Department for Business Innovation & Skills

BIS ANALYSIS PAPER 04

Estimating the effect of UK direct public support for innovation

NOVEMBER 2014

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Acknowledgments

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Foreword

Innovation is a key driver of economic growth and increased welfare. All successful, modern innovation systems have an innovative business sector at their heart. Improving production processes and creating new products and services is vital for international competiveness, business success, and the creation of high value jobs. It is also vital to addressing large-scale social and environmental challenges. To be prosperous and successful in future decades, the UK economy needs a high-performing science and innovation system at its heart.

A well-established range of market and system failures mean there is an essential role for government in actively supporting innovation. This support needs to take a range of forms, as recognised in the whole-of-government approach taken in the Industrial Strategy. It also requires choices to be made about the best use of limited public financial, capital and human resources. This means there is a vital need for high quality evidence to understand better the processes that drive innovation and growth, assess whether government action is having its intended effects and provide insights for the future direction of policy.

On that basis, I welcome the rigorous analysis in this paper as an important contribution to further building the evidence base on the impacts of public support for innovation. It is spiriting to see government investment in direct innovation support having substantial, robust impacts on business innovation in the economy.

However, this analysis is itself innovative, applying econometric techniques to certain matched data sets in a manner that has not been done before in the UK. As with all such analysis, as our knowledge progresses further we need to test and strengthen the basis for our conclusions. New also questions arise. I look forward to seeing what further insights this type of work can help to uncover in the future.

I would like to personally thank all of the contributors to this project, and particularly the National Physical Laboratory, without whose detailed econometric analysis this report would not have been possible.

Mark Franks

Head of Knowledge & Innovation Analysis

Executive Summary

- This paper presents new analysis of direct UK innovation grant funding programmes, combining data from the ONS, the UK innovation survey and Innovate UK. It uses Propensity Score Matching to robustly assess the causal impact of innovation grant support. It considers this in the context of the recent broader economic literature on innovation to consider its likely impact on the UK Economy.

- The findings relate to firms in receipts of a range of different funding sources, including Innovate UK funding. Of those firms in receipt of support around 35 per cent had received financial support from Innovate UK with around 20 per cent of this group receiving support during the analysis period.

- The analysis suggests that grant support substantially increases UK firms' innovation performance, with significant impacts noted for SMEs (with 10 to 250 employees) and large firms (with more than 250 employees). No conclusions could be drawn on micro firms in this analysis due to issues with the sample size and identification of an effective counterfactual.

- Impacts were noted across a broad range of measures providing evidence of input, behavioural and output additionality from innovation support. The analysis found that Large Firms and SMEs as a group were more likely to: invest more in Research and Development (R&D); collaborate; employ Science, Technology, Engineering and Mathematics (STEM) graduates; use technical information; engage in product innovation; engage in process innovation and introduce novel products to market. Projects that involve cooperation with universities and Public Sector Research Establishments (PSREs) were shown to have additional impacts over and above projects just involving finance support.

- In terms of the impact of public funding for innovation on private funding for innovation this analysis finds no evidence of deadweight/crowding out. Indeed, the *opposite* is observed with public funding *crowding in* around 30 per cent more private funding (in addition to the public funding provided) over the short term. This consistent with the broader econometric literature on direct funding. This also suggests crowding in increases over the longer term.

- The analysis could not draw any serious conclusions about the impacts on turnover, employment and productivity over the three year period examined, as a longer time series would be needed. However, we know from the broader literature that product innovation raises UK firms' labour productivity, potentially linking the outputs observed in this study to higher economic growth[1]. These results are consistent with both previous UK economic evaluations of support measures and the broader econometric

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[1]Griffith, R.; Huergo, E.; Mairesse, J.; and Peters, B. (2006), "Innovation and productivity across Four European Counties", Oxford Review of Economics Policy, 22(4), 483-498. (ii) Criscolo, C. (2009), 'Innovation and Productivity: Estimating the Core Model Across 18 Countries', Chapter 3, Innovation in Firms: A Microeconomic perspective, OECD Innovation Microdata project.

literature on R&D, which find substantial private and social returns to innovation. A recent comprehensive review of the returns literature places average private returns at around 30 per cent per year with social returns recorded at 2-3 times this level. This demonstrates the large positive economic spillovers associated with innovation.[2]

- Consistent with the new findings in this report, the wider literature also finds collaboration delivers greater innovation benefits than more ‘closed’ forms of innovation; and that grant-based forms of innovation support the broader development of firms’ absorptive capacity (the ability to innovate as captured in the skills, networks and experience of its people) in a way that indirect measures do not[3].

- Broader evidence also suggests policies to support innovation are inter-dependant. For example, the evidence around policy mix suggests grants are more effective when combined with broader forms of complementary support such as tax credits and business support[4] than when used in isolation. Also, the final impact of the innovation is contingent on very context specific economic framework conditions, including the functioning of markets, the Intellectual Property regime and the characteristics of institutions. These conditions vary by innovation area[5].

- Further work may analyse the impacts of grant support on particular subsets of innovative firms, for example micro firms and particularly large firms supporting substantial UK supply chains. Also, applying this type of impact analysis to other parts of our innovation infrastructure e.g. the National Physical Laboratory is an area for exploration. Particularly of interest, but also particularly challenging technically, will be considering whether this analysis could extend to look at long run economic impacts on the firms in the survey e.g. turnover, employment, productivity and importantly, spillovers, to relate these findings with positive findings to the broader econometric literature.

