ECONOMIC EVALUATION OF THE R&D TAX CREDIT

October 2016

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Department of Finance

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Irish Government Economic & Evaluation Service

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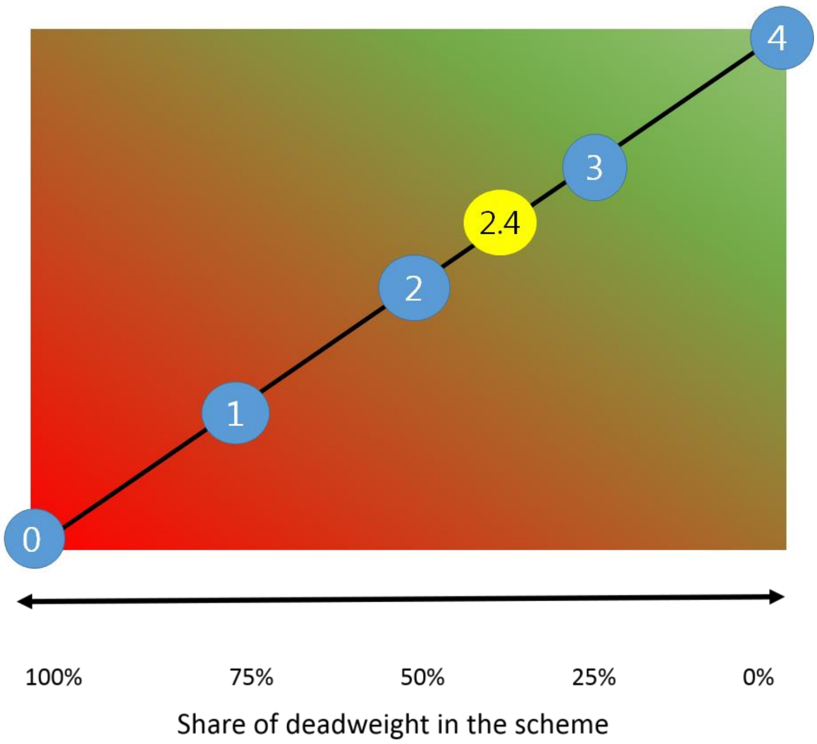
1. Executive Summary

- *This evaluation of the R&D tax credit is part of a series of rolling tax expenditure evaluations that are conducted by the Department in accordance with the Guidelines for Tax Expenditure Evaluation (published in 2014). For large tax expenditures, such as the R&D tax credit, evaluations are performed regularly in order to improve the evidence base underpinning tax policy and to determine if tax relief schemes remain fit for purpose.*
- *Ireland has a 25% tax credit for R&D expenditure which can be set against a firm's corporation tax liability, meaning that for every €4 of R&D conducted, the firm can keep €1 of its corporation tax due. In other words, the Exchequer foregoes €1 of corporation tax revenue.*
- *The primary policy objective behind the tax credit is to increase business R&D in Ireland, as R&D is considered an important factor for increased innovation and productivity (alongside other factors such as openness to trade, the level of competition, infrastructure and human capital). Reflecting these considerations, the Government's Innovation 2020 Strategy aims to achieve the EU 2020 target of increasing overall (i.e. public and private) R&D expenditure in Ireland to 2.5 per cent of GNP by 2020.*
- *More broadly, the R&D tax credit forms part of Ireland's corporation tax "offering" aimed at attracting jobs and investment into Ireland and developing a strong, innovation-driven enterprise sector. These aspects of the R&D tax credit are not the focus of this evaluation.*
- *This paper evaluates whether the tax credit results in additional R&D expenditure by firms, meaning R&D that would not have taken place in the absence of the tax credit. This additionality is calculated using a treatment and control group framework, which is considered to be a more robust form of evaluation than relying on self-assessment by firms.*
- *The review also assesses the value for money of the tax credit to the Irish taxpayer. On this point, we note that the range for the "bang for the buck" (BFTB), i.e. the additional R&D done per euro of tax revenue foregone, can range from 0 to 4 in Ireland's case. There will be firms who would conduct R&D regardless of the existence of the credit, and so they have a BFTB of 0, and there are firms who would only perform R&D in the presence of the credit, and so they have a BFTB of 4 (as the tax credit is 25%).*
- *Our analysis indicates the tax credit achieves reasonable additionality. We estimate that of the R&D conducted by firms since 2009, 60% is additional R&D i.e. the tax credit incentivises firms to perform R&D that would not have occurred in the absence of the tax credit policy.*
- *We find that, on average, the BFTB for the Irish R&D tax credit is 2.4, which is at the higher end of values in the existing literature.*
- *With 60% additionality, this means that deadweight is a noteworthy 40% of observed R&D since 2009. Because the tax credit scheme is a general measure, meaning all firms are entitled to avail of it, our deadweight estimate indicates partial crowding out i.e. firms replacing their own financing with public financing.*
- *Analysis of the firm characteristics of the R&D tax credit show that it is mainly older, larger and non-Irish firms who derive financial benefit from the scheme, although it is typically Irish firms who benefit more from the repayable credit element of the scheme.*
- *The cost of the tax credit reached €553 million in 2014, with outstanding (unused) credits of €592 million in addition to this. Approximately 25% of the unused credits relate to R&D conducted prior to 2009, highlighting the strong legacy costs of this tool. The remaining 75% of unused credits refer to R&D conducted since 2009 and, as they are classified as repayable credits, could take the form of a tax refund to firms in future.*

- *When considering the policy objective of increasing business R&D, it is important to place the tax credit in relation to other policy supports (both financial and non-financial). We note that public financial support for business R&D also comes in the form of direct support (grants from the enterprise development agencies). Whilst this analysis took account of grants in so far as was possible, further work that examined the interactions and overall impact of the range of BERD public financial supports would be of value.*
- *While it is always possible that the R&D tax credit could be better targeted to ensure greater value for money, such an assessment would need to be balanced against competing policy considerations which, again, are not the focus of this evaluation.*
- *We further note that this evaluation does not represent a full cost-benefit analysis, which would have involved evaluation of second order effects (innovation) and third order effects (economic growth and overall welfare). It may be the case that, despite the clear cost to the exchequer and the deadweight, the existence of the scheme generates spill-overs of sufficient magnitude such that this cost is justified. In the case of R&D-innovation, such an analysis is quite demanding in methodological terms, typically involving strong assumptions and subject to notable imprecision and measurement error.*
- *The infographic below summarises our results and places them in the context of the overall tax credit scheme, which could theoretically carry either no deadweight (so 100% additionality) or full deadweight (so 0% additionality). The Irish R&D tax credit demonstrates reasonable additionality, but the deadweight indicates that there may be scope to increase the "bang for buck" without materially damaging business incentives to invest in R&D.*



2. Introduction

This evaluation of the R&D tax credit is part of a series of rolling tax expenditure evaluations that are conducted by the Department, in accordance with its *Guidelines for Tax Expenditure Evaluation* (Department of Finance, 2014). For large tax expenditures, such as the R&D tax credit, reviews are performed regularly in order to improve the evidence base underpinning tax policy and to determine if tax relief schemes remain fit for purpose.

The last time the Department carried out an appraisal of the R&D tax credit was in 2013 when a full policy review was undertaken. This was broader in scope than the current evaluation and involved a public consultation and survey of R&D-performing firms. A number of policy recommendations were brought forward and implemented at that time. That approach is not repeated in this evaluation which focuses on the R&D performance of firms who use the tax credit.

R&D is a key input to innovation, which in turn is a key driver of productivity and long-run economic growth. Stimulating additional R&D through public policy measures is an important component of the Government's *Innovation 2020 Strategy*, which seeks to make Ireland a global innovation leader and to increase public and private investment in research to reach Ireland's intensity target of 2.5% of GNP by 2020, in line with the EU 2020 Strategy. It is of obvious importance to evaluate the public policy measures used to achieve this aim, particularly to ensure their continued relevance and impact, and to examine their cost and relative advantage over other forms of government intervention.

The paper first sets out why R&D is important for economic growth and why government intervention may be warranted. Following this, the current level of business R&D and Government support is reviewed. The previous review of the R&D tax credit recommended greater alignment between the different forms of support for business R&D; with this in mind, care was taken to include information and analysis on R&D grants to enterprises where appropriate in this analysis. A later chapter introduces the methodology we employ, which relies on a treatment and control group framework implemented through difference-in-difference regression analysis. Following this, our results for additionality are outlined, along with discussion on the firm characteristics and dynamics associated with this. A short conclusion ends the paper.

3. Policy objectives – rationale for Government support of R&D

Key Points	*R&D can promote productivity and economic growth, through its effect on innovation. Typically firms underinvest in R&D from a social perspective and so there is a strong rationale for Government support. Public support comes in the form of grants (direct support) or tax incentives (indirect support). It is important that public support results in additional R&D activity, rather than private firms simply replacing in-house financing with public funding.*

3.1. Research and development as a source of economic growth

From the development of modern growth theory, and in particular from the study of the sources of growth, one of the key insights has been that growth per-capita ultimately comes from changes in worker productivity. In the classic exogenous growth model, as presented by Solow (1956), capital accumulation reaches a steady-state and growth in output is ultimately driven by changes in total factor productivity (TFP). Endogenous growth models, such as developed by Romer (1986), are more explicit in their treatment of TFP, as they model the dynamics of TFP, and sources of changes in productivity. Extensions of endogenous growth theory have generally modelled economic growth as dependant on specific types of knowledge accumulation, such as education, training, and scientific research. Aghion and Howitt (1990) model growth through a process of creative destruction, highlighting the importance of innovation in this process. These theoretical macroeconomic approaches indicate that research and development is an important source of growth, in as much as it contributes to ideas and products which affect productivity.

There are no fixed rules on how much R&D should be conducted by Government itself, business enterprises or higher education institutions. But although the optimal allocation by each sector is impossible to ascertain, it remains the case that all three sectors have an important role to play in developing an innovation-based economy. Like most advanced economies, the Irish Government supports R&D by conducting research itself as well as funding basic research in the higher education institutions and through fiscal supports for in-company applied research. However, the focus of this review is exclusively on business R&D (BERD).

Box 1: application of endogenous growth theory to Ireland

An application of endogenous growth theory was conducted as part of Ireland's Stability Programme Update in 2011. Analysis of a simulated R&D subsidy using the QUEST III endogenous growth model developed by the European Commission was carried out. The research considered the macroeconomic effect of an R&D tax credit equal to 0.1% of GDP. In this model, the increase in business expenditure on R&D results in a permanent increase in Irish GDP of 0.22% in the long-run. This long-run impact on the level of GDP was smaller than for other structural reforms simulated by the Commission, e.g., reducing price mark-ups (increasing competitiveness) increases GDP by over three times as much as an R&D tax credit in the long-run, according to their model. As the Commission's model allows for decreasing returns to R&D inputs, the long-run impact is a permanent increase in the level of GDP but not its growth rate.

3.2. Research and development as a public good

While generally agreed that research and development provides an important contribution to economic growth, this in and of itself does not justify public support for R&D. If all benefits of R&D captured by the private firms conducting the research, profit maximisation implies that the level of R&D conducted would be such that the marginal benefit and marginal cost would be equal, and therefore inducing additional R&D would not be of net benefit. However, there is strong consensus in the economic literature which considers the social returns to R&D to be greater than the private returns – see Hall and Van Reenan (2000) for an authoritative survey. This indicates that because firms will maximise private gains, the socially optimal level of R&D will be higher than the level produced by private firms alone. As such, R&D activity creates a positive externality which policymakers may seek to address by encouraging additional R&D activity by firms.

There are a number of reasons why this is the case. Firstly, innovations resulting from research and development are rarely fully excludable, that is, the benefits from a new technology or idea are available to other firms to at least some extent. These are known as knowledge spill-overs. Secondly, because of asymmetric information and uncertainty about the returns to an R&D project, firms may be financially constrained from conducting a higher and more optimal level of research. Because of these market failures, private R&D is likely to be below the optimum level from a societal perspective. For these reasons, most developed economies now use tax incentives or subsidies in order to incentivise additional R&D expenditure by firms.

3.3. Methods of R&D support

Policy makers have a number of tools at their disposal with which to support R&D, whether directly or indirectly. As an alternative to supports to business enterprises or higher education institutions, one option commonly taken is for the government to engage in R&D activity directly. Although falling, government expenditure on R&D (technically known as Government Budget Appropriations or Outlays on R&D, or GBAORD) accounted for over 12% of all R&D expenditure within the EU in 2014 (Eurostat). The share for Ireland was 5%, compared to 8% a decade previously.

In relation to the support of business R&D, which is the focus of this review and considered in greater detail in subsequent chapters, fiscal interventions can take the form of direct or indirect supports. Direct support involves the payment of grants and awards to businesses in order for them to conduct R&D. One reason for the popularity of direct support is the large differences in the risks and return between basic and applied research. While basic research is important for growth and innovation as a whole, often the private returns which can be gained from it are too low to induce firms to undertake such research. Although direct support still makes up the majority of government support provided for R&D (in OECD countries), indirect supports have become increasingly popular. Chiefly these are delivered through tax incentives, whereby a percentage of R&D expenditure can be used to reduce a firm's corporation or payroll taxation liability, with the excess tax credit from R&D sometimes provided as a repayable credit. One of the advantages of tax incentives over direct measures is that they are a market-based intervention, allowing firms to allocate resources in the manner they deem most efficient. They are also relatively easier to administer, and an increase in their size or scope typically involves less new administrative resources than scaling up a grant programme. On the other hand, it is more difficult to target tax supports at particular categories of firms or R&D activity.

3.4. R&D Additionality

Even when the existence of an externality is accepted, such as in the case of research and development, it does not automatically follow that government intervention is the correct policy choice. If government tax incentives or grants merely offset the spending of private firms, who use the public funding not to do additional R&D, but to replace their own expenditure, then the burden of funding is simply transferred from the private to public sector. This problem makes the task of measuring the impact of government R&D incentives of extreme importance.

The analysis of such incentives is usually quantified in terms of the amount of "*additionality*" which an intervention or programme induces. That is, the additional R&D undertaken as a result of a policy incentive *which would not have otherwise been conducted*. It is also important to quantify the *"deadweight*" resulting from a policy, which in this case refers to R&D which would have been conducted regardless of the policy incentive.

If one can sufficiently measure the additionality, then the *"bang for the buck" (BFTB)* may be calculated as the ratio of the additional R&D expenditure created to the cost of the policy measure (in the case of a tax incentive this will be the revenue forgone as a result of the policy). The additionality and the BFTB are two separate concepts, although they are sometimes conflated in the evaluation literature, and both are required for a comprehensive review of public policy.

Ideally, one could conduct randomised controlled trials to determine additionality, with some firms randomly being assigned a tax incentive or other policy support (the treatment group), while others are given no support (the control group). While this method could provide robust results, it is generally neither feasible nor practical in the case of tax incentives, not least given EU State Aid rules. Instead, economists use a number of econometric methods in order to estimate causal relationships in the absence of a controlled experiment. The various approaches which may be used are discussed in detail in Chapter 6.

3.5. Distinguishing R&D additionality from the social return to R&D

Given the strong theoretical and empirical evidence for the existence of externalities related to R&D, it may be tempting to view the quantitative effects of a tax incentive (that is, the amount of R&D additionality), as a measure of the social return in and of itself. However it is important to realise that the motivation for public intervention comes from the *welfare* returns delivered by additional R&D. Therefore, innovation and R&D additionality are not synonymous; nor are productivity and R&D additionality. It may be the case that a policy induces additional R&D with an extremely low or extremely high social rate of return, varying across firms and across individual projects. It is also worth noting that the magnitude of spill-overs generated by publically subsidised R&D may differ from those generated by unsubsidised R&D activity as, for example, firms may choose to prioritise projects with the highest level of private return when using a tax credit. Put another way, even if it can be established that an R&D incentive results in firms doing more R&D, this is a necessary but not sufficient condition for it to be regarded as effective.

To measure the full social return of a policy intervention, one would need to measure both the first order R&D effect mentioned above and the resulting knock-on effects which the intervention gives rise to. A comprehensive cost-benefit analysis involving second order effects, such as the impact of the additional R&D on firm performance, and third order effects, such as the macroeconomic impact on output and welfare, would be required in order to fully capture the effect of a policy. However, such analysis is mired in measurement issues, and most studies confine themselves to measuring additionality or first order effects, i.e. additional R&D expenditure per unit of cost (see Mohnen and

Lokshin (2009) for a recent survey of such evaluations). Studies that do attempt to measure the social rate of return have typically found a high (but imprecise) range (see Hall et al. (2009) for a review of this literature).

The European Commission's Expert Group on R&D Tax Incentives notes that while innovation additionality, productivity additionality and economic growth additionality are all contingent on R&D additionality, it is too difficult to precisely quantify these spill-overs to the extent that they can be used to inform specific policy recommendations. In other words, the range of estimates for the social return to an R&D tax incentive is much too wide to provide a basis for targeted R&D policy decisions (European Commission, 2008). However, this does not preclude a specific policy design recommendation arising from the first order effect (i.e. R&D additionality and its efficiency costs).

3.6. Recent external reviews of Irish R&D policy

Bearing the above discussion in mind, it is important that any instruments which seek to create R&D additionality be as targeted as possible in order to maximise the benefits provided. The European Commission's Research and Innovation Observatory (RIO) publishes annual reports at a country level in order to support better policy making in research and innovation. The 2015 RIO country report for Ireland states that Ireland compares favourably with the EU average in a number of areas, such as publications per thousand of population, and the 10% most cited publications. But the report also identifies a number of weaknesses, such as the low level of public-private co-publications.

Additionally, the report identifies Ireland's fiscal consolidation as having been particularly aggressive in cutting government R&D, and as such Ireland is well below the EU average and the OECD median. As a result of this, Ireland faces many challenges in returning to a trend of sustained public investment in R&D. Given this, it is worth noting that while government activity in R&D has declined in recent years, business R&D, as well as direct and indirect supports or BERD, have expanded dramatically. Ireland's *Innovation 2020 Strategy* contains a commitment to increase public investment in R&D, and to use this to leverage increased business R&D.

The RIO report also makes a number of recommendations, among them increasing the amount of public R&D carried out, improving the R&D share of small and indigenous companies, and encouraging cooperation between educational institutions and private enterprises. The report also recommends that Ireland streamline the many small grant-based schemes currently in operation. This would reduce the complexity firms are faced with when availing of incentives, as well as help with the identification and assessment of overlapping or redundant schemes.

The IMF 2016 Article IV report echoed many of the RIO recommendations. The IMF stressed the need to encourage greater innovation activity by domestic SMEs and to enhance their partnerships with education institutions. The report also recommended greater capital expenditure on R&D by the government.

The 2015 OECD Economic Survey of Ireland warned about declining growth in total factor productivity in Ireland. The Survey highlighted that public support for business R&D has become increasingly skewed toward tax credits and recommended rebalancing innovation support towards direct grants.

4. BERD in Ireland: Composition and Trends

Key Points

Business expenditure on R&D (BERD) has seen a large rise in Ireland between 2003 and 2014, with growth especially strong among Irish firms. Most firms conducting R&D are small and Irish, but total expenditure on R&D is dominated by large, non-Irish firms (although the expenditure share of Irish firms has been increasing moderately over time). Expenditure on R&D is concentrated in the manufacturing and ICT sectors.

