more persons engaged) in the manufacturing sector in each year according to R&D status.



Source: Annual Business Survey of Economic Impact 2015

However, reviewing the average employment per R&D active and non-R&D active foreign-owned agency firms in the manufacturing sector further informs the analysis. As can be seen in Figure 36, the average employment for R&D active firms increased from 2003-2008, after which it declined and then rebounded in 2012.

Figure 36 Average employment per firm in each year by foreign-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms in the manufacturing sector.



Source: Annual Business Survey of Economic Impact 2015

In comparison the, average employment per firm in non-R&D active foreign-owned agency firms is lower than for R&D active firms and decreased up to 2011, after which there was some gradual growth.

The evidence thus points us towards a number of conclusions:

- **Amongst foreign-owned agency firms (with 10 or more persons engaged) in the manufacturing sector, R&D activity is a characteristic of firms that contribute most to employment between 2000 and 2014.**
- **The employment performance of R&D active foreign-owned agency firms (with 10 or more persons engaged) in the manufacturing sector has masked the poorer performance in employment amongst the cohort of non-R&D active firms in the manufacturing sector between 2000 and 2014.**

The conclusions are underpinned by the data which shows:

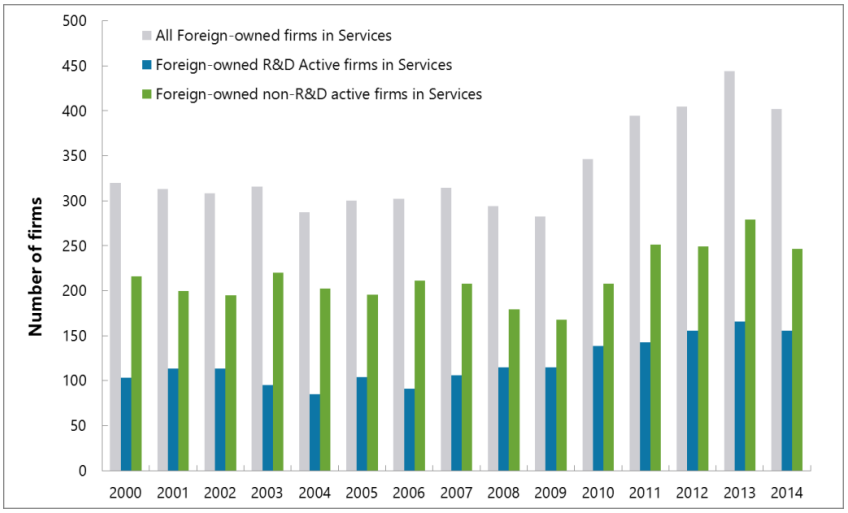
- greater overall sustainability of employment in R&D active foreign-owned agency firms in the manufacturing sector which only declined by 7% overall between 2000 and 2014 in comparison to the decline of 72% in non-R&D active firms during this time period.
- more sustained employment by R&D active foreign-owned agency firms which leads to an increase in the contribution from 57% of employment by agency foreign-owned firms in the manufacturing sector in 2000 to 82% in 2014.
- a higher average employment per firm in each year for the R&D active cohort foreign-owned agency firms over the non-R&D active foreign-owned agency firms.

- an increase in average employment per firm over the 2000-2014 time frame for the R&D active foreign-owned agency firms, in comparison to a reduced average employment per firm for the non-R&D active cohort of foreign-owned agency firms over the time frame.

Within the services sector, employment in the cohorts of foreign-owned R&D active agency firms (with 10 or more persons engaged) increased across the 2000-2014 time period, as can be seen in Figure 34. This realised 150% growth in employment by R&D active foreign-owned agency firms in the services sector. In comparison, employment in non-R&D active foreign-owned agency firms in the services sector remained more static from 2000-2006, and then showed fluctuating employment levels from 2006-2014 with an overall decline measured between 2006-2014 such that there was an overall decline of 9% between 2000 and 2014. This difference in growth behaviour led to the R&D active firms increasing their contribution to total employment, by foreign-owned agency firms in the services sector, from 29% in 2000 to 53% in 2014.

For the services sector, there were, on average, 100 R&D active foreign-owned agency firms in each year up to 2007, after which the number of R&D active firms has been steadily increasing, with 155 such firms recorded in 2014. There was an average of 206 non-R&D active foreign-owned agency firms in each year up to 2007, and following a fall in firm numbers between 2007 and 2009, the number of non-R&D active firms has typically been increasing in each year, reaching 247 firms in 2014, as can be seen in Figure 37. It is noted that over this 2000-2014 time period the proportion of foreign-owned agency firms that are R&D active has increased from 32% in 2000 to 39% in 2014, in the context of a growth of 26% in the total number of foreign-owned agency firms in the services sector during this period.

Figure 37 Number of foreign-owned agency firms (with 10 or more persons engaged) in the services sector in each year according to R&D status.

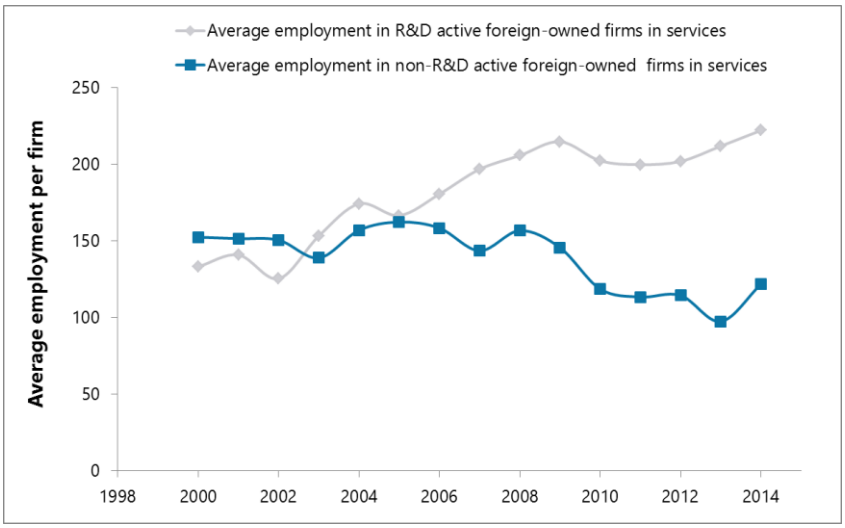


Source: Annual Business Survey of Economic Impact 2015

In the context of growing levels of firms across both R&D active and non-R&D active categories, it can be concluded that changes to employment of the R&D active cohort of firms is not simply a substitution effect due to re-categorisation across a constant set of firms: i.e. it cannot simply be the case that non-R&D active firms are being reassigned over time as R&D active firms, which would push up employment from the R&D active cohort of firms with a corresponding decrease in employment in the non-R&D active category of firms. Though, as noted previously, the details of firm churn are difficult to account for precisely in moving across years.

The average employment per foreign-owned agency firm in the services sector in each year was estimated for R&D active and non-R&D active firms and is shown in Figure 38. The data indicates that the average employment for R&D active firms has been higher than for the non-R&D active firms since 2005.This average employment continued to increase up to 2009, after which it declined and then rebounded to surpass 2009 levels in 2014. The increasing number of firms, coupled with the increasing average employment level per firm amongst cohorts of R&D active firms in the services sector thus gives rise to the increased year on year employment growth recorded. In contrast, the average employment in non-R&D active foreign-owned firms remained static up to 2007, after which the average employment level per firm declined, and continued to do so between 2008 and 2013.

Figure 38 Average employment per firm in each year by foreign-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms in the services sector.



Source: Annual Business Survey of Economic Impact 2015

Overall the evidence supports the conclusions that:

- **Amongst foreign-owned agency firms (with 10 or more persons engaged) in the services sector, R&D activity is a characteristic of firms that have been driving growth in employment by foreign-owned agency firms in the services sector between 2009 and 2014.**

- **The employment performance of R&D active foreign-owned agency firms (with 10 or more persons engaged) in the services sector has masked the more static employment performance amongst non-R&D active foreign-owned agency firms in the services sector between 2000 and 2014.**

The conclusions are underpinned by the data which shows:

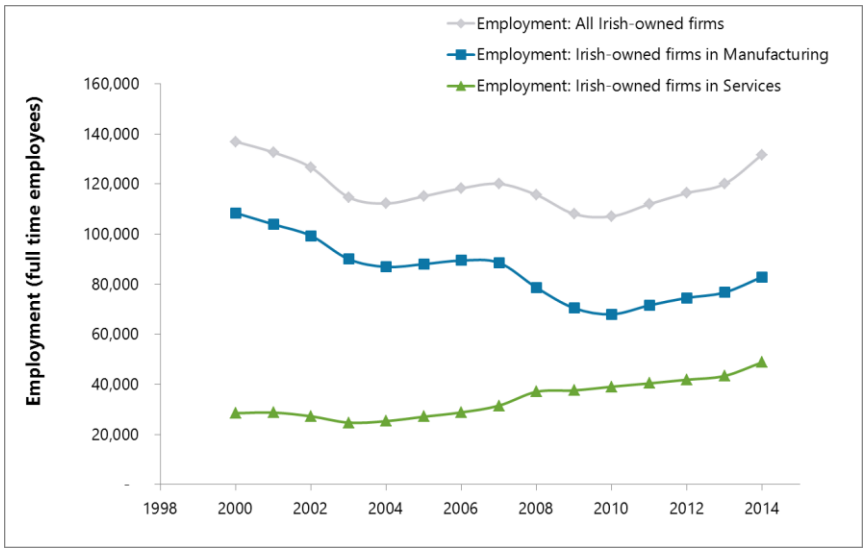
- 150% growth in employment by R&D active foreign-owned agency firms in the services sector over the 2000-2014 time frame while employment in non-R&D active foreign-owned agency firms declined by 9% during this time period: this led to an increase in the contribution from 29% of employment by agency foreign-owned firms in the service sector in 2000 to 53% in 2014.
- Successive year on year growth in employment from 2006 to 2013 by R&D active foreign-owned agency firms in the services sector.
- A higher average employment per firm in each year from 2003 onwards for the R&D active cohort foreign-owned agency firms over the non-R&D active foreign-owned agency firms in the services sector.
- A growing average employment per firm for the R&D active cohort of foreign-owned agency firms over most of the period from 2002 onwards in comparison to a declining value for the non-R&D active foreign-owned agency firms over most of the period from 2005 onwards.

3.4.3 Irish-owned Firms

For Irish-owned firms (with 10 or more persons engaged), employment[106] declined over the 2000-2010 period, and since then employment levels have been growing. The decline in employment can be related to a decline in employment in the manufacturing sector up to 2010, as indicated in the data presented in Figure 39.

[106] ABSEI firms represent 70-78% of employment in Irish owned-agency firms between 2005 and 2014 and between 80-88% of employment in foreign-owned agency firms- based on comparison of data reported in the ABSEI and the Annual Employment Survey (AES).

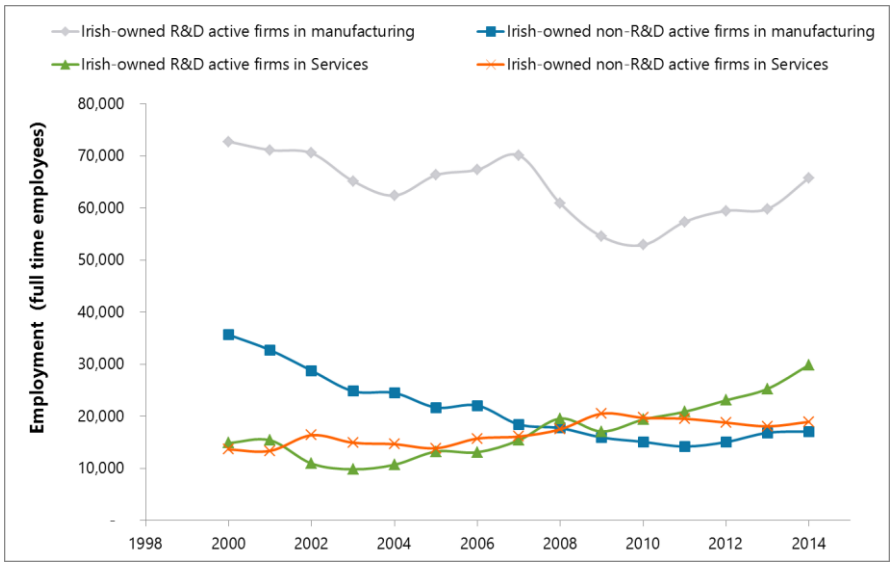
Figure 39 Employment in Irish-owned agency firms (with 10 or more persons engaged): combined employment in the manufacturing and services sectors[107]; employment in the manufacturing sector; employment in the services sectors.



Source: Annual Business Survey of Economic Impact 2015

However, when the yearly employment levels in the manufacturing and services sectors are disaggregated according to the contribution of R&D active and non-R&D active cohorts of Irish-owned firms, a more revealing picture emerges as can be seen in Figure 40.

Figure 40 Employment in Irish-owned agency firms (with 10 or more persons engaged): employment in the manufacturing sector and services sectors for R&D active and non-R&D active firms.



Source: Annual Business Survey of Economic Impact 2015

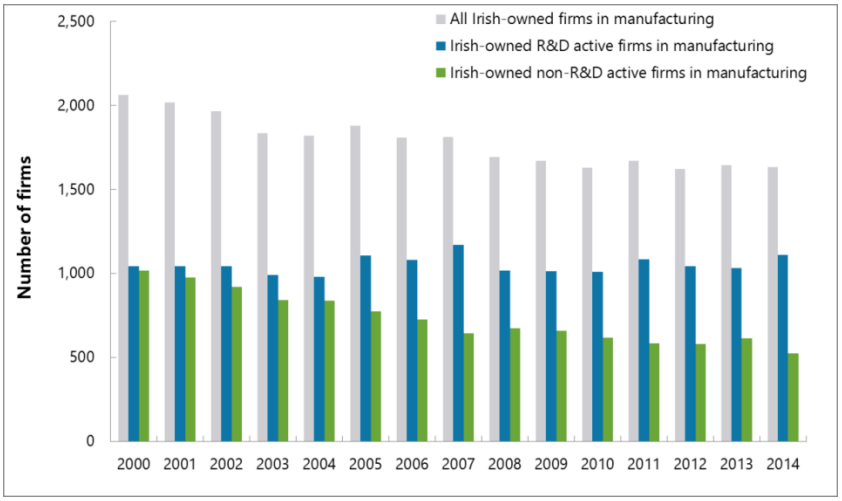
[107] Employment in Primary Production and Construction are not included.

In the manufacturing sector, employment in R&D active Irish-owned agency firms (with 10 or more persons engaged) declined between 2000 and 2004 and then started to increase until 2007. Employment in R&D active Irish-owned firms again declined during the recessionary period, but has demonstrated 24% growth between 2010 and 2014. However the employment levels of 2000 had not as yet been achieved by 2014-employment was still lower by 7,000 in 2014 than in 2000. In comparison, overall employment in non-R&D active firms in 2014 was 17,000 - 18,500 lower than in 2000. There has been 20% growth in employment since 2011-2014 for non-R&D active firms, though this is from a much lower base than for the R&D active cohort of manufacturing firms.

In the manufacturing sector, the numbers of Irish-owned R&D active firms showed an increasing trend up to 2007 after which the number remained reasonably constant up to 2014. In comparison there was a consistent decline in the number of non-R&D active Irish-owned firm over the 2000-2014 period, from 1,016 to 523, as can be seen in Figure 41.

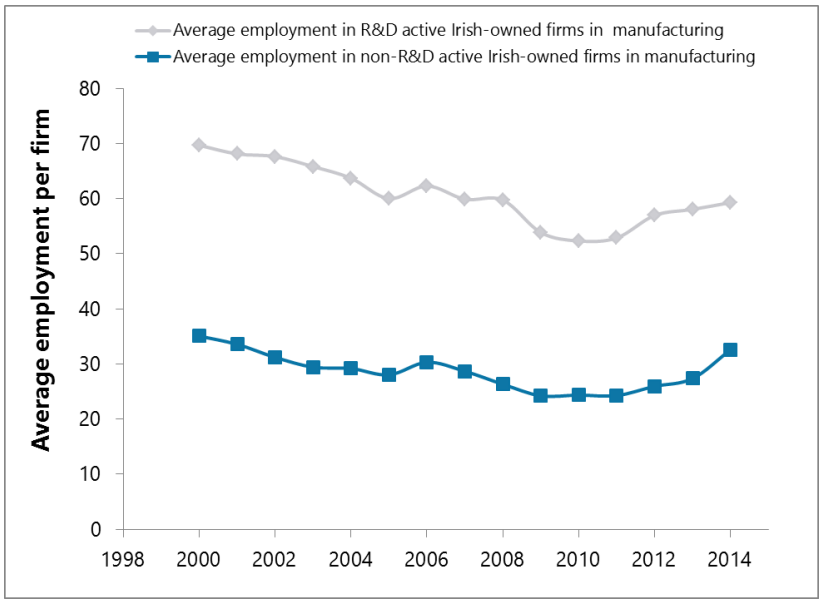
The average employment per Irish-owned agency firm in the manufacturing sector in each year was estimated for R&D active and non-R&D active firms and is shown in Figure 42. The data indicates that the average employment per firm decreased for both cohorts from 2000-2010, followed by some growth since 2012. However, R&D active firms remained consistently larger employers over the full time period.

Figure 41 Number of Irish-owned agency firms (with 10 or more persons engaged) in the manufacturing sector in each year according to R&D status.



Source: Annual Business Survey of Economic Impact 2015

Figure 42 Average employment per firm in each year by Irish-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms in the manufacturing sector.



Source: Annual Business Survey of Economic Impact 2015

In summary it can be concluded that:

- **Amongst Irish-owned agency firms in the manufacturing sector (with 10 or more persons engaged), R&D activity is a characteristic of firms that contribute most to employment in the manufacturing sector and between 2000 and 2014.**
- **The declining employment levels for Irish-owned agency firms (with 10 or more persons engaged) in the manufacturing sector between 2000-2010 is associated with the declining average employment per firm in non-R&D active firms coupled with a decline in the number of non-R&D active firms in the enterprise base and a decline in average employment per firm amongst a more constant number of R&D active firms during this period.**

The conclusions are underpinned by the evidence which shows:

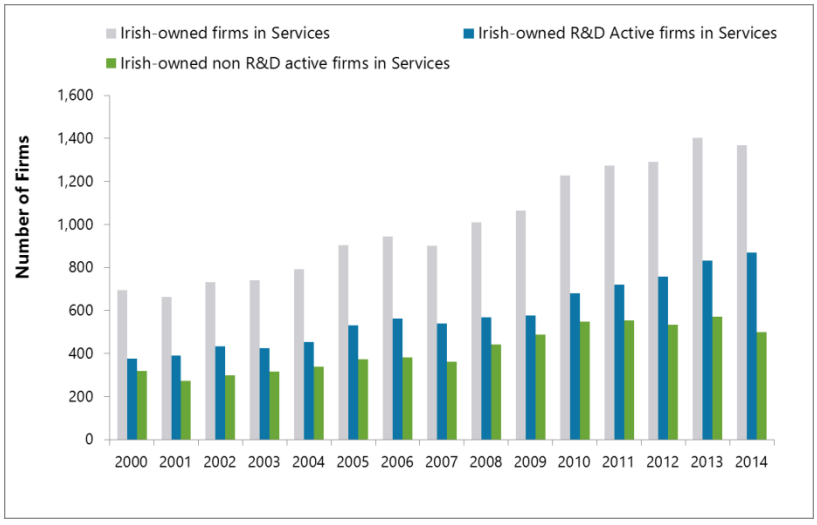
- That while employment levels declined in R&D active Irish-owned agency firm in the manufacturing sector by 10% (7,000) between 2000 and 2014, there was a decline of 52% (18,500) in employment levels by non-R&D active Irish-owned agency firms during this time frame. This led to an increase in the contribution by R&D active Irish-owned agency firms to total employment by Irish-owned agency firms in the manufacturing sector from 67% in 2000 to 80% in 2014.
- The non-R&D active cohorts of firms were responsible for 73% of the total decline in employment in Irish-owned agency firms in the manufacturing base between the 2000 and 2014 levels.

- A higher average employment per firm in each year from 2000 onwards for the R&D active cohort of Irish-owned agency firms over the non-R&D active Irish-owned agency firms in the manufacturing sector.
- A declining average employment per firm in non-R&D active Irish-owned firms in the manufacturing sector - from 35.1 persons per firm in 2000 to 24.3 persons per firm in 2010 - coupled with a decline in the number of firms from 1,016 to 619. In tandem there was a decrease in average employment per firm in R&D active Irish-owned firms in the manufacturing sector from 69.7 persons per firm to 52.3 persons per firm, though the number of firms remained more constant between 2000-2010 at an average of 1,045 with a standard deviation of 55.

Within the services sector, employment in the cohorts of Irish-owned R&D active agency firms (with 10 or more persons engaged) has largely been increasing year on year across the 2003-2014 time period. In comparison, employment in non-R&D active Irish-owned agency firms in the services sector did grow from 2003-2009, but has been declining at a slow rate since then, as can be seen in Figure 40. The contribution by R&D active firms to employment in the services sector surpassed that of non-R&D active firms in 2010 and this category of firms has remained the larger contributor to employment in the sector to 2014.

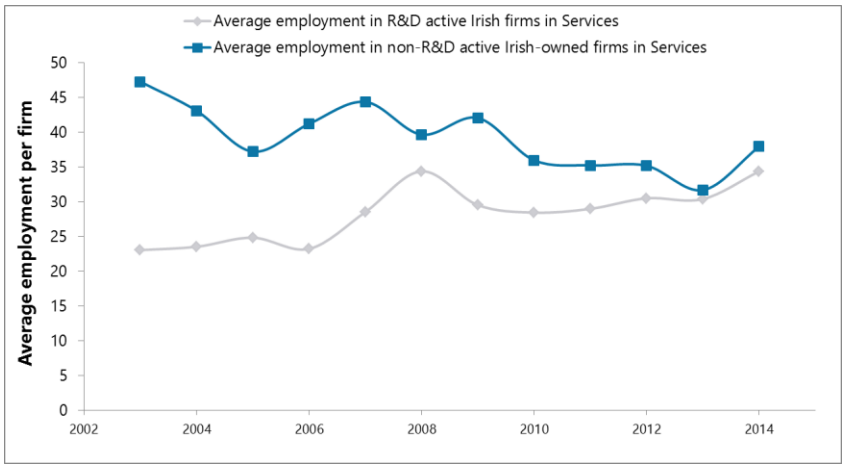
The number of R&D active firms in the services sector has been increasing throughout the 2000-2014 period, while the number of non-R&D active firms in the services sector increased up to 2010 and has remained reasonably static since, as indicated in Figure 43.

Figure 43 Number of Irish-owned agency firms (with 10 or more persons engaged) in the services sector in each year according to R&D status.



Source: Annual Business Survey of Economic Impact 2015

Figure 44 Average employment per firm in each year by Irish-owned agency firms (with 10 or more persons engaged) for cohorts of R&D active and non-R&D active agency firms in the services sector.



Source: Annual Business Survey of Economic Impact 2015

Overall between 2003 and 2014, the average employment per firm in the R&D active category of firms has been growing. In comparison, the average employment per firm has declined for non-R&D active firms over this same time period. While the average employment per firm was higher for the non-R&D active firms in 2003 than for the R&D active firms, in 2014 the two cohorts of firms converged to a similar value, as can be seen in Figure 44.

In summary it can be conclude that:

- **Amongst Irish-owned agency firms (with 10 or more persons engaged) in the services sector, R&D activity is a characteristic of firms that have been driving the growth recorded in employment since 2009 by Irish-owned agency firms.**
- **The employment performance of R&D active Irish-owned agency firms (with 10 or more persons engaged) in the services sector has masked the relatively poorer performance of employment amongst non-R&D active Irish-owned agency firms in the services sector between 2009 and 2014.**

The conclusions are underpinned by the data which shows:

- 101% growth in employment by R&D active Irish-owned agency firms in the services sector over the 2000-2014 time frame and while employment in non-R&D active Irish-owned agency firms increased by 39% overall during this time period, employment declined by 8% in 2014 from its peak in 2009. This led to an increase in the contribution by R&D active firms to total employment by Irish-owned agency firms in the services sector, from 52% in 2000 to 61% in 2014.
- Successive year on year growth in employment from 2007-2014 by R&D active Irish-owned agency firms in the services sector.
- A growing average employment per firm since 2003 for the R&D active cohort of Irish-owned-agency firms- from 23.1 in 2003 to 34.4 in 2014- and a declining average

employment per firm from 2003 for the non-R&D active cohort –from 47.3 in 2003 to 37.9 in 2014. Thus, in 2014, average employment per firm for the R&D and non-R&D active cohort had converged.