[2] Frontier Economics, (2014), Rates of Return to Investment in science and Innovation, A Report for the Department of Business, Innovation and Skills (BIS)
[3] BIS Economics Paper 15 and Roper, S., Hewitt-Dundas, N. (2014), ‘The legacy of public subsidies of innovation: input, output and behavioural additionality effects’, Enterprise Research Centre
[4] Cunningham, P.; Gok, A.; and Laredo, P. (2012). ‘The Impact of Direct Support to R&D and Innovation in Firms’, Compendium of Evidence on the Effectiveness of Innovation Policy Intervention
[5] Nesta, (2011), Measuring Wider Framework conditions for successful innovation – A systems review of UK and international innovation data and ‘The impact of Innovation Policy Mix’ (2013), Compendium of Evidence on the Effectiveness of Innovation Policy Intervention, Manchester Institute of Innovation Research (MIoIR)

1. Introduction

Innovation has been a long standing area of interest for UK economic policy. The links between economic growth and innovation are well established the literature[6] and has resulted in a range of government action to address a number of identified market and system failures[7]. However, it remains major area of focus - R&D investment is still relatively low by international standards, even when controlling for our industrial mix[8]. As the UK continues with its economic recovery there is strong interest in the potential of business innovation as part of the solution to address the so-called “productivity puzzle”[9] and to boost long-term economic growth.

But as with all government policies, and particularly those which operate at the boundary of the public/private sector interaction, close consideration needs to be given to the additionality of any measures[10]. Confidence is needed that any interventions will create extra economic activity rather than duplicate or displace activity that would have happened otherwise; to do this good quality impact analysis is needed.

However, evaluation of specific innovation policy measures is highly challenging for a number of reasons[11]. Establishing a robust counterfactual is one. Innovative firms are different in character from general firms making identifying comparison groups challenging. However it is a key element of impact assessment[12] and is needed to determine causality and the ‘quantum’ of impact once other influences are controlled for. This paper examines the literature around the impact of innovation to examine the mechanisms through which it influences economic growth. It also provides robust new causal evidence of the impact of UK direct public support’s impact on innovation.

[6] BIS Economics Paper 15
[7] BIS (2014) ‘The case for public support for innovation at the sector, technology and challenge area levels
[8] BIS (2014) ‘Insights from international benchmarking of the UK Science and Innovation System’
[9] BIS (2014) Innovation Report 2014 ‘Innovation, Research and Growth’ for a description
[10] HMT (2014) Green Book: appraisal and evaluation in central government
[11] SMART INNOVATION: A Practical guide for Evaluating Innovation Programmes, A study for DG Enterprise and Industry, European Commission
[12] HMT’s Magenta Book (2011)

2. Recent evidence on the impact of innovation

This chapter draws on recent econometric analysis and literature reviews to demonstrate how innovation generates economic growth.

The economic impact of innovation

The latest evidence from the UK and beyond continues to demonstrate the importance of persistent business-led R&D for stimulating firm performance, survival, exports[13] and economic growth at the national level – showing large private and social returns, including substantial positive externalities. A recent comprehensive review of the returns literature places average private returns at around 30 per cent a year with social returns recorded at 2-3 times this level.[14] Also, evidence suggests direct innovation support develops a firm's absorptive capacity in a way that indirect measures do not through increasing the skill sets of staff and increasing the ability of firms to engage externally.[15] These findings accord with previous economic evaluations of UK innovation grant support programmes for SMART and Collaborative R&D[16] which estimated benefit-cost ratios in the order of £9:1 and £7:1 respectively.

Impacts from different types of R&D manifest over different timescales. 'Basic' research generally takes longer to impact and its returns are more 'social' in nature. For example, benefits may accrue through benefits to the environment and better public services. Applied R&D tends to have faster impacts on economic growth, however more of the gains from the process tend to be internalised by the firm conducting the R&D.[17] More recent literature has placed an increased emphasis on the economic impact of complementary 'intangible' assets such as economic competencies (marketing, management skills, marketing etc), and ICT[18] and the role of Intellectual Property.[19]

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[13] BIS (2014) Highly Innovative Firms and Growth and Cefis. E, Marsalia (2004) Matter of Life and Death: Innovation and Firm Survival*

[14] Frontier Economics, (2014), Rates of Return to Investment in science and Innovation, A Report for the Department of Business, Innovation and Skills (BIS). These figures are included in the report's Executive Summary.

[15] Roper, S., Hewitt-Dundas, The legacy of public subsidies for innovation: input, output and behavioural additionality effects, Enterprise Research Centre (2014)

[16] Evaluation of the Collaborative Research and Evaluation Programmes (2011) PACEC, Evaluation of Grant for Research and Development and SMART (2009) PACEC

[17] Jaffe, Adam B.; Trajtenberg, Manuel; Fogarty, Michael S. (May, 2000) The American Economic Review Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors. Vol. 90, No. 2, Papers and Proceedings of the One Hundred Twelfth Annual Meeting of the American Economic Association, pp. 215-218.

[18] Corrado, C., et al. (2005), "Measuring Capital and Technology: An Expanded Framework", in Corrado, C., Haltiwanger, J., and Sichel, D. (eds.), *Measuring Capital in the New Economy*, Chicago: The University of Chicago Press

Newer examinations of how the innovation process works have emphasised the move away from 'in house' R&D approaches and linear technology transfer out of the research base to an 'open innovation model' where firms have more fluid, interactive collaborations with each other and the academic community, increasing the importance of 'network' type interventions[20].

Evidence has also increasingly emphasised the importance of skills to facilitate effective innovation, ranging from good STEM skills to management competencies[21]. Indeed, recent research has used vector auto-regression techniques to examine the chain of causality linking firm's innovation to its subsequent growth. The analysis suggests the growth process starts with increased employment, which then leads to future increases in R&D spending and new to market products, which in turn lead to future increases in sales.

The impact of public support for innovation

Broadly, evidence[22] shows that public investment in R&D carried out by the private sector leverages additional private R&D investment (input additionality). Both R&D tax credits (an indirect measure) and grants (a direct measure) have been shown to leverage private funding.