Having stagnated during the economic downturn, business expenditure on research and development in Ireland experienced renewed growth from 2011 to 2014 (Figure 1). While BERD grew by 13% over the period, R&D intensity (BERD as a percentage of GDP) has remained stable at 1.1% since 2009, having grown from 0.76% in 2003.[1]

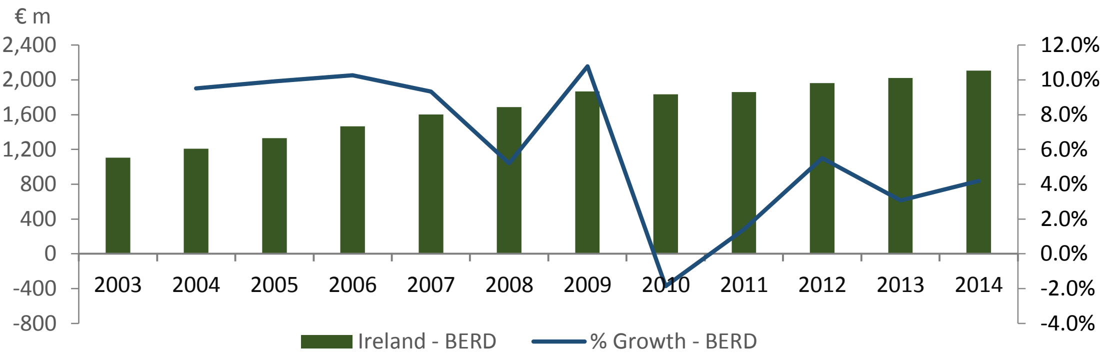


Figure 1: Business expenditure on R&D, millions of Euro, 2003-2014
Source: Eurostat

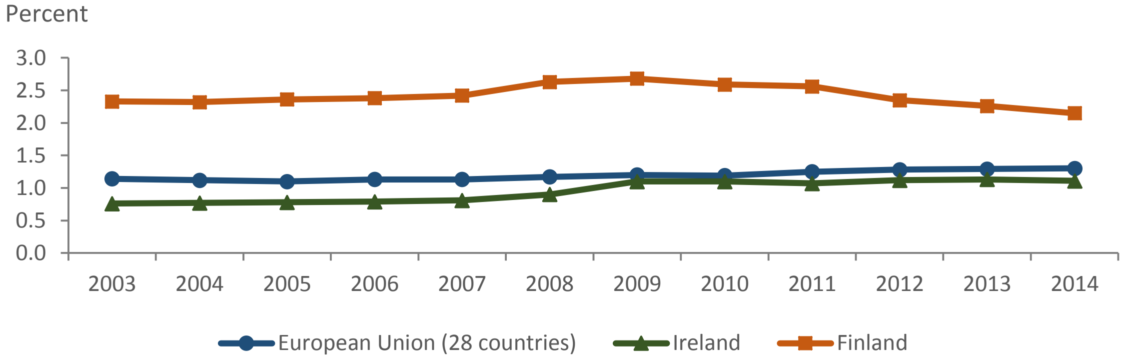


Figure 2: R&D Intensity (BERD as % GDP), 2003-2014
Source: Eurostat

[1] Data in this section rely on the BERD survey, conducted by the CSO on behalf of Eurostat, which is the most authoritative source for estimates of R&D for Ireland. It is a targeted survey which is issued to all enterprises believed to be actively engaged in research and development across all business sectors of the economy. Eurostat statistics on R&D are compiled using guidelines laid out in the Frascati manual, published in 2002 by the OECD.

The EU average also remained stable, with investor uncertainty and financial constraints potentially contributing to this. Likewise, Finland, the EU leader saw a significant decline due to difficulties in its electronics sector (Figure 2). BERD in Ireland is now slightly below both the euro area and EU-28 average level, and among the high income Western European economies it is at the middle to lower end of the distribution. (Figure 3). As mentioned in the Introduction, the policy goal set out in the Government's *Innovation 2020 Strategy* is to increase overall R&D expenditures to 2.5% of GNP (which is roughly 2.0% of GDP). As a whole, the EU aims to increase overall R&D to 3% of GDP as part of the Europe 2020 targets.

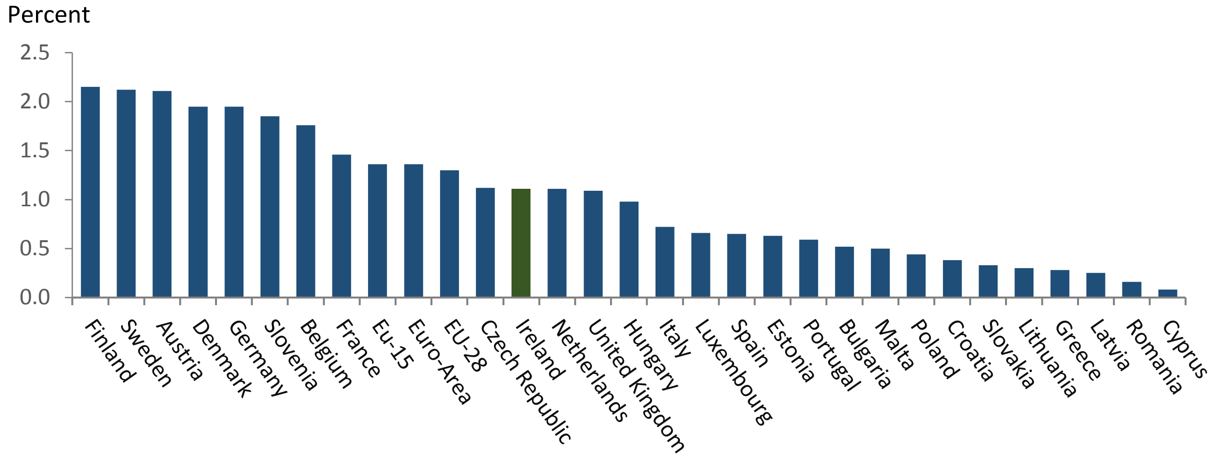


Figure 3: Business expenditure on R&D as a percentage of GDP, European Union, 2014
Source: Eurostat

Having remained relatively constant since 2007, the share of BERD in Ireland attributable to Irish firms has grown considerably since 2011, now accounting for 36% of total R&D expenditure by firms. This is largely a reflection of the composition of firms undertaking R&D, of which 80% were Irish in 2013, up from 75% in 2012 (Figures 4 and 5).

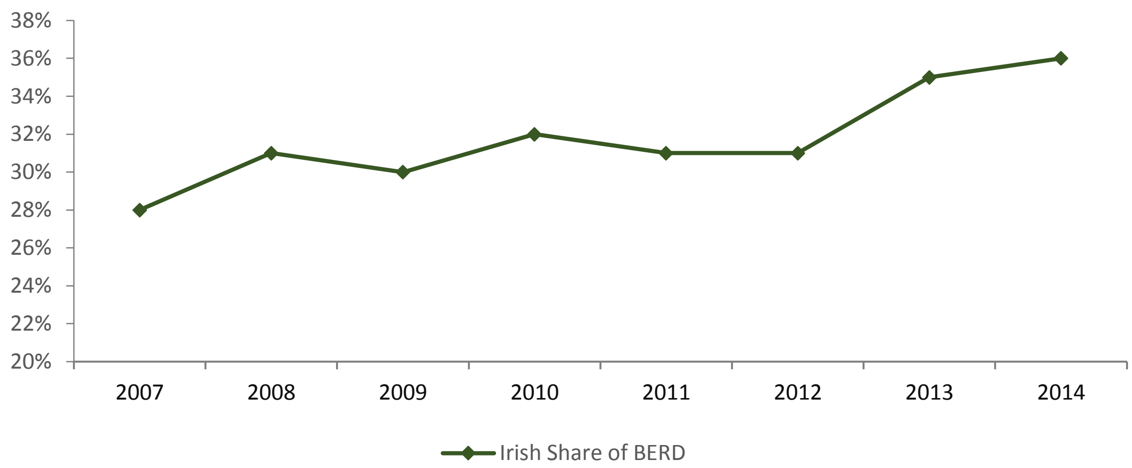


Figure 4: Share of BERD by Irish firms 2007-2014
Source: CSO

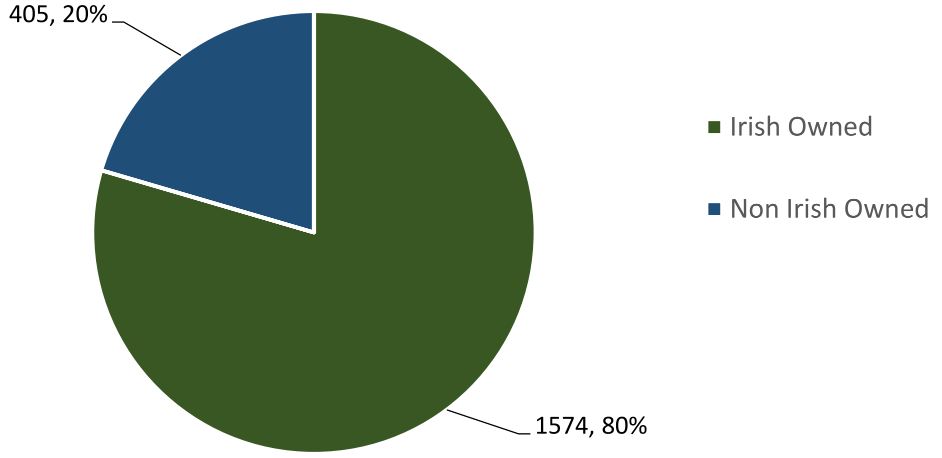


Figure 5: Distribution of number of firms active in R&D, Irish and non-Irish 2013
Source: CSO

As of 2013, roughly two-fifths of business R&D expenditure is in the manufacturing sector while the remainder comes from the services sector (Figure 6). At 32%, 'Information and communication services' remains the largest source of spending within the services sector, followed by 'Professional, scientific, and technical activities' and 'Wholesale, retail, and storage', at 15% and 6% respectively.

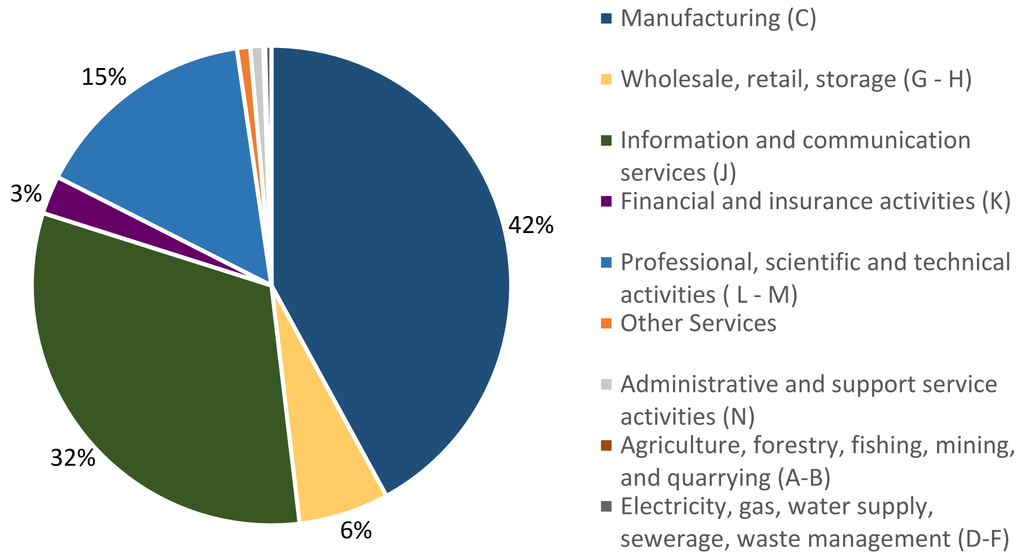


Figure 6: Business Expenditure on R&D, sectoral distribution, 2013
Source: CSO

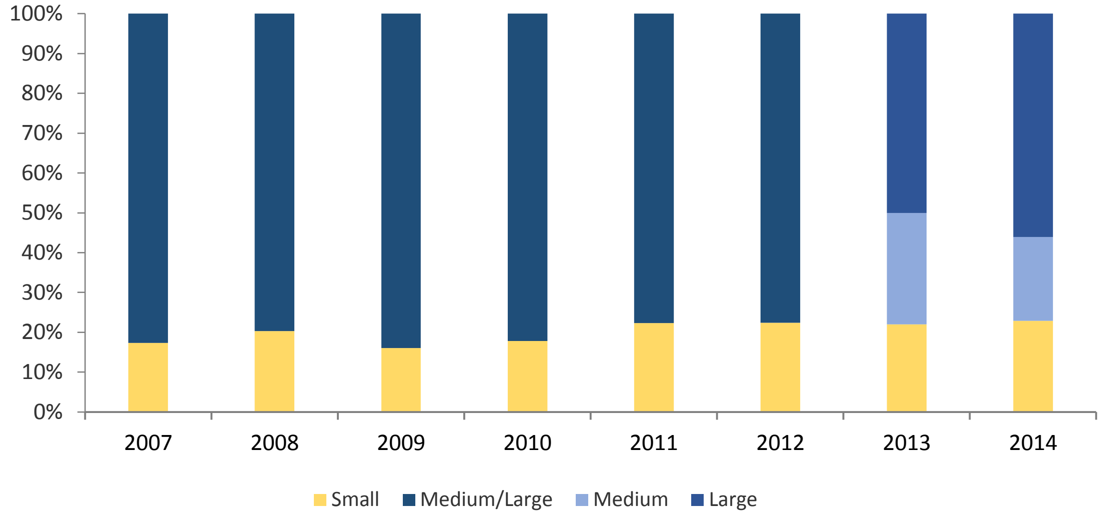


Figure 7: Share of R&D expenditure by firm size, 2007-2014
Source: CSO

Small firms accounted for 23% of BERD in 2014, however as of 2013 they account for 74% of the number of firms engaged in R&D (Figure 7 and 8).[2] The breakdown of large and medium company expenditures on R&D is roughly two to one in 2013 and 2014 (Figure 7). In 2014 large firms were responsible for 56% of R&D expenditure, while making up 7% of the total firms engaged in R&D (Figure 7 and 8). Meanwhile medium-sized firms accounted for 21% of R&D expenditure and 19% of firms engaged in R&D.

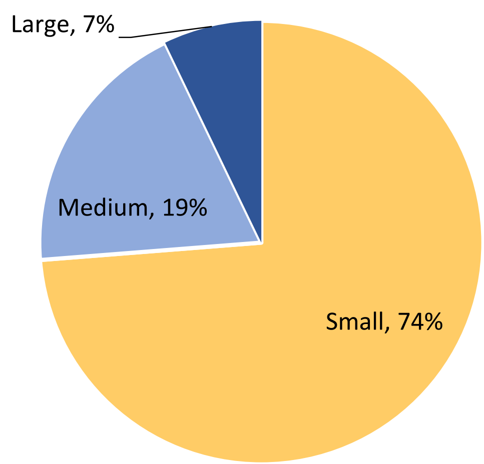


Figure 8: Enterprises engaged in R&D, size distribution, 2013
Source: CSO

[2] The European Union defines small firms as those firms employing less than 50 people, medium firms as those employing greater than 49 and less than 250 people, and large firms as employing more than 249 people.

5. Government support for BERD in Ireland

Key Points

Compared to the OECD average, Ireland provides a relatively high amount of public support for BERD, and this is dominated by the R&D tax credit. The exchequer cost of the tax credit has risen substantially over time due to increased claims and the introduction of a repayable credit in 2009. Older, larger and non-Irish firms account for the majority of the cost. R&D grants to firms have also risen over time, albeit less steeply than the credit, and are concentrated in manufacturing and ICT.

In keeping with the evaluation framework set out in the Department's *Tax Expenditure Guidelines*, in undertaking evaluations of R&D supports, it is not sufficient to focus solely on whether policy objectives in terms such as R&D growth have been met. The evaluation must also consider the costs of the tax expenditure, and determine whether the revenue forgone is being used to achieve the policy's stated objectives in an efficient manner. Efficiency in a policy evaluation context means that the policy provides value for money, a judgement which can be informed by comparing the unit costs of alternative policies which pursue the same outcomes.[3]

Within the OECD, Ireland provides a relatively high amount of public support for research and development carried out by businesses (Figure 9). Where public support is relatively low, the majority of it is provided directly. The majority of Ireland's support is delivered through indirect means i.e. the tax credit. Among the countries providing a higher level of public support to R&D than Ireland (when expressed as a percentage of GDP), only three provide the majority of this indirectly. While Figure 9 provides insight into Ireland's standing relative to other OECD economies, it should be noted that there are many factors contributing to the effectiveness of such supports, including their design and general macroeconomic framework conditions such as the level of competition and openness to trade.

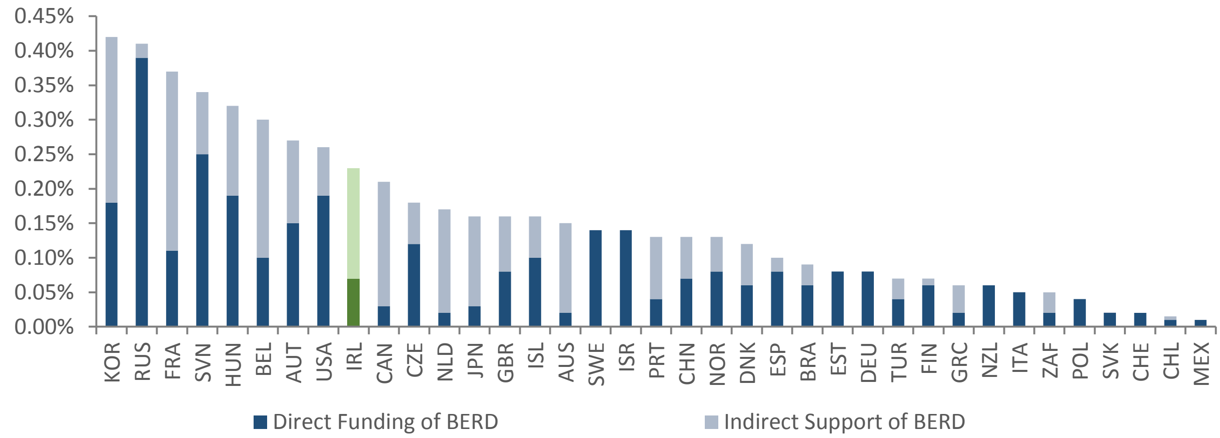


Figure 9: Government Support for Research and Development, % of GDP, 2013
Source: OECD
Note: OECD takes Irish data from 2012

[3] Efficiency also has an economic meaning – that resources are being used optimally – and this is also an important component of the evaluation. If, for example, resources (R&D tax credits) were found to have little bearing on outcomes (the economic benefits of additional R&D expenditure), then that would represent an inefficient outcome and resources should be reallocated.

It is also worth contrasting Figure 9 with Figure 3. It is not the case that the more public support a country provides, the greater the R&D expenditure conducted by private firms. Finland and Germany, for example, provide relatively low levels of public support for R&D (and almost exclusively through grants), yet are two of the best performers in terms of BERD in the OECD. This implies there are other factors to consider in relation to BERD growth besides direct and indirect supports.

5.1. Indirect support

Ireland introduced an R&D tax credit in Finance Act 2004. Initially the scheme employed an incremental system, with incremental R&D expenditure since the base year of 2003 eligible for the credit. However, over 2012 to 2015, the scheme evolved into a full-volume scheme, meaning that all R&D expenditure is currently eligible for the credit.[4] While a full-volume scheme is less costly to administer, it gives rise to inefficiencies as it supports pre-existing R&D which would have taken place even in the absence of R&D tax credits. The other main change to the tax credit occurred in 2009, when the credit became repayable, meaning firms could request a refund if their R&D claim was greater than their tax liability (which can be nil or positive). This was designed to enhance the scheme's attractiveness to the enterprise sector, and could be considered particularly beneficial to firms in the business start-up phase.[5] The primary objective of the tax credit is to incentivise additional BERD. The credit is available to all firms, within the charge to Irish tax, that undertake R&D activities in the European Economic Area.