- The increasing average employment per firm coupled with an increasing number of Irish-owned agency firms in the services sector that are R&D active – from 425 to 869-has led to the continued increases in employment in this cohort of firms.

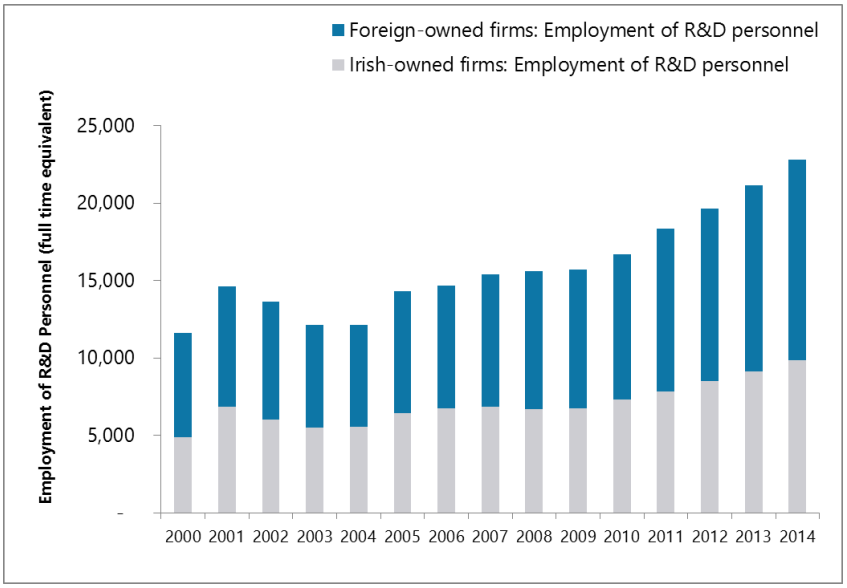
While a causal relationship between R&D activity in agency firms and employment growth is not proposed, **there is clear correlation between engagement in R&D and enhanced employment performance for both Irish-owned and foreign-owned agency firms and this has positive implications for the Irish economy**.

3.5 R&D Active Firms and Employment of R&D Personnel

3.5.1 Trends in Employment of R&D Personnel

For agency firms (with 10 or more persons engaged), employment of full time equivalent (FTE) R&D personnel increased across the total base in the manufacturing and services sectors between 2000 and 2014 as can be seen from Figure 45, with foreign-owned agency firms accounted for between 53% and 58% of R&D personnel across the time series

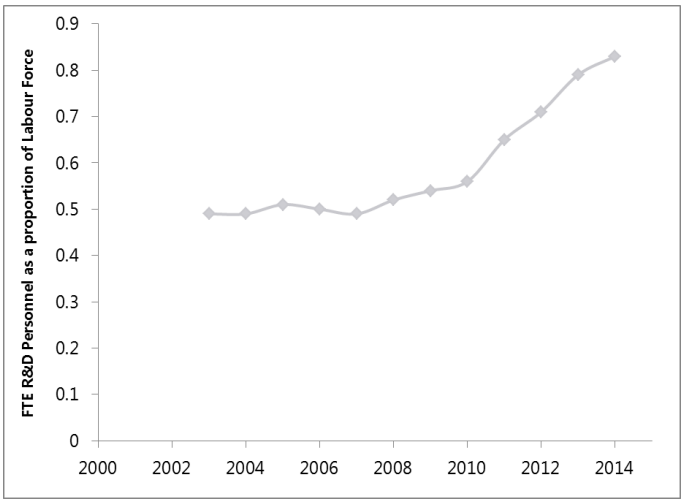
Figure 45 Employment of FTE R&D personnel across the manufacturing and services sectors in foreign and Irish-owned agency firms (with 10 or more persons engaged).



Source: Annual Business Survey of Economic Impact 2015

In comparison there was a decline in overall employment (full time employees) in agency firms in the manufacturing and services sectors during this time period.

Figure 46 FTE R&D Personnel employed in all firms in the Irish enterprise base as a proportion of the total labour force[108].



Source: Eurostat

More generally, the proportion of FTE R&D personnel contributing to the labour force across the total firm base in Ireland has been growing since 2003 (at least). Figure 46 shows that the proportion of FTE R&D personnel contributing to the labour force in Ireland has been increasing since 2003, with particular acceleration in the growth rate from 2010 onwards, in part amplified by the decline in employment in the broader labour force at this time.

The bar chart in Figure 47 presents the proportion of FTE R&D personnel in the private sector that contribute to the labour force across a range of European countries for 2003 and 2014. As can be seen by comparing the values in 2003 and 2014, there was a significant jump in the proportion of R&D personnel in the private sector contributing to the labour force between 2003 (0.49) and 2014 (0.83). This has led to an increase in Ireland's performance for this indicator relative to the performance of other European countries: Ireland was at the EU average in 2003, and moved ahead of the EU average in 2014.

In summary, the data supports the conclusion that **throughout the 2000-2014 period, there was greater resilience of employment of R&D personnel over other employment roles in the enterprise base in Ireland**.

This conclusion is underpinned by the evidence that shows:

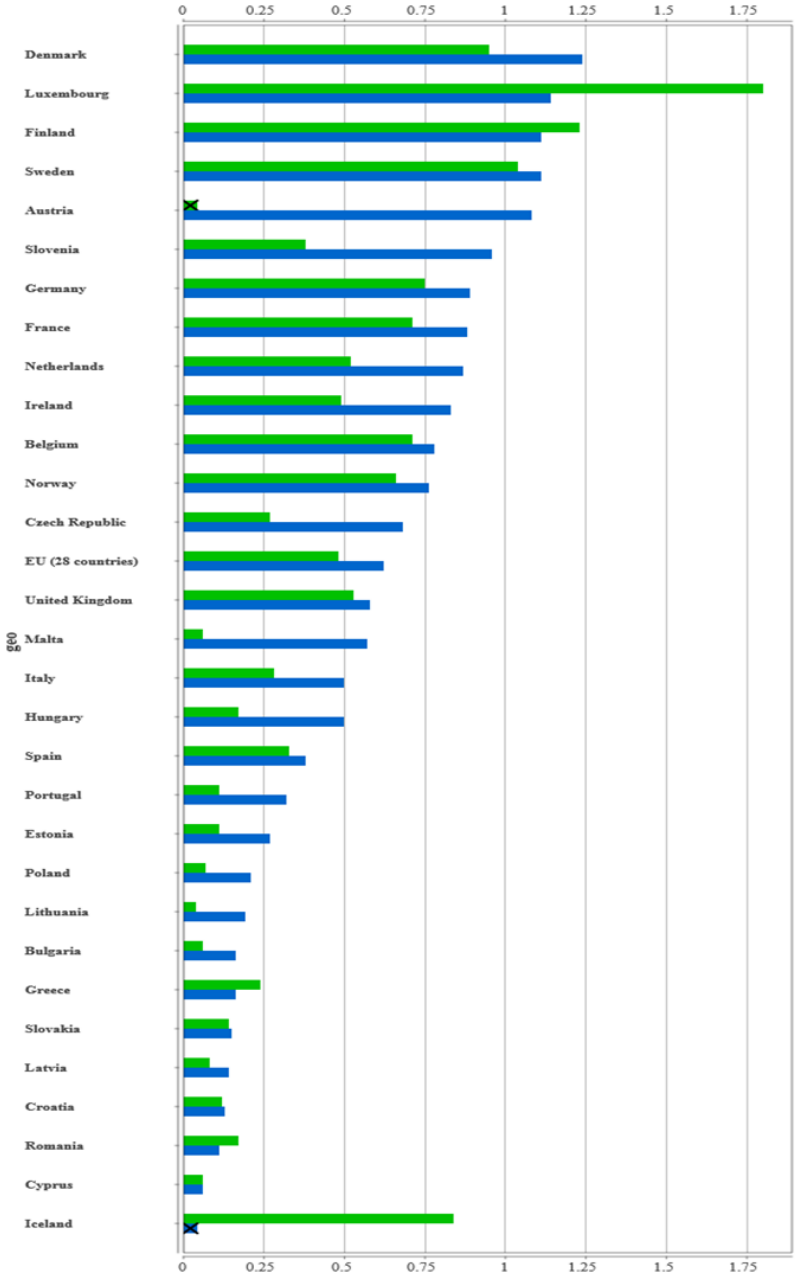
- Across all agency firms (with 10 or more persons engaged), employment of R&D personnel grew by 96% across the manufacturing and services sectors between 2000 and 2014. This compares to a decline of 10% in overall employment (full time employees) in

[108] Labour force is the population of employed and unemployed that are available for work.

agency firms (with 10 or more persons engaged) in the manufacturing and services sectors during this time period.

- Between 2003-2014, employment of FTE R&D personnel increased by 77% across the total firm base in Ireland. This contrasts with the ~ 5% growth in employment across the total labour force between 2003-2013 more generally.
- The contribution to the labour force by R&D FTE personnel in the private sector increased from 0.49 in 2003 to 0.83 in 2014, to bring Ireland above the EU average for this indicator in 2014.

Figure 47 Full time equivalent R&D Personnel in the private sector as a % of the labour force across a number of countries = Blue is 2014, Green is 2003.[109]



Source: Eurostat

[109] http://ec.europa.eu/eurostat/tgm/mapToolClosed.do?tab=map&init=1&plugin=1&language=en&pcode=tsc00002&toolbox=types

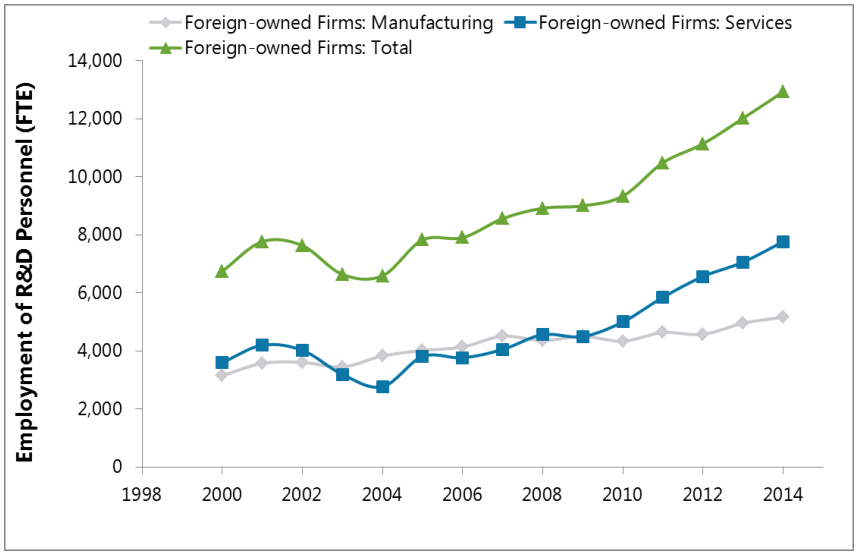
3.5.2 Employment of R&D Personnel in Foreign-owned Agency Firms in the Manufacturing and Service Sectors

There was a 92% increase in employment of FTE R&D staff in foreign-owned agency firms (with 10 or more persons engaged) between 2000 and 2014, with employment of R&D personnel increasing by approximately 6,200 over this period.

As can be seen in Figure 48, employment of R&D personnel increased in both the manufacturing (64%) and services sectors (115%) during this time frame. From common levels of employment of R&D personnel in the two sectors in 2000, the higher growth rate in employment of R&D personnel in the services sector led to the services sector accounting for 72% of R&D personnel employed by foreign-owned firms in 2014.

The employment trend for R&D personnel in the services sector mirrors the trend for overall employment in R&D active firms in the services sector over the 2000-2014 time frame. For the manufacturing sector however, R&D personnel employment demonstrates positive growth overall across the 2000-2014 time period, in comparison to an overall decline in total employment in foreign-owned R&D active firms in the manufacturing sector for the 2010-2014 period,. Thus, the evidence implies that there was greater resilience in employment in R&D roles in the foreign-owned R&D active agency firms in the manufacturing sector over employment in other roles.

Figure 48 Employment of R&D personnel in all foreign-agency firms[110] (with 10 or more persons engaged) and by manufacturing and services sectors.



Source: Annual Business Survey of Economic Impact 2015

[110] Manufacturing and services sectors combined.

In summary, the data supports the conclusion that **throughout the 2000-2014 period, employment of R&D personnel by foreign-owned agency firms (with 10 or more persons engaged) in the services sector was mirroring the increased employment more generally in the services sector. However, in the manufacturing sector, there was greater resilience of employment of R&D personnel over other employment roles in foreign-owned agency firms in Ireland**.

3.5.3 Employment of R&D Personnel in Irish-owned Agency Firms in the Manufacturing and Service Sectors

There was a 102% increase in employment of FTE R&D staff in Irish-owned agency firms (with 10 or more persons engaged) between 2000 and 2014, with employment of R&D personnel increasing by approximately 5,000 over this period.

As can be seen in Figure 49, employment of R&D personnel increased in both the manufacturing (66%) and services sectors (141%) during this time frame. From similar levels of employment of R&D personnel in the two sectors in 2000, the higher growth rate of employment of R&D personnel in the services sector led to the services sector accounting for 58% of R&D personnel employed by Irish-owned firms in 2014.

The employment trend for R&D personnel in the services sector mirrored the trend for overall employment in R&D active firms over the 2000 to 2014 time frame. However, between 2000-2014, the growth in employment of R&D personnel was higher (at 141%) compared to employment growth across all employment roles for Irish-owned firms in the services sector (101%).

The employment trends for R&D personnel in the manufacturing sector exhibited characteristics similar to those seen for total employment in R&D active Irish-owned firms in the manufacturing sector. However the employment declines were not as large for the R&D personnel employment. Thus, despite fluctuation in employment levels over the time frame, an overall 66% growth in employment of R&D personnel was measured between 2000 and 2014. This is in comparison to the overall 10% decline in employment registered for total employment by Irish-owned agency firms in the manufacturing sector.

In summary, the data supports the conclusion that **throughout the 2000-2014 period employment of R&D personnel by Irish-owned firms in the services sector was mirroring the increased employment more generally in the services sector. However, in the manufacturing sector, there was greater resilience of employment of R&D personnel over other employment roles in Irish-owned agency firms in Ireland.**

Figure 49 Employment of R&D personnel in all Irish-owned agency firms[111] (with 10 or more persons engaged) and by manufacturing and services sectors.

Source: Annual Business Survey of Economic Impact 2015

3.6 R&D and High Value Jobs

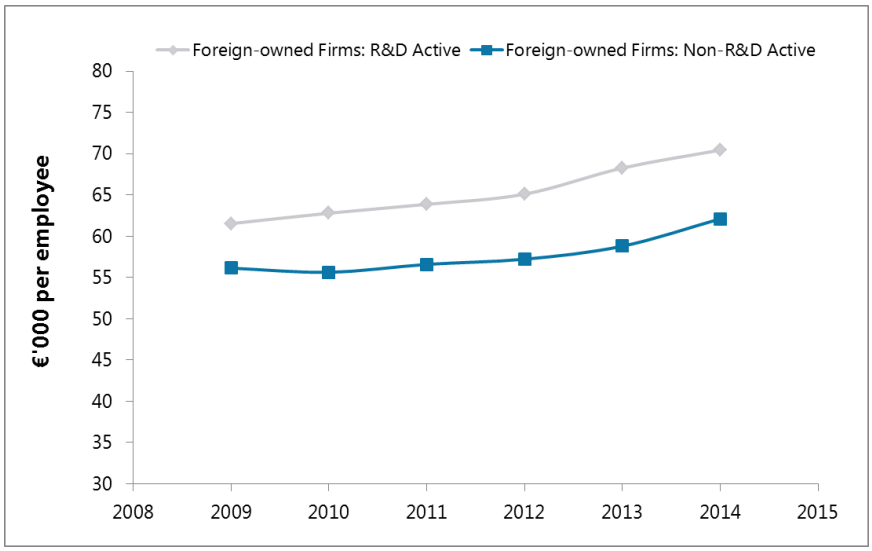
3.6.1 Higher Value Jobs in R&D Active Firms in Ireland

An average payroll per employee was estimated for R&D active and non-R&D active agency firms[112] (with 10 or more persons engaged). For foreign-owned firms it was found that in 2009, the payroll per employee was higher in R&D active firms than non-R&D active firms and remained so up to 2014, with the gap between average payroll per employee in R&D active and non-R&D active firms widening over the time period as can be seen in Figure 50.

[111] Manufacturing and services sectors combined.

[112] This estimate is based on the actual responses to the ABSEI survey in each year rather than data representing the total population of agency firms.

Figure 50 Average payroll per employee in foreign-owned agency firms (with 10 or more persons engaged. – across all full time employees.



Source: ABSEI: Insight extraction for DJEI

For Irish-owned firms it was found that in 2009, the payroll per employee was higher in non-R&D active firms, but since that time, the payroll per employee declined for non-R&D active firms, as can be seen in Figure 51. For R&D active firms however, the payroll per employee was relatively constant until 2012 after which time two successive increases were recorded in 2013 and 2014, resulting in an overall increase in average payroll per employee between 2009 and 2014. The evidence thus indicates that employment in R&D active agency firms relates to employment in higher value jobs than in non-R&D active agency firms.

Figure 51 Average payroll per employee in Irish-owned agency firms (with 10 or more persons engaged) – across all full time employees.

Source: ABSEI: Insight extraction for DJEI

Furthermore, the average payroll per R&D active firms is compared to average earnings per employee in the total economy as set out in Table 7. As data on average earnings is not available according to firm ownership, average payroll per employee across all R&D active agency firms is used for comparison purposes. Based on a comparison of 2014 data, it can be seen from the data in Table 7, that average payroll per employee across all R&D active firms in 2014 is higher than the average payroll per employee in non-R&D active firms and significantly higher than overall average earnings per employee in Ireland in 2014.

Table 7 Average payroll per employee for cohorts of R&D active and non-R&D active agency firms (with 10 or more persons engaged) in 2014, and average earnings per employee in the total economy in Ireland in 2014.

	Average payroll per employee in agency firms in 2014	Average earnings per employee in Ireland in 2014
Average Payroll per employee for all R&D active agency firms	€59,385	
Average Payroll per employee for all non-R&D active agency firms	€53,783	
All employees in Ireland		€35,768[113]

Source: ABSEI: Insight extraction for DJEI, CSO

Based on the evidence presented it is concluded **that employment in R&D active firms relates to employment in higher value jobs across these firms**.

3.6.2 Higher Value Jobs for R&D Employees[114] in Ireland

The average labour costs per FTE employee engaged in R&D[115] in firms in Ireland have been estimated at €72,500 in 2013 (or €87,500 for workers in foreign-owned companies and €55,000 for workers in Irish-owned firms). An estimate of average annual labour cost per FTE employee in Ireland was also estimated for 2013[116] as €47,121[117,118].

[113] As reported by the Central Statistics Office (CSO) in Ireland.

[114] The distinction between employment and employees is noted: Employment is all those persons in employment – self employed and employees.

[115] This includes administrative employees and technicians as well as researcher employees and amounts to 17,103 R&D FTE across all firms in 2013.

[116] CSO published figures for FTE employees for Q2 2013 which was 1,377,200 FTE employees.

[117] It is noted that labour costs are estimated per employee not employment- All full-time or part-time workers paid a specific wage or salary or who had a contract of employment are defined as employees. Persons not working for salary

Thus, it can be concluded that, **employment of R&D personnel has been a source of growth in employment over the past decade and the evidence indicates that this employment is in high-valued jobs**.

3.7 Estimate of the Wider Economic Impacts by R&D Active Firms

Estimates of the wider employment and value added impacts of R&D active agency firms have also been made through assessment of the knock-on effects in the domestic economy.

The detailed methodology utilised for arriving at sectoral level multipliers[119] for employment and value added of agency firms in Ireland were developed elsewhere[120], and applied to the case of R&D active agency firms. Limitations of the methodology are acknowledged and set out in Appendix 1 along with the set of multipliers and calculations used for this exercise.

Based on direct employment of 184,500 full time employees in R&D active agency firms (with ten or more persons engaged)[121] in the services and manufacturing sectors in 2013, and a total impact multiplier of 1.91 for R&D active agency firms in 2013, it is estimated that the total employment impact of R&D active agency firms was 352,000 full time employees in 2013.

A number of further assumptions were made in an effort to also take into account the employment in R&D active agency micro firms (firms with less than ten persons engaged) and an estimate is made of an additional 16,529 in direct employment in R&D active agency firms related to these micro firms. Taking into account these micro firms leads to an estimated total employment impact of R&D active agency firms of 384,000 full time employees in 2013.

Based on CSO full time employee data for Quarter 4 2013[122] **it is estimated that in 2013, R&D active firms supported in the region of a quarter (between 24% and 26.5%) of full time employees across the total economy in Ireland in 2013 (based on a total full time employment impact of between 352,000 and 384,000)**.

Direct value added stemming from the activity of R&D firms is estimated at €42 bn in 2013. However, when the impact on the domestic economy is also considered, the **wider value added impact stemming from the activity of R&D active firms is estimated at €76.1bn.** Thus,

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e.g. family members, directors, partners, outside pieceworker's etc., are not considered employees but other persons engaged. These workers are included separately but not used in the calculation of derived variables.

[118] FTE data for employees is not readily available per economic sector and so the comparison to the average total labour costs per FTE employee in key sectors cannot be made.

[119] Sectoral level multipliers were developed across a number of sub-categories of the manufacturing and services categories.

[120] Indecon on the Assessment of the Economic Impact of Exports on the Irish Economy

[121] Employment estimates for R&D active firms were extracted from the ABSEI which surveys firms with 10 or more persons engaged.

[122] In Q4 2013, the number of full time employees across all NACE Rev 2 economic sectors was 1.453 million, Quarterly National Household Survey, CSO.ESQ06

value added stemming from R&D active agency firms can be estimated as accounting for in the region of 44% of GDP (at constant prices) and 54% of GNP (at constant prices) in 2013.

3.8 Summary of Key Findings on the Economic and Enterprise Performance of R&D Active Firms in Ireland

3.8.1 Firm R&D Activity and Sales and Exports Performance

- Amongst agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in sales and exports between 2003 and 2014.
- The sales and export performance of R&D active agency firms (with 10 or more persons engaged) have masked the poorer performance of sales and exports from the cohorts of non-R&D active agency firms over the 2003-2014 period.
- Amongst foreign-owned agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in sales and exports between 2003 and 2014.
- The sales and export performance of R&D active foreign-owned agency firms (with 10 or more persons engaged) have masked the decline in the value of sales and exports from the cohorts of non-R&D active foreign-owned agency firms over the 2003-2014 period.
- Amongst Irish-owned agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in sales and exports between 2003 and 2014.
- The sales and export performance of R&D active Irish-owned agency firms (with 10 or more persons engaged) have masked the poorer performance of sales and the lower level of export growth from the cohorts of non-R&D active Irish-owned agency firms over the 2003-2014 period.
- While a causal relationship between R&D activity in agency firms and sales and export growth is not proposed, there is clear correlation between engagement in R&D and enhanced sales and export performance for both Irish-owned and foreign-owned agency firms and this has positive implications for the Irish economy.

3.8.2 Firm R&D Activity and Value Added Performance

- Amongst agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in value added between 2003 and 2014.
- The value added performance of R&D active agency firms (with 10 or more persons engaged) has masked the poorer performance of value added from the cohorts of non-R&D active agency firms over the 2003-2014 period.
- Amongst foreign-owned agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in value added between 2003 and 2014.

- The value added performance of foreign-owned R&D active agency firms (with 10 or more persons engaged) has masked the poorer performance of value added from the cohorts of foreign-owned non-R&D active agency firms over the 2003-2014 period.
- Amongst Irish-owned agency firms (with 10 or more persons engaged), R&D activity is a characteristic of firms that have been driving growth in value added between 2000 and 2014.
- The value added performance of Irish-owned R&D active agency firms (with 10 or more persons engaged) has masked the poorer performance of value added from the cohorts of Irish-owned non-R&D active agency firms over the 2000-2014 period.
- While a causal relationship between R&D activity in agency firms and value added growth is not proposed, there is clear correlation between engagement in R&D and enhanced value added performance for both Irish-owned and foreign-owned agency firms and this has positive implications for the Irish economy.