Tax credits and grants have a range of characteristics which determine their appropriateness for a given situation. For example, grants can be targeted at high additionality projects or mission-led priorities like energy innovation, whereas tax incentives work cross-sector and intervention requires less active management. At a system level there is evidence of complementarity from employing both measures simultaneously.[23]

The international evidence on R&D grants, and particularly fiscal incentives, impact on output additionality is thin, with a relatively small number of robust impact evaluations having been conducted. Previous UK evaluations of direct support have put UK interventions at the higher end of recorded impact of programmes across a range of countries[24].

Although it's difficult to measure the effect of grants on a firm's productivity directly we can make the following observations: (1) public financial support increases inputs to innovation activity; (2) an increase in innovation activity (e.g. higher business spending on innovation) increases the likelihood of introducing new products; and (3) product innovation tends to raise a firm's labour productivity (turnover per employee). And, thus, it's reasonable to

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[19]Intellectual Property Office (2013) Innovation, patenting and licensing in the UK: Evidence from the SIPU; Intellectual Property Office (2012) Patent Incentives: returns to patenting and the inducement for research & development Intellectual Property Office
[20] BIS Economics Paper 15
[21] BIS (2014) Highly Innovative Firms and Growth
[22] Frontier Economics, (2014), Rates of Return to Investment in science and Innovation, A Report for the Department of Business, Innovation and Skills (BIS)
[23]Cunningham, P.; Edler, J.; Flanagon, K.; Laredo, P. (2013) 'Innovation Policy Mix and Instrument Interaction', Compendium of Evidence on the Effectiveness of Innovation Policy Intervention.
[24]Cunningham, P.; Gok, A.; and Laredo, P. (2012). 'The Impact of Direct Support to R&D and Innovation in Firms', Compendium of Evidence on the Effectiveness of Innovation Policy Intervention

suppose that public financial support should have at least an indirect effect on labour productivity, because it has an observable impact on the resources committed to innovation and this in turn will generate productivity growth.[25]

Evaluating the impact of innovation at a system level

Determining optimal policy mix mainly from static economic evaluation evidence is risky. Evidence shows policies are inter-dependant and the final impact of the innovation is highly contingent of very context specific ‘economic framework conditions – market functioning, Intellectual Property regime, the characteristics of institutions etc.[26] However, when used in addition to a range of other evidence sources, impact evidence can support decision making.

A fresh literature review[27] of the evidence shows a wide range of market and system failures impact innovation areas. Importantly, the way these innovation failures combine with ‘sector’ failures creates unique issues for each area of innovation examined. For example, a broad range of *different* market failures causes credit constraints in different sectors. This implies the optimal policy mix will vary by innovation area, dependent on the specific challenges faced and the infrastructure in place.

In addressing each of these areas a ‘systems’ view of innovation shows that different R&D funding policies often perform different functions and should often be viewed as complements rather than substitutes. For example, different R&D funding mechanisms target different Technology Readiness Levels (a measure to assess the maturity of a technology), and a firm’s needs are not homogeneous. Tax credits and grants can be combined in helpful ways to support different firm types, and ‘pull and push’ policies can be used to balance building competencies with providing market incentives. A tentative general finding of the evidence[28] is that more integrated forms of support are beneficial, for example, policies which combine financing ‘valley of death’ activities with training to develop commercial skills tend to have more significant impacts.

Investment in research and development in the UK

An international benchmarking review of innovation policy has shown UK investment in R&D is relatively low, even after controlling for industrial structure[29], with the UK coming 2nd bottom compared to 8 comparator countries. Data from the Office for National Statistics shows that in the UK:

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[25] (i) Griffith, R.; Huergo, E.; Mairesse, J.; and Peters, B. (2006), “Innovation and productivity across Four European Counties”, Oxford Review of Economics Policy, 22(4), 483-498. (ii) Criscolo, C. (2009), ‘Innovation and Productivity: Estimating the Core Model Across 18 Countries’, Chapter 3, Innovation in Firms: AMicroeconomic perspective, OECD Innovation Microdata project.
[26] Nesta, (2011), Measuring Wider Framework conditions for successful innovation – A systems review of UK and international innovation data and ‘The impact of Innovation Policy Mix’ (2013), Compendium of Evidence on the Effectiveness of Innovation Policy Intervention, Manchester Institute of Innovation Research (MIoIR)
[27] BIS (2014) ‘The case for public support for innovation at the sector, technology and challenge area levels
[28] and ‘The impact of Innovation Policy Mix’ (2013), Compendium of Evidence on the Effectiveness of Innovation Policy Intervention, Manchester Institute of Innovation Research (MIoIR)
[29] BIS (2014) ‘Insights from international benchmarking of the UK Science and Innovation System’

- Total BERD was £17 billion in 2012 (1.1 per cent of GDP).
- 8 per cent of BERD was funded by direct grants from government (£1.3 billion).
- 8 per cent of BERD was funded by R&D tax credits (£1.4 billion).

Around 11 per cent of firms in the UK Innovation Survey (2010 to 2012) received at least 20 per cent of the money they spent on R&D from central government or the EU - in the form of grants or subsidised loans - through a wide range of schemes that support innovation.

3. UK direct public support for innovation: new analysis in a UK context

This chapter sets out the methodology and data used in our new analysis of grant support.

Methodology

Objectives of the analysis

Previous attempts to assess the impact of direct financial support for R&D have a number of limitations:

- They tend to look at specific schemes (e.g. Innovate UK's Smart scheme, which tackles the funding gap often experienced by many small and early-stage companies with innovative ideas and high growth ambition and potential) rather than the direct innovation support as a whole. And, thus, they generally involved quite small samples of firms, limiting what analysis can be done quantitatively.