5.1.1. Credit claims over time

The majority of BERD support in Ireland is provided indirectly through tax incentives. The scheme has been very popular with the enterprise sector in Ireland. Since the introduction of the R&D tax credit, the number of claims has increased rapidly, with more than a tenfold rise from 2004 to 2014 (Figure 10). Most of this expansion in uptake happened between 2008 and 2012, with the number of claims having stabilised since then, likely due to the fact that the majority of firms engaging in R&D are now claiming the credit.

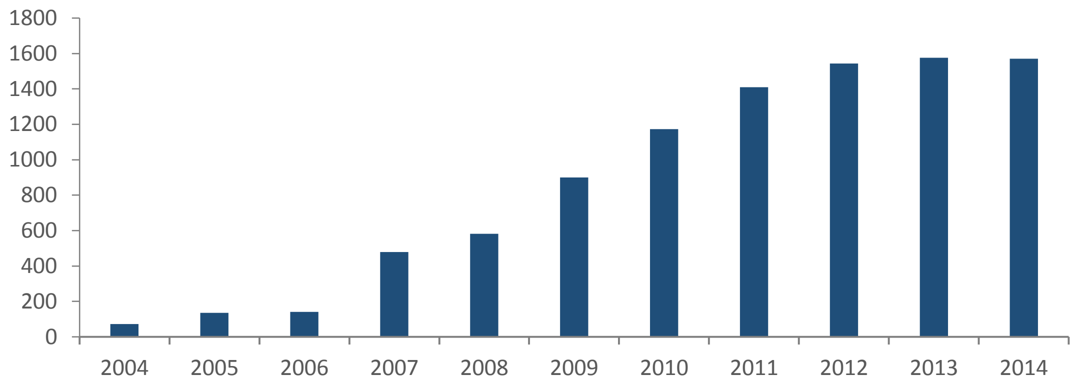


Figure 10: Total number of R&D tax credit claims, 2004-2014
Source: Revenue Commissioners and CSO

[4] Qualifying expenditure is defined with reference to the Frascati Manual, the OECD's statistical manual on R&D. Since the credit was introduced in 2004, Revenue have modified their interpretation of what constitutes R&D. Since 2015, Revenue's interpretation is narrower than that outlined in the Frascati Manual but over the period under review in this evaluation (2007-2014) it was more in line with the OECD definition. Revenue regularly publish and update guidelines to assist firms in determining their qualifying expenditure.

[5] The accounting treatment of the repayable credit as 'above the line' also improved financial indicators for firms, such as their EBITA (Earnings before interest, tax and amortization), which are of interest to potential investors.

The exchequer cost of the tax credit is equivalent to 12% of all corporation tax receipts in 2014, costing €553 million (Figure 11). While corporation tax receipts increased by 32% from 2011 to 2014, the cost of the R&D tax credit has almost doubled over the same period. Most of the rise in the proportion observed in Figure 11 has been driven by the rising cost of the tax credit, although falling corporation tax receipts during the recession also contributed to the rise.

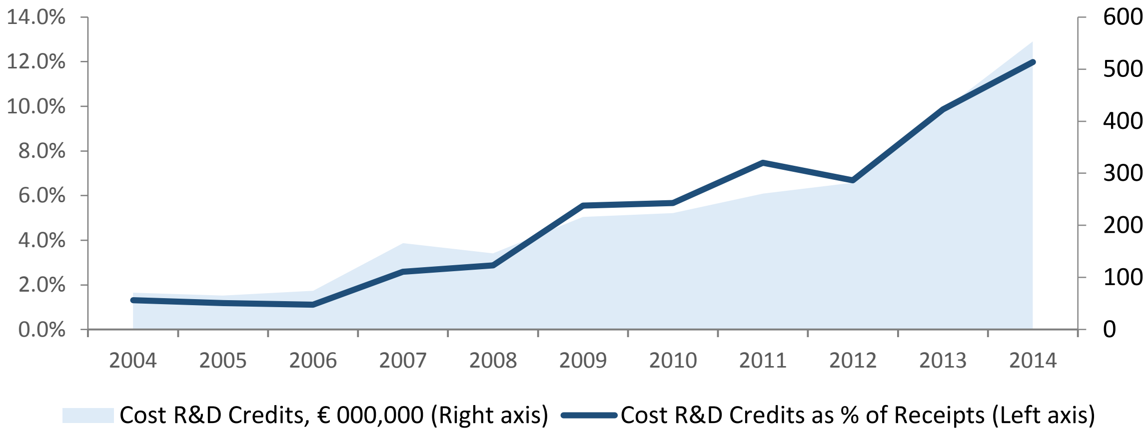


Figure 11: Cost of R&D Tax Credit in millions of Euro, and as a percentage of Corporation Tax Receipts, 2004-2014
Source: Revenue Commissioners and CSO

The exchequer cost of the tax credit has two main components: foregone tax revenues from a firm making a claim against their positive tax liability and firms receiving a repayable credit when their claim is greater than their tax liability (which can be nil or positive). The repayable credit has increasingly become a larger proportion of the total cost (Table 1 and Figure 13). There are no usage restrictions placed on the repayable tax credit, meaning that an unprofitable firm can benefit from the scheme indefinitely. In fact, there are 159 firms who received a repayable credit every year between 2009 and 2014. Of this cohort of firms, 97% are Irish, and 75% have less than 50 employees. These firms also account for 63% of all repayable credits arising between 2009 and 2014.

Table 1: The cost of the R&D tax credit since 2009

		Of which (Millions €):		
Year	**Exchequer Cost (Millions €)**	**Offset against current year tax liability**	**Offset against previous year tax liability**	**Repayable credit**
2009	216	153	30	33
2010	224	142	16	65
2011	261	152	3	106
2012	282	142	4	137
2013	421	182	4	236
2014	553	227	1	326

Source: Revenue Commissioners

As a proportion of the exchequer cost of R&D tax credit support, the repayable credit has risen from 15% to 60% from 2009 to 2014 (Figure 13). While the portion of the exchequer cost that is attributable to reduced corporation tax liabilities has grown 29% (this growth refers to the amount of foregone revenue due to the credit reducing a positive tax liability), the repayable credit is now ten times larger in 2014 than in the year of its introduction (Figure 12).[6] This is a notable development, given the improvement in the Irish economy generally and profit levels particularly since 2009.

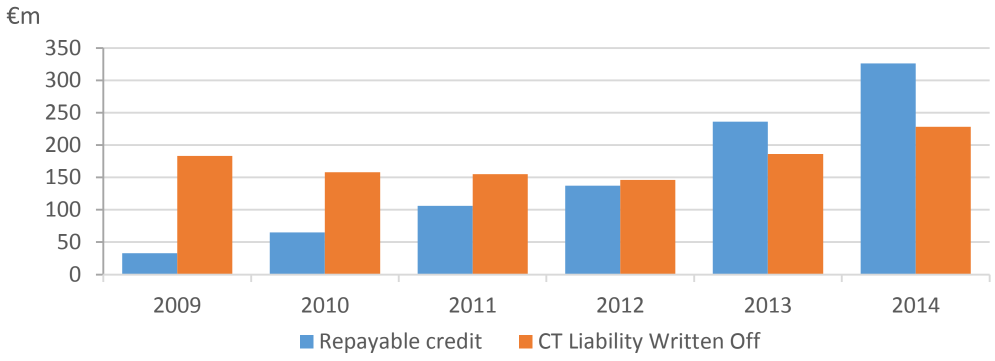


Figure 12: Components of the total exchequer cost
Source: Revenue Commissioners

The cost of the repayable credit is determined by two factors: the amount of R&D performed and the tax liability of firms. Due to the fact that the credit and repayable credit apply at a rate of 25%, the repayable credit element of the scheme will be more sensitive to changes in the tax liabilities of firms, which are driven by profit performance, than to changes in firms' R&D expenditure.

In addition to the immediate exchequer cost of the R&D tax credit, one must also account for the costs already incurred which will be paid out in future years, which consist of tax credits carried forward by firms, and future repayable credit payments built up. As of end-2014, the outstanding credits have reached €592 million. This represents historical R&D activity that the Exchequer must pay for in future (unless firms wind up prior to generating a tax liability). Approximately three-quarters of this amount has built up since 2009 (€439 million). This latter amount could be repaid to the firm rather than offset against tax, which is the only option for outstanding credits generated before 2009.[7] The fact that one-quarter of the outstanding credits relate to R&D conducted before 2009 highlight the substantial legacy costs associated with this policy tool.

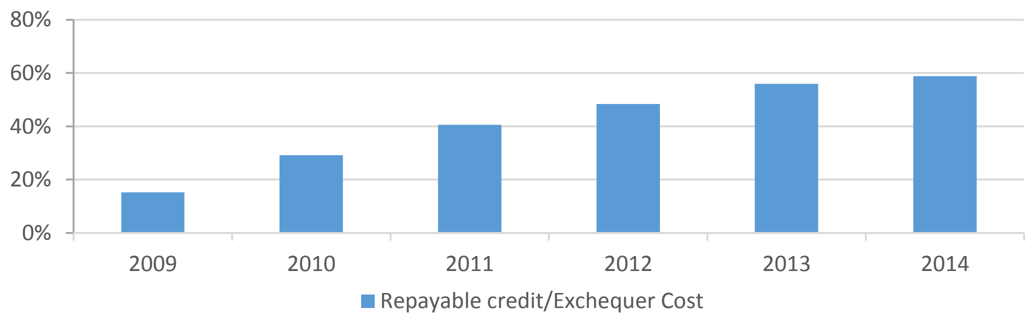


Figure 13: Repayable credit as a % of total exchequer cost
Source: Revenue Commissioners

[6] Strong growth in the second and third year of the scheme are to be expected, given the structure of the repayable credit (payments over three years). Assuming, for argument's sake, no R&D in subsequent years, we would expect to see growth in the repayable credit of 100% in year two and 50% in year three of the scheme.
[7] All figures quoted here assume firms have input their claims on their corporation tax returns correctly.

5.1.2. Firm characteristics

Although the headline numbers on the tax credit are important to understand the level and trends of public support for business R&D, firm characteristics provide additional insight and are particularly relevant in assessing the efficiency of the tool. 68% of R&D claims in 2014 came from firms with less than €1 million in net income.[8] However, a sizable minority (18%) of firms making claims had net incomes between €1 and €5 million. Also notable are the number of firms with negative or no income making claims, which make up 14% of claims in 2014 (Figure 14).

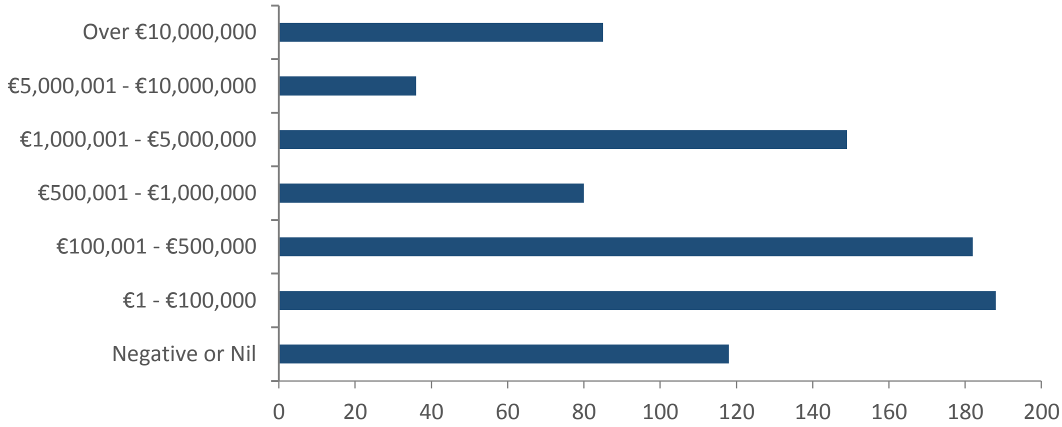


Figure 14 Number of R&D Credit tax cases by net income (claimed in current tax year), 2014
Source: Revenue Commissioners

As mentioned above, the exchequer cost of the tax credit has two main components: foregone tax revenues from a firm making a claim against their positive tax liability and firms receiving a repayable credit when their claim is greater than their tax liability. In terms of firm ownership, non-Irish firms typically account for the majority of the total exchequer cost; given they perform the majority of R&D in Ireland, this is unsurprising.[9] Irish firms typically account for the majority of the repayable credit cost (Figure 15). 2013 and 2014 were atypical years, however; in 2014, 31% of the repayable credit was paid to Irish firms, while the remaining 69% went to non-Irish firms.

For both the total exchequer cost and the repayable credit, recipients tend to be larger, and older, than other firms. In 2014, 76% of the repayable credit was paid to firms with more than 250 employees (Figure 16), while 77% was paid to firms older than 16 years (Figure 17).[10]

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[8] This only includes claims made against income in that year, and does not include credits claimed against previous years, or previous claims carried forward, and as such, the number of claims made, 838, is smaller than the total claims made in 2014 against all income (1,570). Net income is a Revenue Commissioners' definition meaning trading profits from a company's accounts, plus expenses not allowable for tax, minus tax depreciation. It provides a sense of how profitable a firm is.

[9] Non-Irish ownership is not directly observable from Revenue records. However, a marker has been developed by Revenue to identify non-Irish owned entities where information is available. Due to the availability of new information, this marker is more comprehensive from 2014 onwards. Therefore it is the 2014 designation that is relied on throughout this analysis.

[10] Note the definition of age refers to the date a company registers with Revenue and not the date of incorporation.

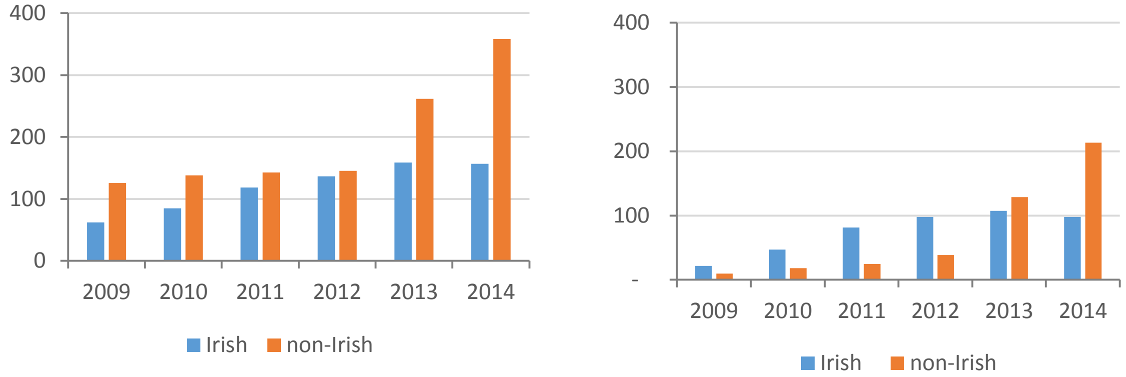

Figure 15: Exchequer costs (left) and repayable credit payments (right) by ownership (€ Millions)
Source: Revenue Commissioners

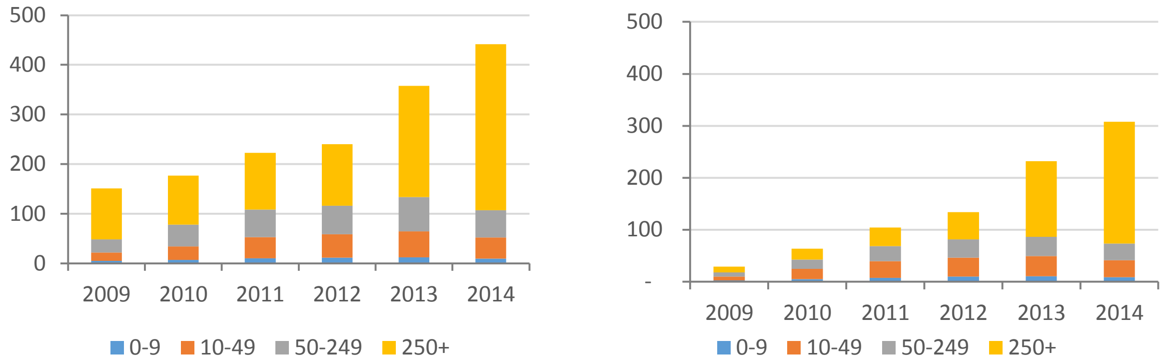

Figure 16: Exchequer costs (left) and repayable credit payments (right) by firm size (€ Millions)
Source: Revenue Commissioners

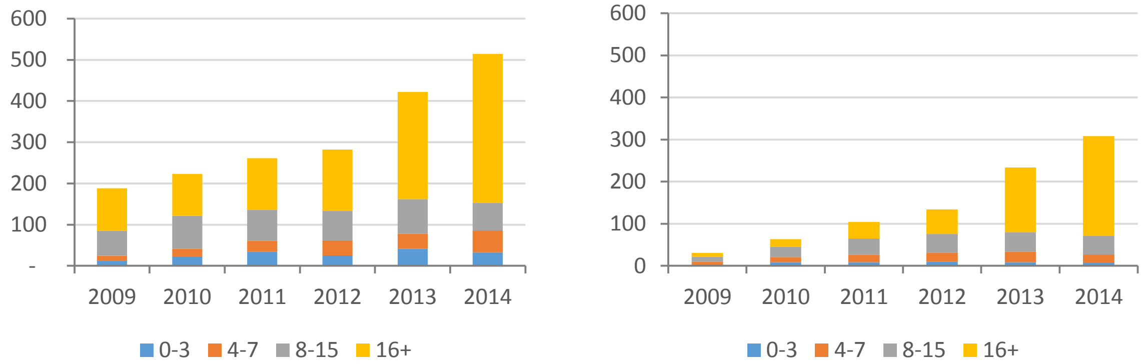

Figure 17: Exchequer costs (left) and repayable credit payments (right) by firm age (€ Millions)
Source: Revenue Commissioners

5.2. Direct support

In addition to the R&D tax credit, grants for R&D are also provided to Irish and non-Irish firms through Enterprise Ireland and the IDA respectively.[11] Although the total amount provided in grants has risen 42% since 2007, it has fallen 20% from its 2010 peak, and has fallen as a share of total R&D support (over 2007-2014) from about half to less than 20% due to the large increase in the repayable tax credit.

Table 2: Grant Support for R&D

Year	R&D Grants to Irish Firms (Millions €)	R&D Grants to non-Irish Firms (Millions €)	Total (Millions €)
2007	33	36	69
2008	48	39	87
2009	64	55	119
2010	59	63	122
2011	50	58	108
2012	52	44	96
2013	55	59	114
2014	52	46	98

Source: Enterprise Ireland and IDA

Note: R&D grants to Irish firms exclude Innovation Vouchers

From 2007-2014, direct support for R&D rose from €70 million to over €120 million in 2010, although it has now fallen to just under €100 million in 2014 (see Table 2). In expenditure terms, the share of grants between Irish and non-Irish firms has been evenly split over the period, with Irish firms receiving 53% of grant expenditure in 2014.

While in terms of expenditure Irish and non-Irish firms receive similar amounts, Irish firms make up the vast majority of grants awarded (Figure 18). This is largely because of the difference in the distribution of firm sizes. Non-Irish firms tend to be larger, fewer in number, and therefore receive larger grants on average, while being a minority of the grants awarded.