3.8.3 Firm R&D Activity and Employment Performance in Agency Firms

- Amongst agency firms (with 10 or more persons engaged) in the manufacturing and services sectors, R&D activity is a characteristic of firms that contribute most to employment between 2000 and 2014.
- The employment performance of R&D active firms (with 10 or more persons engaged) in the manufacturing and services sectors has masked the poorer performance in employment amongst the non-R&D active firms between 2000 and 2014.
- Amongst foreign-owned agency firms (with 10 or more persons engaged) in the manufacturing sector, R&D activity is a characteristic of firms that contribute most to employment between 2000 and 2014.
- The employment performance of R&D active foreign-owned agency firms (with 10 or more persons engaged) in the manufacturing sector has masked the poorer performance in employment amongst the cohort of non-R&D active firms in the manufacturing sector between 2000 and 2014.
- Amongst foreign-owned agency firms (with 10 or more persons engaged) in the services sector, R&D activity is a characteristic of firms that have been driving growth in employment by foreign-owned agency firms in the services sector between 2009 and 2014.
- The employment performance of R&D active foreign-owned agency firms (with 10 or more persons engaged) in the services sector has masked the more static employment performance amongst non-R&D active foreign-owned agency firms in the services sector between 2000 and 2014.
- Amongst Irish-owned agency firms in the manufacturing sector (with 10 or more persons engaged), R&D activity is a characteristic of firms that contribute most to employment in the manufacturing sector between 2000 and 2014.
- The declining employment levels for Irish-owned agency firms (with 10 or more persons engaged) in the manufacturing sector between 2000-2010 is associated with the declining

average employment per firm in non-R&D active firms coupled with a decline in the number of non-R&D active firms in the enterprise base and a decline in average employment per firm amongst a more constant number of R&D active firms during this period.

- Amongst Irish-owned agency firms (with 10 or more persons engaged) in the services sector, R&D activity is a characteristic of firms that have been driving the growth recorded in employment since 2009 by Irish-owned agency firms.
- The employment performance of R&D active Irish-owned agency firms (with 10 or more persons engaged) in the services sector has masked the relatively poorer performance of employment amongst non-R&D active Irish-owned agency firms in the services sector between 2009-2014.
- While a causal relationship between R&D activity in agency firms and employment growth is not proposed, there is clear correlation between engagement in R&D and stronger employment performance for both Irish-owned and foreign-owned agency firms and this has positive implications for the Irish economy.

3.8.4 R&D Active Firms and Employment of R&D Personnel

- Throughout the 2000-2014 period there was greater resilience of employment of R&D personnel over other employment roles in the enterprise base in Ireland.
- Throughout the 2000-2014 period employment of R&D personnel by foreign-owned firms (with 10 or more persons engaged) in the services sector was mirroring the increased employment more generally in the services sector. However, in the manufacturing sector, there was greater resilience of employment of R&D personnel over other employment roles in foreign-owned agency firms in Ireland.
- Throughout the 2000-2014 period employment of R&D personnel by Irish-owned firms (with 10 or more persons engaged) in the services sector was mirroring the increased employment more generally in the services sector. However, in the manufacturing sector, there was greater resilience of employment of R&D personnel over other employment roles in Irish-owned agency firms in Ireland.

3.8.5 R&D and High Value Jobs

- Employment in R&D active firms relates to employment in higher value jobs across agency firms.
- Employment of R&D personnel has been a source of growth in employment over the past decade and the evidence indicates that this employment is in high-valued jobs.

3.8.6 Estimate of the Wider Economic Impacts by R&D Active Firms

- It is estimated that R&D active firms supported between 34% and 37% of full time employees across the manufacturing and services sectors in Ireland (based on direct and indirect employment, but not including employment impacts on other sectors) in 2013.

- Overall, the wider employment impact of R&D active agency firms in 2013 was estimated at between 352,000 and 384,000 full time employees, and this relates to in the region of between 24% and 26.5% of full time employees across the total economy in 2013.
- The estimated wider value added impact stemming from the activity of R&D active firms is estimated at €76.1bn.
- Value added stemming from R&D active agency firms can be estimated as accounting for in the region of 44% of GDP (at constant prices) and 54% of GNP (at constant prices) in 2013.

Chapter 4: Economic and Enterprise Impacts from Public Investment in R&D

4.1 Introduction

This chapter sets out the evidence that demonstrates that public investment in R&D has realised positive economic impacts in terms of exports, value added and employment and new firm formation and has supported the transformation of the Irish enterprise base through investment in human capital and knowledge generation towards one which can compete globally based on knowledge activities.

Evidence is presented with regards to:

- The economic and enterprise impacts from public investment which are directly focused towards firms to stimulate increased R&D activity.
- The economic and enterprise impacts from public investment directed towards the HEIs (and DJEI and IDA funded R&D facilities).
- The economic and enterprise impacts from public investment aimed at international engagement in R&D.

4.2 Impacts from National Financial Public Supports Directed to Firms in Ireland for R&D

4.2.1 Impact on Enterprise R&D Activity from State Funded Grant-aid for R&D and R&D Tax Credits

As clearly shown in Chapter 3, engagement in R&D is correlated with the growth in firm sales, exports, and value added and, sustainment and growth in employment that has been underpinning the Irish economy for more than a decade. Consequently a key objective for Ireland towards driving economic growth is to stimulate continued and increased investment in R&D in firms in Ireland. Primary vehicles for public investment in this regard are through State funding for grant-aid and through the R&D tax credit scheme: IDA and EI operate funding schemes aimed at providing financial support directly to foreign-owned and Irish-owned firms to support engagement in R&D, and the R&D tax credit scheme is administered through the Revenue Commissioners.

With a focus on stimulating increased R&D activity in the base of foreign-owned firms in Ireland, allocation of grant-aid to firms for R&D projects has grown to 60% (just under €60m) of IDA's total grant-aid budget each year. This investment has supported R&D expenditure of €500m p.a. by IDA client firms for these approved projects: there has been a yearly investment in the region of €500 p.a. million by foreign-owned firms over much of the period between 2009 and 2014, as can be seen in Table 8.

Table 8 Numbers R&D project approvals by IDA and R&D investments by foreign-owned firms per year[123].

IDA	2009	2010	2011	2012	2013	2014
Number of Approved RDI Projects	62	37	41	23	27	29
FDI Investment in R&D Projects	€500,000,000	€500,000,000	€700,000,000	€517,000,000	€467,000,000	€4,690,000,000

Source: IDA

Furthermore, emerging findings from an analysis of EI and IDA R&D grant-aid data to firms over the 2000-2012 period and ABSEI data from 2000-2013[124,125] indicate that, providing grant aid support for R&D activity in firms leads to increased R&D expenditure in agency firms. Based on analysis using the average non-grant-aided firm in the comparator analysis it is estimated that a €1 increase in grant-aid paid leads to a €12 increase in R&D carried out by agency firms that receive grant-aid. When benchmarking is against 'similar' non-grant-aided firms, it is reported that there is a €1.64 increase in R&D carried out by firms per €1 increase in grant-aid. Furthermore, the analysis indicates that firms that win grant-aid support for R&D through the EI or IDA grant-aid schemes experience 26.5% higher growth in R&D expenditure in the year after winning a grant relative to the average non-grant-aided firm[126], or a 19.8% higher R&D expenditure in the year after winning a grant when comparator analysis is based on 'similar' non-grant-aid firms.

A survey of 64 foreign-owned agency firms that had engaged in an R&D project supported by the IDA R&D fund[127] confirmed the positive impact to the levels of R&D carried out by firms stemming from receiving grant-aid for in-house R&D - 100 % of the firms indicated that after engaging in the funded R&D project that they were now more likely to invest in future R&D projects in Ireland[128]. 30% of these firms indicated that the R&D project would not have gone ahead without the support, and a further 60% of the firms indicated that without the R&D grant-aid, the R&D project would have been either smaller in scope, or significantly delayed: less

[123] IDA Annual Reports

[124] 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.

[125] 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

[126] Based on an analysis with similar firms, it was estimated that grant winners experienced 19.3% higher R&D growth in the year after winning.

[127] This represented ~ 50% of firms that engaged in the programme over the 2003-2009 period.

[128] Evaluation of Enterprise Supports for Research and Development, Forfás, 2013

than 10% of firms indicated that they would have gone ahead with the proposed project, at the same size and scale, in the absence of the grant-aid.

Similar findings for agency firms were found through a survey of 50 companies that had undertaken 126 projects supported through the EI-RTI funding over the 2000-2004 period. These firms indicated that in the absence of the public support provided through the RTI scheme that: 21% of projects would have been abandoned; 40% of projects would have been delayed; and 28% would have proceeded at a reduced scale. Furthermore, 62 % of 203 agency firms who received funding for in-house R&D under the EI-RTI scheme between 2000 and 2006, cited an increased R&D budget as a result of the EI-RTI funding, with this increase averaging 36%.

Recent empirical analysis of the R&D tax credit points to positive economic impacts of this policy tool also.[129] Using a treatment and control group econometric approach, the evaluation concluded that firms conducted significantly more R&D in the presence of the scheme than they would have done in its absence. It estimated that of the R&D carried out by firms over 2009-2014, 60% was additional R&D (meaning carried out as a direct result of the R&D tax credit).[130] When considering the additional R&D in relation to the costs of the scheme, the evaluation found that for each €1 of foregone tax revenue by the State, €2.40 of additional R&D was carried out by the typical firm. For comparison, the most efficient 'bang for buck' this scheme could achieve would be €4.00 (given the tax credit is worth 25% of R&D expenditure).

The findings of an earlier 2013 review of the tax credit, which relied on a self-assessment survey technique to draw its conclusions, also concluded that the scheme had positive benefits for firms.[131] Survey data of 269 R&D active firms in 2013 indicated that public support through the R&D tax-credit had significant stimulation effects for R&D.[132] The survey indicated that:

- 217 firms were currently claiming the tax credit and that 82.5 % of these firms were also receiving grant-aid from EI or IDA, whilst 62.5% of firms that had previously claimed the R&D tax credit (24 firms) have been in receipt of R&D grants.
- 67 firms in the survey indicated that they had not been R&D active prior to claiming the R&D Tax Credit. Of firms that had been R&D active prior to the R&D tax credit claim

[129] Economic Evaluation of the R&D Tax Credit, Department of Finance, October 2016

[130] This result automatically implies that the scheme funds some R&D that would have been conducted by firms anyway (i.e. there is also a deadweight cost associated with the scheme).

[131] Crowe Horwath (2013) "Final Report to Department of Finance in respect of a survey of R&D Active Companies"

[132] 331 firms responded in the survey, 81% (269) of the respondents were active in R&D in Ireland – 103 described themselves multinational firms (39.8%) and 156 as indigenous Irish organisations (60.2%) – and this cohort effectively represents the dataset used for the analysis because those who were not active were eliminated from the survey process at the first stage. A total of 217 respondents indicated that they currently claim the R&D Tax Credit; this represents approximately 14.7% of the total number claiming the R&D Tax Credit according to Department records.

(128), 53 firms (of the 109 that responded to the question) indicated that there had been an increase in R&D expenditure in the firm in subsequent years following the first claim[133].

- 135 firms (60% of those that responded to the question) indicated that in the absence of the R&D Tax Credit, their firm would have invested less in the R&D that the firm was conducting, with 61 firms indicating that they would have lost the R&D function to other countries and 45 firms indicating that the R&D project would have been delayed.

The IDA target is to win a cumulative €3bn in new R&D investment projects, including in-house and collaborative R&D projects with companies and universities by 2019, and encourage 120 additional companies to engage in R&D across the FDI portfolio. The availability of direct grant support and R&D tax credits for foreign-owned firms is considered integral to the ability for Ireland to win such projects.

Overall, the evidence supports the **conclusion that public investments by way of grant-aid to firms and through the R&D Tax Credit Scheme stimulates firms to undertake R&D in Ireland to a greater extent or more immediately than they would do in the absence of such financial support**.

4.2.2 Return on State Investment from Grant-Aid to Firms for R&D

An econometric analysis was carried out to determine the impact of public funding provided through the IDA grant-aid scheme for R&D. The analysis was based on a sample of 54 plants that were approved funding for 81 projects through the IDA scheme between 2003 and 2008[134].

The analysis estimated a net sales impact of €3.899 billion and an estimated value added (economic value added - EVA)[135] of €1.366 billion from State funding of €273 million for grant-aid funding of R&D projects to these foreign-owned firms: the additional sales/value added figures were adjusted to account for deadweight, displacement and the multiplier effect in order to arrive at a net figure that is attributable to the public R&D funding. From a cost benefit perspective this indicates that a return of €5 was achieved in the year 2009 for every €1 of grant approved by IDA. The estimate is likely to underestimate the potential return as it does not take into account the lapsed time period generally required before the full economic impact of an R&D programme can be determined. Further analysis was undertaken, complemented with company views, and the results project that cost-benefit-analysis over the 5 year time frame 2009-2013 is likely to be in the region of €1:€25.5.

[133] 4 firms indicated R&D Expenditure had decreased, and 4 other firms indicated that R&D expenditure was redirected towards different types of R&D activity in the firm.

[134] Evaluation of Enterprise Supports for Research and Development, Forfás, 2013

[135] EVA is an estimate of value added calculated from the ABSEI data and based on sales revenue minus the expenditure on materials and services.

Analysis of the impacts from grant-aid to firms through the EI-RTI scheme was also undertaken and was based on a sample of 208 companies (involved in 682 R&D projects) which includes both Irish and foreign owned companies for which complete ABSEI date was available for 2002-2010[136]. Cost- benefit was calculated for the sample of 208 companies based on the change in value added over the period from when a company first received a grant approval to 2010: to determine attribution, adjustments were made to account for deadweight, displacement and the multiplier effect. The cost-benefit-analysis returned an estimate of €1.82 in net EVA in the year 2010 for every €1 of state support provided[137]. This is a conservative estimate, and does not fully account for the lapsed time period generally required before the full economic impact of an R&D programme can be determined.

In summary, it can be concluded that **direct grant-aid support to firms to undertake R&D realises positive returns to the State on its investment through additional value added produced by firms**.

4.2.3 Employment Impacts from State Funded Grant-aid to Firms for R&D

The employment impact from IDA grant-aid to foreign-owned firms was probed through monitoring of the employment performance of the R&D grant-aided firms over a period of time compared with those firms that did not receive R&D grant approvals[138].

The employment data for these cohorts is shown in Figure 52, and it is noted that a common baseline point has been adopted for the 2003 data of all categories. It is found that:

- For the cohort of plants that availed of the R&D Fund between 2003 and 2009, total employment grew by 12.8% from 2003 to 2011.
- For those plants that did not avail of the R&D fund between 2003-2009, employment fell by 6.2% from 2003-2011.
- For the total population of IDA client plants, employment fell by 0.7% from 2003 to 2011.

Therefore, employment grew faster in foreign-owned companies that availed of the R&D fund than companies that did not. Furthermore, although impacted by the recession, the R&D funded firms were above average in terms of employment growth over the period 2003-2011 and employment remained significantly above the 2003 base[139].

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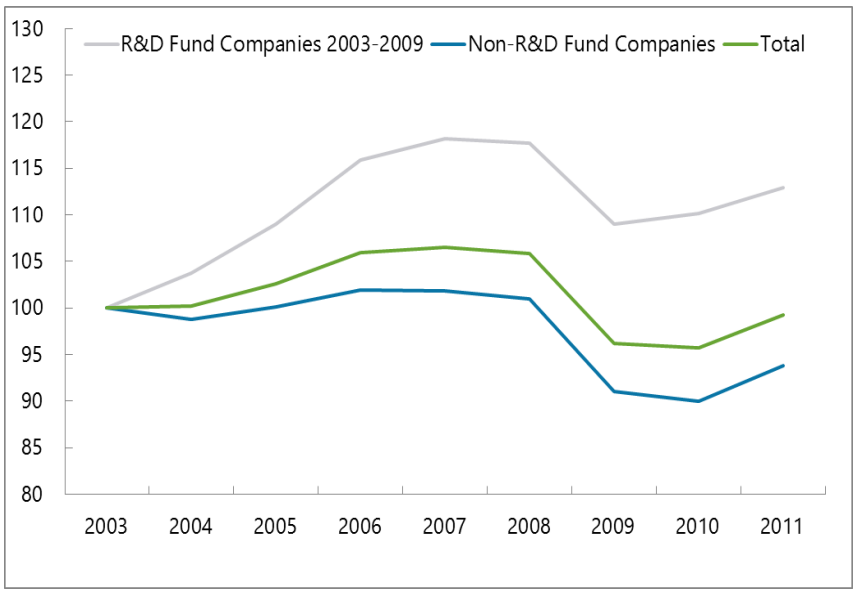
[136] Evaluation of Enterprise Supports for Research and Development, Forfás, 2013

[137] The impact of both the boom period and the recession is evident, in that if we apply the same methodology to the period 2007 the return stands at €3.34.

[138] Using 2003 as the base year.

[139] It is noted that the EI client base includes Irish-owned firms plus foreign-owned firms from a small number of sectors. Thus, employment values associated with the IDA client base does not reflect the full gamut of foreign-owned firms and so should not be directly compared with absolute employment values reported for 'foreign-owned' firms.

Figure 52 Employment growth in IDA client firms 2003-2011[140].



Source: Annual Business Survey of Economic Impact

Responses from a survey of 64 foreign-owned agency firms that had received IDA grant-aid for R&D further validated the conclusion that the IDA R&D funding supported sustained employment: 76% of firms indicated that they had maintained a larger staff presence in Ireland than without the project.

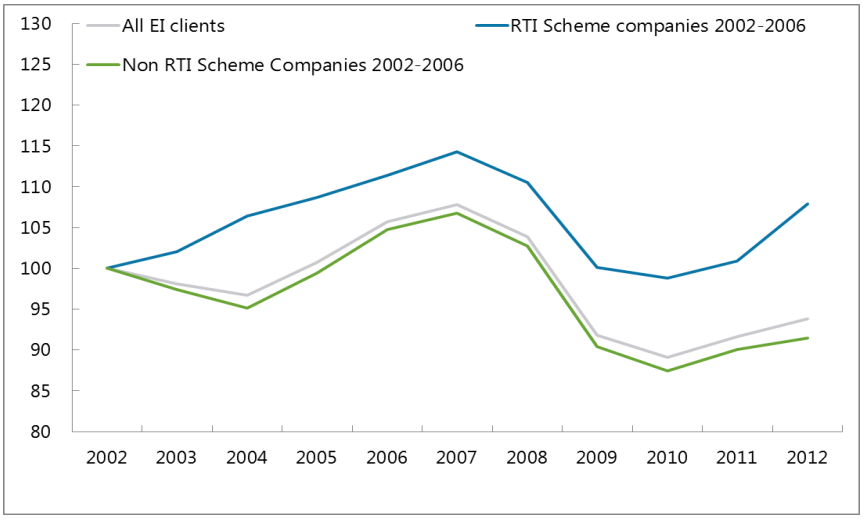
Furthermore, 63% of firms indicated that the R&D project had led to a rise in skills levels. This indicates that the R&D grant-aid supported enhanced capability within the firms to undertake higher value jobs which in-turn helped the firms to 'move up the value chain'.

The cohort of firms that were approved for funding through the EI-RTI scheme between 2000 and 2006 also demonstrated a greater degree of resilience in employment over the recessionary period than the total EI client firm base[141], as can be seen in Figure 53. Over the 2002-2012 period, the 'RTI cohort' experienced 8% growth in net employment compared with a 6.2% decline in employment in the total EI client base. Although employment is on the rise for the total client base since 2010, employment in the 'RTI cohort' has rebounded at a faster rate and pace.

[140] Reproduced from Evaluation of Enterprise Supports for Research and Development, Forfás, 2013.

[141] It is noted that the EI client base includes Irish-owned firms plus foreign-owned firms from a small number of sectors. Thus, employment values associated with the EI client base should not be directly compared with absolute employment values of 'Irish-owned' firms.

Figure 53 Employment growth in EI companies 2002-2012[142].



Source: Annual Business Survey of Economic Impact

A survey of 203 companies that received funding under the EI-RTI scheme between 2000 and 2006 found that:

- 7 in 10 companies employed new staff as a result of EI R&D funding with the majority (89%) still employing these staff after the completion of the project. Thus, while the EI RDI funding may have provided for funding of this staff initially, the data indicates that the increased capability developed as part of the R&D project undertaken led to increased employment in these companies in the longer term with 61% of redeployed workers still employed in the R&D area post the R&D grant-aid.
- The companies had developed increase capability in knowledge based activity through skills gained in the areas of strategic planning (91%), application management (87%), idea generation (85%) and process management (82%).

Overall the evidence base supports the conclusion that **public investment, by way of R&D grant-aid funding to firms, supports employment growth and greater resilience in employment in both foreign-owned and Irish-owned agency firms and employment in higher value jobs**.

4.2.4 Transforming, Sustaining and Growing the Enterprise Base through State Funded Grant-aid and R&D Tax Incentives for R&D

Foreign-owned agency firms have reported that IDA grant-aid for R&D projects have supported transforming company operations in Ireland to higher value ones, raised the skills levels employed in their base in Ireland, and upgraded the technical capability in Ireland. In the survey

[142] Reproduced from Evaluation of Enterprise Supports for Research and Development, Forfás, 2013.

of 64 foreign-owned agency firms that had received IDA R&D grant-aid (over the 2003-2009 period)[143], the biggest impact across the firms was towards upgrading their technical capability – indicated by 90% of respondents. Interviews with a number of FDI firms indicated the importance of this was in upgrading the company base in Ireland to be in a position to support the strategy of their parent company. Furthermore 62% of the firms in the survey indicated that the project had led to a raise in skills levels- supporting the firm in transitioning to higher value operations.

Firms also indicated that engagement in the IDA R&D project had supported sustained or improved company performance:

- 30% of firms reported that the IDA grant supported a larger turnover than would have been achieved without the R&D project.
- 60% of the firms indicated that if the R&D project not been undertaken, turnover would have been moderately or a lot lower: respondents indicated that the R&D projects had kept companies competitive by modernising their approach and offering something that was in line with their parent company requirements.

35% of 64 firms engaged in a survey of foreign-owned agency firms indicated that the impact of the IDA grant-aided R&D project that they had engaged in was the maintained presence of the subsidiary in Ireland. Firm interviews qualified this strong statement with the message that Ireland was no longer seen as a production base, but had managed to re-invent itself as location for activities that were further up the value chain. In many cases this had resulted in a loss of production related jobs, but had also seen an increase in higher skilled jobs.

Furthermore, of 22 companies asked whether they considered that the company was more embedded in Ireland as a result of the R&D project supported by the IDA R&D funding, 88% of the firms answered positively.

The transforming nature of activities in foreign-owned firms in Ireland is demonstrated through the changing focus for which IDAs provides grant-aid to firms.

The uptake of the grant-aid with the corresponding investment in R&D by FDI firms demonstrates that FDI firms are seeking to transform their activities to higher value ones to anchor the subsidiaries in Ireland. Indeed, in a survey of 64 foreign-owned agency firms that were engaged in an IDA grant-aided R&D activity, it was found that the business objectives for undertaking the R&D activity were focused on:[144]

- Helping the company to grow in Ireland- 22%
- Transforming the capability of the company in Ireland -23%
- Embedding R&D in the company in Ireland -20%

[143] Evaluation of Enterprise Supports for Research and Development, Forfás, 2013

[144] Evaluation of Enterprise Supports for Research and Development, Forfás, 2013.

In fact, from the IDA survey of its clients in 2012[145], R&D was identified as the most common area in which foreign-owned client companies are seeking to expand their mandate, with 36% of responding companies indicating this and with 9% of the responding firms signalling their intent of seeking an R&D mandate through undertaking R&D activity.

Furthermore, from a survey of R&D active firms, it was found that for the group of respondents that were Irish subsidiaries of MNCs and that had competed and won an R&D project from the parent company, 84.6% of them highlighted that the R&D Tax Credit had played a part in the win, supporting firms to embed in Ireland.

Irish-owned agency companies that were awarded R&D grant-aid from EI also reported positive impact in support of their business performance and transformation of their operational activities based on the R&D project. A survey of 203 companies that received EI-RTI funding between 2000-2006 found that:

- Overall, 7 in 10 companies achieved their commercialisation objectives.
- 3 in 4 businesses achieved at least 1 or more new/improved processes as a result of the RTI funding.
- On average, 4 products per firm were either introduced or improved as a result of RTI funding.
- 33% of companies said their productivity improved a lot since the completion of the EI funded RDI project and 49% said it improved a little.

Furthermore, more than 68% of EI client firms responding to the EI client survey in 2014 consider that EI's R&D support and Innovation activities were important to their businesses over the next two years[146], with 75% indicating that EI R&D and Innovation supported activities undertaken have had a positive impact on their company.

Thus, from the available evidence, it is concluded that **public investment by way of grant-aid and through the R&D Tax Credit scheme for R&D engagement by firms is key to the endeavours of the business base to transform their operations towards knowledge-based activities and leads to higher value jobs. Furthermore, these public supports for R&D help to sustain and embed foreign-owned firms in Ireland.**

Case Study: Cook Medical

Cook Medical, a US medical devices manufacturer, has maintained a manufacturing and distribution facility in Limerick since 1996. It serves the needs of physicians in the fields of gastroenterology, urology, obstetrics, and gynecology, through local product development,

[145] IDA Client Survey 2012

[146] EI Client Survey 2014

production and distribution.