- They often look at financial support in isolation rather than in combination with other forms of support, such as, cooperation with universities and PSREs which are noted as key aspects of effective modern business innovation.

- They require participants (grant-holders) to make judgements about what might have happened without public support to estimate a counterfactual case.

This analysis aims to address these issues and estimate the impact of grants for R&D on innovation by participating firms. Particular aims of the study are as follows:

- It assesses the impact from direct innovation support as whole. This support is provided by a range of different public organisations; principally it covers all of Innovate UK. In terms of the sample examined, around 50 per cent had experienced some form previous engagement with Innovate UK, 35 per cent had received some grant funding from Innovate UK and 20 per cent were receiving grant funding from Innovate UK during the analysis period.

- It examines the interaction between financial support and cooperation with universities and PSREs.

- It explicitly constructs the counterfactual by pairing 'treated' firms with 'untreated' firms using Propensity Score Matching (made possible by the large sample size).

The challenge – identifying a counterfactual

It's important to recognise that a firm, particularly one that chose to participate in an innovation programme, may well have developed a new product even if it hadn't received public support. The extent to which a firm would have carried out activity anyway is known as deadweight[30] and should not be ascribed to the policy as impact.

The impact of *public support* on some form of innovation, such as product innovation, is best thought of as the likelihood of a given firm innovating with the benefit of public support minus the likelihood of the same firm innovating in the absence of this support (the counterfactual).

Therefore, at the heart of policy evaluation is a missing data problem. That is, you can never observe the outcome that would have occurred if a given firm hadn't participated in the programme. We therefore need some way of assessing the counterfactual outcome for a participating firm.

If treatment were assigned randomly, then this missing data problem would disappear. That is, we could simply use the expected outcome for 'untreated' firms as a proxy for what the expected outcome for the participants would have been in the absence of 'treatment'. However, participation in innovation support programmes is the result of a complex mix of self-selection (firms have to apply) and vetting by public sector experts (only the best projects are funded). It follows that the participating firms are not a random sample from the population. And, if the participants differ systematically from the rest of the population, then the counterfactual outcome for 'treated' firms is unlikely to be drawn from the same distribution as that for 'untreated' firms.

A solution – Propensity Score Matching

A solution to the missing data problem can be found if we make the following assumptions:

- Conditional Independence: A firm's decision to apply for an award is largely determined by its observable characteristics, previous R&D expenditure, and whether it made use of public support in the past. Given appropriate firm-level data for such variables, we can estimate the likelihood that a firm with particular characteristics will apply for a grant. Moreover, although, there remain unobservable aspects of a firm's situation that affect it's propensity to apply for a grant, it's assumed that none of these factors are correlated with the variables in our model so do not affect the expected outcome for a given type of firm.

- Common Support (the overlap between the propensity scores for treated and untreated individuals): The ranking and sifting of bids by civil servants will be subject to some randomness. That is, grants are awarded based on the observable characteristics of the applicants and the quality of their bids. However, the process of ranking bids is subject to a fair amount measurement error at the margin. There are some unfunded bids that are 'above-the-line' in terms of quality but do not get funded. Consequently, there will be a lot of similarities between successful bids and unsuccessful bids.

[30] See HMT Green Book

If these assumptions are correct, then it should be possible to estimate the likelihood of a given firm applying for, and receiving, a grant for its R&D activities. Moreover, given an appropriate firm-level data set, we should be able to pair each 'treated' firm with an 'untreated' firm that shares the same propensity score. This is the basis of a Propensity Score Matching methodology that has been used to assess the impact of R&D grants in other countries using data from the Community Innovation Survey (CIS).[31]

An appropriate dataset can be constructed by linking two ONS datasets: BERD data and the UK Innovation Survey (UKIS). The BERD data come from an annual survey of firms that perform R&D and, among other things, this survey asks whether a firm received direct public support for R&D. The UKIS is carried out every two years and provides detailed information about a firm's innovation activities, as well as, whether it developed any new products or services during the period. For this study we used the two most recent waves of the survey: UKIS (2008-2010); and UKIS (2010-2012).

It is important to note that in innovation terms this is a relatively *short time period;* and previous evidence has shown direct grant support has a lagged long term impact[32]. Benefit durations of a decade are not uncommon[33] particularly for the impacts of spillovers.

Finally, it is possible to link observations (enterprises) in one survey to those in the other survey using information from the Interdepartmental Business Register (IDBR). In particular, for an enterprise from a given wave of the UKIS, we can use the BERD data to find out: (1) whether it received public financial support during that wave of the UKIS; (2) whether it received public financial support during a previous wave of the UKIS; and (3) whether it has a general history of performing R&D.

As mentioned at the start of this section, an ideal dataset would be constructed by randomly assigning firms to treatment from some target population and observing the outcome. In reality it is often impractical to construct these data sets in real-world contexts. However, we can construct a dataset with similar statistical properties from the non-experiment data we have to hand.

The Propensity Score Matching approach allows us to construct a quasi-experimental dataset in which grant-holders are matched with highly similar non grant-holders. We can therefore use the outcome for these matched 'untreated' firms as a proxy for the outcome

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[31] Aerts, K., and Schmidt, T., (2008), 'Two for the price of one?: Additionality effects of R&D subsidies: A comparison between Flanders and Germany', Research Policy, Volume 37, Issue 5, Pages 806-822. Czarnitzki, D., and Fier, A., (2002), 'Do innovation subsidies crowd out private investment? Evidence from the German service sector,' Konjunkturpolitik, 48 (1), pp. 1-25. Czarnitzki, D., and Licht, G., (2006) 'Additionality of Public R&D Grants in a Transition Economy. Economics of Transition', Vol. 14, No. 1, pp. 101-131. Czarnitzki, D., Ebersberger, B., and Fier, A., (2007), 'The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and German', The Journal of Applied Econometrics, Vol. 22, pp. 1347-1366. Ebersberger, B., (2004), 'Labour Demand Effect of Public R&D Funding', VTT Working Paper No. 9, VTT, Espoo, Finland Ebersberger, B., and Lehtoranta, O., (2008), 'Effects of Public R&D Funding,' VTT Working Paper No. 100, VTT, Espoo, Finland. Foreman-Peck, J., (2013), 'The Effectiveness and efficiency of SME innovation policy', Small Business Economics, Vol. 41, pp. 55-70.