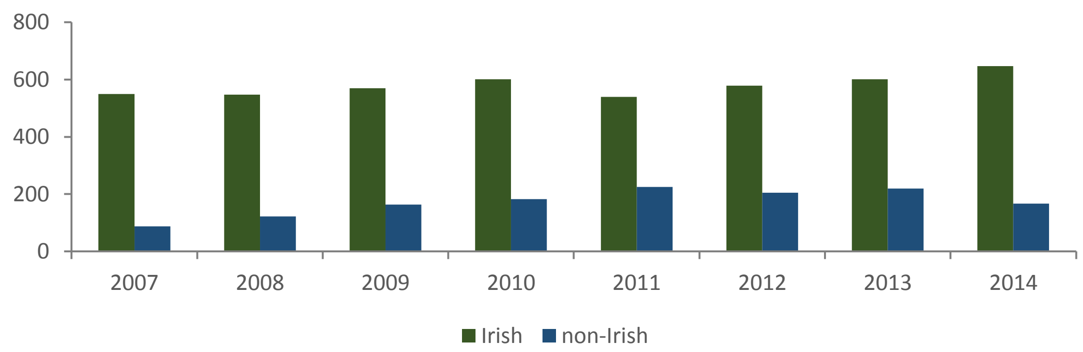

Figure 18: Number of R&D grants paid to Irish and Non-Irish firms, 2007-2014

Source: Enterprise Ireland and IDA

At an industry level, total grant payments are dominated by Manufacturing and Information and Communication, which accounted for 46% and 40% respectively. Professional, Scientific, and Technical

[11] The definition of R&D used by the enterprise agencies is in line with the Frascati Manual.

Activities also received a sizable proportion of grant payments, at 6.1%, while all other sectors received a combined 4.5%. While the overall level of support for Irish and non-Irish firms is reasonably similar, the industry distribution varies between the two. Support provided to Irish firms is concentrated in the Information and Communication sector, and also a small number of grants across a variety of sectors (Figure 19). Support to non-Irish firms, meanwhile, is heavily concentrated in manufacturing, with few grants provided outside of the three main sectors.

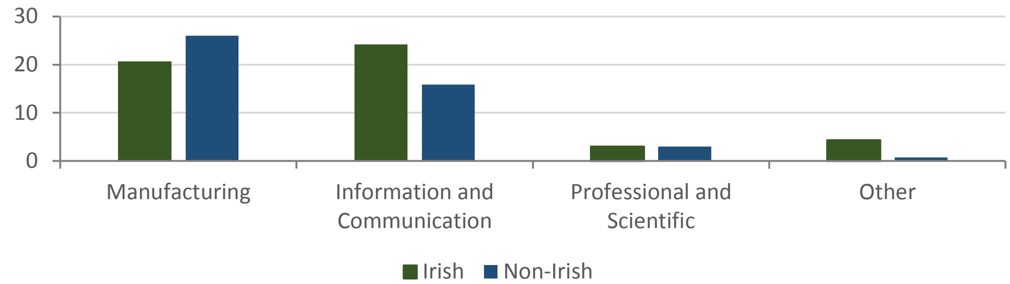

Figure 19: Distribution of R&D grants paid (millions of Euro), by industry, 2014
Source: Enterprise Ireland and IDA

Overall, the average grant paid to very large firms (those with 250+ employees) has declined significantly from 2007 to 2014. This is largely due to the increased number of grants paid, which tripled over the period, while the total paid only rose by 48%. For smaller firms, the grant amount paid has grown proportionately with the number of grants, keeping average grant payments at just under €100,000 (Figure 20). The smallest firms (0-9 employees) account for roughly one fifth of all grant expenditure by the enterprise agencies, whereas the largest firms account for two fifths (Figure 21).

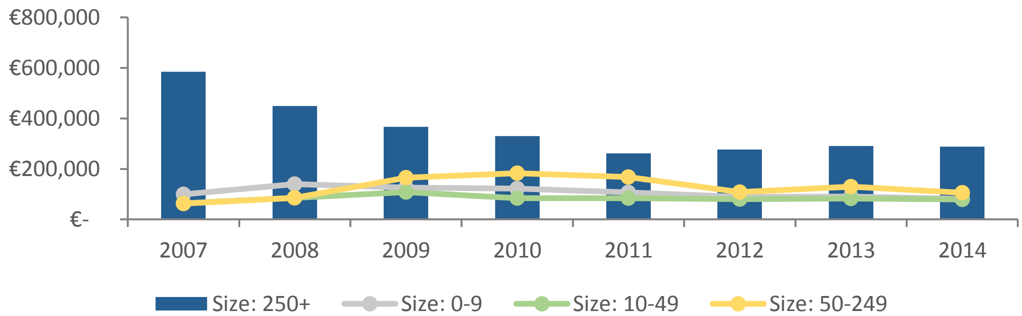

Figure 20: Average R&D grant amount in Euro by firm size, 2007-2014
Source: Enterprise Ireland and IDA

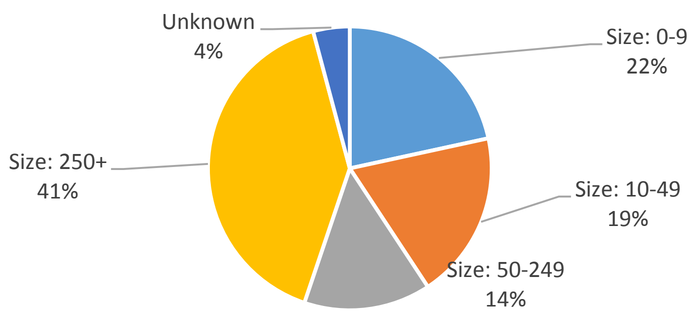

Figure 21: Share of R&D grants paid (millions of Euro) by firm size, 2014
Source: Enterprise Ireland and IDA

5.3. Comparing direct and indirect support

In policy evaluation, comparing the unit costs of different policy tools with the same aims is a useful sense-check on value for money. Unfortunately comparison in this case is imperfect as the employee numbers for firms receiving grants are based on plant-level data whereas the employee numbers for the tax credit are based on taxable entities. A taxable entity may consist of more than one plant. If this could be corrected for, it would still very likely remain the case that the unit costs of the tax credit are higher than the unit costs of grants (Figure 22).

Figure 22 shows that the tax credit cost per employee peaked in 2009, the year the repayable credit was introduced. This period also coincided with the recession (i.e. falling profits and tax liabilities) and considerable job losses. One reason the tax credit costs more per employee is its much greater coverage; no firms are excluded from claiming it either in its form as a tax deduction or as a repayable credit, whereas the number of firms and employees who will be impacted by grants is a function of the expenditure allocation to the enterprise development agencies and, more broadly, the government's budget constraint.

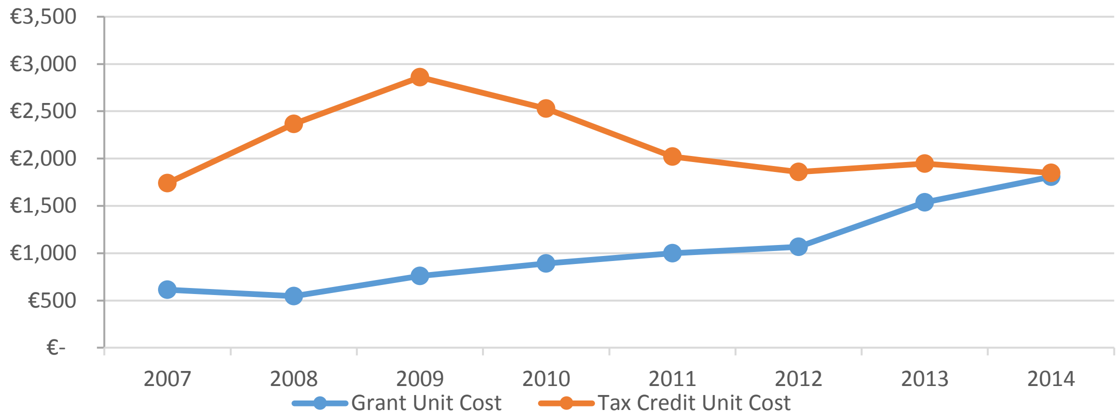

Figure 22: Average cost of support per employee, 2007-2014
Source: Revenue Commissioners, IDA, EI

Although Figure 22 gives us some sense of relative costs (albeit imperfectly), it is not sufficient to conclude on which policy tool is a better use of public funds as we do not know the additionality (and deadweight) associated with R&D grants. Furthermore, assessing the spill-overs from grant-supported R&D and tax credit-supported R&D would also be important in such a comparison. For example, the spill-overs associated with basic research are considered higher than those of applied research; a grant might be better able to target research closer in nature to basic research than a tax credit.

To the best of our knowledge, there has only been one published evaluation of the input additionality of R&D grants to firms in Ireland that does not rely on self-assessment.[12] This study, Görg and Strobl (2007), found evidence that R&D additionality decreased with grant size for Irish firms i.e. they found additionality effects for small grants but not for large ones. The authors found no evidence for additionality for non-Irish firms. As its methods are different to the current evaluation, the results are unfortunately not directly comparable.

Since it was introduced, the repayable credit has been the primary method of public support, making up 51% of the total public support for BERD in 2014, which now amounts to more than €600 million

[12] Appropriate methods for determining additionality are reviewed in the next chapter.

between the repayable credit, tax credit, and grants provided by the IDA and Enterprise Ireland (Figure 23).

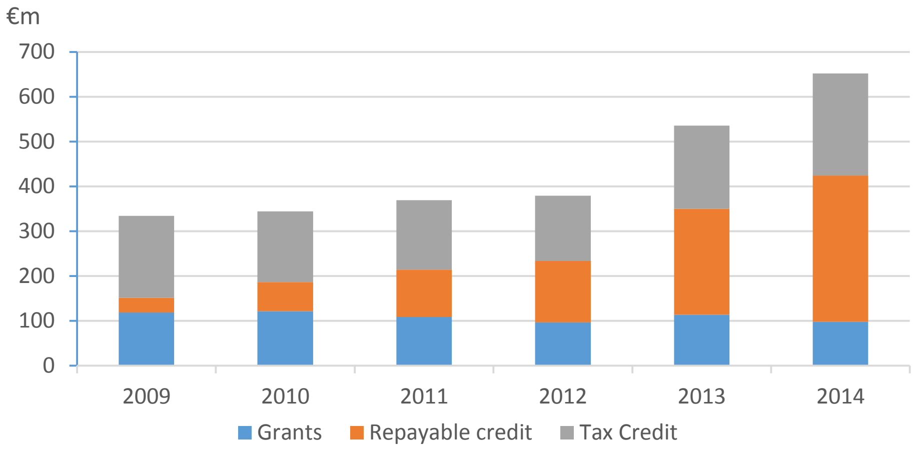

Figure 23: Public support for BERD (€)
Source: Revenue Commissioners, IDA, EI

As a percentage of GDP, total public support for BERD has almost doubled from 0.20% to 0.39% from 2009-2014, largely driven by the increase in the repayable credit from 0.02% to 0.20% (Figure 24).[13] Given the size of the repayable credit, it is important to note that much of its expenditure is going to firms which conduct significant amounts of R&D, and these firms tend to be larger and older.

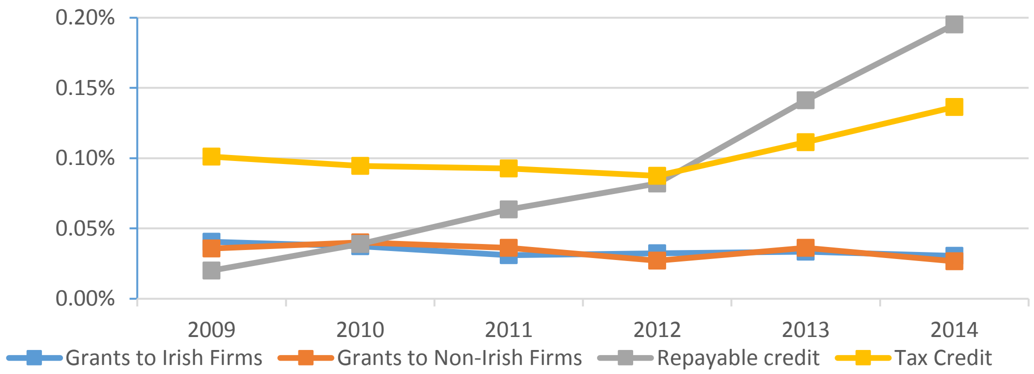

Figure 24: Public support for BERD (% GDP)
Source: Revenue Commissioners, IDA, EI, CSO

[13] Note that the Irish data point in the OECD data described in Figure 9 refers to 2012 data, and is consistent with what is presented here.

6. Review of R&D evaluation methodologies

Key Points

Evaluation of R&D tax credits is mainly achieved through either structural modelling or treatment evaluation, with the latter becoming increasingly common as an empirical tool due to improvements in data availability. Evaluations in other OECD countries have produced a range of estimates for additionality and it is clear that a scheme's design plays a key role in results.

This section discusses the methods used by economists to evaluate the effects of policy measures, specifically with regards to R&D. Examples of studies which have used a similar methodology to the current paper (i.e. treatment evaluation) are also provided and briefly discussed.

6.1. Survey and self-assessment

Among the various methods of evaluating the additionality of R&D, perhaps the simplest method is to simply ask firms via survey to ex-post estimate the level of additionality as a result of an incentive. (Mohnen and Lokshin, 2009). This method has several obvious flaws. Firstly, firms may be in no better position than the surveyor to evaluate the counterfactual, that is, the amount of R&D expenditure had there been no fiscal incentive. Secondly, firms may have an incentive to exaggerate claims of additionality if they perceive the survey as affecting the likelihood of future policy measures. Thirdly, because the full effects of R&D incentives are thought to happen over the long-term, snapshot estimates of additionality may underestimate the true effect. Given these inherent limitations, it is somewhat surprising to note that self-assessment of additionality has proved (in some studies) to be relatively accurate when matched with estimates derived from econometric techniques (Bureau of Industry Economics, 1993) (Haegeland and Møen, 2007). In the 2013 R&D tax credit evaluation, the Department of Finance commissioned a survey of firms' views of the scheme. 60% of firms who completed the survey stated they would have invested less in R&D in the absence of the scheme. This result is consistent with a previous evaluation carried out by the Department of Finance in 2010, in which Irish firms surveyed estimated that the R&D tax credit was responsible for a 75% increase in R&D spending, while non-Irish firms estimated the impact to be 29%.

6.2. Structural equation modelling

More empirical methods of investigating additionality generally fall into two groups: structural model estimation and treatment evaluation. As this paper uses the treatment evaluation method (specifically using a difference-in-difference approach) we will discuss this method in detail, and provide only a brief outline of the structural model method here.

Structural equation modelling (SEM) involves defining the relationship between a set of explanatory variables, and one or more dependant variables, with the use of economic theory and regression analysis. This method has been successfully applied in the Australian and UK contexts (Thomson, 2009; HMRC, 2010). In the case of investigating the impact of R&D incentives, this usually involves one of two methods. The first method is to estimate an R&D demand regression, including the cost of R&D as a right-hand side (RHS) variable, and a dummy indicating the presence or absence of a tax incentive. An alternative method is to estimate the demand equation including the marginal cost of R&D on the firm level, which allows for variation in the treatment. In the 2013 R&D tax credit evaluation, the Department of Finance attempted this approach but found it challenging to calculate the user cost of capital (i.e. the firm's cost of R&D) as the variables of interest are not mandatory fields in the corporation tax form. Nor was it possible to link sufficient samples of firm data from the Revenue Commissioners to the Companies Registration Office, a source which did contain the necessary financial data. The resulting sample of firms with data merged from both sources was too small for use in econometric analysis. As a result of this experience, the Department recommended greater focus on the issue of data availability in tax expenditure evaluation.

6.3. Treatment evaluation

In the contemporary literature evaluating R&D policy measures, there has been a shift away from the structural models discussed above towards reduced-form treatment evaluation studies. These quasi-experimental methods can be seen as less theory driven than structural models, and as such provide more objective, non-theoretic estimates (Cerulli, 2010). In relation to Ireland, the OECD has recommended that Ireland use such methods in order to evaluate the R&D credit, stating *"Ireland needs to carry out more evaluation of its particular scheme using statistical methods to generate control groups to isolate the effect of the credit beyond other factors"* (OECD, 2013). Two of the most common non-structural methods and their place in the literature are described below: the matching approach and the difference-in-difference approach.

The matching approach uses observable variables in the data to identify similar firms which only differ by participation in a given treatment. Propensity scores can be calculated in order to match firms with similar probabilities of participating in the treatment (Blundell and Costa Dias, 2000). Thus, the matching method deals with the problem of selection in control group approaches where the control group can be used as the counter-factual to the treatment group. The key advantage of this method is that, unlike difference-in-difference studies, matching can exploit cross-sectional data rather than requiring panel data. An example of use in relation to R&D policies is provided by Czarnitzki et al. (2011).

The difference-in-difference approach is a well-established method used to identify the impact of a policy or event by comparing the change in an outcome or behaviour over time between a treatment group and an unaffected control group. This may be feasible when it is possible to identify a group unaffected by a policy shock, but which are otherwise randomly distributed. This is commonly achieved by using a regression model involving a vector of control variables and a dummy variable which differentiates between the treatment and control group. As difference-in-difference studies rely on non-experimental data, it must first be established that the factors which determine selection into the treatment and control group are exogenous, and that factors impacting the dependant variable are controlled for via observed characteristics.

The difference-in-difference approach has become increasingly popular in the evaluation of R&D policy. As more governments are now using R&D incentives, and so panel data are more readily available, this approach has become increasingly feasible over the past decade. Below are some relevant examples of studies which have used difference-in-difference methods to evaluate R&D schemes.

Hægeland and Møen (2007) presents a difference-in-difference approach to indirect R&D supports. In this study, the authors evaluate Norway's R&D tax incentive scheme. The scheme (ScatteFUNN), which began in 2003, provides approved firms with a repayable tax credit of between 18% and 20% of R&D expenditure up to a defined cut-off point. In their analysis, the authors identify the cut-off point as a discontinuity within the scheme, allowing for a difference-in difference approach in order to estimate the effect which the scheme has had on R&D expenditure. Through this approach they found that the scheme generated between 1.3 and 2.9 krone in additional R&D expenditure per krone forgone.

Also using this method to evaluate R&D tax incentives, Cornet and Vroomen's 2005 study investigates the extension of the Dutch R&D tax credit (the WBSO). The changes to the scheme included an additional credit for firms starting R&D, as well as raising the upper-bound on the first tax credit bracket. As in the case of SkatteFUNN, these changes created a natural experiment, which allowed the authors to use a difference-in-difference approach. The additional credit for starters was estimated to produce an extra €0.50 to €0.80 R&D per €1 of tax incentive, while the estimate for the change in the upper bound was an extra €0.10 to €0.20.

Görg and Strobl (2007) have extended the difference-in-difference method to evaluating direct R&D incentives. Their study investigates the effectiveness of grants provided to the manufacturing sector in Ireland to induce an increase in R&D spending. Following on from the recommendations by Blundell and Costa Dias (2000), Görg and Strobl combine a difference-in-difference estimator with a non-parametric matching approach in their study. The authors find limited evidence for additionality from grants provided to Irish firms (additionality disappears once the grant given is too large, indicating crowding out), and no evidence of additionality from those provided to non-Irish firms. In another paper using the same methodology and dataset, they find that if grants are large enough, they promote the exporting activity of experienced exporting firms but have no impact on the decision to start exporting for the first time (Görg and Strobl, 2008).

Likewise, Lach (2002) uses a difference-in-difference model to examine R&D subsidy schemes. This study, using data from Israel, attempts to identify differences in the effect of R&D subsidies between firms, based on characteristics such as size. Using a difference-in-difference estimator, the author estimates the mean treatment effect using unsubsidised firms as a control group. Additionality is estimated to be positive for the scheme. However for large firms it appears as though this is statistically insignificant, indicating that most of the subsidy is simply used to offset privately financed R&D expenditure.

7. Methodological approach

Key Points

Financial incentives for firms to conduct R&D were altered by the introduction of a repayable credit in 2009. We exploit this variation in the policy to assess, using Revenue taxpayer data, whether firms conduct additional R&D as a result of the tax credit scheme. We establish a treatment and control group, and, using regression analysis, compare their R&D levels both before and after 2009 to assess whether the credit causes R&D activity that would not have occurred in the absence of public support.