The Irish facility received an R&D grant from the IDA in 2012, to help in the development of an Innovation Centre, and to add R&D capacity to develop a range of class 3 medical devices for its Peripheral Intervention Strategic Business Unit.

The new Peripheral Intervention products Cook has been able to develop off the back of this R&D grant-aid have contributed to double digit growth in its market share. And not all of the projects are complete yet.

This growth has had significant direct and indirect employment effects. The Limerick facility added approximately 25 professional skilled jobs as a direct result of the IDA grant. External engineering service providers have also been continuously engaged in building production lines and equipment for the new products, leading to further indirect job creation.

Around the time of the initial IDA grant the management of Cook's Limerick facility also identified an opportunity to speed up its R&D process by developing and leveraging the indigenous supply chain. This has led to a significant increase in headcount amongst Cook's indigenous partners: c.85-95 jobs in four indigenous suppliers alone. With Cook Medical's growing market share the headcount continues to rise throughout the supply chain.

The investment has also had significant downstream academic benefits. Cook acts as the R&D centre for Peripheral Intervention, and has increased its academic researcher headcount from 5 to 15. It has also initiated several new research projects with the University of Limerick. It has spent €500,000 on direct funded Peripheral Intervention research, and is actively considering the addition of 20 researchers specific to the area, subject to Enterprise Ireland/IDA support. Cook attests that this development of a stronger and larger R&D team would never have happened without the previous support.

Cook Medical set up a dedicated in-house research team of 3 people in 2015 on the back of the initial grant- the first outside of the United States.

Cook Medical also commenced a collaborative research project with the CÚRAM SFI Research Centre in 2015, which will look at the opportunities to apply emerging new research technology into their next generation of devices.

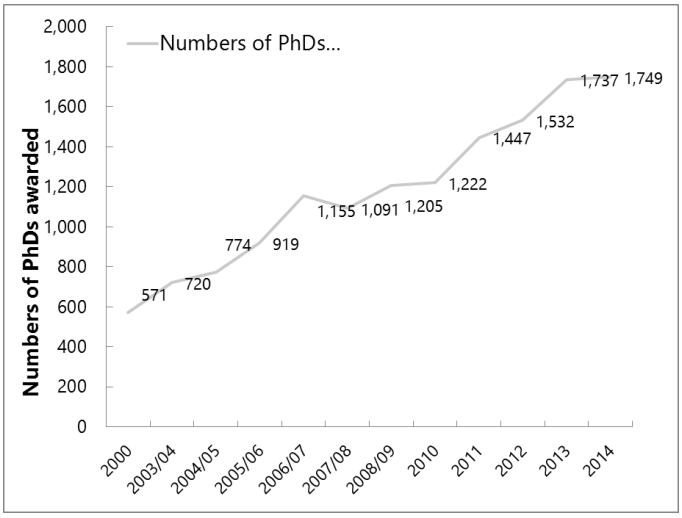
Source: Cook Medical

4.3 Enterprise Impacts and Behavioural Change in Enterprise from Public Investments in R&D in Irish HEIs

4.3.1 Impacts from Public Investment in Support of Human Capital Development

A key part of the rationale for public investment in R&D within the HEIs is to support the development of the human capital required by industry. Enrolments for PhDs have been increasing - from 5,988 in 2007/2008 to 8,158 PhD enrolments in 2014/2015 - and the yearly level of PhD graduates has subsequently been increasing as can be seen in Figure 54, with approximately 1,800 PhD students graduating in 2014.

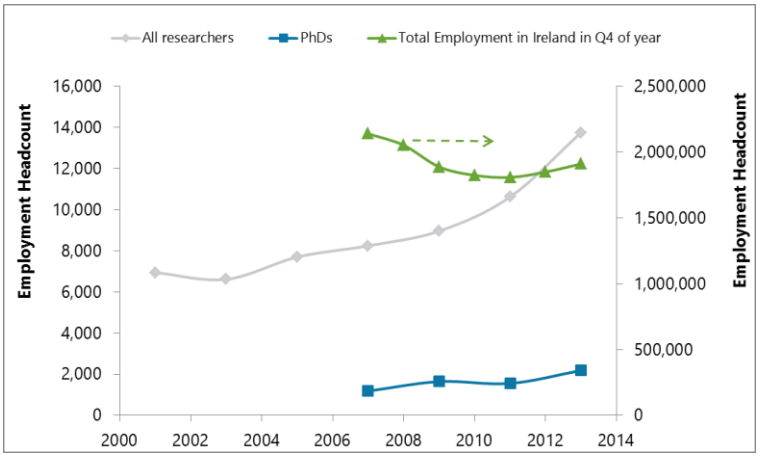
Figure 54 Numbers of PhDs awarded from HEIs in Ireland.



Source: HEA Annual Report

Since the year 2000, the level of research qualified personnel that the enterprise base requires has been consistently increasing: from 6,937 in 2001 to 13,750 in 2013 – an overall 98% increase. As can be seen in Figure 55, this increase continued throughout the period (2007-2011) of decline in employment in the broader economy: employment of researchers increased by 29% between 2007 and 2011, while employment in the total economy declined by 15.5%.

Figure 55 Employment of PhD qualified workers across the Irish enterprise base over time.



Source: BERD-CSO, QHNS-CSO

Thus, the researchers produced via the public investment in R&D in HEIs in Ireland can clearly be seen to be in demand by the enterprise base in Ireland and this was resilient to the economic recession, indicating the importance that the enterprise base has placed on this cohort of research employees. As set out previously in Chapter 3, R&D active firms are key contributors to exports sales, and value added in the economy. Thus, the increasing demand for researchers by

the enterprise base indicates that this supply of knowledge based capital is critical for firms that are key to sales, exports and value added growth in the economy.

The enterprise demand for highly qualified researchers is demonstrated by the increasing employment of PhDs between 2007 and 2013, with enterprise data reported by the CSO[147] indicating that employment of PhD qualified personnel increased from 1,179 in 2007 to 2,181 in 2013 (16 % of all researchers and 9% of all R&D staff in 2013) an increase of 85% over this time period. The increase in employment of researchers and PhDs over this time frame indicates the increased importance of R&D to firms and the need for the associated human capital to undertake the activity. The trend of increasing PhD employment[148] was observed across different enterprise size and ownership over the period 2007-2013.

Furthermore, in a survey of recent graduates it was found that PhD graduates are increasingly finding employment within the first 9 months of graduation[149]: increasing from 53% of graduates finding employment in Ireland (63% of graduates overall found employment within 9 months either in Ireland or abroad) in 2009 to 62% in 2014 (78% of graduates overall found employment within 9 months either in Ireland or abroad), with approximately two-thirds (68%) of employer organisations who recruited graduates with PhD qualifications agreeing that the position(s) actually required this level of education[150].

This survey also revealed that for the PhD graduates from 2014, 63% of the PhD graduates employed in the Republic of Ireland had their first employment in the non-market services sector, with approximately 30% of the PhD graduates employed in the Republic of Ireland employed in industry. This is consistent with the findings from an analysis of 978 'team leavers' attributed to SFI awards that have expired or will expire during a 14 year period of 2005-2019: 39% of the 'team leavers' that were PhD qualified are currently employed in industry. It is acknowledged that this may not have been their first employment position but is their position in 2015[151].

Indeed, additional analysis based on 11,000 PhD graduates from Irish Universities graduating over the period 1995-2011 reveals that over time Irish trained PhD graduates increasingly move into industry as is indicated in Figure 56[152].

[147] Survey of Business Expenditure on R&D, CSO

[148] As measured by headcount.

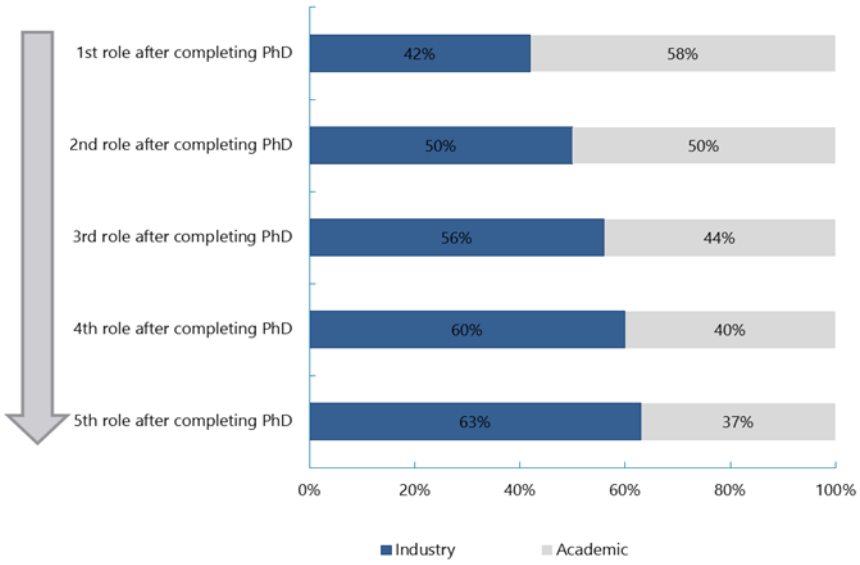
[149] What Do Graduates Do? The Class of 2014. An Analysis of the First Destination of University and College of Education Graduates, A report by the Higher Education Authority, April 2016

[150] What Do Graduates Do? The Class of 2014. An Analysis of the First Destination of University and College of Education Graduates, A report by the Higher Education Authority, April 2016

[151] SFI analysis based on LinkedIn data.

[152] Career path insights for PhD graduates from Irish Universities Dr. Diarmuid O'Brien – Trinity College Dublin

Figure 56 Employment location of 11,000 PhD graduates from Irish Universities (graduation between 1995 and 2014)[153].



Source: LinkedIn

The value attributed to research graduates and in particular PhD graduates can be seen in comparison of graduate salaries according to qualification. The salary data presented in Figure 57 indicates that research graduates are gaining employment in high value jobs –whichever their sector of employment. The data shows that more than 90% of PhD qualified graduates in 2014 achieved salaries of more than €25,000, with 31% achieving €45,000, which is significantly higher than the average earnings per employee across the total economy in Ireland (€35,768 in 2014).

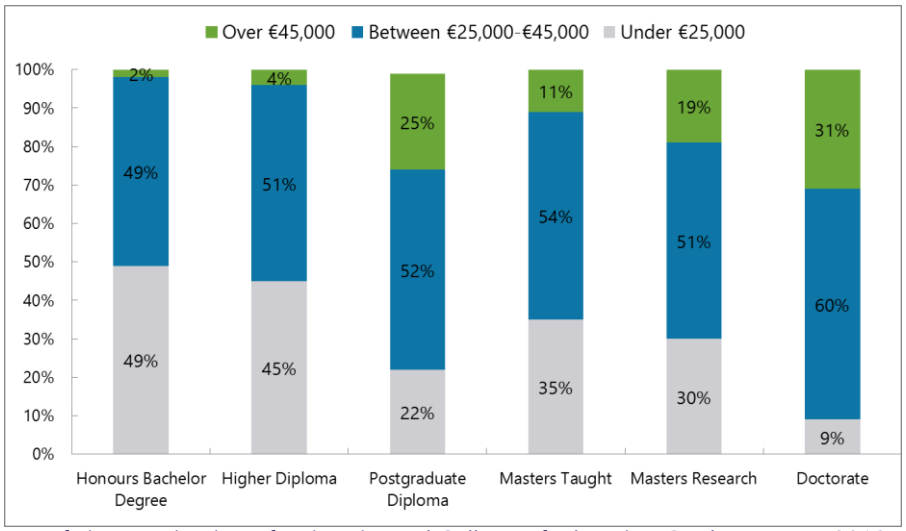
The higher value jobs achieved by employees with higher qualification levels is further demonstrated by an analysis of the positions that PhD qualified graduates take-up on entry to industry, presented in Figure 58. Based on an analysis of PhD graduates from Irish Universities (graduating between 1995 and 2014) it is shown that PhD qualified employees take on more senior positions when they move into industry than those with bachelors[154] degrees[155].

[153] It is recognised that PhD qualified personnel may not necessarily move in to a research role.

[154] Bachelors degree data from LinkedIn

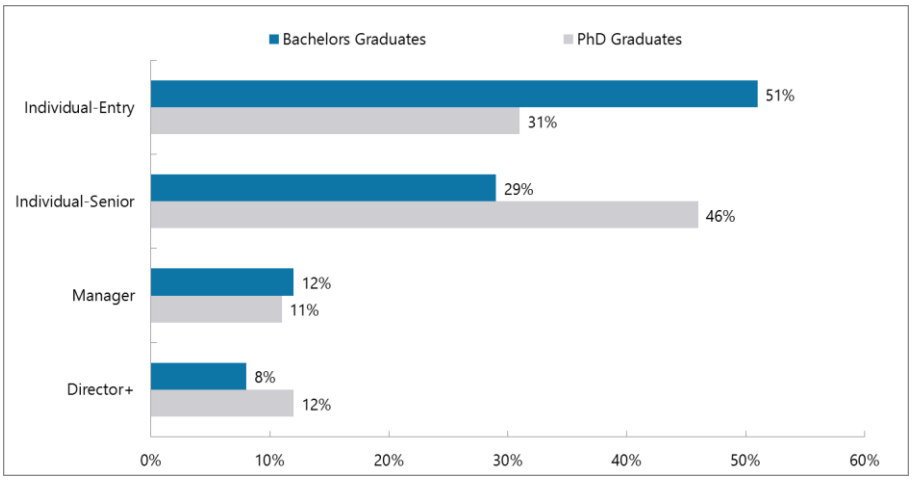
[155] Career path insights for PhD graduates from Irish Universities Dr. Diarmuid O'Brien – Trinity College Dublin

Figure 57 2014 graduates from Irish HEIs – salary range of those in employment and associated qualification[156].



Source: Survey of First Destination of University and College of Education Graduates-HEA 2016

Figure 58 Employment position on entry to industry of PhD graduates from Irish Universities (graduation between 1995 and 2014) and bachelor graduates.



Source: LinkedIn

The evidence presented supports the conclusions that **public investment in R&D in the Irish HEIs supports the development of**:

- **The research graduates required by the cohorts of firms in the Irish enterprise base that contribute most to positive sales, exports and employment performance in the Irish economy (R&D active firms).**
- **Knowledge based human capital who gain employment in higher value jobs in Ireland.**

[156] What Do Graduates Do? The Class of 2014. An Analysis of the First Destination of University and College of Education Graduates, A report by the Higher Education Authority, April 2016

4.3.1.1 Higher education reform in support of the development of higher quality researchers

In addition to the focus on developing research qualified graduates in HEIs, the higher education system is undergoing major reform on foot of the National Strategy for Higher Education to 2030 and a key element of this is the development of greater synergy across the three key pillars of research, teaching and learning.

For example, University College Cork (UCC) has set an explicit compact objective to strengthen the integration of research, teaching and learning through the greater engagement of researchers in teaching activities and by maximising opportunities for students to participate in research programmes throughout their undergraduate studies. It is pursuing this through five interrelated strands of activity:

- Researchers teaching about their research.
- Undergraduate modules on research skills.
- Undergraduate students carrying out research.
- Postgraduate teaching assistants.
- Scholarship of teaching and learning.

As part of this, the University is mapping the extent of student involvement in research within UCC's suite of undergraduate programmes.

In a similar vein and at the same time illustrating how research can support graduate formation within the Institute of Technology sector, Dundalk Institute of Technology (DkIT) has set a specific compact objective to ensure that its teaching and learning agenda is research-informed. This includes activities such as:

- School and Departmental Research Days.
- Research Summer Schools.
- Final-year student project opportunities in research centres where appropriate.
- Researchers' involvement in programme development and contribution to the teaching agenda as appropriate.

As well as the instances cited above, DkIT has reported hosting Research Days and summer schools.

Research activity within a higher education institution has a clear impact on the research students enrolled there. It also benefits the undergraduate population in a range of ways.

Many courses have been designed based on the knowledge gained through a research group's activity and the consequent recognition of the importance of rolling this out through new educational offerings. This ensures that students are being educated in the State-of-the-Art content. Some examples in practice of the integration of R&D learnings being integrated into the undergraduate teaching in the Irish HEI system are:

- TCD: The Institute of Neuroscience has developed a BA (Mod) in Neuroscience as well as MSc and PhD Neuroscience programmes.

- Maynooth University: The work of the Innovation Value Institute has led to the development of new Masters programmes.
- Waterford Institute of Technology: Research underway at TSSG (the Telecommunications & Software & Systems Group) has informed the development of WIT's MSC in Computing.

Furthermore, the research knowledge of the lecturer can have a strong influence on the quality of the teaching delivered. It enables him/ her to educate students about the latest developments in the field. It also empowers him/ her to engender interest among the students about the future potential of the subject matter and their ability to be part of that.

Since 2004 the numbers of researchers working in Universities and Institutes of Technology has increased and the proportion of researchers that have PhD qualifications has also increased: from 53% in 2004 to 60% in 2012[157]. Thus, indicating the increased level and quality of researchers in the HEIs that can be leveraged towards integrating research elements into undergraduate education.

A number of HEIs have included aspects of informing their educational provision by research as specific objectives in their compact with the HEA, including:

- **UCC:** One of UCC's 2013-17 strategic goals is to deliver research-inspired teaching and learning with a world-class student experience. It has a specific objective to this effect in its 2014-16 compact with the HEA and one of the five constituent strands of activity involves researchers teaching students about their research.
- **TCD:** As part of ensuring that its education provision is informed by research, Trinity has set itself a compact objective to increase the proportion of research-productive staff from 70% (2010/11) to 80% by the end of 2016. By the end of 2014, they had reached 75%.

Undergraduate students can be given the opportunity to undertake research projects as part of their course studies, often with the oversight of post-docs or PhD students. This gives them a hands-on feel for research work.

In addition, the opportunity for students to see, and sometimes to use, world-class research facilities helps them to understand better the research that is underway in their field of study and the techniques that are applied on a day-to-day basis to generate results.
Some examples in practice of the increased opportunities for undergraduates in the HEI system to develop skills in R&D include:

- **UCC**: In delivering on one of its 2014-16 compact objectives with the HEA, UCC highlights that every final year student is given the opportunity to conduct independent research.
- **Dundalk IT**: In 2014, over 70 students undertook research projects in partnership with academic researchers in the Institute's research centres.

[157] Survey of Research & Development in the Higher Education Sector 2012/2013, DJEI , The Higher Education R&D Survey 2006, Forfás.

During the summer, nine students were embedded in the Institute's research students and, additionally five international students (from Brazil and the US) undertook research summer projects.

The extent to which this takes place naturally depends on the research intensity of the institution. The ultimate effect lies in how students are exposed to, and educated in, the latest research – both knowledge and skills – pertaining to their particular field of study. It thus helps them to be as ready as possible for future careers either as researchers or otherwise within research-active innovative environments. These latter may be within research centres yet equally can take the form of R&D-active enterprises. The students' exposure to research thus enhances their attractiveness to future such employers right across Ireland.

The evidence presented supports the conclusions that **public investment in R&D in the Irish HEIs supports the development of**:

- **more attractive graduates to the enterprise base:**
  - **Public investment in R&D activity within HEIs in Ireland supports design of cutting-edge course content and higher quality of delivery resulting in the development of graduates with State-of the-Art knowledge.**
  - **Public investment in R&D activity within HEIs in Ireland supports the development of graduates that have an understanding and practical experience of research.**

4.3.2 Impacts from Public Investment in Support of Knowledge Exchange between HEIs and Enterprise

4.3.2.1 Knowledge exchange via specialised training

There have been a number of specific national investments made in R&D facilities which have a key mandate also to provide training. The knowledge generation within these facilities underpins their ability to deliver training in emerging areas of science and technology which are of relevance to the advancement of the enterprise base in Ireland.

A. National Institute for Bioprocess Research and Training

The National Institute for Bioprocess Research and Training (NIBRT) was established as an independent research organisation to support the growth of the bio-pharma sector in Ireland through the conducting of research relevant to bio-pharmaceutical manufacturing and disseminating the results of this research through the provision of highly specialised training.

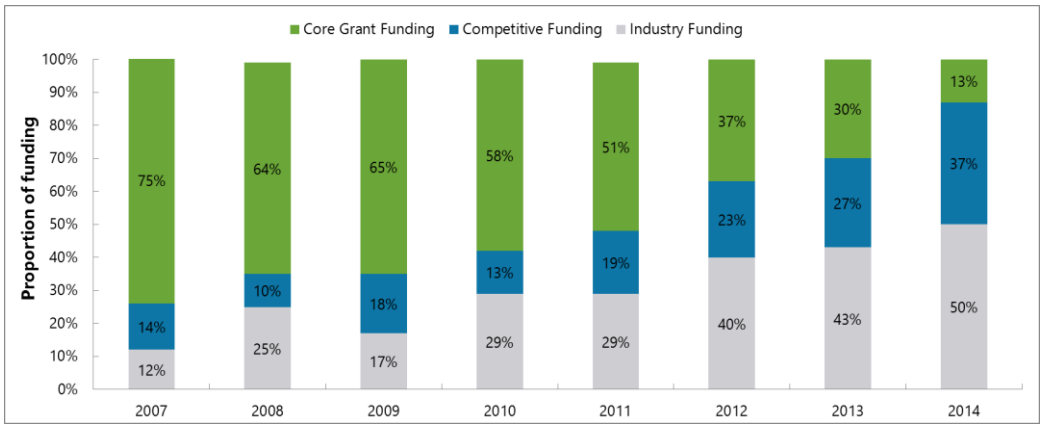
NIBRT trains people annually to work in all areas of bioprocessing, and has a well-developed training programme with over 3,800 trainees trained during 2015 (+15% on 2014).

Since January 2012, over $4.2bn of foreign direct investment has been made into the Irish bioprocessing sector, creating over 3,200 jobs. Based on the feedback from ten of the companies engaging with NIBRT, it is evident that NIBRT has: played a key role in attracting some of these businesses to Ireland; supported new entrants to their business in gaining the

skills they need to operate in a lab environment and helps their experienced staff acquire new skills.

Evidence of the growing importance of this facility to the bio-pharma industry sector is demonstrated by the increasing level of NIBRTs funding that stems from industry, as can be seen in Figure 59. Furthermore, in 2014, industry funding for Training and Services accounted for 50% of the total industry funding at €1.172 million. In addition, NIBRT has received over €3 million in in-kind equipment contributions from industry.

Figure 59 NIBRT Funding sources 2007-2014[158].



Source: NIBRT

Furthermore based on interviews across a broader range of stakeholders, it is considered that NIBRT has positively impacted on the enterprise base in Ireland by:

- Increasing the speed of industry growth.
- De-risking investments in biotech by increasing the size of the trained workforce.
- Helped to attract FDI.
- Encouraged more collaborative research projects.
- Helped Ireland win a high market share of biopharma FDI in future.

B. Irish Centre for High-End Computing

The Irish Centre for High-End Computing (ICHEC) is a national body established under the aegis of NUI Galway. Amongst its primary activities are:

- Provision and support of the National High-Performance Computing (HPC) Service.
- Participation in competitive research projects in technical computing e.g. H2020.

[158] Post Project Review of the National Institute for Bioprocessing Research and Training (NIBRT), Final Report for IDA Ireland, Frontline, December 2015

- Provision of commercial services related to HPC and technical computing to industry, semi-state and the public sector.
- Provision of training and education initiatives in support of the National HPC Service and commercial initiatives.

Public investment in ICHEC has supported the development of internationally renowned expertise in HPC[159] as well as the provision of world class infrastructure to the wider R&D community in Ireland. The knowledge generation in ICHEC underpins its ability to deliver training to researchers in HEIs, individuals seeking work, as well as upskilling of existing staff in firms in complex new areas of technology related to HPC and Data Analytics: covering the development of key skills that are in demand by industry but that are not formally taught at HEI level. The provision of this specialised training benefits existing companies to upskill existing staff as well as supporting the development of specialist skills in graduates and researchers that provide a pipeline of skills available to industry.

The type of enterprise impacts arising from ICHEC based training is illustrated in the case study for General Motors.

In conclusion, **public investments towards specific R&D facilities is supporting the training of existing staff and new entrant staff to meet skills requirements of enterprise in emerging sectors for Ireland**.