[32] Guellec, D. and B. van Pottelsberghe de la Potterie (2000),"The Impact of Public R&D Expenditure on Business R&D",OECD Science, Technology and Industry Working Papers, 2000/04, OECD Publishing

[33] Frontier Economics, (2014), Rates of Return to Investment in science and Innovation, A Report for the Department of Business, Innovation and Skills (BIS)

that would have been observed for the 'treated' firms had they not participated in the programme.

The right information

The appropriate matching variables are those that describe the information available at the moment of assignment and simultaneously explain the outcome of interest. Matching variables should be selected before the time of assignment because otherwise matching variables could be affected by the treatment itself. The following principles apply:

- We should not include measures like current R&D expenditure as this will be affected by the receiving of a grant for innovation.

- We can include information about a firm's previous history of investing in R&D; and whether or not the firm was awarded a grant in the past. To some extent this will help control for the unobservable abilities and propensities of a firm's management team, assuming these are fixed over time.

The aim is not develop the most accurate prediction of assignment to treatment. Rather the specification of the assignment model should be as parsimonious as possible without compromising the Conditional Independence Assumption. In particular, it should only include variables that directly affect the outcome for the following reasons. Firstly, unnecessary variables will increase the variance (standard error) associated with any estimates. Secondly, it is very important to ensure that enough random factors are left in the error term to maintain a large common support.

Two modes of support

Firstly, this study looks at two forms of support:

- Significant direct financial support: Because the BERD data show that most firms with in-house R&D receive some form of direct financial support, this study focussed on firms that received significant financial support through grants and awards. For the purpose of this study, a firm is said to have received 'significant' support if over 20 per cent of its in-house R&D spending comes directly from government. Around 11 per cent of firms in the UK Innovation Survey (2010 to 2012) received at least 20 per cent of the money they spent on R&D from central government or the EU - in the form of grants or subsidised loans - through a wide range of schemes that support innovation.

- Cooperation with the public sector: Any form of cooperation with universities, PSREs or government agencies. Hence, this includes collaboration with public sector researchers on specific projects but may also include wider forms of cooperation and networking.

Secondly, cooperation with public sector and being a grant-holder are highly correlated.

- 32 per cent of the firm identified as grant-holders also collaborated with the public sector.

- 45 per cent of firms that collaborated with universities and PSREs were also grant-holders.

No doubt the correlation between these two forms of support is partly a reflection of their inherent complementarity. However, it's important to recognise that it is also baked-in to schemes like Collaborative R&D (CRD). Indeed, coefficients in the propensity score confirm a strong correlation between previous grants and current collaboration. It is useful to examine separately in the analysis to examine whether collaboration generates additional impacts.

Three forms of additionality

The 'additionality' generated by public support is the difference between the average of some (policy relevant) outcome variable for the 'treated' firms and the average of this variable for the matched 'untreated' firms. The impact of the support is the size of this additionality as a percentage of the average for the matched 'untreated' firms.

The concept of additionality is particularly relevant to answering questions about the impact of small changes in the size of the support schemes while keeping the basic nature of the scheme unchanged. Specifically, it gives us information about the effects of taking a grant away from an otherwise successful applicant.

This study focusses on three forms of additionality based on information from the UKIS:

- Input additionality as measured by the intensity of a firm's spending on R&D (from all sources of funding) as a percentage of its turnover and through the build-up of STEM skills in the labour force.
- Behavioural additionality as measured by the use of technical sources of information, such as, scientific journals and engaging in the process of innovation itself.
- Additional output from innovation activities as measured by the development of new products and processes.

Why is the analysis robust?

There are a number of reasons to regard the analysis as robust. The Propensity Score Matching approach has previously been used to assess the impact of grants in other European countries (e.g. Finland and Germany) using similar data sources. Estimation was carried out using a widely used programme 'PSMatch2' written by E. Leuven (University of Oslo) and B. Sianesi (UCL and IFS). Furthermore, the data sources – UKIS and BERD – are well established ONS datasets, involving a large number of respondents[34] and data-linking based on the IDBR is also a well-established technique.

The use of Propensity Score Matching to construct a quasi-experimental dataset has a number of advantages over other econometric methods.

- With matching we are not extrapolating beyond the region of common support and the calliper for an acceptable match (which determines the closeness of the match) was set

[34] 6,000 from UKIS (2008-10); and 8,500 from UKIS (2010-12).

to 0.001. That is, we are not making claims about the impact on firms that aren't in the target population.

- Standard diagnostic tests showed that means of the control variables were the same for 'treated' firms and matched 'untreated' firms. And, there was a strong overlap between the propensity scores for the treated and untreated firm, which is crucial for the validity of the method.

- Blundell and Dias (2009) say that matching is robust to certain forms of misspecification in a way that fully parametric methods are not.[35]

Finally, the data linking between the UKIS and the BERD data is probably not perfect even though it was based on response units. That is, some enterprises will have been misclassified as grant-holders because of confusion over which member of an enterprise group was actually awarded the grant. However, the classic errors-in-variables model says the measurement error in an independent variable generally causes a *downward bias* in the magnitude of estimated coefficients. And, thus, statistically significant coefficients remain informative in the case of moderate measurement error.