As highlighted above, this evaluation adopts a treatment evaluation methodology. The main analysis implements difference-in-difference estimation through fixed effects regression analysis.

7.1. Establishing the counterfactual

When identifying the causal impact of an intervention, in this case the R&D tax credit, a counterfactual analysis is needed: *what R&D would firms have conducted in the absence of the scheme*? However, this is unobservable (outside of an experimental setting where the credit could be randomly assigned to firms). It is not possible to compare the R&D levels of R&D credit claimants with that conducted by firms not claiming the credit as all R&D-conducting firms are likely to claim the credit, given the Irish scheme contains no restrictions based on firm size or other characteristics.[14] Neither can we compare R&D-conducting firms to firms who never conduct R&D as those who choose to perform R&D evidently see a profitable investment opportunity, making them fundamentally different in nature to other firms and therefore not comparable. This is the classic self-selection issue in evaluating public policy.

To overcome this, the evaluation exploits an important policy change in 2009 which changed the nature of the scheme for a specific subset of R&D-conducting firms. This is known as a *quasi-experimental* approach or a *treatment evaluation*. In 2009, the R&D tax credit became a repayable tax credit, meaning that if a firm's corporation tax liability was less than the claim submitted for the R&D tax credit, the firm could request that the excess be repaid to them as a cash payment, to be paid in three instalments over three years. To the extent that firms in the start-up phase are likely to have cash flow or profitability issues, such firms may find the policy change particularly beneficial. It also served to protect R&D spending by all firms in the recession. The repayable credit is limited each year to the greater of the corporation tax payable by the firm in the preceding ten years or the payroll liabilities for the period in which the relevant R&D expenditure is undertaken.

7.2. The treatment and control groups

This policy change creates two groups for comparison. First, a treated group of firms who changed from not receiving to receiving a financial benefit from the tax credit scheme, as they were previously not generating sufficient profits and therefore tax liabilities. Second, a control group of firms who were not treated, as the introduction of the repayable credit was irrelevant for them given they already gained financial benefit via reduced tax liabilities. We observe the outcomes (i.e. R&D

[14] This highlights a drawback, from an evaluation perspective, with policies that are designed to have general access. The greater the degree of equal treatment under a policy, the more difficult it is to establish the counterfactual situation using a control group. Although it is possible that small firms may conduct R&D but not apply for the credit due to its administrative burden, we deem this scenario unlikely as by 2009 the scheme was in its sixth year and familiar to all firms. In any case, we have no way of observing such small firms as the CSO's BERD survey does not have a specific question on whether firms apply for the tax credit.

expenditure) for the two groups in two time periods, firstly before the treatment and then after the treatment. Neither group is exposed to the treatment in the first time period. One group, the treatment group, is exposed to the treatment in the second period while the other group, the control group, is not exposed to it. As we observe the same firms within a group both before and after the treatment, the average change in outcomes in the control group can be subtracted from the average change in outcomes in the treatment group to establish the *average treatment effect*. Having data on the same firms in both periods and thus being able to perform this "differencing" both across the groups and across time is essential in order to (i) remove biases in second period comparisons between the treatment and control group that could be the result of permanent differences between those groups and (ii) remove biases from comparisons over time in the treatment group that could be the result of trends common to all firms.

Firms are assigned to the treatment and control group based on their ex ante behaviour in 2007 and 2008.[15] If firms did not have a positive tax liability in either or both of these years in the pre-treatment period, then the tax credit in its original form was of no financial benefit to them. *However, once refundability was introduced through the repayable credit in 2009, their financial incentives changed relative to all other R&D-conducting firms.* For firms in the control group, making the scheme repayable did not change the policy incentive they face (the R&D tax credit). Meanwhile, firms in the treatment group can now avail of the R&D tax credit through its new repayability element, changing the cost of performing R&D for this subset. The hypothesis is that these treated firms react differently than control firms to this policy change by – on average - increasing their R&D activity. As the repayable credit improves the financial incentive to conduct R&D by a similar magnitude as the overall credit, the additionality result obtained from examining the behaviour of treated firms relative to the control group can be generalised to the tax credit overall.

The identification strategy of the evaluation is to compare the two groups in a regression framework and assume that, conditional on both observable time-varying and unobservable permanent differences between them, the difference in their R&D growth is due to the fact that for one group – the 'treated' firms whose financial incentives have changed due to the introduction of the repayable tax credit – the overall R&D tax credit scheme is now more immediately valuable (and certain). They have a greater financial incentive than other R&D-conducting firms to increase their research activities after 2009, and the incentive is no longer conditional on generating a positive tax liability, as was the case under the original tax credit scheme.

Firms who are in the treatment or control group are held fixed over the analysed period: assignment is based purely on their ex ante behaviour in 2007 and 2008. Yet, as with all policy changes, it is likely and indeed observed that some firms in the treatment group stop receiving repayable credits in the post-2009 years and that firms in the control group can also receive repayable credits in later years. In the case of the control group, it can be argued that their incentives have not changed; they previously enjoyed the financial benefit of the tax credit and now they still get the same magnitude of benefit albeit through a repayable credit. Their overall financial incentive (the reduction in costs in performing R&D) has not changed, whether they avail of the tax credit on positive tax liabilities or avail of the repayable credit. However, we do note that the length of time over which the financial benefit is received changes (due to the repayable credit instalments being over three years rather than a tax reduction in one year) so although the total benefit is unchanged, the annual benefit may be somewhat less for an unprofitable control firm compared to a profitable control firm. This is one

15 The number of firms claiming the credit before 2007 was very small – see Figure 10 in Section 4 – so we focused on the two years prior to the introduction of the repayable credit.

justification for comparing treatment and control groups in an overall post-treatment period (i.e. treating 2009-2014 as one period) rather than on an annual basis. We use the full time period in the data available to us, i.e. run the regression up to and including 2014 data, because additionality for R&D would typically occur over a number of years.

The 'contamination' of the treatment and control group in a quasi-experiment based on historical data is hard to avoid, and in this instance likely creates a downward bias to our results. A priori, we expect that if some firms in the control group receive the repayable credit in a majority of post-2009 years, this makes our empirical estimate a lower bound on the true additionality (as – assuming that they more typically act like treated firms and view the repayable credit as a new financial incentive to conduct R&D - such firms push up the control group's average R&D in the post-treatment period, and therefore reduce the difference between that and the treatment group's average level of R&D). In treatment evaluation of tax policy in particular, it is always challenging to obtain a pure control group as no new tax policy or policy change can confer advantage on certain firms or prevent other firms from changing their status in order to derive benefit from the policy in subsequent years; to do so would run the risk of distorting competition and trade.

7.3. Random assignment

Assignment to the treatment or control group must be random or exogenous. We believe this condition is met when the timing of the policy change announcement is considered. The policy of introducing a repayable tax credit was not announced with a long lead-in. It was first publically mooted in a Tax Strategy Group paper on the Department of Finance's website in November 2008, and subsequently took legal effect in the Finance (No 2) Bill from January 1 2009.[16] Firms did not have much time to adjust or manipulate their R&D investments in response to this unforeseen and uncertain event. In addition, even if the policy had been announced much longer in advance, it is difficult for most firms to adjust their R&D quickly as projects and upfront financing tends to be determined on a multi-year basis (e.g. the enterprise agencies typically pay R&D grants to firms over a number of years for a single research project, or executive boards typically approve new research projects on a scheduled basis).

The majority of taxpayers in Ireland are voluntarily compliant and Revenue's audit and risk management interventions are effective tools in supporting compliance. The current evaluation assumes that taxpayers fully and accurately report tax returns. Various quality assurance tests were performed on the data to ensure they were of high enough quality to use in the analysis.

7.4. Other control variables in the analysis

One of the challenges with this approach is distinguishing between the effect of the repayable tax credit and other potential changes in the macroeconomic environment that affect R&D outcomes in the treated and control group differently. This is important given the severe recession in Ireland at the time of the policy change, which would be expected to increase the value of a repayable credit. The role of the year dummies as period fixed effects highlight this problem – a year dummy can pick up a macroeconomic shock but we are assuming the effect on R&D is the same, on average, for all firms in the sample. However, as we have panel data, we employ firm-level fixed effects to control for unobserved permanent differences between firms. A firm-level fixed effect can refer, for example, to the firm's industry, its ownership status or its age relative to other firms. To illustrate, one can envisage that non-Irish ownership is a firm-level fixed effect which would influence the response to a negative

[16] The Minister for Finance's Budget 2009 speech, given in October 2008, made no reference to the repayable credit.

economic shock (perhaps a non-Irish firm has easier access to finance than an Irish firm). In addition to the year dummies, we also employ a size control (employee headcount) in all regressions. This does vary over time and can be thought of as aiding the interpretation of the coefficients on the year dummies: we estimate an average response to macroeconomic shocks similar for firms in both groups that is conditional on their individual firm size and unobserved permanent differences between the two groups. Robustness checks in relation to this issue are detailed in the results section.

7.5. Modelling R&D outcomes

Hall and Van Reenan (2000) remains one of the most authoritative surveys on the impact of fiscal incentives on R&D investments. In their survey, they outline a structural model as follows:

$$\ln(R\&D) = \alpha + \beta\rho_{it} + \gamma\ln(output)_{it} + \mu_i + \varepsilon_{it} \quad \textbf{Eq (1)}$$

Where ρ represents the user cost of capital and μ represents firm-level fixed effects.

We can take equation 1 as the starting point for our model, but replace the user cost of capital with an indicator of whether a firm is in the treatment group. We will also replace the output control variable by an employee control variable, which, like output, can be interpreted as a proxy for firm size. As we are conducting difference-in-difference estimation, we also add period and group fixed effects.

The general model for difference-in-difference estimation is as follows:

$$Y_{it} = \beta_0 + \beta_1 Treat_i + \beta_2 Posttreatment_t + \theta Treat_i . Posttreatment_t + u_{it} \quad \textbf{Eq (2)}$$

β_1 is the coefficient on the group fixed effects and β_2 is the coefficient on the period fixed effects. θ is the coefficient of interest and is interpretable as the average treatment effect.

The models we run, which join the difference-in-difference approach with the insights of the work by Hall and Van Reenan (2000), are as follows:

$$\ln(R\&D)_{it} = \alpha + \mu_i + \sum_{t=1}^{t=T}\delta_t D^{year\ t} + \sum_{t=1}^{t=T}\theta_t D^{year\ t}.D^{treatment} + \gamma\ln(employees)_{it} + \varepsilon_{it} \quad \textbf{Eq (3)}$$

$$\ln(R\&D)_{it} = \alpha + \mu_i + \sum_{t=1}^{t=T}\delta_t D^{year\ t} + \theta D^{year\ post-treatment}.D^{treatment} + \gamma\ln(employees)_{it} + \varepsilon_{it} \quad \textbf{Eq(4)}$$

Note that as we specify firm-level fixed effects in the regression, the group-level fixed effects (β_1 above) will drop out of the results. The same is true for other permanent differences between firms that we could use as controls - namely the firm's industry, its ownership status and its age relative to other firms in the sample. The interaction between time and treatment, which is needed to give us θ, the average treatment effect, can be specified on an individual year basis (equation 3), or by comparing the overall post-treatment period to the overall pre-treatment period (equation 4).

Following Bertrand et al. (2004), we adjust the standard errors in the model by clustering them on the individual firm's panel identifier, which allows for arbitrary correlation of the residuals among individual time series but assumes the errors are independent across firms. This approach corrects for both autocorrelation and heteroscedasticity.[17]

Our dataset contains all firms who ever availed of the R&D tax credit over 2007 to 2014. The sample for determining additionality of the credit is restricted to firms who had a positive R&D credit (i.e. positive R&D expenditure) in either or both of the years prior to the treatment year. Firms with an R&D expenditure level greater than €250 million were also excluded from the regression analysis as we deem them to be outliers. We also only include firms who were eligible for the policy change (i.e. they had a positive tax credit claim in 2009). Note that in order to use the natural log of R&D as our dependent variable, we set ln(R&D) equal to zero for firms with no R&D. This is equivalent to assuming that all firms do €1 euro of "informal" R&D, a standard assumption in the literature. Table 3 provides a summary of both the sample and treatment assignment.

Table 3: review of sample and treatment assignment in main model

	Sample	Treatment assignment
1	R&D < €250 million in all years	Tax liability = 0 in pre-treatment period
2	R&D > 0 in pre-treatment period	
3	R&D > 0 in year of policy change (2009)	

7.6. Descriptive statistics to motivate the identification strategy

Table 4 provides descriptive statistics that motivate our identification strategy. We construct the growth rate for R&D from the period just before the treatment to just after the treatment i.e. growth between 2008 and 2010. We use a weighted growth formula (see equation below) in order to reduce the influence of extremely large values in either period, and we only apply it to the sample of firms that we will subsequently use in our regression analysis.

R&D growth formula in Table 3: $(R\&D_{2010} - R\&D_{2008}) / (0.5*R\&D_{2008} + 0.5*R\&D_{2010})$ **Eq (5)**

Table 4: R&D growth for regression sample

	Growth in R&D from 2008 to 2010 (%)		**Difference (in % points)**
	Treated group: firms with zero tax liability in pre-treatment period	**Control group: firms with positive tax liability in pre-treatment period**	
25th percentile	-0.62	-0.95	0.33
Median	0.00	0.00	0.00
75th percentile	0.71	0.61	0.10
Mean	0.00	-0.10	0.10**
Standard error	1.26	1.26	
Mean R&D level in 2008 before treatment	€ 252,258	€ 298,669	
Number of observations	900	1230	

**Difference in mean growth is significant at the 5% level

We compare these growth rates for our treated and control group and observe a positive difference between the two at various points on the distribution of growth rates. The statistical significance of

[17] Autocorrelation occurs when the error terms in a time series are correlated with each other. Heteroscedasticity occurs when the variance of the error term is not constant. In the presence of either the test statistics used to determine the significance of the regression estimates are no longer valid.

this difference is checked via a t test, which indicates that the mean growth rates for the treated and control group are different from each other. This table suggests that the tax credit scheme does provide additionality but we note that the number of observations is not large (whereas in the regression analysis more data are utilised). It is worth noting that the average level of R&D in the pre-treatment period is higher for the control group than the treatment group. This is not unexpected as control groups firms are, by definition of the treatment assignment, typically more profitable than treatment group firms and arguably face fewer financial constraints to conducting R&D. This is a firm-level initial difference between the two groups which we can control for in the regression analysis.

In the main analysis, the two-group comparison of Table 4 is embedded in a regression analysis using equation 4. This has several advantages over descriptive statistics. First, we can include control variables. This improves the comparison between the two groups and reduces unexplained variance in the model (which will improve the precision of statistical tests of significance). Second, these controls can allow us to see if certain firm characteristics, such as employee headcount, are associated with particularly high or low R&D outcomes. Finally, we can utilise more data in the regression analysis i.e. firm-level data from all years, not just the years immediately prior and post the introduction of the repayable credit. This will improve the precision of our results.

8. Data description and analysis

Key Points

Our outcome of interest in this analysis is R&D expenditure, which can be constructed using the Revenue data. The composition of these estimates is in line with the BERD survey i.e. R&D activity is concentrated in larger, older, foreign firms typically in manufacturing. By contrast, when we look at the firm characteristics of our treatment group, we observe they are more likely to be small and young compared to firms in the control group.

The data used in this evaluation come primarily from the Revenue Commissioners' in-house database on corporation tax receipts. This database contains case-level information on income, tax liabilities and tax deductions such as the R&D tax credit.[18] At the request of the Department of Finance, officials in Revenue prepared a panel dataset for the years 2007-2014 containing all cases that had ever availed of the R&D tax credit (i.e. conducted R&D). Over the panel, 2014 is the latest year of available data. In addition, Revenue merged employee numbers to the dataset using returns completed by tax-registered employers. Department of Finance officials were subject to the usual restrictions on data and taxpayer confidentiality.

The other data used in the analysis came from the enterprise development agencies, Enterprise Ireland (EI) and the Industrial Development Agency (IDA), who provided data on R&D grants given to firms, aggregated to industry and firm-size level. Micro-level data on R&D grants were not made available for analysis.[19]

Although the CSO-Eurostat BERD survey remains the most authoritative source for business R&D activity in Ireland, R&D expenditure as calculated in the Revenue dataset is presented in this chapter, alongside further details of the exchequer cost for our chosen treatment and control group.

8.1. Firm ownership

While R&D has risen for both non-Irish and Irish firms, Irish firms in particular have seen strong growth in R&D, reaching 75% of the level of R&D performed by non-Irish firms in 2012 (Figure 25). Atypical activity by non-Irish firms in later years masks this trend. Overall, the trend of strong R&D growth by Irish firms is consistent with the BERD data, although the BERD data record that their share of total expenditure is much smaller than presented here (see Figure 4 above). This may indicate the BERD survey is not capturing all R&D-conducting Irish firms. But we also note that although the Revenue definition of BERD is in line with the OECD's Frascati Manual, as is the BERD survey, the lack of detailed definition-prompting questions of R&D on the corporation tax form compared to a CSO survey form may result in firms providing different responses on the two forms.

[18] A Revenue case refers to a tax-paying entity. Firms may have one registration with Revenue but could operate at multiple locations or plants across the country. Affiliates or subsidiaries register separately with Revenue, but are identifiable as a group in the Revenue data.

[19] The issue of linking all possible R&D data sources remains an important policy evaluation challenge.

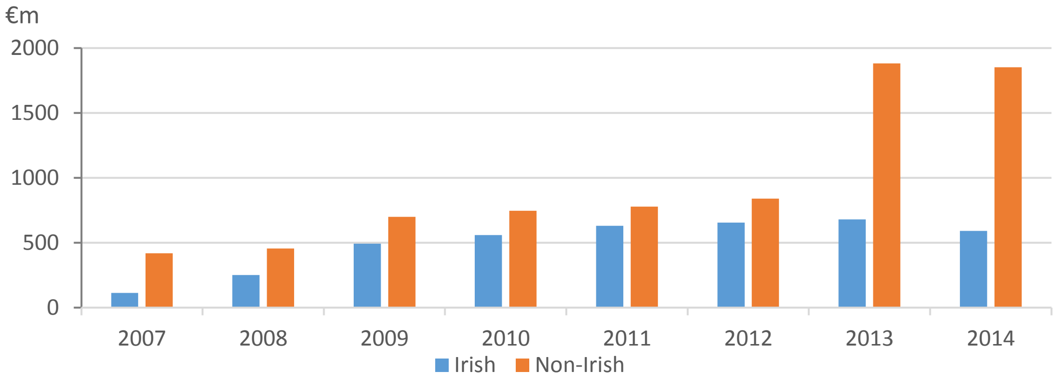

Figure 25: R&D by firm ownership
Source: Revenue Commissioners

8.2. Firm industry

R&D activity supported by the tax credit is largely concentrated in the Manufacturing (C), Wholesale and retail trade (G), Information and communication (J), and Professional, scientific and technical activities (M) sectors, which account for over 90% of R&D spending (Figure 26). This share has remained stable from 2007-2014, although manufacturing was unusually high in 2013 and 2014. Again, the Revenue data are consistent with BERD surveys in terms of industry concentration.