Case Study: ICHEC and General Motors

Event Title: Diploma in Applied Science (HPC System Design & Development)

Event type: Springboard programme

Training Level: Intermediate

Location: NUI, Galway

Organizers: ICHEC, NUI Galway, General Motors

Trainers: ICHEC staff

No. of Attendees: 11

Attendees: 11 students selected through interview process

In May 2014, General Motors approached ICHEC for assistance in taking up a corporate opportunity to bring a high skills technical support centre to Ireland. GM were in the process of bringing the support of their worldwide HPC operation back in-house and wanted to set up a

[159] A Study on harnessing Big Data for innovation led growth: an assessment of Ireland's progress and further policy requirements, A Report by IDC , Commissioned by the Department of Jobs, Enterprise and Innovation on behalf of the Taskforce on Big Data, January 2015

team of HPC system administrators in Ireland to manage and support this. The timeline for transition was very short with a go-live date of October 2014, yet ICHEC was able to design and prepare a Diploma level course to train technical graduates in the fundamentals of operating a HPC infrastructure. Despite the early start date of 5th August, a total of 13 offers were made from 27 applicants via Springboard and 11 people accepted these offers. 10 of the people who started the course completed and graduated and as a result all 10 were offered and accepted full-time permanent positions with GM.

4.3.2.2 Knowledge exchange via HEI-enterprise collaborations

A. Transformation of Businesses Towards Knowledge Based Operations

As indicated in the funding data presented in chapter 2, funding to support HEI-enterprise collaboration has been achieving increased focus over the past 10 years. The policy objectives for supporting such activity are plentiful, but some of the key ones are to: increase the absorptive capacity for R&D in firms (from a low base or in new areas of science and technology) with a view to increasing/maintaining R&D activity in the enterprise base and supporting transformation of the business base to knowledge based activities; to support new knowledge generation that has a potential vehicle for subsequent commercialisation via the industry partner; supporting co-ordination and networking across enterprise on industry R&D agendas; and supporting the development of human capital in areas of relevance to the enterprise base.

There have been a number of funding programmes initiated to support HEI-enterprise collaboration over the years. These include significant investments in now historical centre programmes such as SFI Centres for Science Engineering and Technology (CSETs), SFI Strategic Research Clusters (SRCs), EI Advanced Research Enhancement Centres (AREs), and EI/IDA Competence Centres (CC) and the current and increased investment in a new suite of programmes such as: the SFI Research Centre Programme, the EI Technology Gateways Programme (TG) and the EI/IDA Technology Centres Programme (TC). The range of programmes reflects the different needs of firms within the enterprise base: from firms with no R&D capacity to leading edge companies seeking to stay abreast of latest scientific developments. The evolution of these centre programmes reflects changes in the maturing capability and capacity in the HEI system, outcomes of the Prioritisation Exercise and maintaining alignment with the needs of the enterprise base. There are also a number of newer programmes such as the SFI Strategic Partnerships and EI New Frontiers Programme that have been initiated in recent years as well as programmes that have been in operation for several years including: the SFI Industry Fellowships scheme; the EI Innovation Vouchers (IV) scheme and Innovation Partnerships (IP) scheme; the IRC Enterprise Partnership scheme - Postgraduate and Postdoctoral; the IRC Employment-based scheme[160]; and the InterTrade Ireland Fusion Scheme.

The behavioural, and enterprise and economic impacts reported from firms engaged in a number of the HEI-enterprise collaboration programmes that were/are in operation were

[160] 40% of the IRC's STEM postgraduate scholars currently on the enterprise facing schemes.

reported through a series of evaluations of HEI-Collaboration Programmes, and the key findings from these evaluations are set out in Appendix 2.

In summary the evidence indicates that **public investment in HEI-enterprise collaboration programmes is supporting firms to:**

- **Access expertise, knowledge and capabilities in support of future business growth.**
- **Engage in more R&D than they would have done in the absence of the collaboration.**
- **Develop new and improved goods, processes and services.**

Analysis of firm turnover amongst firms indicates that investment in these collaboration programmes leads to positive net turnover impacts across the firms. The net turnover impact experienced by firms and the net turnover impact projected into the future for these firms is shown in Table 9 for a number of the State programmes for HEI-enterprise collaboration. The data here highlights **that in the short term a €1 investment in the specific programme reviewed leads to between €5.85-€7.65 return in terms of net turnover impact. In the longer term, this return on investment is expected to rise to between €12 and €28 per €1 investment by the State.**

Table 9 Estimates of Net Turnover impact from State investment in HEI-Industry collaboration programmes.

State Funding Programme	Net Turnover Impact experienced	Net Turnover Impact-projected
Advanced Research Enhancement Centres	€5.85	€12.31
Innovation Partnerships	€6.69	€26.35
Innovation Vouchers	€7.65	€27.76

Source: Enterprise Ireland

Furthermore, the HEI-collaboration programmes are shown to lead to increased employment across firms and increased value added in the economy. Table 10 sets out the return on investment in terms of the estimated net value added[161] (EVA) from State funding of a number of programmes. 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**

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

longer term, this ROI is expected to rise to between €4.5 and €11 per €1 investment by the State.

Table 10 Estimates of Net EVA impact from State investment in HEI-Industry collaboration programmes.

State Funding Programme	Net EVA impact-experienced	Net EVA impact-projected
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

B. Impact of Public Support for HEI-Enterprise Collaborations

Overall, the number of collaborative engagements between HEIs and enterprise is shown to be increasing at a fast pace. This finding is based on an analysis of approvals through the funding programmes[162] that have operated between 2006 and 2014. It can be seen in Figure 60 that the number of State supported HEI-enterprise collaborations[163] has been dramatically increasing between 2006 and 2014: from 86 in 2006 to 1,371 in 2014[164].

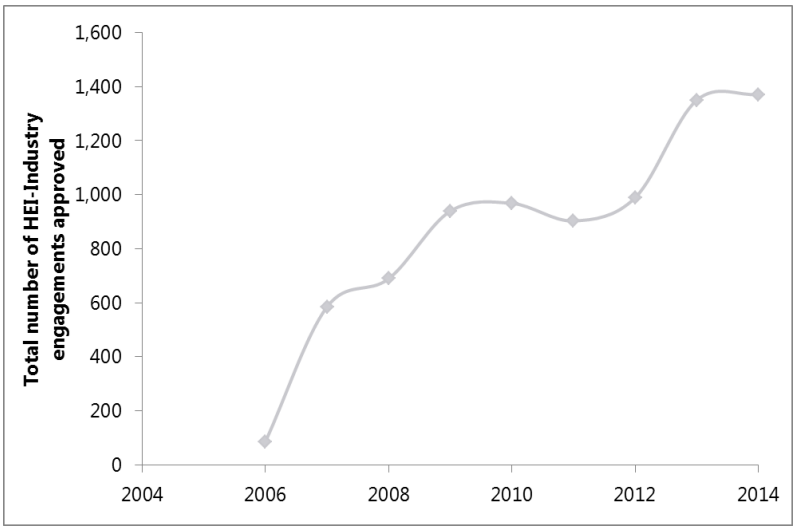
Approvals associated with the innovation voucher programmes contribute to a large proportion of the number of overall collaborative engagements approved as can be seen in Figure 61. These are smaller level funding approvals (€5,000) and support firms in terms of entry level, or smaller scale innovation projects that HEIs undertake in their behalf. When the innovation voucher engagements are excluded, then the number of approvals across the remaining collaboration programmes show a significant and steady increase since 2010, as can be seen in Figure 61.

[162] Funding programmes for collaboration include: SFI- CSETS; SFI- Industry Fellowships; SFI- Research Centres; SFI- Spokes; SFI- Strategic Research Clusters; SFI- Strategic Partnerships; EI ARE- Technology Gateways; EI- Innovation Partnerships; EI- Innovation Vouchers; EI- New Frontiers; EI/IDA - Competence Centres/Technology Centres; InterTrade Ireland- Fusion; IRC- Employment Based Programme; IRC- Enterprise Partnership- Postgraduate; IRC- Enterprise Partnership- Postdoctoral.

[163] The data represents the number of collaborations by firms with HEIs. In programmes where a project approval relates to a single approval of funding to the HEI to engage with multiple partners – for example Technology Centres and Technology Gateways - the number of HEI-enterprise collaborations relates to the number of firms that have engaged with the HEI under the approved Centre/project approval.

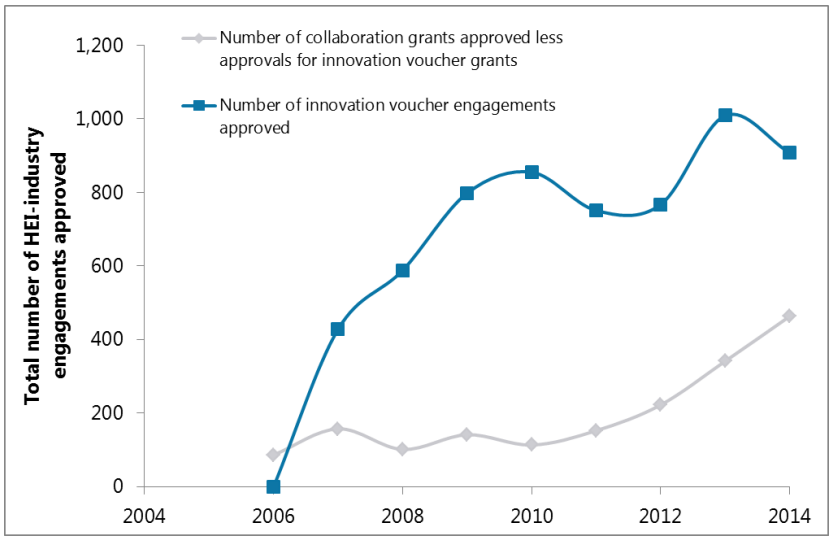
[164] It is noted that engagements related to the first round of CSET funding are not included here, as these would mainly have been approved prior to 2006.

Figure 60 Total number of HEI-industry collaborative engagements approved through State funding programmes between 2006-2014.



Source: DJEI, Agency Grant Data

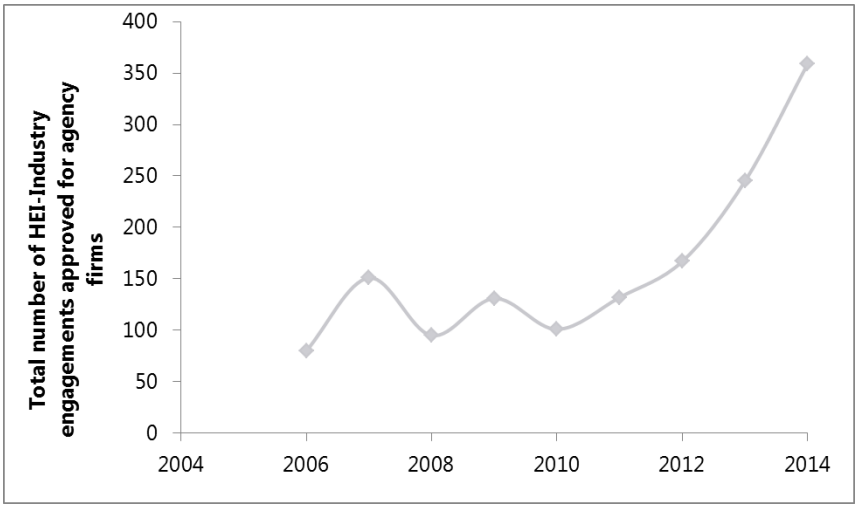
Figure 61 Number of HEI-industry collaborative engagements approved through State funding programmes between 2006 and 2014: number of approvals for collaborative engagements-less approvals for innovation voucher grants and total number of innovation voucher engagements approved.



Source: DJEI, Agency Grant Data

Excluding the innovation voucher approvals, it was found that approximately 80% of the approvals for HEI-industry engagement were to agency firms between 2006 and 2014, thus the trend in agency firm uptake of collaboration grant supports, as shown in Figure 62, can be seen to mimic the trend in total grant approvals over this time period. When innovation voucher approvals are included in the analysis, it is estimated that 53% of all approvals were to agency firms.

Figure 62 Number of HEI-industry collaborative engagements approved for agency firms-less innovation vouchers approved for agency firms between 2006-2014.



Source: DJEI, Agency Grant Data

State support across a range of R&D programmes encourages both foreign and Irish-owned firms to engage with the HEIs: for example, between 2006 and 2014, 55% of agency firm partners in the SFI Research Centres were foreign-owned and 45% were Irish-owned, and 73% of agency firm partners in the Irish Research Council's Employment Based Programme were foreign-owned and 27% were Irish-owned[165].

It is the evolution of the capacity, capability and research centre landscape in the publicly performing R&D base, the improved ease of access to HEI R&D for firms through KTI initiatives and Technology Transfer Office infrastructure, alongside the increasing recognition by firms that they must innovate to survive and grow, that has supported the increased level of engagement of firms with HEIs.

However, not only are more collaborations being initiated, but firms are demonstrating increased commitment to these engagements as demonstrated by the levels of cash contributions for collaboration activity. For example, while industry contributions to previous SFI funded centres (CSETs and SRCs) were predominantly in-kind contributions, the initial group of 12 SFI Research Centres had, by the end of September 2016, signed contracts 394 worth €43 million cash funding from industry - with €20.6 million industry co-investment actually banked by the end of June 2016[166]. Similarly, HEI-industry collaborations funded under EI schemes have demonstrated overall increased contributions by industry to the engagements: with cash contributions increasing from €3.5 million in 2012 to €8.4 million in 2015.

[165] Analysis of grant data linked to ABSEI data by Insight, 2016.

[166] There is a projected €355 million State investment across the twelve SFI Research Centres with a target of leveraging a further industry commitment of €190 million of which over €60 million is to be cash.

Thus, the **evidence indicates that public support for HEI-industry collaboration is feeding a fast growing demand by enterprise to engage with HEIs to undertake R&D activities**: for both small scale short time frame projects (innovation vouchers) and for larger scale longer-term R&D projects.

B1. Economic impacts of foreign-owned firms engaged in State supported HEI-enterprise collaborations

An analysis of the exports, value added and employment of foreign-owned agency firms actively engaged in State funded HEI-enterprise collaborations[167] during 2009-2014 was carried out[168]. Due to the nature of the methodology employed, the data should be considered as indicative rather than in absolute terms.

Based on an analysis of the firm response to the ABSEI in each year, it is determined that collaboration is a characteristic of firms that contribute significantly, at a reasonably stable level, to exports by foreign-owned agency firms, with an indicative average contribution to exports of 39% (by responding firms) per year between 2009-2014.

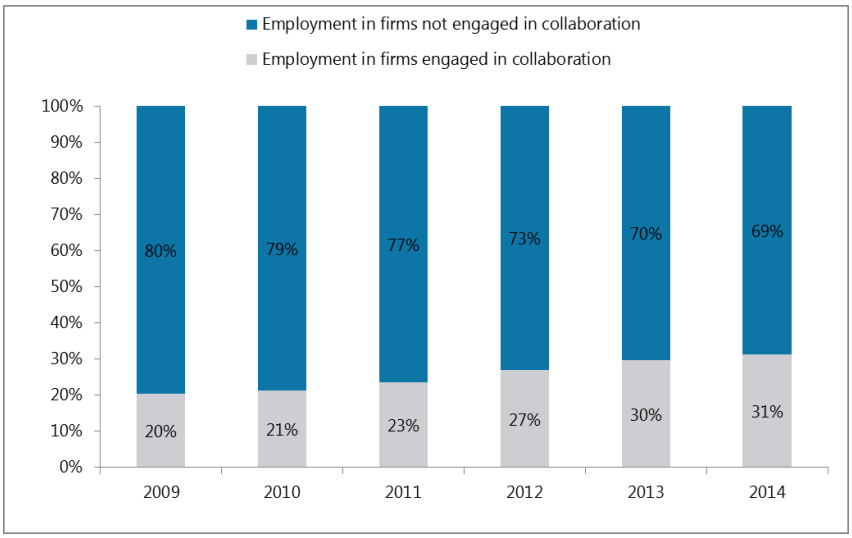
Similarly, the collaborating cohort of foreign-owned agency firms which responded to the ABSEI were also found to be strong contributors to value added in each year: an indicative estimate of the contribution from these collaborating firms was measured at 46% of total value added by foreign-owned agency firms (that responded to the ABSEI) between 2009 and 2014.

Figure 63 demonstrates that collaborating foreign-owned agency firms were also accountable for a significant and increasing proportion of employment in foreign-owned firms responding to the ABSEI over the 2009-2014 time frame. For the cohort of collaborating firms that responded to the ABSEI, the estimated average employment per firm increased from 553 to 616 persons engaged per firm between 2009 and 2014.

[167] Estimates of the start and end date of each project were made and for each year firms were then determined to State-support active, or not, in that year in accordance with the start and end dates.

[168] It is noted that the analysis is based on the actual responses in the ABSEI, and so figures presented do not fully match to the total ABSEI values reported previously in chapter 3- which represent the performance of all of the firms in the agency enterprise base (that have 10 or more persons engaged). However, the foreign-owned agency firms responding to the ABSEI did account for the majority of exports, value added and employment in each year, representing: between 98% and 99% of all exports reported in the ABSEI by foreign-owned agency firms across 2009 and 2014: 98% of value added reported in the ABSEI for foreign-owned firm in each year between 2009 and 2014; and between 91% and 94% of total employment reported in the ABSEI for foreign-owned firms between 2009 and 2014. It is further noted that employment reported in the ABSEI survey is based on firms with more than 10 persons engaged- thus employment values presented will be less than the employment in the total foreign-owned agency firm enterprise base even in the event of a full response rate.

Figure 63 Indicative employment contribution in foreign-owned firms responding to the ABSEI: according to firms active in HEI-enterprise collaboration and those not active in HEI-enterprise collaboration.



Source: Insight/DJEI: ABSEI, Agency Grant Data

Thus, it can be concluded that **collaboration with HEIs is a characteristic of foreign-owned agency firms that contribute significantly to exports, value added and employment by foreign-owned firms**.

Case Study: SFI Research Centre, the Alimentary Pharmabiotic Centre (APC)

The APC Microbiome Institute, hosted in University College Cork, was originally funded by SFI in 2003 and was recently designated an SFI Research Centre. In August 2015, it announced the creation of 50 additional hi-tech jobs. The new jobs have arisen largely from the ability of APC to attract new industrial partnerships. The APC Microbiome Institute currently partners with eight global corporations with a broad footprint in Ireland accounting for over 7,000 jobs. In addition, APC has established partnerships with nine other international companies that had no prior relationship with Ireland.

Source: Source: Innovation 2020, Excellence, Talent, Impact: Ireland's strategy for research and development, science and technology, DJEI, 2015

B2. Economic impacts of Irish-owned firms engaged in State supported HEI-enterprise collaborations

An analysis of the exports, value added and employment of Irish-owned agency firms actively engaged in State funded HEI-enterprise collaborations[169] during 2009-2014 was also carried

[169] Estimates of the start and end date of each project were made and for each year firms were then determined to be State-support active, or not, in that year, in accordance with the start and end dates.

out.[170] Due to the nature of the methodology employed, the data should be considered as indicative rather than in absolute terms.

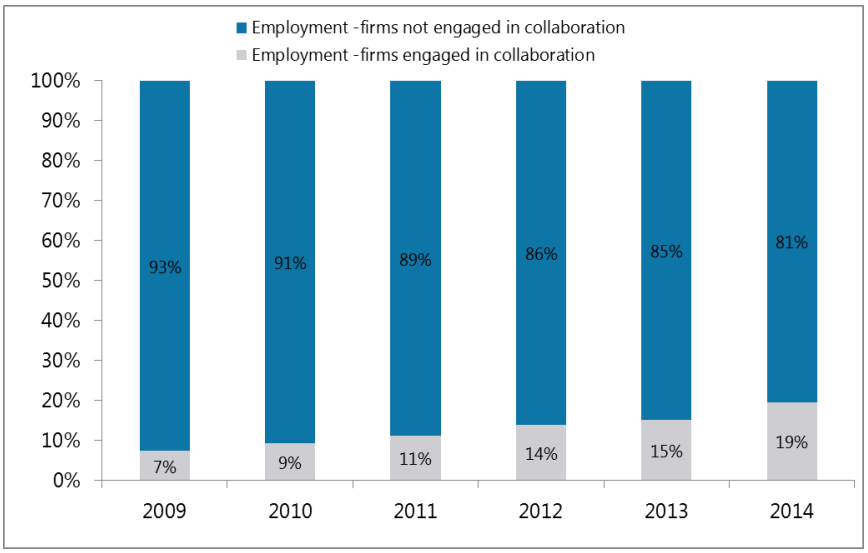
Based on an analysis of the firm response to the ABSEI in each year, the indicative contribution to exports by the cohort of collaboration active Irish-owned firms was found to grow consistently across the 2009 to 2014 time frame, albeit from a low base: the estimated contribution of collaboration active Irish-owned firms increased from 7% of total exports in 2009 to 17% in 2014.

Similarly, based on analysis of the firms responding the ABSEI, it was found that collaborating Irish-owned agency firms were also found to be strong contributors to value added in each year. The indicative contribution to value added by the cohort of collaboration active Irish-owned firms can be seen also to be growing consistently across the time frame, increasing from 4% of total value added by Irish-owned agency firms in 2009 to 16% in 2014. This estimate can be related to an increase in the average exports per firm for Irish-owned collaborating firms from €1.7 million per firm in 2009 to €4.5 million per firm in 2014.

In addition, further analysis of the firms responding the ABSEI indicates that employment in Irish-owned agency firms that collaborate on R&D with HEIs has been increasing year on year and the data analysis indicates employment in this cohort of firms increased from 7,500 in 2009, to 23,000 in 2014. This corresponds to an increase in the contribution to employment in Irish-owned agency firms by the collaborating firms from 7% in 2009 to 19% in 2014 (based on the responding firms), as can be seen in Figure 64. There was also an increase in average employment per firm from 2009 to 2014 of 35.5 to 61.6 persons engaged per firm.

[170] As before the analysis is based on respondent data so figures presented will not fully match to the total ABSEI values reported previously in chapter 3. However, the Irish-owned agency firms responding to the ABSEI, did account for the majority of exports, value added and employment in each year, representing: between 91% and 96% of all exports by Irish-owned agency firms across 2009 and 2014: between 87% and 91% of total value added reported in the ABSEI for Irish-owned firms between 2009 and 2014; and between 82% and 90% of total employment reported in the ABSEI for Irish-owned firm between 2009 and 2014. It is further noted that employment reported in the ABSEI survey is based on firms with more than 10 persons engaged-thus employment values presented will be less than the employment in the total Irish-owned agency firm enterprise base even in the event of a full response rate to the survey: the impact on employment of the 10 person criteria is greater with the cohort of Irish-owned firms than is the case for foreign-owned firms.

Figure 64 Indicative employment in Irish-owned-owned firms (with 10 or more persons engaged): according to firms active in HEI-enterprise collaboration and those not active in HEI-enterprise collaboration.



Source: Insight/DJEI: ABSEI, Agency Grant Data

Thus, it can be concluded that **collaboration on R&D with HEIs is a characteristic of Irish-owned agency firms that have been increasingly contributing more to total exports, value added and employment by Irish-owned agency firms**.

Case Study: Dairy Master

Dairymaster, based in Kerry, is a leading manufacturer of milking equipment, with customers in 40 countries. It has pioneered advances in such areas as milking parlour equipment, automatic scrapers, automatic cow feeding systems and farm management software. Dairymaster makes 95% of its parts in its highly automated site in Kerry, supporting 370 jobs and an average growth in sales of 20% per annum for over ten years. In order to sustain its global leadership and grow its markets, Dairymaster has consistently invested in R&D. This investment is at a multi-million euro level, both in-house, and through collaboration with higher education institutes. Through this collaboration, the company has accessed additional expertise and capability and has widened its product portfolio to improve market penetration to 10,000 farms worldwide. Dairymaster has collaborated with a number of higher education institutions on four Enterprise Ireland-funded Innovation Partnership projects, worth more than €1m over the past five years, and has also collaborated with Technology Gateways and Technology Centres. Dairymaster is also collaborating at a European level through a pan-EU research consortium dealing with robotics. This sustained investment in R&D, both in-house and through collaboration, has resulted in significant sales growth and in a 100% increase in sustainable and high added-value employment over the past six years.

Source: Innovation 2020, Excellence, Talent, Impact: Ireland's strategy for research and development, science and technology, DJEI, 2015

C. Impact of Local Collaborations on Firm Level International Activity in R&D

Firms in the Irish enterprise base also benefit from increased international engagement in R&D on the back of networks built through their collaboration activity with the HEIs. It has been found that companies are much more likely to be involved in European RD&I Funding Programme projects (from which firms have been shown to reap many benefits and economic impacts - see section 4.4) when there is local collaboration and this increases significantly when an Irish HEI takes the coordination role.

- There were 1,960 participations by Irish organisations in FP7 - in 433 cases (23%) this was in the co-ordination role and 1,517 (77%) as a participant:
- Out of total participations, 833 had local collaborations (43%) and the remaining 1,127 (57%) did not have any local collaboration.
- Out of total 833 participations which had local collaborations, 370 (44%) are by companies.
- This compares to just 247 participations (22%) by companies out of the 1,127 participations in which there was no local collaboration.