Limitations

We did not estimate a separate model for large firms or primes (particularly large firms at the top of supply chains) due to concerns around sample size and time constraints. That is, we only supplied estimates for two samples: Sample (1) just SMEs; Sample (2) SMEs and large firms. However, the similarity of results between the SMEs and the all firms group suggests that these results are robust to stripping out the primes. The estimated impact for sample 2 is larger than it is for sample 1. The results hint at a difference between large firms and SMEs. However the confidence intervals in the analysis mean we cannot draw robust conclusions about this.

Further work is needed as the current study is mainly focused on SMEs as this is where the matching methodology is expected to work best. It is important to note a distinction between large firms (250+ employees) and primes. It is reasonable to expect Propensity Score Matching to work less well for primes because their unique natures make the matching approach less plausible. However, remember that primes will account for a small fraction of these observations. Furthermore, the matching was done on local enterprise units rather than whole companies (or enterprise groups) and this gives the matching procedure many observations to use.

Finally, firms were systematically dropped from the analysis if it wasn't possible to find a good match. (The calliper was set to 0.001.) In principle, it is legitimate to match across size classes using a propensity score[36] which means that you can perform the analysis without exact matching within 'boxes'. However, this involves strong assumptions about the irrelevance of firm-specific unobservables.

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[35] Blundell, R. and Dias, C. (2009) 'Alternative Approaches to Evaluation of Empirical Micro Economics', The Journal of Human Resources, Vol. 44(3), p. 566 – 640.
[36] Rosenbaum, P. and Rubin, D.B. (1983) \The Central Role of the Propensity Score in Observational Studies for Causal E_ects," Biometrika, vol. 70, no. 1, 4155.

Results

Impact of grants on innovation

Table 1 provides estimates of the impact of receiving a grant (where this is over 20 per cent of the money spent on R&D by a firm) compared with firms not receiving a grant but who are similar on a range of other characteristics. The analysis provides estimates for both large firms and SMEs as a single group (referred to throughout the analysis as All Sizes) and SMEs separately.

The results below are expressed in terms of an increased probability of conducting an innovative activity compared with the control group. We observe large and statistically significant results on all of the measures of innovation activity and output examined. For example, we can see from the top level cell that All Sizes group receiving a grant are 32 per cent more likely to use technical information than a matched group of similar firms.

The analysis attempted to examine micro firms[37] but they were dropped from the analysis due to difficulties in obtaining a large enough control group to draw statistically significant conclusions.

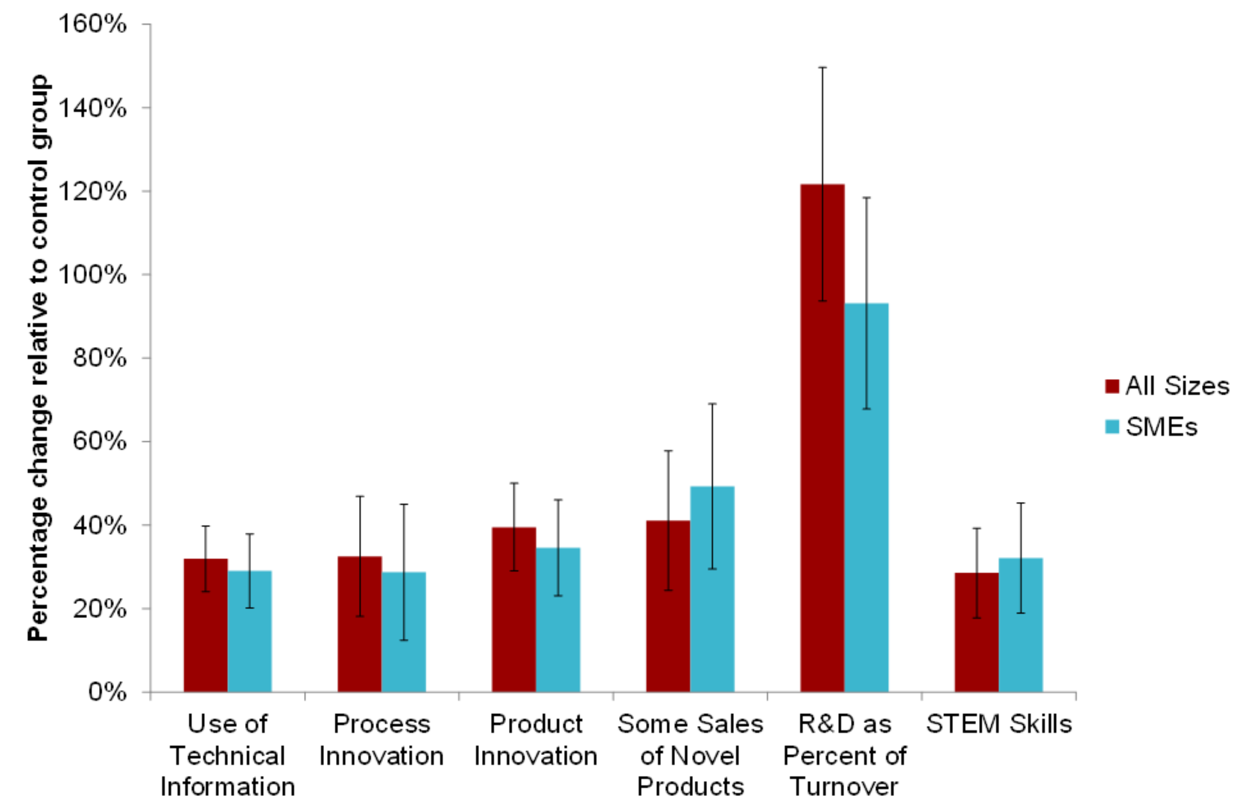
Table 1: Impact of financial support (grants)