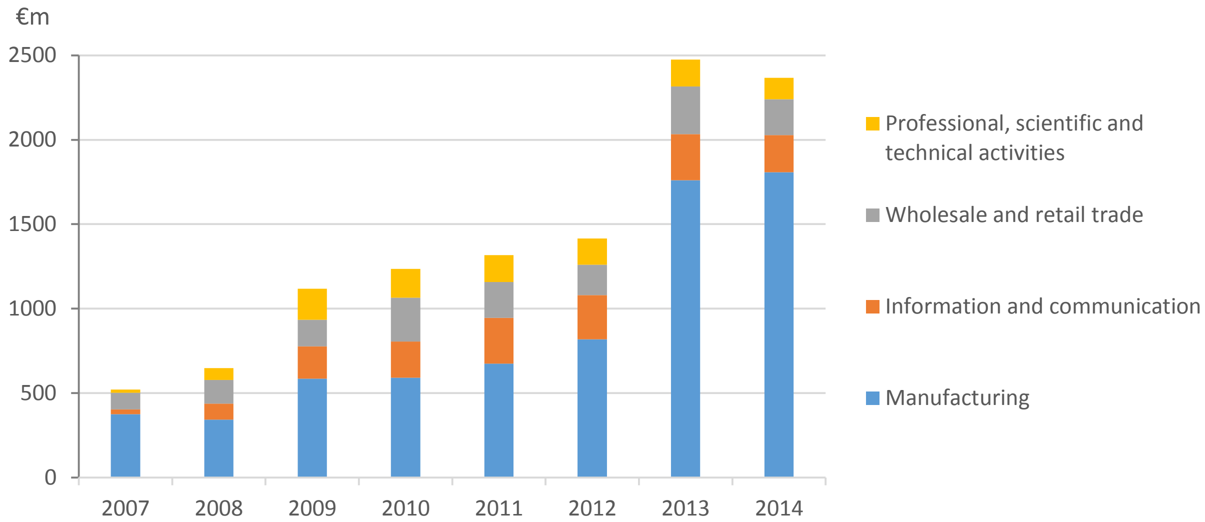

Figure 26: R&D by Industry
Source: Revenue Commissioners

8.3. Firm age

The BERD data do not have an age variable and, to the best of our knowledge, this is the first time that R&D activity by age has been publically outlined using an Irish data source.[20] While the overall amount

[20] However we note that the age variable refers to the year the company first registered with the Irish tax authorities, rather than the year that the firm was born. Nevertheless, the variable provides a good indication of the development of the firm in Ireland relative to all other firms in Ireland.

of R&D conducted has increased since 2007, annual R&D expenditure by each age category has not necessarily followed the aggregate trend (Figure 27).[21]

In the case of the youngest firms (those aged up to 3 years old), total R&D has been relatively flat since 2009. The numbers of young firms claiming has declined over time, with a peak of 525 firms in 2010 and a trough of 253 firms in 2014 (this does suggest, though, that the typical young firm today does more R&D than a typical young firm in the late 2000s). Small increases in the number of 4-7 year old firms doing R&D explains some but not all of the drop in 0-3 firms, with the reminder due to such firms ceasing either business or R&D operations.[22]

The 4-7 year category's total R&D increased at a steady rate over most of the time period but in the case of firms aged 8-15 years, total R&D has dropped dramatically since 2010, although it remains above their levels performed in 2007/2008. This decline mainly results from more firms entering this age category over time, as the average level of R&D conducted by the 4-7 years category over most of the period was considerably lower.

The overall increase in R&D has been driven by the very oldest firms (those over 16 years old); their activity accounts for almost seven-eight's of total cumulative growth in R&D over 2007-2014. If the latest two years of data are excluded, this contribution by the oldest firms drops to a little over half of total cumulative growth over 2007-12 (2013 and 2014 were atypical years of activity for this age category). The increase in total R&D in the final two years under review is not caused by inter-category movement i.e. it relates to firms that were and remain in the oldest category.

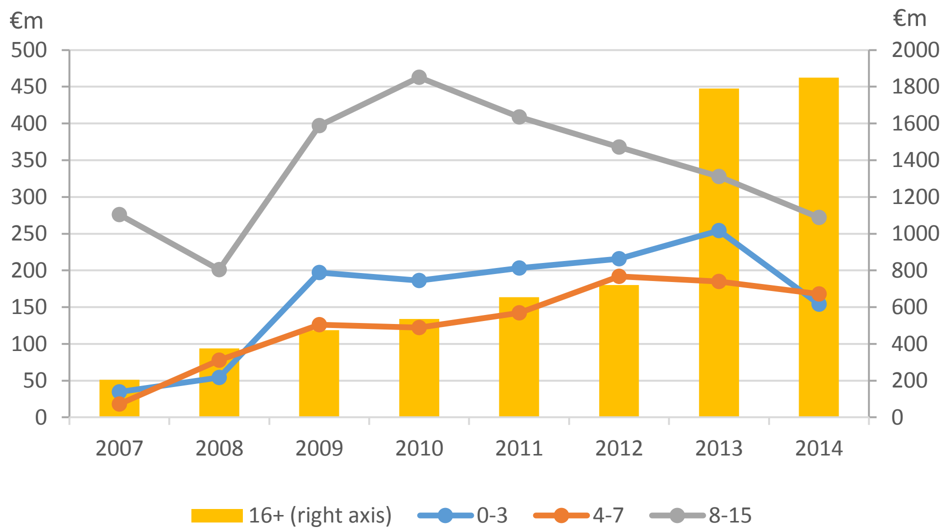

Figure 27: Total R&D by Firm Age
Source: Revenue Commissioners

[21] Unlike employee size categories, there is no convention on age categories. Age categories here were chosen to reflect the different stages of firm development.
[22] The 0-3 age category is the only one to experience annual declines in numbers, but this is unsurprising: all categories experience "deaths" but only the higher three can experience "transitions" from a lower category. 0-3 experiences "births" rather than "transitions", and survival chances typically increase with age.

The observed flat performance of young firms, in particular, is worrying, given the focus in policymaking on the link between firm age and innovation.[23] While the large jump in R&D by the youngest age group between 2008 and 2009 is indicative of short-term sensitivity for this cohort to the change in the credit policy, it does not answer the question of whether, over the long-run, a young firm does additional R&D *because* of this policy tool. Figure 27 shows that in the post-treatment period (i.e. 2009 onward), the youngest age category of firms conducts approximately four times as much R&D as previously, driven by a typical young firm doing more rather than a greater number of young firms doing R&D than previously. So whilst it does superficially appear from Figure 27 that the loosening of financial constraints changed behaviour (by untying the financial benefit of the tax credit from the requirement to have profits and thus a positive tax liability), a more rigorous means of assessing this is provided in our regression analysis, *which can account for other factors that may determine these firms' levels of R&D*.

Figure 28 shows the average R&D conducted by 'young in 2009' firms in our assigned treatment and control group for the regression analysis. The average R&D jumps very notably in 2009, the year the repayable credit was introduced, which in line with what we observe in the previous figure. It remains elevated throughout the post-treatment period relative to similarly aged firms in the control group, suggesting this group in particular was responsive to the repayable tax credit. It must be noted, however, that young firms make up a minor proportion of overall firms in the regression sample. Most importantly, though, the regression analysis will account for other factors that may determine these firms' levels of R&D, such as their size, their underlying characteristics and the general macroeconomic conditions of the time.

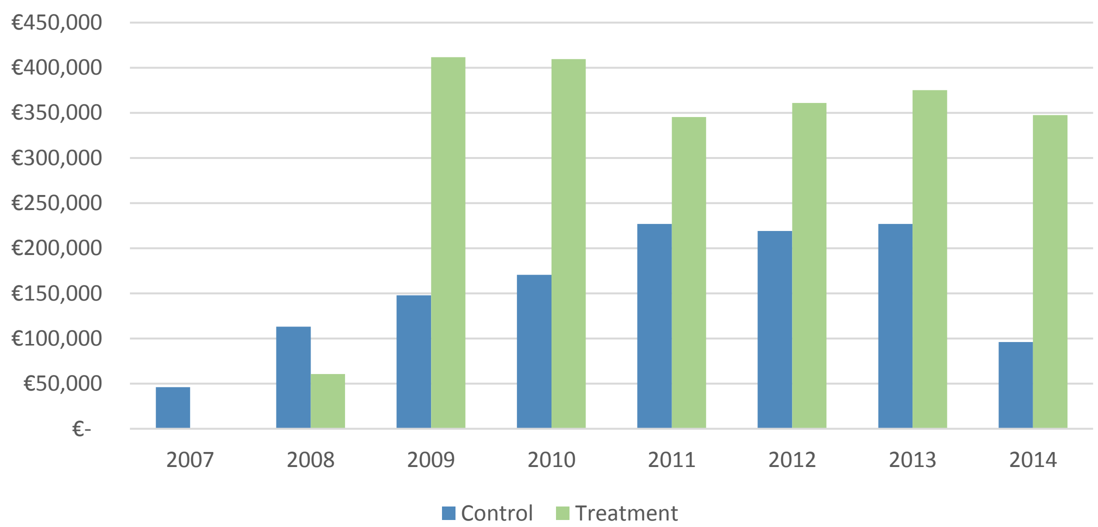

Figure 28: Average R&D by treatment and control group, young firms in 2009
Source: Revenue Commissioners

A distinction must be drawn between the first cohort of young firms affected by the introduction of the repayable credit – who will be examined in the model looking at changes in the level of R&D conducted by firms – and future cohorts of young firms, for whom the impact of the repayable credit can only be observed in their decision to start R&D rather than in a change in their level of R&D.

[23] We note, though, that currently the economic evidence indicating higher rates of private return to R&D for young firms compared to older firms is based on US studies. No premium for young firms has yet been found for European firms (see Cincera and Veugelers (2014)).

8.4. Firm size

Our dataset can also be analysed according to firm size, which is considered another important component in determining R&D outcomes. We observe that, despite the majority of R&D conducting firms being small (as shown in Figure 8 previously), the majority of R&D expenditure is conducted by firms with more than 250 employees (Figure 29). The number of firms in the largest two size categories did not vary substantially over 2007-2014, implying their typical R&D expenditure was a lot higher by the end of the period than the beginning.

The smallest firms (0-9 employees) also showed strong R&D growth from 2007-2014, and are still well above their 2007 level, despite a decline in 2014. The number of small firms conducting R&D is higher in the post-2009 period (it remains stable over 2010-2013 and dips in 2014). By contrast, the 10-49 category experienced steady growth in the number of firms doing R&D each year. We note that it is possible that firms move between size categories; for example, firms in the smallest size category of 0-9 may move into a higher size category by the end of the time period (or a larger firm fall into a smaller size category). In our dataset, two fifth's of firms never change size category while a further third of firms only change size category once over the eight year period.

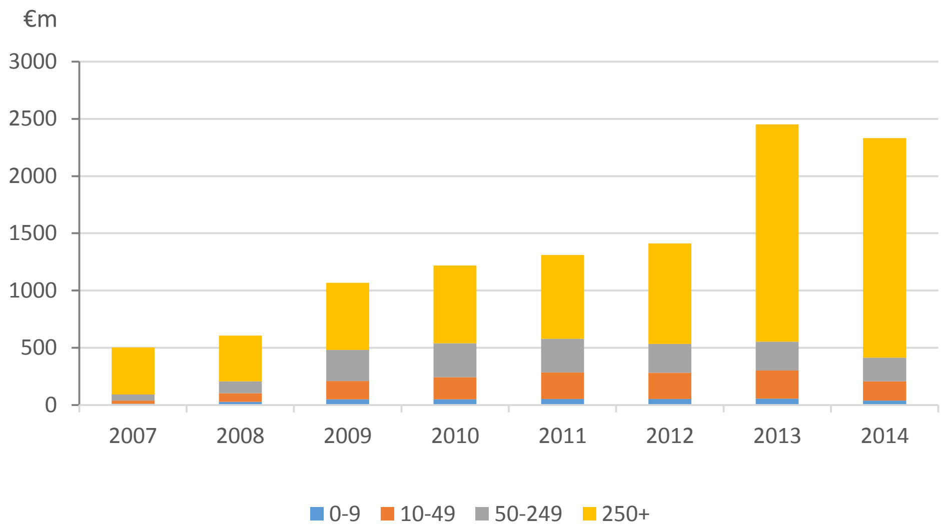

Figure 29: Total R&D by Firm size
Source: Revenue Commissioners

8.5. Treatment and control group

Table 5 provides an indication of the firm characteristics in 2009 of the treatment and control group used in the regression analysis (treatment assignment can be reviewed in Table 3 in previous chapter). The ownership shares are similar for both groups. There are more young and small firms in the treatment group compared to the control group (as expected, as such firms would typically generate lower profits and tax liabilities).[24] These firm-level fixed characteristics are controlled for in the regression but nevertheless give a better sense of the firms within the regression data.

[24] Note that, unlike the data presented in other figures, firm size and firm age are based on the firm's status *in 2009* in Table 5 and Figure 28, as that was the year of the policy change. In all other parts of the evaluation, firm characteristics refer to the particular year under review (e.g. in Figure 27 a firm may appear in a 0-3 years age category in 2010 but transition to an older category by the end of the time period).

Table 5: Treatment and control characteristics in 2009

		Treatment	Control
Firm Ownership	Irish	96%	94%
	Non Irish	4%	6%
Firm Size	0-9	40%	15%
	10-49	39%	55%
	50-249	16%	23%
	250+	5%	7%
Firm Age	0-3	35%	7%
	4-7	22%	29%
	8-15	27%	34%
	16+	16%	30%

Source: Revenue Commissioners

We note that it is not that common for a firm to conduct R&D every year. This reflects the project-led nature of R&D. Only a quarter of firms conduct R&D in five or more years over the eight year period. As we look at the average treatment effect over a number of combined years (2009-2014) in our regression analysis, this does not affect the results obtained.

9. Econometric results

Key Points

Regression results indicate reasonable additionality from the Irish R&D tax credit scheme. We are able to control for observed time-varying differences and unobserved permanent differences between firms in order to strengthen our interpretation of the results. We do not find evidence that younger or smaller firms are particularly responsive to the policy change in 2009, whereas a priori we expected them to be the firms most sensitive to the introduction of the repayable credit.

9.1. Additionality

The previous section outlined in detail the R&D activity of firms, which is our dependent variable, or outcome of interest, in the regression analysis. Equation (4) in Section 7 is our model of choice for determining how the change in tax credit policy impacted on R&D. As mentioned before, the average treatment effect can be presented on an annual basis by interacting the treatment with each year dummy or with a dummy to capture all years from 2009 to 2014 inclusive. The latter is our preferred presentation, given the issue of group contamination mentioned in the methodology in Section 7, but the former is available in the Appendix. The model is robust to the inclusion or exclusion of outliers (i.e. the coefficients stay very stable) but we choose to exclude them. Again, these results are available in the Appendix.

As shown in equation (4), we employ group and period fixed effects and use a proxy for firm size (employee headcount) as a further time-varying control. As we use a firm-level fixed effects specification alongside the difference-in-difference approach, the group fixed effects drop out of the results (i.e. subtracting two identical (fixed) variables leaves you with zero). The firm-level fixed effects specification is very important to our approach as it controls for permanent differences between firms in the treatment and control group which would affect R&D outcomes, such as nationality of ownership, industry and age relative to other firms.

The econometric results are presented in Table 6. Looking firstly at the year dummies in column 1, we can see that – relative to 2007 (the omitted base year) – all firms did more R&D on average, but this effect tapered off over time. There is a minor jump in 2009. The employee variable is strongly significant and implies that for every 1% increase in its employees, a firm conducts 2.7% more R&D. This is consistent with results in the R&D literature, for example Coad & Rao (2010).

The average treatment effect (ATE) is positive and significant, at 0.912 log points. This suggests treated firms did respond to the policy change: we interpret the coefficient as meaning that, due to a change in their financial incentives, they performed more R&D relative to the group who had not experienced a change in incentives.

9.2. Robustness checks

Although our dependent variable is R&D net of grants (as per the definition set out in the Revenue Commissioners' R&D Tax Credit Guidelines for firms), it is possible that the incidence and timing of R&D grants may affect residual R&D which must be funded from other sources. Grants may be a determinant of R&D behaviour that we capture in the regression and misattribute to the treatment. To avoid this, we obtained industry-level data on the distribution of grants for non-Irish and Irish firms from the IDA and Enterprise Ireland respectively. When we include this as a control in our first robustness check in column 2, it is itself an insignificant variable and does not materially change the magnitude or significance of our result for the average treatment effect.[25]

We run further robustness checks in the other columns in Table 6. As mentioned previously, the policy change took place during a period of severe economic distress and it is not possible to definitively state that firms in the treated and control group would react similarly to this in terms of R&D outcomes. Perhaps control firms were in a better position to weather the recession (being on average more profitable than treated firms), meaning that their R&D, which is a typically pro-cyclical variable, recovered very quickly after 2009 compared to treated firms. This could bias downward our ATE in column 1. We control for this in column 3 by including annual growth in gross value added for industry and services. As a stand-alone variable it is insignificant but when it is interacted with the treatment we observe that treated and control group firms respond differently to the economic cycle: as growth increases, a treated firm increases their R&D by less than a control firm. In other words, the gap between them increases. Similarly, during an economic growth contraction, the gap between them decreases. We interpret this to mean that control firms' investment is more sensitive to the economic cycle. Importantly, we note that this robustness check does not change the ATE, suggesting the potential omitted variable bias from this source was not as substantial as expected. Following Gorg and Strobl (2014), we attempt to control for group-specific reactions in another way in column 4, by creating the industry-group-level average R&D, in the period before and after 2009. This will capture industry-group specific effects that differ before and after the policy change. We find that its inclusion slightly increases the average treatment effect, but we note that this additional variable itself is of no individual significance.

In column 5 we make the treatment assignment "stricter" by only assigning the treatment status if a firm appears in both 2007 and 2008 and has a zero tax liability in both years. However, this makes the average treatment effect insignificant because there are too few firms and too little variation in the treatment group now (approximately one in seven firms in the sample is treated as opposed to three in seven in the original treatment assignment). In this instance, the magnitude of the effect would have to be extremely large for the average treatment effect to be of statistical significance (in other words it is likely that the comparability of our two groups is reduced by this stricter treatment assignment). But this stricter treatment assignment is not critical; 80% of the treated firms under column 1 actually have zero tax liabilities in both years (as opposed to 20% who have a zero tax liability in only one of those years) and we feel this is a reasonable proportion.

In column 6 we return to our original treatment assignment but make the sample "stricter" by only including firms who have positive R&D in both 2007 and 2008. These firms can be considered as most R&D-active and, a priori, we expect to see an increase in the coefficient of interest. The proportion of treated firms in this sample is more balanced, like in column 1 and unlike in column 5. The average treatment effect rises as expected, although there is a very substantial reduction in the number of observations used in the sample.

Comparing the ATE results of columns 1 and 6 in Table 6 supports the interpretation that zero values for R&D do not drive our preferred result for additionality as, if they did, we would expect the average treatment effect in column 6 to be lower than in column 1 and this is not the case. By definition of the sample, there are more observations with zero R&D in the pre-treatment period in column 1

[25] This control is not based on firm-level grants data but instead captures whether a firm is in an industry that garners a large share of R&D grants, for Irish and non-Irish firms respectively.