This indicates that companies are more likely to have participations in projects when there is a local collaboration (e.g. by another company or HEI). Furthermore, when HEIs take the co-ordination role (108 times), 66% of local participations (119 out of 180 in total) are by companies. This indicates that when HEIs take the co-ordination role, there is a relatively higher level of collaboration by Irish companies.

4.3.3.3 Knowledge exchange via commercialisation

A. Spin-out Firms and Licencing Based on Knowledge Generated in HEIs

Public policy in Ireland aimed at commercialisation of knowledge generated in the HEIs has been focused towards delivering new firm formation and supporting increased use of the knowledge generated in the HEIs by enterprise to deliver new product and process innovations by the enterprise base.

Based on analysis across the total publicly performing R&D system, it can be seen in Figure 65 that there has been a dramatic increase in the number of Licences, Options and Assignments (LOAs)[171] since 2007, increasing from 55 to over 200 in 2015 (an approximate 4 fold increase from the start of the Technology Transfer Strengthening Initiative (TTSI) funding in 2007) with

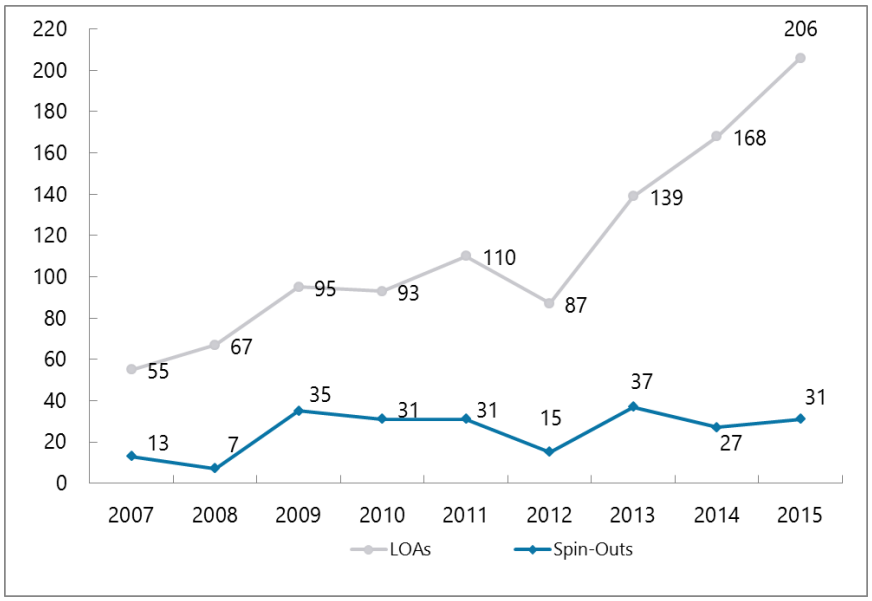
[171] A **licence** is an agreement between a RPO and one or more third parties, whereby intellectual property rights are transferred for the purpose of commercialisation. The RPO retains ownership of the intellectual property but permits the licensee to exploit it in accordance with contractual terms and conditions.

An **option** agreement is one in which the RPO grants a potential licensee or assignee a period of exclusivity during which it can decide whether it may wish to take a licence to the intellectual property and negotiate the terms of a licence agreement. The option period may include evaluation of the IP by the potential licensee (including assessing the technology). This is may be called an Option & Evaluation agreement.

An **assignment** is an agreement transferring ownership of intellectual property rights from the RPO to a third party.

the number of licences and assignments specifically reaching over 140 per annum in 2015 (more than a factor of 10 increase since before 2007).

Figure 65 Annual numbers of spin-outs firms and LOAs from Irish HEIs[172].



Source: Knowledge Transfer Ireland

The dip in 2012 is attributed to a reduction in the EI Commercialisation Fund in 2009 and 2010 resulting in a reduced pipeline of projects for commercialisation and reduced research & Technology Transfer Office (TTO) staff numbers[173].

As can also be seen in Figure 65, the number of spin-out firms also increased dramatically from 8 in 2006 to 31 in 2015.

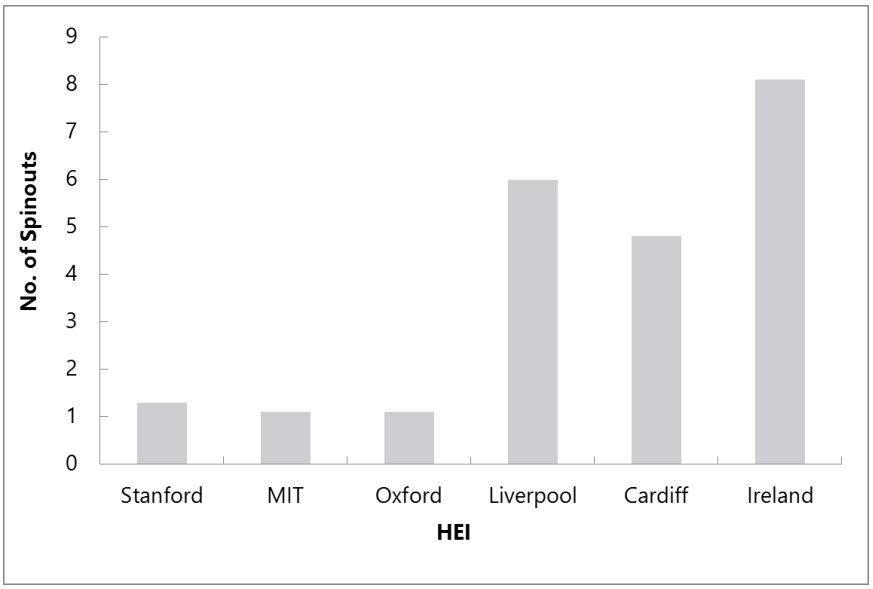
The commercialisation performance of the Irish publicly performing R&D system compares well to internationally renowned HEIs when outputs are compared and normalised based on the level of R&D expenditure[174]. This is true when comparing numbers of spin-out firms in Ireland across all comparator HEIs reviewed, and for the number of LOAs generated in Irish HEIs when compared with the US HEIs, as demonstrated in the data presented in Figure 66 and Figure 67. 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.

[172] Based on: KTI annual reports and Knowledge Transfer Surveys 2014 and 2015; A review of the performance of the Irish Technology Transfer System 2007-2012.

[173] A review of the performance of the Irish Technology Transfer System 2007-2012

[174] Knowledge Transfer Ireland analysis.

Figure 66 The number 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[175].



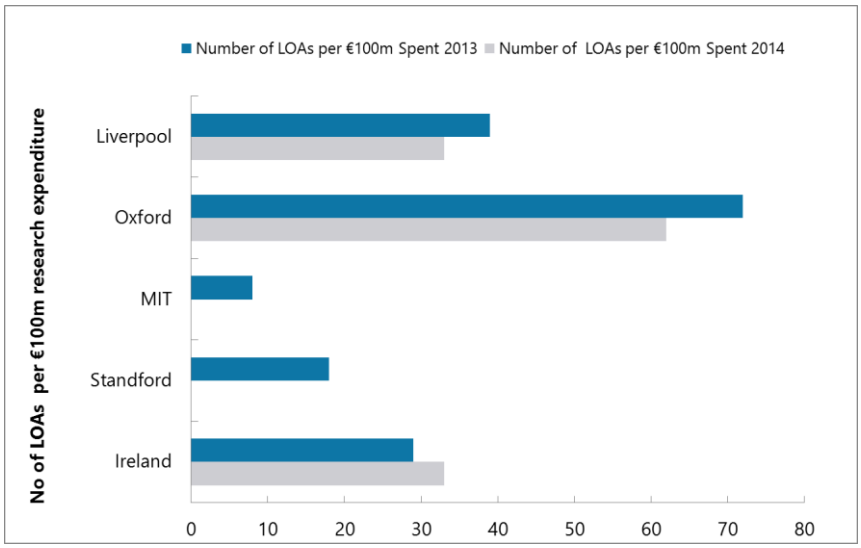
Source: Source: Knowledge Transfer Ireland

As indicated previously, policy in Ireland has focused on achieving commercialisation of knowledge generated from public investments by supporting ease of access to the knowledge by the enterprise base. Consequently revenue generation through licensing from the publicly performing R&D system tends to be lower than in other countries[176]. There has, however, been an increase in aggregate revenue from licensing in 2015 which was over €5.6 million, up three-fold on the 2014 figure of €1.8 million. This differential can be accounted for by a few, very significant deals in the year. The majority of licence income (74%) in 2015 was related to the licensing in the university sector whereas in the previous year it related mainly to the sale of crop and plant varieties by Teagasc. Furthermore, while the realisation of equity is unpredictable, depending on external factors such as the maturity of the spin-out and market forces, three HEIs realised revenue from the sale of spin-out company equity in 2015. The total revenue was over €2.9 million, up on the €1.4 million reported in the previous year.

[175] 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.

[176] Knowledge Transfer Ireland Annual Review and Annual Knowledge Transfer Survey 2015

Figure 67 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[177].



Source: Source: Knowledge Transfer Ireland

38 previous licences from the Irish publicly performing R&D system led to market launches of products or services in 2015. 23 of these (61%) were from six Universities and 11 were from four Institutes of Technology (IoTs). Four products or services were brought to market related to licences from Teagasc[178]. A review of new products and services that came onto the market in 2014 based on licenses from Irish research performing organisations (RPOs)[179] indicated 30 such products were launched. Once IP has been transferred, the RPO may not be aware of the contribution of their IP to the products or services offered by licensees, particularly when the IP leads to improvements in existing products, rather than the development of a completely new product line. Therefore the number returned will be an underestimate of the contribution made by licences from publicly performing R&D system to new launches. The bulk of the products launched in 2014 (90%) were based on licences to Irish companies[180].

Case Study: Dublin Institute of Technology licencing to Bridgestone Global

Dynamet, a breakthrough enabling technology for rubber testing and analysis, was developed by researchers in Dublin Institute of Technology (DIT) Bolton Street between 2011 and 2016 and licensed to Bridgestone by DIT Hothouse, the technology transfer office at DIT.

Dynamet, which stands for 'dynamic multi-axial elastomer testing', uses the bubble inflation

[177] Knowledge Transfer Ireland analysis

[178] Knowledge Transfer Ireland Annual Review and Annual Knowledge Transfer Survey 2015

[179] HEIs and publicly performing research organisations.

[180] Knowledge Transfer Ireland Annual Review and Annual Knowledge Transfer Survey 2015

method to subject elastomer samples to equi-biaxial fatigue loading, allowing rubber samples to be tested whilst being stretched in two directions simultaneously, according to researcher Mark Johnson at DIT's School of Manufacturing and Design Engineering.

After identifying the Dynamet technology as having immediate commercial application, DIT Hothouse worked quickly to protect the intellectual property, develop a commercialisation strategy and launch a direct marketing campaign targeted at companies in the rubber product space.

The technology will allow Bridgestone to perform accelerated usage and testing across its various tyres and industrial rubber products, like conveyor belts and rubber tracks. Dynamet is a platform technology with potential applications extending beyond the rubber industry, enabling DIT Hothouse to license the technology to companies across diverse sectors. "We intend to launch a new marketing campaign in summer 2016 targeted at companies in the medical industry for use of the technology to characterise blood vessels, such as the aorta, in the design of the next generation of stents and vascular implants", said Paul Maguire, Licensing Executive at DIT Hothouse.

Source: Annual Review & Annual Knowledge Transfer Survey 2015, Knowledge Transfer Ireland

Case Study: Avectas

The core technology used within Avectas is based on 8 years of research led by the company founders Dr Michael Maguire and Dr Shirley O'Dea at Maynooth University. This platform technology was licensed to the company when it span out from Maynooth University and has subsequently been further developed within the company.

The first products that Avectas developed were instruments from their electrospinning and electrospraying brand Spraybase®, which can be used for research in many industries including cosmetics, food science, medicine and pharmaceuticals. Spraybase® is a CE marked, customisable benchtop instrument that can be used for electrospraying and electrospinning of a wide range of polymers, proteins, biologics and more. Spraybase® devices can now be found in hundreds of academic and industry research labs around the world.

During 2014, the team expanded their offering by launching products, services and partnership opportunities relating to their proprietary delivery technologies, and has continued to refine these since then. Whilst the Spraybase® equipment enables the custom building of materials which are compatible with the human body, Avectas have now advanced their technology to enable introduction of materials directly into the cells themselves. This offers the potential not just to treat, but to cure some rare and neglected diseases. Avectas is entering phase I clinical trials in man which aim to demonstrate the safety and feasibility of this approach.

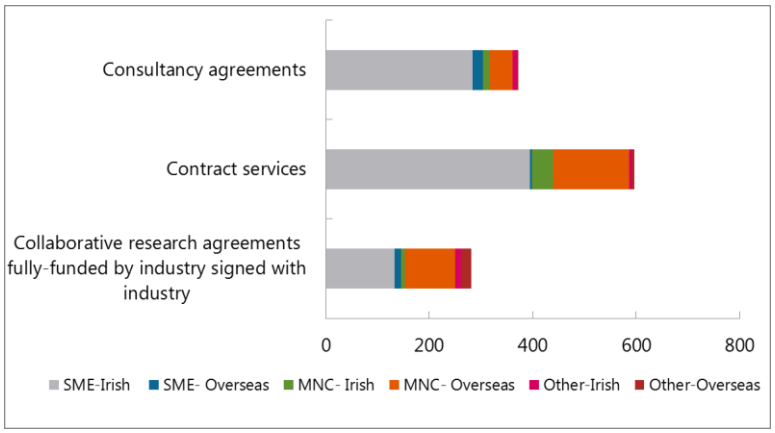
Avectas' business headquarters are still in Maynooth, where they are now the anchor tenant in the new
MaynoothWorks Business Incubator. They have a research team of 18 in Ireland, and also have US offices in Cambridge, Massachusetts. The commercialisation of the technology has been

supported by Irish Government and EU grants, Enterprise Ireland and the EU FP7 Programme, as well as the University by means of patent and spin-out support.
The company benefitted from the sensible business approach taken by the University during the spin-out and technology licensing process. "Our ongoing relationship with the University has helped us in several ways" adds CEO and co-founder, Michael Maguire. "Several of our excellent staff have come from the University talent pool, and our migration into the flexible new facilities in MaynoothWorks is giving us a terrific competitive edge."

Avectas' research is beginning to attract the interest of the pharmaceutical industry, and the Avectas technology is now being tested in the labs of some of the largest pharmaceutical companies. Another example of their success is their recent multi-million euro collaboration and investment from Adapt Pharma which will support the continued development of the technology platform with the aim of advancing therapeutics across a number of disease areas.

Source: A review of the outcomes reported in the Annual Knowledge Transfer Survey 2014, IP Pragmatics, Knowledge Transfer Ireland

Figure 68 Numbers and types of companies that have executed a research contract: fully funded collaborative; contract services; or consultancy agreement with a public research organisation in Ireland in 2015[181].



Source: Knowledge Transfer Ireland

[181] Collaborative research programmes-fully funded (contract research) are where the RPO and company work together on a research project of mutual interest -funding is solely from the company.

Contract services projects are where the company specifies the work to be undertaken by the RPO and pays the costs of the work programme, but not a commercial fee (as is the case for consultancy). They may include projects that involve a "work order". These projects are not considered "research" as the intention is not to create new knowledge but rather to provide a particular solution.

Consultancy involves the RPO providing professional-level work to an external client organisation through an academic, researcher or other member of RPO staff in exchange for a full commercial fee. This work does not require new research activity and publication is not expected.

Furthermore, as can be seen in Figure 68, there are many types of ways other than licencing that enterprise pays to access knowledge generated in the Irish publicly performing research system and many interactions taking place that are fully paid for by industry:

- 282 fully funded collaborative agreements with industry.
- 597 contract services with industry.
- 372 consultancy services agreements.

This indicates the relevance and excellence of the R&D being undertaken and its use in supporting both Irish-owned and foreign-owned enterprises to innovate[182].
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. Spinout HPSUs achieved 18% more turnover than average non-spinout HPSUs: as indicated in Table 11 , the average turnover and value of exports is higher for HPSU spin-outs than for the HPSU population as a whole.

Table 11 Turnover, Exports and Employment for average HPSU Spin-out HPSU non-Spin-out.

Impact	Average HPSU Spin-Out	Average HPSU
Turnover	€877K	€740K
Exports	€435K	€425K
Employment	8 Employees	10 Employees

Source: Enterprise Ireland

B. Regional Enterprise Impacts from Public Investments in R&D in HEIs

All HEIs (Universities and IoTs) have an associated incubator facility in which early stage companies can develop. In addition to space for the company, services offered to the incubated company include advice on IP, networking events and access to professional services. In 2015 there were just over 750 companies based in Campus Incubation Centres and two thirds of those where based in centres outside Dublin.

Based on 115 responses from interviews with 124 companies which located themselves in the State funded incubation centres, it was found that access to the R&D expertise in the HEIs was one of the top three motivators for locating the company in the campus incubator in the HEIs[183]. HEI R&D expertise is thus key to many start-ups and 64% of responding companies reported

[182] It is noted that due to definitional changes around contract service, and collaboration the data from 2015 are not fully comparable across previous years, thus it would be unwise to draw firm conclusions until a more longitudinal dataset can be established.

[183] Evaluation of the Campus Incubation Programme: Report for Enterprise Ireland , Frontline 2014-ammended June 2016

that they had worked with their host institution on R&D: across all companies in the incubation centres €166 million was invested in R&D between 2011 and 2013.

73% of responding companies indicated that the support that they received from the centre had allowed them to innovate in some way, with the most common types of innovation as:

- 71% of companies interviewed had developed new products.
- 45% had developed new processes.
- 44% had developed informal and iterative development and research.

Furthermore, companies within the campus incubation facilities exhibited strong growth. Net turnover increases in firms as a direct result of the campus incubation programme were measured as €310 million over the 2009-2013 period, which represents an increase in turnover of €3.61 for every €1 invested in the campus incubation facilities by EI[184].

Post incubation, 94% of companies in the incubation centres planned to remain in the local area and 80% of past companies surveyed stated they have remained in the area. Thus, it can be concluded that R&D activity in HEIs is a key attractor of companies to locate in campus incubation centres: once there, the companies build R&D linkages with the host HEI, and post incubation the company remains engaged with the HEI on R&D (89% of current incubation companies indicated that they plan to continue their engagement with HEIs post incubation-mainly in R&D) thus increasing the impetus to companies to locate in the region where the HEI is located.

According to the 22 RPOs[185] that returned data the total number of incubator clients at the end of 2015 was 754 (755 in 2014). Nearly 2/3 of these incubation companies are located outside of Dublin, as can be determined from the data which is presented in Appendix 3.

Employment in companies in the campus incubation programme was 2280 FTE in 2015 (up from 1,600 FTE in 2014 (partial reporting)). Thus, the regional spread of these incubation companies will have economic impacts in the areas where the HEI (and incubation centres) are located, with high potential for future firm growth considering the knowledge-based nature of many of these firms.

Analysis of the behaviour of active spin-outs from the publicly performing R&D system also indicates that the spin-outs firms from HEIs tend to stay located near to their founding institution (we note that some percentage of spin-outs are also the campus incubation companies). All but one (99%) of the active spin-outs are still located in Ireland, although a number have subsidiaries operations overseas. 72 of the 97 (74%) active spin-outs were located in the region of their founding institution[186]. Almost 65% of the spin-outs are based in Dublin. Table 12 shows the current location of the active spin-outs from each of the founding RPOs, with the home location for each RPO highlighted by the blue cells.

[184] Evaluation of the Campus Incubation Programme: Report for Enterprise Ireland , Frontline 2014-ammended June 2016

[185] HEIs and publicly performing research organisations.

[186] Knowledge Transfer Ireland Annual Knowledge Transfer Survey Impact Study 2014, IP Pragmatics

So it can be concluded from the evidence that **public investment in the Irish publicly performing R&D system, technology transfer and company incubation infrastructure in HEIs drives enterprise impacts at a regional level through attracting new firms to remain in the areas where HEIs are located**.

Additionally, the **public investment is supporting strong growth in firms that utilise the campus incubation facilities, with an increase in turnover of €3.61 reported for every €1 invested in the campus incubation facilities by EI**.

Table 12 Location in 2015 of the spin-outs that were active in 2014 for each of the founding RPOs, with the home location for each RPO highlighted by the blue cells.

Location/RPO	DCU	DIT	MU	NUIG	TCD	UCC	UCD	UL	WIT	Teagasc	Total
Dublin	4	5	4	1	26	3	17	2		1	63
Cork					1	7		1			9
Galway				6				1			7
Limerick						1		4			5
Waterford									2		2
Maynooth			1								1
Tralee, Co. Kerry								1			1
Ballybrittas, Co. Laois				1							1
Omeath, Co. Louth			1								1
Leixlip, Co. Kildare			1								1
Ballindine, Co. Mayo				1							1
Summerhill Co. Meath							1				1

Source: IP Pragmatics, Survey of Spin-outs 2014

Overall the evidence points to **growing impacts from commercialisation of publicly performed R&D in Ireland** as demonstrated by:

- An annual rate of licencing and spin-out firm creation that is comparable with performance internationally.
- A demand for new knowledge by the existing and start-up enterprise base in Ireland and abroad through mechanisms such as licencing, consultancy, contract R&D and fully funded industry collaborations.
- Impacts through new products and service innovations by firms which are based on licences from Irish RPOs.
- The population of a pipeline of innovative HPSUs in Ireland which achieve higher turnover and employment than HPSUs born outside the publicly performing R&D system.
- Strong growth in firm turnover from firms that utilise the campus incubation facilities.

- Regional enterprise impacts associated level with new firms locating and remaining in the areas where HEIs are located.

4.4 Economic and Enterprise impacts from Public Investment for International Engagement in R&D

4.4.1 Economic and Enterprise Impacts from Public Investment by Ireland in the EU RD&I Funding Programmes

The EU's multi-annual RD&I Funding Programmes represents the main instrument for funding and supporting RD&I at a European Level. The Seventh European Framework Programme (FP7) ran from 2007-2013 and had a budget of €50.5 bn, and the current Programme- Horizon 2020 (H2020) - will run from 2014-2020 with a planned budget of €80 bn. Ireland invests in the European Funding Programmes through three primary avenues:

- Contribution to the overall European Budget: 1.2% budget over the 2007-2013 period, and an estimated 1.2% over the 2014-2020 period[187].
- Supporting a National Contact Point Network.
- Providing National Funding to firms to engage in European funded activity: Eg Eurostars programme is a joint programme between EUREKA and the EU Seventh Framework Programme for Research and Technological Development: SMEs can receive up to 50% of their costs of participating in the project. The 50% funding contribution is made up of both National and EU funds (75% national funding and 25% European Commission funding).

There are a variety of instruments in the European Funding Programme through which research actors in the Irish R&D system can participate, and some of which national funding bodies can also apply to. These include funding of excellent research across a range of thematic areas, funding of human capital, infrastructure funding, funding for collaborations with other public research performers and/or enterprise in Ireland and abroad, and funding in support of commercialisation.

In total, the **drawdown by Irish entities from FP7 was 1.4% of the total FP7 budget at €625 million, exceeding the national target of €600 million (1.2%). This represented a net gain for Ireland based on a contribution of 1.2% towards the EC budget over the period of the FP7 programme**.

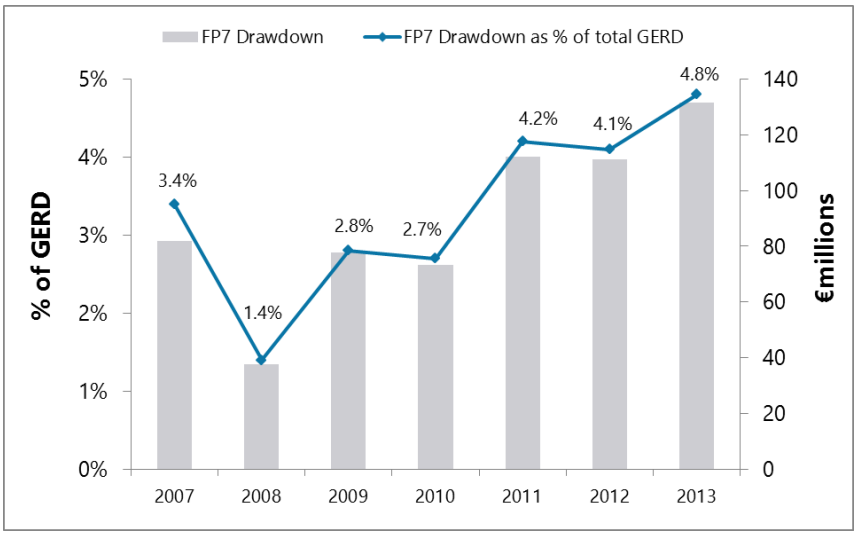
The draw down by Irish-based organisations was €273 million in the first two years of H2020, representing 1.9% of the total allocated budget.