Outcome Variable	Sample	Best Estimate (%)	Lower Bound (%)	Upper Bound (%)
Use of Technical Information	All Sizes	32	24	40
	SMEs	29	20	38
Process Innovation	All Sizes	32	18	47
	SMEs	29	12	45
Product Innovation	All Sizes	40	29	50
	SMEs	35	23	46
Some Sales of Novel Products	All Sizes	41	24	58
	SMEs	49	29	69
R&D as Percent of Turnover	All Sizes	122	94	150
	SMEs	93	68	118
STEM Skills	All Sizes	29	18	39
	SMEs	32	19	45

Figure 1 shows the same results and adds confidence intervals at the 95 per cent level. This highlights the point that whilst we observe large impacts for both ‘All Sizes’ as a group and SMEs, separately, we cannot say with statistical confidence that the impact of one group is larger than the other.

[37] Those with less than ten employees

Figure 1: Impact of grants: percentage change in outcome variable



These results provide strong evidence in the impact of grant funded programmes. We find impacts all along the causal chain.

Input additionality

Input additionality is achieved in terms of funding. Receiving a grant is found *to double a firm's spending on innovation.* But how much of this additional spending on R&D comes from the firms themselves rather than from the grant? In other words, do we observe deadweight (which reduces additionality) or the opposite effect where public funding *crowds in* private funding.

An approximate answer to this question can be found as follows. Let 'g' denote funding from grants; 'f' denote the firm's own spending that would have occurred without a grant; and 'Δf' denote additional spending by firms as a result of receiving a grant. The analysis gives us two related equations: (a) the semi-elasticity equation, which in this context gives us a change in firms spending as a result of grant support, is $(g + \Delta f)/f = 1$; and (b) the equation for the proportion of government funding among treated firms is $g/(f + \Delta f) = 1/2$. Using these results, and a little algebra, shows that $\Delta f/f = 1/3$.[38] And, thus, the semi-elasticity for a firm's own spending is around 0.3.

[38] The equation for the semi-elasticity gives $g = f + \Delta f$. Substituting for 'g' in the other equation gives $(f - \Delta f)/(f + \Delta f) = ½$. Dividing top and bottom by 'f' gives $(1 - \Delta f/f)/(1 + \Delta f/f) = ½$, which implies that $2 – 2.\Delta f/f = 1 + \Delta f/f$. Solving for $\Delta f/f$ gives the result.

In other words, receiving a grant stimulates around 30 per cent increase in a *firm's own spending on innovation in addition to the grant funding.*

When interpreting these results we should note that this is the short run elasticity, examining leveraged investment over three year period. This could significantly understate the long-term effect. Evidence from both fiscal incentives and direct measures suggest the long run effect of such a measure is substantially larger. A study of tax credits from a panel of OECD countries noted short term additionality of around 0.22 per cent increase per 1 per cent increase in tax credits corresponded to 0.84 per cent increase in the long run[39]. A separate study which compares both grants and fiscal measures has noted grant impacts on input additionality are longer lived.[40] We also note input additionality from this analysis in terms of 29 per cent increased likelihood of grant holding firms employing staff with STEM.

Behavioural additionality

The results note an increased likelihood of conducting a range of innovation activities the literature has shown to be associated with subsequent economic performance[41]. For the All Sizes group grant support is associated with a 40 per cent increased chance of being product innovators and a 32 per cent chance of being process innovators. This group of grant recipients is also 32 per cent more likely to be using technical information.

Output additionality

The study finds that grant holders (All Sizes) are 41 per cent more likely to introduce novel products to market. We also know from the broader literature that product innovation raises UK firm's labour productivity, linking the outputs here to economic growth[42].

Impact of cooperation

Table 2 shows the impact on the same measures examined above specifically for firms who collaborate with universities and PSREs compared to a matched group of similar firms. In general, cooperation with public sector and being a grant-holder are highly correlated. That is, 45 per cent of the firms identified as grant-holders also collaborated with the public sector whilst 32 per cent of firms that collaborated with universities and PSREs were also grant-holders. Also, we know that some firms who weren't in receipt of a grant for the purposes of this analysis previously received such support.

No doubt the correlation between these two forms of support is partly a reflection of their inherent complementarity. However, it is important to recognise that a combination of grant support and collaboration is a fundamental characteristic of schemes such as Innovate UK's Collaborative R&D.

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[39] Falk, M. (2006), "What drives business Research and Development (R&D) intensity across Organisation for Economic Co-operation and Development (OECD) countries?", *Applied Economics*, 38(5), 533-47

[40] Guellec, D. and B. van Pottelsberghe de la Potterie (2000),"The Impact of Public R&D Expenditure on Business R&D",OECD Science, Technology and Industry Working Papers, 2000/04, OECD Publishing