Table 6: examining the additionality of the R&D tax credit

		Robustness checks				
	Preferred Model	R&D Grants	Industry growth	Mean R&D	Stricter treatment assignment	Stricter sample
	(1)	(2)	(3)	(4)	(5)	(6)
Dummy for post-treatment year * Dummy for treatment	0.912**	0.917**	0.912**	0.990*	0.332	1.835***
	(0.458)	(0.459)	(0.457)	(0.570)	(0.588)	(0.559)
ln (employees)	2.741***	2.742***	2.742***	2.739***	2.764***	3.408***
	(0.291)	(0.290)	(0.289)	(0.291)	(0.292)	(0.517)
Industry-level R&D grants		-2.094				
		(4.271)				
Industry growth			-0.380			
			(1.863)			
Industry growth * Dummy for treatment			-4.992*			
			(2.690)			
Mean industry-level R&D in pre and post treatment period, by group				-1.16e-07		
				(3.96e-07)		
Dummy for 2008	6.677***	6.693***	6.421***	6.679***	6.664***	0.114
	(0.459)	(0.460)	(0.497)	(0.460)	(0.459)	(0.135)
Dummy for 2009	7.227***	7.251***	6.958***	7.247***	7.544***	-0.285
	(0.401)	(0.405)	(0.441)	(0.406)	(0.362)	(0.277)
Dummy for 2010	5.257***	5.238***	5.041***	5.277***	5.575***	1.640***
	(0.461)	(0.463)	(0.495)	(0.469)	(0.420)	(0.486)
Dummy for 2011	4.458***	4.479***	4.473***	4.478***	4.770***	2.278***
	(0.467)	(0.471)	(0.465)	(0.474)	(0.428)	(0.542)
Dummy for 2012	4.187***	4.204***	4.045***	4.207***	4.499***	2.877***
	(0.482)	(0.482)	(0.496)	(0.491)	(0.441)	(0.589)
Dummy for 2013	3.477***	3.532***	3.357***	3.497***	3.784***	3.699***
	(0.504)	(0.516)	(0.516)	(0.513)	(0.472)	(0.602)
Dummy for 2014	1.409***	1.456***	1.390***	1.429***	1.715***	5.672***
	(0.517)	(0.529)	(0.520)	(0.527)	(0.487)	(0.67)
Constant term	-5.053***	-4.838***	-4.907***	-5.014***	-5.129***	-1.352
	(1.104)	(1.194)	(1.103)	(1.114)	(1.108)	(2.092)
Observations in sample	2,552	2,552	2,552	2,552	2,552	770
R-squared	0.274	0.274	0.276	0.274	0.273	0.291
Number of firms	342	342	342	342	342	103
Firm-level Fixed Effects	YES	YES	YES	YES	YES	YES
Treatment assignment in years before treatment	Either or both	Either or both	Either or both	Either or both	Both	Either or both
Positive R&D in years before treatment	Either or both	Either or both	Either or both	Either or both	Either or both	Both

Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

compared to column 6. If a treated firm in column 1 did R&D in either of 2007 or 2008, but not both years, some of the resulting average treatment effect could be driven by this (assuming they continued to do R&D in the post-treatment period). However, because we eliminate this scenario in column 6, and yet still see a higher ATE, this implies that zero values do not drive our preferred result in column 1.[26] Or in other words, we are not simply seeing high R&D growth due to a low initial level of R&D.

This last robustness check also highlights the importance of sample size and firm clustering. We note that by including firms with positive R&D in either or both of 2007 and 2008 in the sample (as opposed to exclusively both years), we downward bias the results of our preferred model as we have not precisely isolated the firms who are likely to be most sensitive to the policy change. On the other hand, making the sample stricter results in very large reduction in the sample and in clustering of standard errors on a smaller number of firms, which we seek to avoid.

At this point, our preferred estimate of additionality is in column 1 of Table 6. *In order to take it as our result, we must assume that we have captured all variables that could affect the treatment and control group R&D outcomes differently.*

9.3. Firm characteristics for additionality

Following on from this, we may ask what are the channels by which we observe this additionality. It is typically the case that young firms do not have the same access to finance for R&D as older firms and we would expect that a change in their financial incentives would induce more R&D from them compared to others. This relative lack of finance stems from the fact that they have yet to develop a reputation, typically have limited or no access to collateral, and by definition they do not have past profits to rely on. Further, younger firms tend to be less profitable than older firms and we do in fact observe a larger share of them in our group of treated firms (roughly 1 in 3 treated firms are classified as younger than 3 years compared to only 1 in 20 in the control group – see Table 5). We also saw in Figure 28 that their average R&D jumped substantially in 2009 compared to other firms. Therefore, we change the treatment assignment used in Table 6 and now apply "treated" status to firms aged less than three years in 2009 and "control" status to all firms in the sample older than three years in 2009. A priori, we expect to see a positive and significant average treatment effect on these firms.

Unlike a simple visual inspection in Figure 28, the regression analysis controls for permanent differences between the young and older firms. Over and above these controls, and the time-varying control for firm-size, we observe in column 1 of Table 7 that, *relative to other firms*, young firms actually do *significantly less* R&D in the post-treatment period. Although their R&D does increase in the post-treatment period, it is increasing more slowly than other older firms and we cannot say that the repayable tax credit causes additionality for this specific type of firm. Running a similar robustness check as in column 4 of Table 6 (i.e. controlling for differences in the average level of R&D conducted by young and older firms by industry and by pre and post-treatment period) results in a similar ATE being observed (see Appendix). Again, this suggests other barriers to these firms exist besides financial constraints. Indeed, if firm-level profits are added as another form of control, the ATE and all other coefficients again remain identical (see Appendix).

Compared to older firms, for example, young firms may not experience the same economies of scale or have access to the necessary infrastructure to perform R&D or have the same ability to attract a skilled workforce. A recent paper that compared old and young firms in Spain's manufacturing sector

[26] Note the discussion in this paragraph is independent of the decision to start R&D. All firms in Table 6 conduct R&D at some point before the change in policy, so the models under examination refer to the change in the level of R&D (i.e. the intensive margin) and not the decision to start R&D (i.e. the extensive margin).

found a lower degree of persistence in the R&D carried out by young firms, which could reflect the relative inexperience of such firms, resulting in a more erratic implementation of R&D projects which a tax incentive could do little to combat (García-Quevedo et al., 2014). Taking firm size, or interacting it with age, as in columns 2 and 3 of Table 7, we again confirm that the channels through which we might expect the tax incentive to cause additional R&D are not as expected.

We take another approach in the final two columns of Table 7. Instead of identifying plausible channels by which additionality may occur (i.e. our hypothesis that young firms are more financially constrained than older firms and so will react more to a tax incentive), we approach the issue by restricting the sample. We run our preferred model (i.e. column 1 in Table 6 and as per the treatment assignment in Table 3) firstly with the added sample restriction that firms must be less than 3 years old in 2009 and, secondly, that they must be older than this. We find no evidence of additionality when the sample is restricted to young firms and the opposite is the case when the sample is restricted to more mature firms. The proportions of treated firms are reasonably balanced under both specifications, avoiding the issues associated with column 5 in Table 6 above. We note that the sample for the 0-3 regression (column 4) is quite small; if we rerun the models in columns 4 and 5 with wider age categories (0-5 years, and older than 5 years), we increase the sample size (i.e. improve the precision of our estimates) yet still observe similar results (see Appendix).

The results from this section are particularly noteworthy, as the repayable credit would be expected to assist young innovative firms in particular. Our results indicate that the primary beneficiaries of the policy are not young firms (this is true both in terms of the relative magnitude of exchequer assistance, see Figure 17, and in terms of producing additional R&D).

Our results also resonate with the recent productivity literature that suggests that spill-overs between leading and laggard firms have slowed down in recent years (OECD, 2015). Although that research is focused on innovation outputs, the fact that younger firms increase their R&D less than older firms, in spite of a new financial incentive to do so, may shed light on the productivity result. This unexpected outcome needs to be investigated further and policy possibly refocused away from financial support (through tax credits or grants) and more toward regulatory or other supports to stimulate persistent R&D in young firms and ultimately reduce the productivity gap between firms in the same industries.

Overall, the results in this section are useful for policy consideration as they highlight that a tax incentive cannot be relied on in isolation as a policy tool to pursue the outcome of increased business R&D by young or small firms. Such firms likely face other non-financial barriers to R&D expansion and this could usefully be the subject of further research.

Table 7: examining the channels for additionality

	Young firm dummy (1)	Small firm dummy (2)	Young small firm dummy (3)	Young firm sample (4)	Older firm sample (5)
Dummy for post-treatment year * Dummy for young firms	-2.080***				
	(0.655)				
Dummy for post-treatment year * Dummy for small firms		-1.316**			
		(0.590)			
Dummy for post-treatment year * Dummy for young small firms			-2.314***		
			(0.884)		
Dummy for post-treatment year * Dummy for original treatment				0.579	1.131**
				(1.308)	(0.485)
ln (employees)	2.848***	3.165***	2.879***	1.842**	2.969***
	(0.286)	(0.327)	(0.283)	(0.740)	(0.306)
Dummy for 2008	6.590***	6.671***	6.649***	8.560***	6.423***
	(0.458)	(0.458)	(0.457)	(1.363)	(0.484)
Dummy for 2009	3.790***	3.809***	3.788***	8.058***	7.063***
	(0.310)	(0.308)	(0.310)	(1.347)	(0.414)
Dummy for 2010	1.817***	1.835***	1.819***	4.660***	5.266***
	(0.366)	(0.366)	(0.366)	(1.643)	(0.478)
Dummy for 2011	0.998***	1.001***	0.993***	2.542*	4.603***
	(0.351)	(0.350)	(0.352)	(1.458)	(0.490)
Dummy for 2012	0.715***	0.715***	0.708***	3.792**	4.167***
	(0.266)	(0.265)	(0.266)	(1.460)	(0.504)
Dummy for 2013				3.919***	3.383***
				(1.252)	(0.533)
Dummy for 2014	-2.075***	-2.094***	-2.069***	0.763	1.408**
	(0.298)	(0.299)	(0.298)	(1.278)	(0.546)
Constant term	-5.383***	-7.045***	-5.731***	-0.211	-6.231***
	(1.090)	(1.302)	(1.083)	(2.184)	(1.199)
Observations in sample	2,552	2,552	2,552	247	2,305
R-squared	0.276	0.277	0.276	0.403	0.271
Number of firms	342	342	342	39	303
Firm-level Fixed Effects	YES	YES	YES	YES	YES
Treatment assignment in years before treatment	Either or both	Either or both	Either or both	Either or both	Either or both
Positive R&D in years before treatment	Either or both	Either or both	Either or both	Either or both	Either or both
Firm's age in 2009	-	-	-	3 years or younger	4 years or older

Clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: young firms defined as aged 0-3 years and small firms defined as 0-9 employees.

9.4. Dynamic effects

Our main result indicates the tax credit scheme has positive additionality. An interesting follow-up question is whether this effect is stronger in the short or long run. The effect may be stronger in the long-run, for example, if firms need time to build up their research capacity. On the other hand, the effect may be stronger in the short-run if firms are inexperienced and choose to implement projects without much planning. To examine this, we follow Hægeland and Møen (2007) by including an interaction term for the first year in which a treated firm makes a repayable credit claim, the results of which are presented in column 1 of Table 8. If the effect of the repayable credit increases over time, we would expect this coefficient to be negative and significant; if the effect declines over time, the coefficient is expected to be positive and significant.

This dummy does not change the average treatment effect, with the ATE in column 1 in Table 8 similar to our preferred ATE in column 1 of Table 6, and we can find no evidence of any difference in short or long term effects. Adding the robustness check, as per column 4 of Table 6, does not materially change the ATE nor are we better able to distinguish short term from long-term effects in our analysis.

Table 8: Examining dynamic effects in R&D behaviour

	(1)	(2)
Dummy for post-treatment year * Dummy for treatment	0.941*	1.013*
	(0.484)	(0.600)
Dummy for first repayable credit claim	0.966***	0.967***
	(0.289)	(0.289)
Dummy for first repayable credit claim * Dummy for treatment	-0.301	-0.306
	(0.466)	(0.471)
ln (employees)	2.720***	2.718***
	(0.290)	(0.291)
Mean industry-level R&D in pre and post treatment period, by group		-1.06e-07
		(3.98e-07)
Dummy for 2008	6.679***	6.680***
	(0.459)	(0.460)
Dummy for 2009	6.910***	6.928***
	(0.405)	(0.412)
Dummy for 2010	5.104***	5.122***
	(0.467)	(0.475)
Dummy for 2011	4.382***	4.400***
	(0.470)	(0.476)
Dummy for 2012	4.154***	4.172***
	(0.487)	(0.495)
Dummy for 2013	3.460***	3.478***
	(0.507)	(0.515)
Dummy for 2014	1.391***	1.410***
	(0.521)	(0.530)
Constant	-4.979***	-4.943***
	(1.102)	(1.112)
Observations in sample	2,552	2,552
R-squared	0.276	0.276
Number of Firms	342	342
Firm level Fixed Effects	YES	YES

Clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

9.5. Decision to start R&D

The rise in business R&D observed over time is explained by a combination of existing firms changing their R&D levels and by new firms starting R&D. However, *the decision to start R&D* is modelled in a different way to the change in the level of R&D, which is what has been under consideration up to this point.[27] The decision to start R&D would not be expected to be the same as the decision to increase or decrease R&D due to significant start-up costs associated with R&D (e.g. new capital expenditure such as buying equipment or creating laboratories, recruiting and hiring specialist staff).

However, using our dataset we cannot fully investigate the decision to start R&D. By definition, all firms in our dataset do R&D at some point. If we model the decision to start R&D in the post-2009 period using this particular dataset, we will observe a very high probability to begin R&D. This can be understood better by looking at Table 9, which shows the evolution of R&D tax credit claims, broken down by first-time and previous claimants. The highest number of new claimants over our period occurred in 2009, the year the repayable credit was introduced.

To properly model the decision to start, we in fact have to use a different dataset. We need to look at the universe of firms filling out the corporation tax form and not just the subset that do R&D. The Revenue Commissioners are currently creating a panel dataset that covers all firms (i.e. not only firms who conduct R&D).

In future, one useful avenue to explore the decision to start R&D would be to use a binary outcome model (such as a probit model) as per Haegeland and Møen (2007). Briefly, the approach would involve restricting Revenue's broader panel dataset to a sample of firms with zero R&D in all years prior to 2009. The dependent variable would be an indicator variable taking on unit value in the year a firm undertook R&D for the first time. As the sample would be restricted to firms who did no R&D whatsoever before 2009, the dependent variable would indicate when they did R&D for the first time after this period (i.e. what year over 2009 to 2014 inclusive they first began R&D). This would be regressed on a number of firm-specific characteristics, e.g. employees and ownership, alongside year dummies. As we are interested in the impact of the repayable tax credit on the decision to start R&D, the coefficient of interest would be that on the 2009 year dummy variable. A significant positive marginal effect would indicate the repayable credit did encourage new firms to start R&D.

One caveat with any attempt to look at the decision to start R&D is that we cannot control for the fact that there may be firms conducting R&D in the pre-treatment period who only enter the sample in the post-treatment period. This may be a possibility for firms who do not consider it "worth their while" to report R&D on their corporation tax form if they are loss-making prior to 2009 when the value of the tax credit was conditional on positive corporation tax liabilities. In addition, firms do not file corporation tax returns until they commence trading, and may conduct R&D prior to trading. Such firms may bias upward the results for any decision to start R&D specification, and this must be borne in mind in future work.

Despite being unable to examine the causal impact of the tax credit on the decision to start at the present time, we can still look at the characteristics and persistence of firms that start R&D in general and the cohort of firms who started R&D in 2009 in particular.

Table 9 shows a breakdown of R&D credit claims made between 2007 and 2014. As mentioned above, the large increase in new claims upon the introduction of the repayable credit, with claims peaking in

[27] We note that examining the decision to start R&D is relatively uncommon in the tax credit evaluation literature, which mainly focuses on the level of additionality caused by the tax incentive.

2009, is of particular note. It also now appears that the pool of firms who could potentially claim the tax credit has been largely exhausted, with 85% of claims in 2014 being made by firms which have previously availed of the credit (with the vast majority of those having claimed in 2013 as well).

Of the new claims now being made, the claimants tend to be younger and smaller than in the cohort of firms claiming from 2007 to 2009. Although in all years the vast majority of new claims are Irish rather than non-Irish, this proportion increased from 84% in 2007 to 97% in 2014. This compositional analysis possibly indicates that larger, foreign firms were in a better position to take advantage of the credit in the earlier years, with smaller indigenous firms having now had enough time to adjust their activities and benefit from the scheme.

Table 9: Evolution of R&D tax credit claims

	2007	2008	2009	2010	2011	2012	2013	2014
Firms claiming this year* (=a+b+c)	206	434	893	1095	1284	1358	1363	1111
a. Of which first time claimants	-	293	537	401	371	277	232	164
as percentage of claimants this year	-	68%	60%	37%	29%	20%	17%	15%
Cumulative number of unique claims (i.e. new firms) since 2007	206	499	1036	1437	1808	2085	2317	2481
b. Of which claimed last year (i.e. continuing firms)	-	141	328	668	846	1008	1058	888
as percentage of last year's claimants	-	68%	76%	75%	77%	79%	78%	65%
c. Of which claimed before last year (i.e. returning firms)	-	0	28	26	67	73	73	59
Claims in previous year	-	206	434	893	1095	1284	1358	1363
Of which not claiming this year	-	65	106	225	249	276	300	475

**Based on firms claiming an in-year credit. Total number of firms claiming in-year credit each year will be less than the overall number of firms making R&D claims due to carry forward credits. In-year credits are what indicate R&D activity that year.*

Figure 30 shows the proportion of R&D expenditure conducted each year that is done by new claimants. Again 2009 stands out as almost 45% of R&D expenditure that year was due to new claimants. However, by the final years under review, less than 5% of total R&D expenditure was being conducted by new claimants, which is in line with the figures in Table 9.

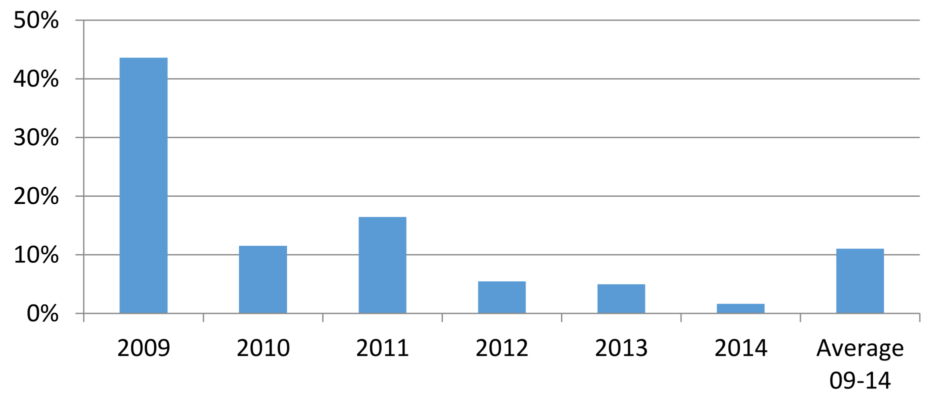

Figure 30: proportion of R&D expenditure conducted by first-time claimants
Source: Revenue Commissioners

Turning to the new claims in 2009 in particular, we observe that this cohort represents a significant amount of R&D still being conducted in Ireland today. If we follow this cohort through time, we observe that they are responsible for almost a quarter of business R&D over 2009-2014 (Figure 31). Given this fact, it is important to determine in future work whether this cohort's strong R&D performance is due to the tax credit or to other factors unrelated to taxation policy.

In terms of their firm characteristics, 92% of this cohort are Irish firms and approximately 60% of them had 50 or more employees in 2009. Figure 32 shows their age breakdown. About a third of this cohort were well established firms in 2009 (aged 8-15 years) while 23% were less than 3 years old.