As shown in Figure 69, the FP7 annual drawdown has been equivalent to 1-5% of the total annual gross R&D expenditure (GERD) in Ireland and, as such, it represents a substantial

[187] Based on estimates provided to DJEI by Department of Finance in October 2013 on Irish contributions to EC budgets.

contribution to the total R&D spent in Ireland, thus adding to the R&D activity funded through national funding programmes.

Figure 69 FP7 drawdown and proportion of total GERD expenditure in Ireland.



Source: FP7 Technopolis Evaluation

The total draw down for HEIs in FP7 was €409 million (65% of the total drawdown by Ireland), and was €168 million from the H2020 programme in the first two years of its operation. This funding adds to the level of R&D activity that is undertaken in the HEIs. Based on the funding won to date by HEIs, this equates to an annual average funding of Irish based HEIs of €52.5 million via the European RD&I Funding Programme mechanism.

In a programme of interviews many respondents agreed that EU investment in research represents a very important contribution to the Irish research base[188].

Based on a survey of applicants to FP7 a number of positive links between national R&D and FP7 funding were found. Over 50% of successful applicants from HEIs considered that their ability to win FP7 funding was improved by their earlier involvement in a nationally funded scheme, with 28% of responses from HEI successful applicants indicating that they benefited from national R&D support for their FP7 project.

55 responses in a survey from successful FP7 applicants who did not receive national support for their FP7 projects indicated that HEI applicants engaged in FP7 for a variety of reasons:

- There was no national funding in the research area of the project (42% of respondents).
- That the project was to address a European rather than a national issue (17% of respondents).

[188] Ex-post evaluation of Ireland's Participation in the 7th EU Framework Programme, Technopolis, 2016

- National schemes would not have funded their international partners (31% of respondents).
- No national funding available for the type of activity performed in the project (27% of respondents).
- The projects focus did not align with Ireland's national priority areas (36% of respondents).
- They were not successful in their application for national funding (16% of respondents).

Furthermore, 117 responses in a survey of successful applicants in HEIs indicated that in the absence of FP7 funding 49% of successful applicants would have abandoned the project, while a further 48% indicated that the project would have been undertaken, but at a reduced scale. Overall HEIs expressed the view that national programmes provide a valuable underpinning support for subsequent success within the European RD&I Funding Programme.

Thus, the evidence indicates that **participation in FP7 has signified a sizeable contribution to Ireland's pool of resources available for R&D in HEIs in Ireland, which complements the funding provided through national public R&D funding programmes**.

In terms of firm engagement in the European FP7 programme, 314[189] companies based in Ireland were involved in 617 successful applications in FP7 (2007-2013) and were responsible for winning funding of €164 million in the FP7 Programme. This drawdown was largely dominated by funding won by SMEs: 72% of the drawdown by companies was by SMEs and 19% of the total drawdown for Ireland (of €625 million) from the FP7 fund was by SMEs.

Relative to other countries, Ireland ranked 5th based on the value of the EC contribution won per thousand SMEs operating in each country and 3rd in the specific programme of FP7 'Research for the Benefits of SME' in which it won €36 million in support of R&D activity in Irish-based SMEs .

To date in H2020 there have been 214 successes, equating to €81.9 million. The business engagement has continued to be dominated by Irish-based SMEs with SMEs accounting for 72% of the awarded funding to Irish-based companies by November 2015. Furthermore Irish-based SMEs have proven very successful in the SME Instrument in Horizon 2020: their applicant success rate is currently at 14%, much higher than the average success rate across all countries of 7%.

Agency firms have accounted for 81% of funding to Irish-based firms in H2020 up to November 2015. Of the Irish-owned agency firms, the pre-HPSU and HPSU cohort are particularly engaged: this cohort accounted for over 40% of successful applications by EI client firms by November 2015 and 33% of funding drawn down, at €19 million. This cohort represents 36 unique companies- 40% of all successful EI client participants by November 2015. Thus, it can be

[189] 161 EI companies, 40 IDA companies and 113 non-client companies.

concluded that the Horizon2020 Programme is an important element in the development of the pipeline of the new innovative firms in Ireland.

Evidence indicates however that the **European Funding Programmes complements the funding available at national level for Irish-based companies and provides further stimulation of RD&I in the Irish enterprise base**:

- 69% of firms responding to a survey[190] indicated that the FP7 Programme complemented Ireland's national funding supports.
- 88% of firms responding to a survey indicated that the FP7 Programme offered opportunities for larger sums of funding than was available through national supports.
- 82 % of firms responding to a survey indicated that the FP7 Programme offered opportunities to secure funding in covering more areas of industrial applied research that are not covered by national funding.

Indeed, 96% of successful applicants indicated that they would have abandoned the project (53%) or would have progressed the project at a reduced scale (45%) in the absence of the FP7 funding. Unsuccessful applicants responding to the survey reinforced that this is what had happened in their case.

However, funding support was only one of the motivations driving firms to engage in FP7. Based on the response (from successful and unsuccessful applicants to FP7) of firms in a survey, the most significant drivers reported were:

- Progress Development of Innovations: 61%
- Access to funding: 61%
- Supporting strategic ambitions: 59%
- Enhancing in-house RDI: 57%
- Potential access to specialist skills: 55%

In addition, between 75% and 86% of firms reported: enhancing your research reputation; developing your research skills through collaboration; enhancing visibility in international markets; monitoring wider technological developments; and enhancing technological reputation, as being significant or moderate drivers.

Case Study: Fuseami Ltd.

Fuseami is a good example of a product that was initially development under FP7 support and was further advance by national funding.

[190] Overall 160 firms that had engaged in FP7 responded to a survey: 73 successful and 87 unsuccessful.

In 2009, TSSG (Telecommunications Software & Systems Group) - led by Kevin Doolin- secured funds from the €11M FP7 project 'SOCIETIES', which "dealt with discovering, connecting and organising people, resources and things across physical and digital spaces". The project included 16 partners from 10 countries, including UK, Norway, France, Greece among others. In Ireland, the project included the participation of TSSG but also Lake Communications and Intel.

Based on trials and feedback that took place during the project, TSSG (Mr. Doolin) apply for national funding in Ireland to commercialise 'the most powerful aspects of the SOCIETIES project'. They obtained a €400k grant from Enterprise Ireland Commercialisation Fund programme.

The first product to be developed was the networking app, fuseami (https://fuseami.com/), which allows conference attendees to have a personalised conference agenda and allows people to discover and form communities of like-minded people.

The first phase of this funding was completed in October 2014 and developed the first iteration of the product. The second phase commenced in November 2014, and has run until September 2015.

Following this they have founded Fuseami Ltd and spun the company out of TSSG. They have now secured further EU funding through the Fiware Accelerator. This has allowed them to hire a CEO and 2 key developers.

Source: Kevin Doolin in 'Ex-post evaluation of Ireland's Participation in the 7th EU Framework Programme, Technopolis, 2016'.

Companies that participated in the FP7 programme report that the engagement had a positive impact on turnover, employment and productivity, implying that the positive benefits highlighted -access to international networks and knowledge, increased research and technological capacity, ability to attract and retain research staff, etc. - have materialised in commercial gains. The majority of survey participants from companies state that participation in FP7 has led to positive economic outcomes:

- 73% state a positive impact in terms of increased employment (with 15% indicating that impact has been high).
- 69% state a positive impact in terms of increased turnover (with 16% indicating that impact has been high).
- 64% state a positive impact in terms of increased productivity (with 16% indicating that impact has been high).

Participants also stated that FP7 has had a positive impact in terms of their resilience to the economic crisis, with 26% stating that the impact was high.

Furthermore, statistical analysis indicates that, on average, higher levels of: R&D expenditure; employment; productivity; sales; exports; and export intensity, are a characteristic of firms that win financial public supports via the European R&D Funding Programmes[191].

A long-term (stretched) potential estimate for the economic impact from Irelands drawdown of €625 million in FP7 has been made based on a macroeconomic input-output model[192]. The estimate indicates **the addition of 2,000 jobs per year and an annual contribution of €300 million to GDP stemming from Ireland's FP7 activity, with this annual economic impact being felt for many years after the end of the FP7 programme (2013)**- with a stretched estimate of the FP7 continuing to realise economic impact out to 2028. Thus, **financial public supports for R&D available to firms based in Ireland via the European R&D Funding Programmes will support economic growth in Ireland in the long run**.

4.4.2 Economic and Enterprise Impacts from Public Investment by Ireland by way of Membership Fees to International Research Organisations

Ireland currently subscribes to membership of the following International Research Organisations:

- European Space Agency (ESA)
- European Molecular Biology Laboratory (EMBL)
- European Molecular Biology Conference EMBC/EMBO
- Eureka
- COST

International Research Organisations (IROs) that Ireland is currently a member of are important for HEIs and the enterprise base because they:

- Allow Irish researchers to access large scale research infrastructure/equipment that is beyond our national resources, e.g., ESA.
- Assist international collaboration, networks and partnerships, e.g., ESA, COST, EMBL and EMBC/EMBO.
- Provide training on very advanced equipment and systems (most IRO organisations).
- Involve SMEs in high quality transnational research, e.g., EUREKA.
- Irovide procurement and related business opportunities for Irish companies, e.g., ESA.

From a survey of researchers in HEIs in Ireland it is clear that the majority of them are aware of the services offered by the IROs that are relevant to their field of research and these researchers value the membership of the IROs for supporting networking and internationalisation of their research activities.

[191] Ex-post evaluation of Ireland's Participation in the 7th EU Framework Programme, Technopolis, 2016

[192] Based on a methodology used by the EC in their evaluation of the FP7 across all firms.

Membership to these organisations allows Irish based researchers to access international knowledge and infrastructure without the State needing to invest in the fully loaded costs of developing the same, which would be beyond the national means. Thus, **national public funding in support of R&D in HEIs by way of membership fees to International Research Organisations complements the national public funding provided directly to HEIs.**

In 2014, 95% of the total budget towards IROs in Ireland was accounted for by the total cost of engagement in mandatory and optional programmes of the European Space Agency, which came to €17.3 million. In 2016, Ireland's planned investment in the ESA remains at €17.3 million. Enterprise impacts stemming from Irish membership of the ESA can be more directly measured than enterprise impacts stemming from membership of the other IROs to which Ireland currently subscribes.

In total, 97 companies have benefitted from ESA contracts over the past 10 years and a total of 45 companies have been engaged with ESA over the past 5 years[193]. Almost 80% of the contracts placed in Ireland by ESA in 2015 were with Irish industry, with the remainder being placed with Irish universities, Institutes of technology and Research establishments. Participation from the enterprise base in Ireland is dominated by Irish-owned firms, with the addition of a small number of foreign-owned firms (4) to the industry landscape over the period 2010-2014.

Total employment among the 45 Ireland based companies that are actively involved in the ESA was 1,662 FTEs in 2013. Employment generated directly as a result of ESA activity was 304 in 2013 which represents 18% of employment within these 45 companies. Employment as a result of ESA was projected to grow to 562 in 2015 and over 1,300 in 2020, almost all of which are high value jobs in science and engineering.

Irish companies involved in ESA contracts continue to expand commercial sales with the value of ESA related income (ESA contracts plus ESA-derived sales, i.e. the commercial exploitation of ESA contracts) in Ireland increasing from €43 million in 2013 to over €70 million in 2015 and projected to reach €133 million by 2020 as demonstrated in Figure 70. The €43 million actually estimated for ESA related income for firms in Ireland in 2013 is made up of €29 million in the ESA contracts and €14 million in ESA-derived Sales.

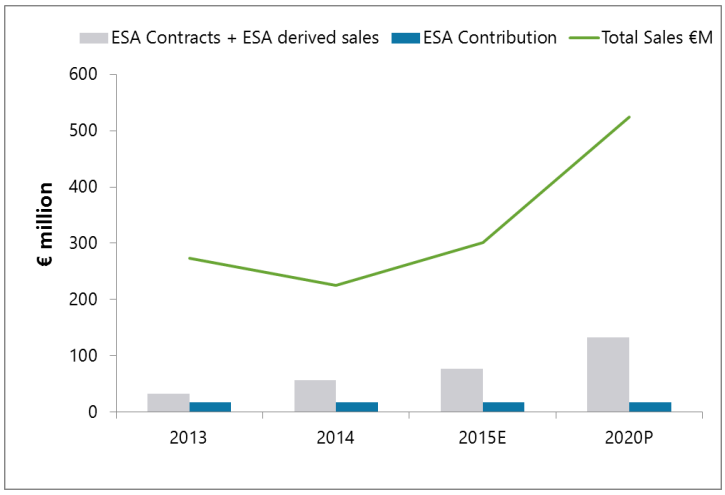
Companies that are involved with ESA have high levels of exports at an average of 74% of all turnover, and based on analysis of the companies currently active in ESA contracts, an estimate of €249 million was made for exports among firms involved with ESA in 2013 with €39 million of these exports corresponding to ESA related income (ESA contracts and derived sales abroad), with an estimate that this will rise to €68 million in 2015.

The cohort of companies in Ireland engaged in ESA contracts is a dynamic and growing community: the number of space companies with ESA contracts doubled in the past 10 years, and is projected to grow further. ESA provides a critical platform for developing IP start-ups as well as extending the technological capabilities of existing businesses in Ireland, especially among Ireland's smaller indigenous firms. The skillsets developed under ESA contracts feed into

[193] Evaluation of Ireland's involvement in the European Space Agency, Technopolis, May 2015

the companies' other commercial activities, supporting sustainable growth in participating companies.

Figure 70 Sales of companies engaged in ESA contracts[194].



Source: Technopolis[195]

Case Study: ÉireComposites

ÉireComposites – ÉireComposites is a design, manufacturing and testing company, involved in lightweight, high-performance, fibre-reinforced composite materials, that serve customers in aerospace, wind energy, marine and automotive sectors. The company started in 2003 after their first ESA proposal received approval in 2002. The company started with about six to seven people. They now have 50 people in Galway with another 15 in a joint venture wind energy company in Germany. ÉireComposites has managed over €15.9m of EU FP6 and FP7 projects relating to composite materials for Aircraft Structures, Space Launchers and Renewable Energy. ÉireComposites has recently been awarded €1.9 million from ESA to produce new lightweight composite technologies for future space launcher and satellite structures.

In an interview with the company, they highlighted that ESA contracts generates a good reputation that in turn allows them to attract the best engineers and provides a positive signal to customers, even if not in a directly related area.

Source: Evaluation of Ireland's involvement in the European Space Agency, Technopolis, May 2015

[194] It is noted that the 2013 ESA contribution is used as a proxy value for each year.

[195] Evaluation of Ireland's involvement in the European Space Agency, Technopolis, May 2015

Case Study: Treemetrics

Treemetrics – TreeMetrics was founded in 2005 and was awarded its first ESA contract in 2011 (ARTES 3-4), under which they developed an innovative system that uses space and ground assets to map forests and monitor tree-harvesting machinery (SATMODO).

Obtaining further ESA funding the company extended the original system for use with forwarder machines as well (the vehicles which collect stacks of partially processed timber in the forest and convey it to the roadside). Under ESA support (SATForM 3D) Treemetrics has also developed a system that uses satellite navigation and Earth Observation data to provide vital insights into the health of forested areas, assisting the owners of forests in identifying the areas most suitable for harvesting.

Treemetrics is already commercialising this technology and the support provided by ESA has already materialised in terms of additional sales, exports and employment in Ireland. The company currently employs 17 people in Cork. The development of these technologies under ESA support, and further commercialisation has translated into steep financial growth for the company as well as an increase in high-value jobs.

Source: Evaluation of Ireland's involvement in the European Space Agency, Technopolis, May 2015

In the absence of Irish membership to the ESA, it was estimated that 40% of the combined turnover of the firms engaged in ESA contracts firms would not arise. This means that in 2013, turnover would have been €164 million for these firms instead of €274 million. It is thus estimated that the total amount of economic value attributable to ESA in 2013 is €110 million.

Based on the consideration that businesses take around 3 years on average for the further commercialisation of the know-how, technology and reputation acquired through ESA contracts, then it was taken to mean that Ireland's investments in ESA in 2010 will be delivering commercial benefits by 2013. It was found that Ireland's €15 million budget (2010) has made a possible €43 million in income, which is a return on the country's public investment of close to 3:1.

Comparing Ireland's ESA budget (2010) with the estimate for total additional economic income of €110 million, a return on investment of around 7:1 is calculated.

With regard to enterprise impacts, membership of EMBL, EMBC and COST are more geared towards realising enterprise impacts through the HEI channel or leveraging European Funding. While Eureka is focused on firm-firm collaboration, the public investment in membership is reasonably low at €33,000 per annum in 2014. EI also provides funding of €1 million per year in support of firm participation in Eureka. However, the uptake by firms based in Ireland has been low at only 60 companies participating in Eureka projects over the past 20 years[196].

It can be concluded that**:**

[196] Review of Irish Membership of International Research Organisations, The CIRCA Group Europe, July 2015

- **National public funding in support of R&D in HEIs by way of membership fees to International Research Organisations complements the national public funding provided directly to HEIs.**
- **National public investment in R&D by way of Irish membership of ESA supports:**
  - **enterprise growth -predominantly in Irish-owned firms-through eligibility to engage in ESA contracts which drive increased company employment, sales, and exports.**
  - **existing Irish-owned firms and start-up high-value adding companies to develop and build R&D capability though eligibility to engage in ESA contracts.**
- **There is a significant economic value attributable to Irish Membership of the ESA and a strong return on investment to the State from public investment in membership of ESA**.

4.5 Summary of Key Findings on the Economic and Enterprise Impacts from Public Investment in R&D

4.5.1 Summary of the Key Messages of the Impacts from National Financial Public Supports Directly to Firms in Ireland for R&D

Overall, the evidence supports the following conclusions that:

- Public investments by way of grant-aid to firms and through the R&D Tax Credit Scheme stimulates firms to undertake R&D in Ireland to a greater extent or more immediately than they would do in the absence of such financial support.
- R&D grant-aid funding to firms to undertake R&D realises positive returns to the State on its investment through additional EVA produced by firms.
- Public investment, by way of R&D grant-aid funding to firms, supports employment growth and greater resilience in employment in both foreign-owned and Irish-owned agency firms and employment in higher value jobs.
- Public investment by way of grant-aid and through the R&D Tax Credit Scheme for R&D engagement by firms is key to the endeavours of the business base to transform their operations towards knowledge-based activities and higher value jobs.
- Public investment by way of grant-aid and through the R&D Tax Credit Scheme for R&D helps to sustain and embed foreign-owned firms in Ireland.

4.5.2 Summary of the Key Messages of the Enterprise Impacts and Behavioural Change in Enterprise from Public investments in R&D in Irish HEIs

The evidence presented supports the following conclusions:

- That public investment in R&D in the Irish HEIs supports the development of:

- the research graduates required by the cohorts of firms in the Irish enterprise base that contribute most to positive sales, exports, value added and employment performance in the Irish economy (R&D active firms).
- knowledge based human capital who gain employment in higher value jobs in Ireland.
- more attractive graduates to the enterprise base:
    - public investment in R&D activity within HEIs in Ireland supports design of cutting-edge course content and higher quality of delivery resulting in the development of graduates with State-of the-Art knowledge.
    - public investment in R&D activity within HEIs in Ireland supports the development of graduates that have an understanding and practical experience of research.

- That public investments towards specific R&D facilities is supporting the training of existing staff and new entrant staff to meet skills requirements of enterprise in emerging sectors for Ireland.
- Public investment in HEI-enterprise R&D collaboration programmes is supporting firms to:
    - access expertise, knowledge and capabilities in support of future business growth.
    - engage in more R&D than they would have done in the absence of the collaboration.
    - develop new and improved goods, processes and services.
- Public investment in HEI-enterprise collaboration programmes supports turnover growth in firms: in the short term a €1 investment in the specific programme reviewed leads to between €5.85-€7.65 return in terms of net turnover impact. In the longer term, this ROI is expected to rise to between €12 and €28 per €1 investment by the State.
- Public investment in HEI-enterprise R&D collaboration programmes are shown to lead to increased employment across firms and increased value added in the economy. In the short term a €1 investment in the specific programme reviewed leads to between €2-€3 return in terms of estimated net value added. In the longer term, this ROI is expected to rise to between €4.5 and €11 per €1 investment by the State.
- Public investment for HEI-enterprise R&D collaborations is feeding a fast growing demand by enterprise to engage with HEIs to undertake R&D activities: for both small scale short time frame projects (innovation vouchers) and for larger scale longer-term R&D projects. This demand is particularly strong amongst agency firms.
- Enterprise collaboration on R&D with HEIs is a characteristic of foreign-owned agency firms that contribute significantly to exports, value added and employment by foreign-owned firms.
- Enterprise collaboration on R&D with HEIs is a characteristic of Irish-owned agency firms that have been increasingly contributing more to total exports, value added and employment by Irish-owned agency firms.

- Firms in the Irish enterprise base benefit from increased international engagement in R&D on the back of networks built through their collaboration activity with the HEIs.
- Commercialisation activities of publicly performed R&D in Ireland are growing and strengthening as demonstrated by:
    - an annual rate of licencing and spin-out firm creation that is comparable with some internationally renowned HEIs.
    - a demand for new knowledge by the existing and start-up enterprise base in Ireland and abroad through mechanisms such as licencing, consultancy, contract R&D and fully funded industry collaborations.
    - impacts through new goods and service innovations by firms which are based on licences from Irish RPOs.
    - the population of a pipeline of innovative HPSUs in Ireland which achieve higher turnover and employment than HPSUs born outside the publicly performing R&D system.
- Public investment in the Irish publicly performing R&D system, technology transfer and company incubation infrastructure in HEIs, drives enterprise impacts at a regional level through attracting new firms to remain in the areas where HEIs are located.
- Public investment in the commercialisation of publicly performed R&D is supporting strong growth in firms that utilise the campus incubation facilities, with an increase in turnover of €3.61 reported for every €1 invested in the campus incubation facilities by EI.

4.5.3 Summary of the Key Messages of the Economic and Enterprise Impacts from Public Investment for International Engagement in RD&I

The evidence presented supports the following conclusions:

- In total, the drawdown by Irish entities from FP7 was 1.4% of the total FP7 budget at €625 million, exceeding the national target of €600 million (1.2%). This represented a net gain for Ireland based on a contribution of 1.2% towards the EC budget over the period of the FP7 programme.
- Participation in FP7 has signified a sizable contribution to Ireland's pool of resources available for R&D in HEIs in Ireland, which complements the funding provided through national public R&D funding programmes.
- European Funding Programmes complements the funding available at national level for Irish-based companies and provides further stimulation of R&D in the Irish enterprise base: in particular SMEs and HPSUs.
- Firms in Ireland that win financial public supports via the European R&D Funding Programmes report that the engagement had a positive impact on turnover, employment and productivity and, on average, higher levels of: R&D expenditure; employment; productivity; sales; exports; and export intensity, is a characteristic of firms that win financial public supports via the European R&D Funding Programmes.

- It is broadly estimated that there will be an addition of 2000 jobs per year and an annual contribution of €300 million to GDP stemming from Irelands FP7 activity, with this annual economic impact being felt for many years after the end of the FP7 programme (2013).
- National public funding in support of R&D in HEIs by way of membership fees to International Research Organisations complements the national public funding provided directly to HEIs.
- National public investment in R&D by way of Irish membership of ESA supports:
    - enterprise growth -predominantly in Irish-owned firms-through eligibility to engage in ESA contracts which drive increased company employment, sales, and exports.
    - existing Irish-owned firms and start-up high-value adding companies to develop and build R&D capability though eligibility to engage in ESA contracts.
- There is a significant economic value attributable to Irish Membership of the ESA and a strong return on investment to the State from public investment in membership of ESA.

Appendix 1: Methodology Employed for Estimates of Wider Economic Impacts by R&D Active Firms

For the purposes of estimating wider economic impacts of R&D active firms, multiplier estimates previously developed by Indecon (2015)[197] were utilised.

In the Indecon (2015) work, wider economic impacts are expressed in terms of Type I and Type II multipliers for employment and GVA.

- Type I or 'indirect' multipliers represent the impacts created through domestically sourced materials and services in production, i.e. sub-supply.
- Type II or 'induced impact' multipliers represent the estimated effects arising through the household expenditure by persons employed directly and indirectly. Type II multipliers should be interpreted with caution, as they assume that all additional income generated through indirect employment is spent in Ireland (as opposed to saved or spent overseas).