[41] See BIS (2014) Highly Innovative Firms and Growth for discussion of these

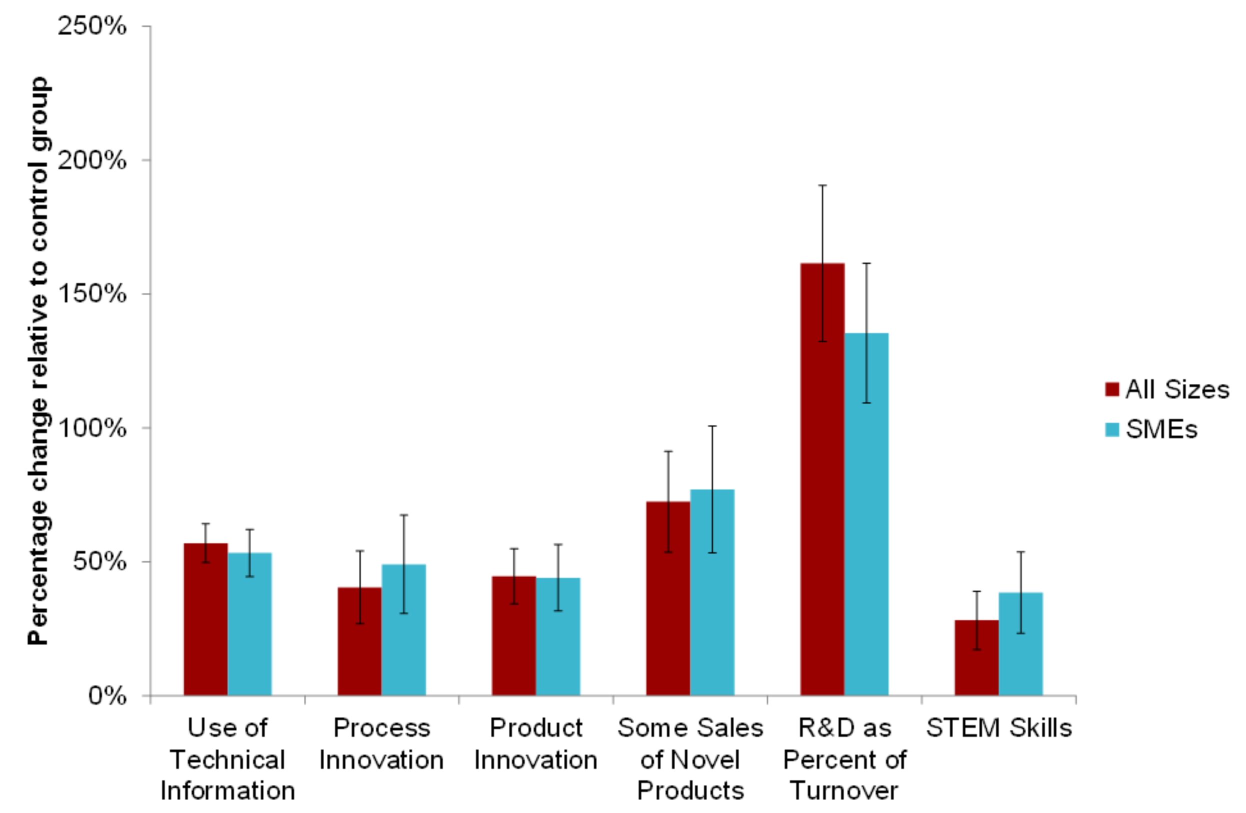
[42] See Griffith, R.; Huergo, E.; Mairesse, J.; and Peters, B. (2006), "Innovation and productivity across Four European Counties", Oxford Review of Economics Policy, 22(4), 483-498. (ii) Criscolo, C. (2009), 'Innovation and Productivity: Estimating the Core Model Across 18 Countries', Chapter 3, Innovation in Firms: A Microeconomic perspective, OECD Innovation Microdata project.

Table 2: Impact of collaboration

Outcome Variable	Sample	Best Estimate (%)	Lower Bound (%)	Upper Bound (%)
Use of Technical Information	All Sizes	57	50	64
	SMEs	53	45	62
Process Innovation	All Sizes	40	27	54
	SMEs	49	31	67
Product Innovation	All Sizes	45	34	55
	SMEs	44	32	56
Some Sales of Novel Products	All Sizes	72	54	91
	SMEs	77	53	101
R&D as Percent of Turnover	All Sizes	161	132	191
	SMEs	135	109	162
STEM Skills	All Sizes	28	17	39
	SMEs	39	23	54

Figure 2 shows that, again, we cannot come to any firm conclusions about whether the size of the impact differs between the two these groups of firms.

Figure 2: Impact of cooperative activity: percentage change in outcome variable



Comparing Tables 1 and 2, collaboration has impacts over and above grant support alone on almost all measures noted. These findings are consistent with the recent literature which has emphasised the importance of firms collaborating to successfully innovate.[43] Recent work looking at where government intervention is needed increasingly emphasises the importance of collaboration and coordination to address network and coordination failures[44].

[43] BIS Economics Paper 15

[44] BIS (2014) 'The case for public support for innovation at the sector, technology and challenge area levels'.

4. Summary

Conclusions

This analysis provides fresh evidence suggesting a positive impact direct UK public policy interventions play in terms of generating additional innovation on a broad range of measures. Impacts are found for both SMEs and large firms and SMEs as a group in receipt of direct government grant support. The results are consistent with evidence of input, behavioural and output additionality consistent with the broader literature on innovation's impact.

The analysis also suggests that collaborative innovation provides additional impacts over and above closed innovation and that grant funding leads to the additional employment of STEM graduates. The links between these outputs and economic growth have been established in a range of other studies in both a UK context and more widely.

Further areas for exploration

This analysis is the first of its kind carried out in the UK. Although the results demonstrate reassuring levels of robustness and consistency with the broader academic literature, there is scope for further analysis to both strengthen our understanding of the issues explored in this paper and better understand the implications.

Potential future areas for examination include analysing the impacts of particular subsets of innovative firms, for example micro firms and particularly large firms supporting substantial UK supply chains. Also, applying this type of impact analysis to other parts of our innovation infrastructure, such as the National Physical Laboratory, is an area for exploration, as is considering more the interactions of grant support with IP.

Of particular interest, but also technically challenging, would be extending this analysis to look at long run economic impacts on the firms in the survey to relate these findings with positive findings from the broader econometric literature.

Further analysis is also needed to examine the spill over impacts of innovation support on the broader economy. Existing evidence on R&D suggests these are likely to be substantially larger than the direct impacts on innovation support alone.

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