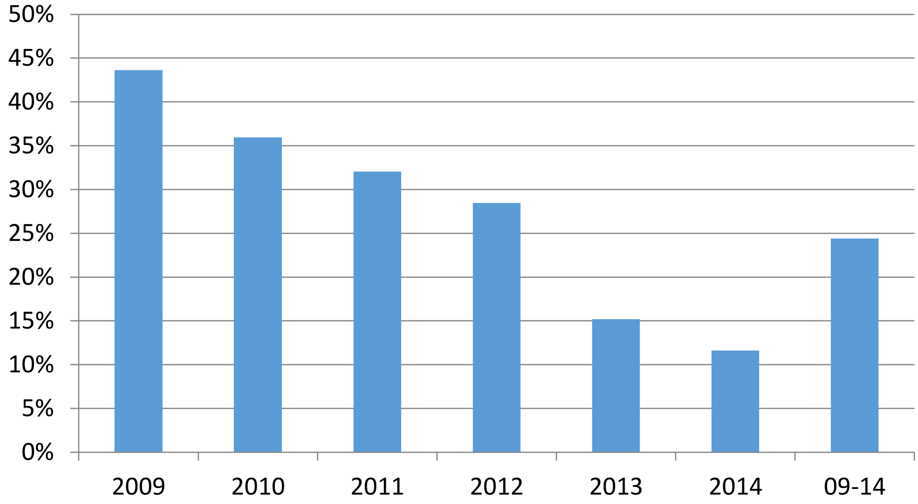

Figure 31: proportion of R&D conducted by the 2009 cohort of first-time claimants
Source: Revenue Commissioners

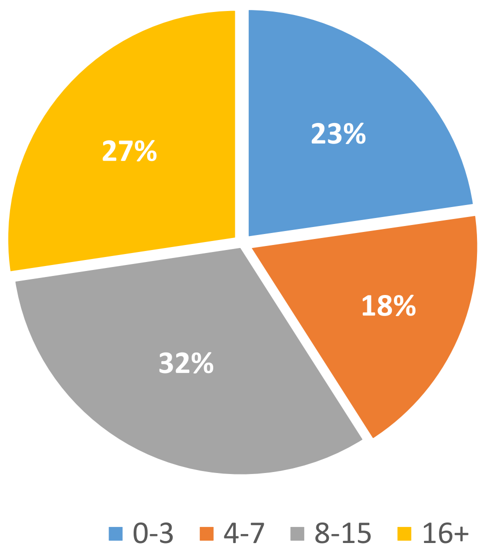

Figure 32: age profile of the 2009 cohort of first-time claimants
Source: Revenue Commissioners

Given this cohort represents a large share of R&D expenditure over 2009-2014, it is unsurprising to see that these firms are persistent i.e. perform R&D in a majority of years. In fact almost one third of these firms conduct R&D in every year after 2009 and over half conduct R&D in 4 or more years. However, 18% of the cohort only claimed in 2009; this is due to a combination of firm death and possible "gaming" of the repayable tax credit system, meaning taking advantage of the repayable credit during the economic downturn but not becoming a genuine or long-term R&D-conducting firm.

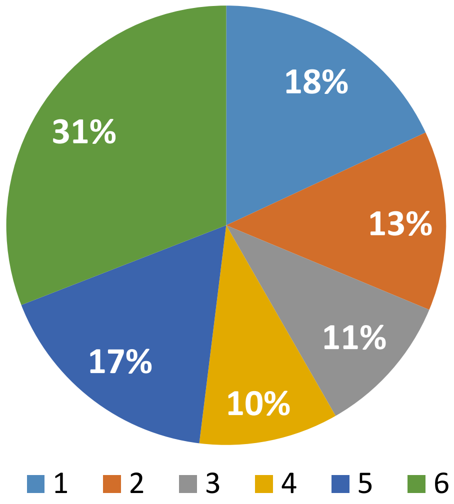

Figure 33: number of years that 2009 cohort of first-time claimants has conducted R&D
Source: Revenue Commissioners

If we classify persistence as conducting R&D in 4 or more years, we observe that persistent firms from this cohort remain in line with this cohort's characteristics generally. The nationality, size and age breakdowns remain virtually the same for "persistent" members of the cohort as for the cohort generally.

The examination of new R&D tax credit claimants (which we assume identifies firms who have never done R&D before) is useful in so far as knowing the characteristics of these firms can give us better information on the types of firms taking up the tax credit and the characteristics associated with persistent use of the tax credit - but it does not tell us how likely any given firm is to undertake R&D for the first time and, most importantly, whether the R&D tax credit is truly an important influence in this decision. This is an important question that could be pursued when the necessary panel data are available.

For now, we note here that our primary result on additionality is one relating to the intensive margin; we observe that the R&D tax credit is associated with reasonable additionality, meaning that firms increased their level of R&D in response to the tax credit. We also note that this additionality result is not driven by firms who typically conducted very little R&D before the introduction of the repayable credit, and this is consistent with the lack of evidence we find for additionality for young firms in particular, who typically do less R&D than other kinds of firm. Without explicitly modelling the extensive margin though, i.e. the decision to start R&D, we cannot conclude on whether tax incentives are more important for the intensive or extensive margin in business R&D, although it would be a useful line of inquiry in future evaluations of this tax credit.

10. How much additional R&D induced per euro of tax revenue foregone?

Key Points	*Although we observe reasonable additionality due to the tax credit, it comes at a considerable cost. The bang for buck, or the additional R&D done per euro of public support, is 2.4. The maximum bang for buck under the Irish scheme would be 4. Our result therefore indicates deadweight or partial crowding out of private funding.*

Our results suggest that the R&D tax credit scheme does stimulate additional R&D. However, this is not enough to conclude that this tax expenditure is successful. Leaving aside the broader issues of whether the extra R&D improves innovation and boosts economic growth, a key question in the evaluation is how much additional R&D was induced per euro of tax revenue foregone. This question is often answered with what is known in the evaluation literature as the "bang for the buck" ratio (BFTB).

Before presenting the ratio related to the regression result, it is worth remembering that for a firm who would *not have undertaken any R&D at all* without the existence of the tax credit scheme, the BFTB is 4 (1 / 0.25), given that the credit has been issued at 25% since 2009. For firms who would have *undertaken R&D in full without the tax credit* the BFTB is 0. This means that any BFTB less than 4 implies "deadweight" i.e. R&D that would have been conducted anyway by the private sector.

Turning to the regression results, recall that the model used to obtain our result is as follows:

$$\ln(R\&D)_{it} = \alpha + \mu_i + \sum_{t=1}^{t=T} \delta_t \, D^{year\ t} + \theta D^{year\ post-treatment} . D^{treatment} + \gamma \ln(employees)_{it} + \varepsilon_{it}$$

Our value for θ is 0.912. Its interpretation is the change in log R&D induced by a firm receiving a financial incentive to conduct R&D – all else equal. This implies that the expected value of the counterfactual R&D in the absence of the tax credit scheme for such a firm is:

$$\ln(R\&D)^{without\ tax\ credit} = \ln(R\&D)^{with\ tax\ credit} - \theta$$

$$R\&D^{without\ tax\ credit} = \frac{R\&D^{with\ tax\ credit}}{\exp(\theta)}$$

We note that firms face an incentive to over-report their R&D expenditure in the Revenue data. To reduce the administrative burden, firms only have to prove their R&D claims if Revenue audits them, and while Revenue operates an effective compliance programme to police claims, it remains the case that not every firm will be subject to official scrutiny. R&D expenditure on the corporation tax form is also supposed to be reported *net* of grant financing but not all firms may do this (accidentally or otherwise). We note, on this basis, that our estimate for BFTB may be biased upward.

Table 10: calculating additional R&D and the bang for buck

Coefficient for average treatment effect	0.912
Exponent for coefficient	2.49
Observed R&D conducted in the post treatment period (2009-2014), in the presence of the tax credit	€10.4 billion
Counterfactual R&D: the R&D that would be conducted in absence of the credit	€4.2 billion
The additional R&D caused by the presence of the tax incentive: the difference between the observed and counterfactual R&D	€6.2 billion
Cost of the scheme (foregone revenue + repayable credit)	€2.6 billion
Bang for buck (BFTB)	€2.40

Note: the figures for nominal R&D assume that the behavioural response to the R&D tax credit, i.e. the coefficient for the average treatment effect, can apply in any time period.

We see that for each euro in foregone revenue, an additional €2.40 is generated in R&D*. This suggests that the policy is achieving its aim of increasing R&D, but with considerable deadweight.* Our regression and BFTB results indicate that the Irish R&D tax credit scheme in its current form is leading to partial crowding out of private funding for R&D.

We note that in many other tax credit evaluations it is stated that obtaining a BFTB of greater than one is considered acceptable. *We believe this assessment is insufficient*. In all schemes where tax is deducted by a percentage of R&D activity it is possible to calculate the minimum and maximum BFTB. Where the maximum BFTB is large, as in the case of Ireland, then obtaining a BFTB greater than one cannot automatically lead to the conclusion that the tax credit policy is successful.

On the scheme's deadweight, Table 10 shows that roughly 40% of the R&D observed over the period would have occurred anyway, i.e. in the absence of the tax credit, while 60% of the R&D observed was due to the tax credit i.e. additional R&D. In older work by Honohan (1997) and Forfas (2003), the assumption of grant deadweight of 80% is used for the purposes of ex ante project appraisal (although this related to employment and other grants from the enterprise development agencies and not to R&D grants specifically). Until updated work is performed on R&D grants, preferably using one of the non- self-assessment methods outlined in Section 6, we cannot conclude on whether the tax credit, with 40% deadweight, is more efficient than R&D grants.

11. Conclusions

This evaluation employed an appropriate counterfactual exercise in order to evaluate the R&D tax credit. By utilising a quasi-experimental design based on a treatment and control group framework, the causality effect of public funding was identified. The use of micro-econometric techniques represents a better evaluation approach given the biases inherent in interviews, case studies and self-assessed surveys.

Overall, our results suggest that the R&D tax credit is reasonably successful in its aim of increasing business R&D. However, this must be immediately qualified by referring to the notable deadweight associated with this unrestricted fiscal incentive. Of the R&D conducted over 2009-2014, we estimate that 60% is additional (due to the tax credit) and 40% is deadweight (would have been conducted without the tax credit).

Due to the parameters of the Irish scheme, i.e. its linear 25% relationship between R&D expenditure and tax liabilities, it is straightforward to assess the economic efficiency of the scheme. From a maximum additional €4 of R&D for each euro foregone, we calculate that the scheme generates €2.40. This means the scheme funds some R&D that would have been conducted anyway. In other words, the State is partially crowding out private funding for BERD, giving rise to a degree of inefficiency.

The *Tax Expenditure Guidelines* refer to efficiency in the evaluation sense of comparing two alternative policy tools to achieve the same outcome. This cannot be determined here as we do not know the additionality generated by R&D grants. On the other hand, we tried to include the grants data where possible in our analysis. We note the unit cost of the tax credit scheme is higher than the unit cost of the grants scheme, but this is not sufficient to draw a conclusion on the relative merits of the two forms of public support for BERD.

In addition, we did not find evidence that the tax credit scheme is effective in encouraging R&D in younger firms, which suggests other barriers to conducting R&D for this type of firm should be examined in greater detail, and public policy tailored appropriately. On the other hand, the scheme appears to be effective for older firms, so a possible policy response is simply to adopt a "wait and see" approach. If market forces allow a firm to grow to a sufficient stage of development, then the tax credit (as it stands) can assist that firm to perform additional R&D. It may give rise to further inefficiencies to try to target inexperienced firms via a tax credit policy that specifically differentiates firms with respect to age.

Many reviews of tax incentives from international organisations suggest that a cash refund, in the form of a repayable credit option, is good for new firms. We provide evidence that such an approach can result in notable deadweight. This does not make a repayable credit a bad thing in and of itself (for example it protects R&D spending during a recession) but suggests careful design is needed to avoid a large cost to the exchequer with little additional R&D from young or other firms to show for it. For instance, currently the repayable credit is limited in generous nominal terms. In order to improve the value for money or BFTB, it may be appropriate to consider reducing it in temporal terms i.e. a firm could only claim the repayable credit a maximum number of times over a given period. Another approach could be to lower the tax reduction for firms that have used the credit for some time. We note that the value of outstanding credits in 2014 was €592 million. Given the size of this future liability to the Exchequer, it is pertinent to consider how to prevent it from increasing even further in future.

Any policy change to the tax credit scheme should involve discussion with the appropriate stakeholders alongside recognition that too much adjustment of the scheme could result in confusion or abuse of the system by firms. It may also be appropriate to maintain tax incentives that are neutral with respect to all characteristics of R&D firms (including the frequency with which they perform R&D) and, instead, re-evaluate other non-financial public policies that stimulate BERD.

This evaluation was limited to examining additional R&D and value for money. A full cost-benefit analysis (CBA) would involve calculating the social return on R&D and market spill-overs, which can be positive (knowledge transfer) and negative (obsolescence). On the cost side, a CBA would have to examine administrative, implementation and opportunity costs of Government funds. The demands involved in a CBA on the specific topic of R&D are onerous, the assumptions very strong (particularly in relation to spill-overs) and the results subject to imprecision. However, a useful further study that would be less demanding could look at particular innovation outputs, for example patent citations, over the recent past in Ireland.

A tax credit can only rectify the market failure of under-investment in R&D if the root of the problem is financing. If, for example, the greatest barrier is insufficient human capital, the tax credit will not solve the failure and in addition runs the risk of considerable deadweight. The Irish R&D tax credit in its current form can be considered a reasonably successful policy tool, in that it does stimulate additional R&D, but the deadweight inherent in the scheme should not be ignored.

12. Appendix

Table 11: other regression results

	Eq (3) (1)	Including outliers (2)
Dummy for 2008 * Dummy for treatment	3.027***	
	(0.909)	
Dummy for 2009 * Dummy for treatment	2.305***	
	(0.698)	
Dummy for 2010 * Dummy for treatment	2.443***	
	(0.807)	
Dummy for 2011 * Dummy for treatment	1.900**	
	(0.821)	
Dummy for 2012 * Dummy for treatment	2.408***	
	(0.847)	
Dummy for 2013 * Dummy for treatment	3.636***	
	(0.895)	
Dummy for 2014 * Dummy for treatment	2.313**	
	(0.968)	
Dummy for post-treatment year * Dummy for treatment		0.916**
		(0.456)
ln (employees)	2.731***	2.740***
	(0.290)	(0.291)
Dummy for 2008	5.452***	6.660***
	(0.606)	(0.458)
Dummy for 2009	6.688***	7.204***
	(0.446)	(0.401)
Dummy for 2010	4.658***	5.242***
	(0.545)	(0.461)
Dummy for 2011	4.086***	4.446***
	(0.560)	(0.466)
Dummy for 2012	3.601***	4.177***
	(0.567)	(0.481)
Dummy for 2013	2.405***	3.478***
	(0.606)	(0.503)
Dummy for 2014	0.867	1.417***
	(0.598)	(0.516)
Constant term	-5.049***	-5.052***
	(1.094)	(1.108)
R-squared	0.283	0.273
Firm FE	YES	YES
Including outliers	NO	YES

Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 11 continued: other regression results

	Mean R&D control (3)	Gross Profits control (4)	Young firm sample (5)	Older firm sample (6)
Dummy for post-treatment year * Dummy for young firms	-2.247***	-2.069***		
	(0.656)	(0.655)		
Dummy for post-treatment year * Dummy for original treatment			0.172	1.215**
			(0.881)	(0.536)
ln (employees)	2.841***	2.854***	2.571***	2.934***
	(0.287)	(0.285)	(0.515)	(0.361)
Mean industry-level R&D in pre and post treatment period, by young/older group	-9.15e-07			
	(7.44e-07)			
Gross profits		1.64e-09***		
		(4.65e-10)		
Dummy for 2008	6.592***	6.591***	7.479***	6.433***
	(0.458)	(0.459)	(1.009)	(0.516)
Dummy for 2009	8.226***	3.824***	7.895***	7.035***
	(0.512)	(0.310)	(0.888)	(0.448)
Dummy for 2010	6.254***	1.847***	5.302***	5.251***
	(0.582)	(0.366)	(1.065)	(0.513)
Dummy for 2011	5.435***	1.028***	4.468***	4.453***
	(0.566)	(0.351)	(0.937)	(0.535)
Dummy for 2012	5.152***	0.711***	4.208***	4.167***
	(0.598)	(0.264)	(1.061)	(0.544)
Dummy for 2013	4.438***	-	3.724***	3.402***
	(0.620)		(1.118)	(0.567)
Dummy for 2014	2.364***	-2.074***	1.650	1.327**
	(0.631)	(0.298)	(1.046)	(0.591)
Constant term	-5.087***	-5.421***	-2.123	-6.502***
	(1.127)	(1.087)	(1.386)	(1.493)
Observations in sample	2,552	2,552	545	2,007
R-squared	0.276	0.277	0.332	0.262
Number of firms	342	342	78	264
Firm-level Fixed Effects	YES	YES	YES	YES
Including outliers	NO	NO	NO	NO
Firm's age in 2009	-	-	5 years or younger	6 years or older

Clustered standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Appendix item 1: Revenue's systems of data management

Tax returns filed with the Revenue Commissioners are recorded on live data management systems where they can be accessed and queried. For more significant analysis, extracts are taken from the live system at a point in time. This is done for the purposes of stability and consistency with published costings and other statistics as this becomes the official record for that particular tax year. The primary data used in this paper are based on a 'snapshot' of the data taken approximately six months after the end of the filing date for each year. This is supplemented by Revenue with additional information from the live systems where necessary. While certain data may be subject to revision subsequently, this is not picked up in the 'snapshot'. However, these revisions are expected to be minor.

Appendix item 2: Issue of missing data in Revenue

All zeroes are converted to missing values in Revenue's analysis files, as their key requirements from the data are to know the number of claims and the sum of values. Identification of blanks versus zeroes is not possible with the Revenue data.

For some variables, a missing value is more than likely a zero. A useful example is the tax credit being claimed for R&D activity in the current period or the overall claim (which is the sum of the current credits and carry forward credits from previous periods). If all components of the claim (i.e. current credits and carried forward credits) are positive but the claim field is not, it is likely a missing variable and not zero. If the value for the overall claim equals the carried forward credit, then the current year credit – which is needed to construct the current year level of R&D – is likely to be zero and not a missing variable.

All data required for the regression analysis were checked in this fashion and adjusted from missing to zero where necessary. When it was not possible to determine if the value should be zero, the value was left as missing.

As mentioned elsewhere, the current evaluation assumes that taxpayers fully and accurately report tax returns.

Appendix item 3: Results from previous evaluations of the R&D tax credit

The Department of Finance's *Guidelines for Tax Expenditure Evaluation* outline the scope and frequency of evaluations. For tax expenditures costing over €50 million, the measure should be reviewed every three years and subject to a full Cost-Benefit Analysis (CBA). Accordingly, the current evaluation was conducted in the first half of 2016. The Programme for Partnership Government 2016 also commits to greater scrutiny of tax expenditures, in order to reform the budget process. Under the vision outlined to create a 'Social Economy', the Programme commits to a stable and broad tax base. It further states that any new tax incentives will be subject to detailed cost-benefit analysis, public consultation and Oireachtas debate.

The Department most recently reviewed the credit in 2013 and concluded that it stood up well in terms of international best practice on fiscal incentives for R&D.[28] Due to data limitations, a full empirical investigation of causality was not possible at that time. However, based on what data were available at the time, the review of tax credits in other jurisdictions and the public consultation, a number of recommendations were made such as phasing out of the base year and relaxing the outsourcing limits. These were subsequently implemented. An externally commissioned firm-level

[28] The 2013 review is available on the Department's website at: http://www.finance.gov.ie/what-we-do/tax-policy/consultations/previous-consultations/rd-tax-credit

survey, which also formed part of the 2013 review, found that the R&D tax credit had been well received by firms, with more than half of those surveyed indicating that their R&D expenditure would have been less in the absence of the tax credit, although some aspects of the scheme, such as the key employee provision, were less well received.

The credit was also reviewed internally in 2010 by the Central Expenditure Evaluation Unit (then located in the Department of Finance but now part of the Department of Public Expenditure and Reform). This earlier review surveyed firms directly and found evidence of additionality and deadweight associated with the tax credit, although these findings were based on a small sample of firms.[29] Many of the recommendations made in the 2010 review were also acted upon, including the introduction of the R&D repayable credit and the addition of R&D-related fields to the corporation tax form.

[29] The drawbacks of evaluating additionality through firms' self-assessment are discussed elsewhere in this report.

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