Employment and GVA multipliers were derived from CSO Input-Output tables at sectoral level, weighted where relevant and aggregated to form an overall assessment of wider impact of agency firms. Employment multiplier estimates were based on 2013 data and permanent fulltime employment only.

A number of limitations were highlighted in the development of multipliers developed to assess direct and indirect economic impacts of agency firms, and are as follows:

- Type II multipliers (income effects) should be interpreted with caution, as they assume that all additional income generated through indirect employment is spent in Ireland (as opposed to saved or spent overseas).
- The assessment is made using a number of data sources: CSO Input Output Tables 2011, CSO export data, DJEI Annual Employment Survey Data 2013, DJEI Annual Business Survey of Economic Impact 2013. As a number of different sources and years are combined to produce the results, they should be interpreted as estimates only and, although informative, treated as such.
- Furthermore, sectoral multipliers derived through the national input-output tables are applied to agency data. While the multipliers have been weighted to reflect individual agency sectoral structures, the application of national sectoral multipliers may not fully reflect the nature of different agency sectors, particularly any differences that may exist in sourcing behaviour. In particular, EI has highlighted that many individual companies, particularly in the Food sector from its client base could have a very different structure to that of the national input-output tables from which the multipliers are derived.
- Indecon advised that in the absence of the CSO producing specific input-output tables for the agency client base, the national input-output tables remain the primary basis and best proxy for analysis in their 2015 study.[198] Other methodologies have been used elsewhere, for example, in Tourism and the Bio Economy.

[197] Indecon on the Assessment of the Economic Impact of Exports on the Irish Economy, 2015

[198] Note, there is no prescriptive methodology for estimating multiplier impacts at more specific levels than those derived through input-output tables at NACE 2 digit level. For example, see recent Teagasc report on the Bio Economy http://www.teagasc.ie/news/2015/201509-09.asp

- A previous analysis of secondary employment and GVA impact was undertaken by Indecon in 2010 for IDA Ireland and 2011 for Enterprise Ireland. This analysis estimated the employment multiplier for Enterprise Ireland at 2.27 (or 130 indirect jobs for every 100 direct jobs) and 1.72 for IDA Ireland (or 72 jobs supported in the wider economy for every 100 direct jobs).
- This differs from the current analysis, estimating the Enterprise Ireland multiplier to be 1.94 and the IDA multiplier to be 1.86. It should be noted that there was a significant difference in methodology and data sources applied between these studies meaning there can be no direct comparison between the results and certainly no suggestion of trend.

These limitations highlight that, while there is value in understanding the wider economic impacts of R&D active firms, the estimation of secondary impacts is not an exact science. This applies as equally to this analysis as to any previous analysis undertaken for the agencies.

From a methodological perspective DJEI were satisfied that all steps were taken to derive the multipliers for the 'all agency firms' analysis according to best practice, that a standard international approach has been used in their calculation and that the analysis represents a best estimate at the overall and broad sectoral levels within the confines of the data. However, the limitations of applying national sectoral multipliers at a more detailed level to the agency client base were fully recognised.

In estimating the employment and GVA impacts of R&D active agency firms, the sectoral multipliers developed in the Indecon 2015 study were adopted to determine total and indirect employment and value added impacts for R&D active firms (with 10 or more persons engaged). The associated multipliers and impacts are shown in Table A1-1 to A1-4.

Based on direct employment of 184,500 full time employees in R&D active agency firms (with ten or more persons engaged)[199] in the services and manufacturing sectors and a total impact multiplier of 1.91 for R&D active agency firms in 2013, it is estimated that the employment impact of R&D active agency firms was 352,000 full time employees in 2013.

As employment reported in ABSEI relates to full time employees in firms with 10 or more persons engaged, there is an under reporting of total full time employees across the agency firm base. Based on data reported in the Annual Employment Survey (AES), the number of full time employees reported in the ABSEI accounted for 89% of all full time employees in agency firms in Ireland in 2013: with an estimated 33,057 full time employees employed in micro firms.

For Irish-owned agency firms with 10 or more persons engaged, ~ 70 % of employment was in R&D active firms. Given that it is likely that firms with less than 10 persons engaged are predominantly Irish-owned firms and then taking a more conservative proportion of 50% of employment in micro firms being in R&D active micro firms, then an estimate is made of an additional 16,529 in direct employment in R&D active agency firms. An overall estimate for direct employment in R&D active firms is then made at 201,040. Using the 1.91 impact multiplier, a higher bound estimate of total employment impact due to R&D active agency firms is made at 384,000 full time employees in 2013. It

[199] Employment estimates for R&D active firms were extracted from the ABSEI which surveys firms with 10 or more persons engaged.

is acknowledged that utilisation of the 1.91 multiplier is also an approximation in this case as there is no sectoral breakdown data estimates for the micro firms.

Based on the total number of full time employees of 1.453 million in Ireland as reported by the CSO for Quarter 4 2013[200] it is estimated that R&D active firms supported approximately a quarter (between 24% and 26.5%) of full time employees across the economy in Ireland in 2013.

Direct value added stemming from the activity of R&D firms is estimated at €42 bn in 2013. However, when the impact on the domestic economy is also considered, direct added value stemming from the activity of R&D active firms is estimated at €76.1bn. Thus, value added stemming from R&D active agency firms can be estimated as accounting for in the region of 44% of GDP (at constant prices) and 54% of GNP (at constant prices) in 2013.

[200] In Q4 2013, the number of full time employees across all NACE Rev 2 economic sectors was 1.453 million, Quarterly National Household Survey, CSO.ESQ06

Table A1-1 Employment impacts in R&D active agency firms in 2013.

Sector	Direct Impact	Indirect Impact	Induced Impact	Total Impact
Food, Drink & Tobacco	34,298	43,390	9,907	87,595
Chemicals and Pharmaceuticals	18,239	4,922	6,882	30,043
Medical Device Manufacturing	21,665	9,151	9,811	40,627
Computer, Electronic & Optical Products; Electrical Equipment	18,863	3,612	4,036	26,510
Other manufacturing	31,098	9,838	8,147	49,084
Computer Programming	17,855	9,798	7,863	35,516
Computer Consultancy	14,981	8,221	6,598	29,800
Business Services	8,644	2,305	3,264	14,212
Financial services	5,533	4,716	3,152	13,401
Other services	13,335	6,318	5,650	25,302
Total Impact	**184,511**	**102,271**	**65,308**	**352,090**
Overall multiplier	***1.91***			

Table A1-2 Employment multiplier estimates for R&D active agency firms in 2013.

Sector	Direct Impact	Indirect Impact	Induced Impact	Total Impact
Food, Drink & Tobacco	1	1.27	0.29	2.55
Chemicals and Pharmaceuticals	1	0.27	0.38	1.65
Medical Device Manufacturing	1	0.42	0.45	1.88
Computer, Electronic & Optical Products; Electrical Equipment	1	0.19	0.21	1.41
Other manufacturing	1	0.32	0.26	1.58
Computer Programming	1	0.55	0.44	1.99
Computer Consultancy	1	0.55	0.44	1.99
Business Services	1	0.27	0.38	1.64
Financial services	1	0.85	0.57	2.42
Other services	1	0.47	0.42	1.9
Total Impact	**1**	**0.55**	**0.35**	**1.91**
Overall multiplier	***1.91***			

Source: The assessment of the Economic Impact of Exports on the Irish Economy, Indecon,2015 and underpinning technical report.

Note: Analysis based on multipliers as estimated for all agency firms (including firms of less than 10 persons engaged) in 2013.

Table A1-3 Value added impacts in R&D active agency firms in 2013.

Sector	Direct Impact (€ million)	Indirect Impact (€ million)	Induced Impact (€ million)	Total Impact (€ million)
Food, Drink & Tobacco	5,303,608	3,707,447	1,184,424	10,195,479
Chemicals and Pharmaceuticals	11,189,730	837,949	454,239	12,481,918
Medical Device Manufacturing	4,204,146	491,955	604,616	5,300,716
Computer, Electronic & Optical Products; Electrical Equipment	5,498,948	1,209,557	890,650	7,599,155
Other manufacturing	2,590,116	1,278,342	1,119,683	4,988,141
Computer Programming	8,503,246	7,713,099	4,243,986	20,460,331
Computer Consultancy	2,316,195	2,100,743	1,155,913	5,572,851
Business Services	1,074,658	236,838	270,466	1,581,962
Financial services	1,139,814	990,508	475,509	2,605,830
Other services	2,377,451	1,869,452	1,082,400	5,329,303
Total Impact	**44,197,912**	**20,435,889**	**11,481,885**	**76,115,686**
Overall multiplier	***1.72***			

Table A1-4 Value added multiplier estimates for R&D active agency firms in 2013.

Sector	Direct Impact	Indirect Impact	Induced Impact	Total Impact
Food, Drink & Tobacco	1	0.70	0.22	1.92
Chemicals and Pharmaceuticals	1	0.07	0.04	1.12
Medical Device Manufacturing	1	0.12	0.14	1.26
Computer, Electronic & Optical Products; Electrical Equipment	1	0.22	0.16	1.38
Other manufacturing	1	0.49	0.43	1.93
Computer Programming	1	0.91	0.50	2.41
Computer Consultancy	1	0.91	0.50	2.41
Business Services	1	0.22	0.25	1.47
Financial services	1	0.87	0.42	2.29
Other services	1	0.79	0.46	2.24
Total Impact	**1**	**0.46**	**0.26**	**1.72**
Overall multiplier	***1.72***			

Source: The assessment of the Economic Impact of Exports on the Irish Economy, Indecon,2015 and underpinning technical report.

Note: Note: Analysis based on multipliers as estimated for agency firms (with 10 or more persons engaged) in 2013.

Appendix 2: Summary of Economic and Enterprise Impacts Reported by Firms that have Engaged in HEI-enterprise State Funded Collaboration Programmes

Appendix 2 Summary of 5 Enterprise impacts reported by firms that have engaged in HEI-enterprise State funded collaboration programmes, and returns on investment for the State.

Programme and Source of Evidence	Research method	Top business reasons for engagement by firms	Influence on R&D behaviour	New product process services: top ranking	Economic Impact- Research Methodology	Economic Impact Estimates	Return on Public Investment
EI ARE- Frontline Evaluation December 2014	Survey of 55 companies	Access academic knowledge and expertise- 78% Help business to grow- 44%		New Products- 46% Improved products- 43% Informal and iterative R&D- 35% Improved processes- 33% New processes- 26%	Based on company responses to survey. Deadweight, displacement, leakage, substitution, multiplier, and optimism bias, discounting taken into account. Turnover impact converted to EVA impact. **No grossing** up to represent full sample of firms engaged in ARE.	Net Turnover impact experienced 2011-2014: €215m (€166m NPV) Net Turnover Anticipated impact 2011-2017: €487m (€348m NPV) FTE jobs created or safeguarded- 2011-2017 experienced and anticipated 2011- 328 FTE 2012- 418 FTE 2013- 509 FTE 2014- 561 FTE 2015- 588 FTE 2016- 630 FTE 2017- 626 FTE Net EVA experienced 2011-2014: €78m (€60 NPV) Net EVA anticipated impact 2011-2017: €177m (€127m NPV)	Net Turnover impact ROI experienced 2011-2014: ROI of €5.85 for every €1 invested in programme Net Turnover anticipated impact 2011-2017: €12.31 for every €1 invested in programme EVA ROI experienced 2011-2014: ROI of €2.12 for every €1 invested in programme EVA ROI anticipated 2011-2017: €4.47 for every €1 invested in programme

Programme and Source of Evidence	Research method	Top business reasons for engagement by firms	Influence on R&D behaviour	New product process services: top ranking	Economic Impact- Research Methodology	Economic Impact Estimates	Return on Public Investment
EI- Innovation Partnerships: Frontline Evaluation January 2014	Interview survey of 40 companies that participated in IP between 2007-2010	Help business to grow- 56% Access academic knowledge and expertise- 51% Test commercial feasibility of ideas- 39%		· New product to the company (32%) · New product to the market (36%) · Improved products to the company (23% · Improved products to the market (16%) · New processes to the company (39%) · New processes to the market (16%) · New services to the company (19%) · New services to the market (10%)	Based on 40 responses to a survey. Deadweight, displacement, leakage, substitution, multiplier, discounting taken into account. Turnover impact converted to EVA impact: impact estimated for 112 trading companies	Impacts experienced 2007-2012 Net Turnover impact increased 2007-2012: €196.1m (€172.1m NPV) Net Turnover Anticipated impact 2007-2012: €912.3m (€677.8m NPV) Net Jobs 2010-171 2011-300 2012-311 2013-381 2014-602 2015-759 2016-423 2017-470 2018-510 Net EVA experienced 2007-2012: €69.8m (€61.3m NPV) Net EVA anticipated impact 2007-2012: €324m (€241.3m NPV)	Net Turnover impact ROI experienced 2007-2012: ROI of €6.69 for every €1 invested in programme Net Turnover ROI anticipated 2011-2018: €26.35 for every €1 invested in programme EVA ROI experienced 2007-2012: ROI of €2.38 for every €1 invested in programme EVA ROI anticipated 2007-2018: €9.38 for every €1 invested in programme

Programme and Source of Evidence	Research method	Top business reasons for engagement by firms	Influence on R&D behaviour	New product process services: top ranking	Economic Impact- Research Methodology	Economic Impact Estimates
EI- Innovation Vouchers- Frontline Evaluation February 2013	Interviews based on 319 companies that had completed vouchers during 2007-2009: 20% of the completed voucher population	Access academic knowledge and expertise- 52% Help business to grow- 50% Test commercial feasibility of ideas- 41%	Only 11% would have gone ahead anyway without the voucher: the remainder would have abandoned altogether or gone ahead at reduced size and or delayed.	Approx. 70% of companies introduced new or improved product, process or service to company or market	Based on 323 responses to a survey. Deadweight, displacement, leakage substitution, multiplier and optimism bias, discounting taken into account. Turnover impact converted to EVA impact, Grossing up to represent full sample of firms engaged in IV.	Impacts experienced 2007-2011: Net EVA €31.13 million Impacts anticipated: 2007-2017: Net EVA of €113.020 Experienced impact to 2011: 807 FTE jobs Anticipated impact to 2011: 1,602 FTE jobs
EI- Competence Centres/Technology Centres		Seeking Competitive Advantage- 86% Knowledge Benefits- 51% Reputational Benefits- 59%	Only 4% would have gone ahead with the work anyway in the absence of the engagement with HEI: the remainder would have abandoned altogether or gone ahead at reduced size and or delayed.	• New product to the company (85%) • product to the market (82%) • Improved product to the company (3%) • Improved product to the market (3%) • New processes to the company (18%) • New processes to the	Based on 52 responses to a survey. Deadweight, displacement, leakage, substitution, multiplier and optimism bias, discounting taken into account. Turnover impact converted to EVA impact. Response reflects all participants engaged- no need for grossing	Impacts experienced: Net Turnover impact experienced 2010-2015: €69m (NPV) Net Turnover Anticipated impact 2010-2018: €749m (NPV) FTE jobs created 2010-2013- 159 FTE FTE jobs anticipated 2010-2018: 371

				market (15%) • Improved process to the company (33%) • Improved process to the market (11%) • New services to the company (19%) • New services to the market (10%) • Improved services to the company (34%) • Improved services to the market (11%)		Net EVA experienced 2010-2013: €25m (NPV) Net EVA anticipated impact 2010-2018: €267.3m (NPV)

Programme and Source of Evidence	Research method	Top business reasons for engagement by firms	Influence on R&D behaviour	New product process services: top ranking	Economic Impact- Research Methodology	Economic Impact Estimates	Return on Public Investment
SFI- CSETS- Forfas Evaluation 2013	Survey of 46 enterprise participants of CSETs	Opportunity to keep up to date with scientific and technical developments- 95% Access to new ideas- 92% Access to Centre expertise- 90% Opportunities for joint research- 88% Access to intellectual property- 83%	As a result of participation in CSET: 95% of participating firms increased expenditure on R&D	As a result of participation in CSET 95% of participating firms increased employment 23 per cent report further development of CSET technologies; 17 per cent report taking licenses of CSET IP, implementing new processes based on CSET IP and employing CSET researchers; 13 per cent report starting a new business venture conducting a clinical trial or generating new products or services based on			

				CSET IP; and c.46 per cent report the use of CSET outputs in two or more of the categories above and 19 per cent in three or more of the categories. It should of course be noted that absolute numbers are small, 13 per cent and 17 per cent equate to 6 and 8 respondents respectively.			

Programme and Source of Evidence	Research method	Top business reasons for engagement by firms	Influence on R&D behaviour	New product process services: top ranking	Economic Impact- Research Methodology	Economic Impact Estimates	Return on Public Investment
SFI- Strategic Research Clusters- Forfas Evaluation 2014	Survey		The programme has stimulated R&D activities that are additional to those that would have occurred in the absence of the programme. For example, one third of companies surveyed stated that they would not have been able to develop the research or technology at all without SRC support, while 29 per cent reported that they would have developed the research/technology at a later date and on a smaller scale. The survey also suggests that, as a result of the programme participating companies will undertake more R&D in the future than would have been the case				

			without the programme. For example, 90 per cent of businesses reported that they plan to undertake further work to develop outputs of the SRC project. On average, businesses plan to spend approximately €500,000 each of further research and development activities related to the work they carried out with the SRCs.				

Appendix 3: Number of Companies in Campus Incubation Centres According to HEIs in 2015

Table Number of Companies in Campus Incubation Centres according to HEI in 2015.

HEI Location of Incubation Centre	Number of Companies in Campus Incubation Centres: 2015
Dublin City University	31
University College Dublin	36
Trinity College Dublin	10
National College of Art and Design	3
National College of Ireland	16
Royal College of Surgeons in Ireland	
Dublin Institute of Technology	76
Dun Laoghaire IADT	41
Institute of Technology Blanchardstown	50
Number of Companies in Campus Incubation Centres in Dublin: 2015	**263**
Maynooth University	8
NUI Galway	33
University College Cork	17
University of Limerick	27
Athlone Institute of Technology	25
Cork Institute of Technology	67
Dundalk Institute of Technology	23
Galway-Mayo Institute of Technology	33
Institute of Technology Carlow	26
Institute of Technology Sligo	
Institute of Technology Tralee	24
Institute of Technology Tallaght	47
Limerick Institute of Technology	100
Letterkenny Institute of Technology	35
Waterford Institute of Technology	26
Number of Companies in Campus Incubation Centres outside Dublin: 2015	**491**
Total Number of Companies in Campus Incubation Centres: 2015	**754**

Source: Frontline, Survey of Campus Incubation Companies

Appendix 4: Glossary of Terms

Absorptive Capacity	Absorptive capacity is a firm's ability to identify, assimilate, transform, and apply valuable external knowledge.
Advisory Council for Science Technology and Innovation (ACSTI)	
Agency Firm/Client Firm	Agency firms are firms that have received support from one of the enterprise agencies - either ongoing, or at some point in time over the analysis time frame.
Annual Business Survey of Economic Impact (ABSEI)	Survey carried out by DJEI to collect data on economic and R&D activities of agency firms with 10 or more persons engaged.
Annual Employment Survey (AES)	Survey carried out by DJEI to collect data on employment across all agency firms.
Business Expenditure on R&D (BERD)	Expenditure on R&D performed in enterprise.
Central Statistics Office (CSO)	
Community Innovation Survey	Survey carried out by Central Statistics Office to collect data on the innovation activities of firms.
Enterprise Ireland (EI)	
European Space Agency (ESA)	
Full time Equivalent (FTE)	An FTE is the hours worked by one employee on a full-time basis. The concept is used to convert the hours worked by several part-time employees into the equivalent hours worked by full-time employees. One FTE employee corresponds to one full year of work by one person.
Government Expenditure on R&D (GOVERD)	Expenditure on R&D performed in Government Sector - regardless of source of funding.
Gross domestic expenditure on R&D (GERD)	GERD = Public funding of R&D (GBOARD) + Private funding of R&D Alternatively GERD = BERD + HERD + GOVERD
High Growth Firms	The OECD defines a High Growth Firm as: An enterprise with average annualized growth greater than twenty percent per annum, over a three-year period, and with ten or more employees at the beginning of the observation period. Growth is thus measured by the number of employees or by turnover.
Higher Education Authority (HEA)	
Higher Education Expenditure on R&D (HERD)	Expenditure on R&D performed in Higher Education Institutions - regardless of source of

	funding.
Higher Education Institutions (HEIs)	
Imperfect information	Missing/incorrect information.
Institute of Technology (IOT)	
Intangible Asset	An intangible asset is an asset that lacks physical substance (unlike physical assets such as machinery and buildings) and usually is very hard to evaluate. It includes patents, copyrights, franchises, goodwill, trademarks, trade names, the general interpretation also includes software and other intangible computer based assets.
Intellectual Property	Intellectual property (IP) refers to creations of the intellect for which a monopoly is assigned to designated owners by law.[1] Intellectual property rights (IPRs) are the protections granted to the creators of IP, and include trademarks, copyright, patents, industrial design rights, and in some jurisdictions trade secrets.[2] Artistic works including music and literature, as well as discoveries, inventions, words, phrases, symbols, and designs can all be protected as intellectual property.
International Research Organisation (IRO)	
Irish Council for Science Technology and Innovation (ICSTI)	
Irish Research Council (IRC)	
Knowledge Based Capital (KBC)	Knowledge Based Capital (KBC) refers to a range of assets that are based on investment in knowledge, including R&D, software and data, intellectual property, firm specific skills, and organisational know-how.
Knowledge Diffusion	The process by which knowledge spreads-amongst people and organisations.
Knowledge Economy	Knowledge is now recognised as the driver of productivity and economic growth, leading to a new focus on the role of information, technology and learning in economic performance. The term “knowledge-based economy” stems from this fuller recognition of the place of knowledge and technology in modern OECD economies.

Knowledge Exchange System	Knowledge exchange system relates to the mechanisms in place to facilitate and promote exchange of ideas, evidence and expertise knowledge across the various actors in the innovation system- including performers of research, users of research and wider groups and communities.
Knowledge spillover	The benefits from a new technology or idea become available to entities outside of the entity in which it originated.
Knowledge Transfer Ireland (KTI)	
Knowledge Workers	Knowledge workers are workers whose main capital is knowledge.
Licences, Options and Assignments	A licence is an agreement between a RPO and one or more third parties, whereby intellectual property rights are transferred for the purpose of commercialisation. The RPO retains ownership of the intellectual property but permits the licensee to exploit it in accordance with contractual terms and conditions. An option agreement is one in which the RPO grants a potential licensee or assignee a period of exclusivity during which it can decide whether it may wish to take a licence to the intellectual property and negotiate the terms of a licence agreement. The option period may include evaluation of the IP by the potential licensee (including assessing the technology). This is may be called an Option & Evaluation agreement. An assignment is an agreement transferring ownership of intellectual property rights from the RPO to a third party.
Market failure	Underinvestment to what is considered to be the socially optimum.
Multi Factor Productivity/Total Factor Productivity (MFP/TFP)	Growth in output that cannot be attributed to the relative contributions of labour and capital.
National Development Plan (NDP)	
Non-rival	Non-rival means that an output can be simultaneously employed by multiple users without diminishing it's basic usefulness. Thus, the initial cost incurred does not get re-incurred as the latter are combined with other inputs in the production process.

Organisation for Economic Co-operation and Development (OECD)	An intergovernmental economic organisation with 35 member countries, founded to stimulate economic progress and world trade. It is a forum of countries describing themselves as committed to democracy and the market economy, providing a platform to compare policy experiences, seeking answers to common problems, identify good practices and coordinate domestic and international policies of its members.
Programme for Research in Third Level Institutions (PRTLI)	
R&D Tax Credit	25% 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.
Research and development (R&D)	
Research Prioritisation Exercise (RPE)	
Science Foundation Ireland (SFI)	
Strategy for Science Technology and Innovation (SSTI)	
Tangible Assets	Physical assets, such as machinery and buildings.
Technology Transfer Offices (TTOs)	
Value Added/Gross Value Added (GVA)/ Economic Value Added (EVA) /Gross Domestic Product (GDP)	There are three ways of measuring GDP: 1) the output/production method (all value added by each producer) 2) the income method (all income generated) 3) the expenditure method (all spending on final demand) <u>GVA vs GDP</u> Gross value added (GVA) is defined as the value of output less the value of intermediate consumption. GVA focuses attention on the value that a company adds to its bought-in materials and services through its own production and marketing efforts within the company. Gross Domestic Product (GDP) of any nation represents the sum total of gross value added (GVA) (i.e, without discounting for capital consumption or depreciation) in all the sectors of that economy during the said year after adjusting for taxes and subsidies.

	EVA In this study, value added (economic value added – EVA) is measured which is an estimate of value added based on sales revenue minus the expenditure on materials and services.