EVALUATION OF THE IMPACTS OF CROSS-VOTE GOVERNMENT ASSISTANCE ON FIRM PERFORMANCE

STAGE 2

IMPACTS OF DIRECT FINANCIAL SUPPORT FOR R&D

MINISTRY OF ECONOMIC DEVELOPMENT

APRIL 2011

Ministry of Economic Development
Evaluation Team
Level 12, 33 Bowen Street
P O Box 1473
Wellington 6140
New Zealand

MED1181545

Preface

This evaluation is one module of several planned for the Cross Vote Evaluation. The objective of the Cross Vote Evaluation is to provide quantitative assessments of the impact of different types of government funded business assistance. It covers all the economic development programmes administered for the Government by New Zealand Trade and Enterprise (NZTE) and the Foundation for Research Science and Technology (FRST), which administers Technology New Zealand (Tech NZ). These programmes capture the bulk of government assistance available for firms at the national level.

There are several types of government funded assistance available to enhance the economic performance of New Zealand businesses. Examples include specific grants for R&D projects, financial assistance to purchase external management advice and assistance to improve a firm's export performance. The nature and objectives of individual programmes vary across different government schemes and different government agencies. However, the programmes are driven by the common objective of improving the business performance of participants and ultimately the New Zealand economy.

Stage 1:

The first stage of the Cross Vote evaluation was completed in 2009. This evaluation was a pilot study testing the ability of the prototype Longitudinal Business Database (LBD) and focusing on one specific government programme administered by NZTE: The Growth Services Range GSR (MED, 2009). That evaluation demonstrated that it was possible to measure the average impact of a government programme on firm performance using econometric techniques and the available New Zealand data[1]. Earlier evaluations had been primarily non-quantitative relying on case studies, interviews, surveys and monitoring data.

Stage 2:

This report presents the second stage of the Cross Vote evaluation, which focuses on the quantitative impact of government R&D assistance to firms. The grants and services evaluated in this report are part of Tech NZ. They are intended to lead to additional R&D undertaken by the firm, which in turn is expected to increase the economic performance of a firm (albeit over a longer time frame). We restrict our attention to those firms that have only ever received FRST assistance and exclude firms that have also received assistance from any other agency, including NZTE. We wish to first examine the impact due to receiving R&D assistance and no other form of business support. Interpretation is more complicated when a firm receives multiple forms of support for various different activities spread across time.

Future stages

The excluded firms receiving both Tech NZ and NZTE are clearly of policy interest; they represent approximately half the Tech NZ investment over the evaluation period. It is our intention to apply a similar robust methodology to these multiple-treatment firms to assess the impact of R&D assistance in combinations with other forms of business support in the next module of the Cross Vote Evaluation. We also recommend repeating this analysis in a few more years to examine the impact at longer time lags.

[1] The evaluation found that GSR support had a significant and positive mean impact on firm performance. GSR supported firms had higher sales and value-added relative to comparable firms. The findings were reported to the Minister.

Disclaimer

Acknowledgements

This evaluation report was compiled by members of the MED Evaluation and Research teams, with Evaluation having the lead role. The contributing authors include David Bartle, Nick Hallett, Oliver Herrmann, Kris Iyer, Michele Morris and Philip Stevens. Thanks to Richard Fabling, Grant Scobie, Lynda Sanderson and Penny Mok for peer reviewing the report and providing feedback that vastly improved the quality of the report. Thanks also to Richard Fabling and Lynda Sanderson for their technical assistance and insightful discussions throughout the analysis and for providing us with their matching code. Thanks to Statistics New Zealand staff for their continued commitment to the prototype Longitudinal Business Database. All remaining errors are of course the authors' own.

[2] Note: The Foundation for Research, Science and Technology and the Ministry of Research, Science and Technology were merged into "Ministry of Science and Innovation (MSI)", established on 1 February 2011.

Table of Contents

List of Tables

List of figures

Executive Summary

This report presents results from an evaluation of publicly-funded R&D assistance provided to New Zealand firms. We use recent econometric techniques to assess the impact of Technology New Zealand's R&D programmes on the economic performance of firms that have received the assistance. The problem of evaluation is that while the programmes' impact (independent of other factors) can truly be assessed only by comparing actual and counterfactual outcomes, the counterfactual is not observed. So the challenge of an evaluation is to create a convincing and reasonable comparison group for assisted firms in light of this 'missing data'. Our methodology involves matching firms that received assistance to comparable unassisted firms based on firm characteristics. We then compare changes (or more precisely difference in changes) in performances of the assisted group with the group of matched unassisted firms.

This is the first time that this type of methodology has been applied in an evaluation of Technology New Zealand. Qualitative evaluation methods that elicit information from programme participants often attribute all or most changes in firm performance to the government programme and these are very important in describing how R&D adds value to the business. However that does not take into account the fact that many firms that seek government assistance are already growing faster and performing better than an average firm. We matched a group of unassisted firms from the Statistics New Zealand prototype Longitudinal Business Database (LBD) which contains high quality and comprehensive firm-level data from 2000 to 2008[3]. A second strength of this evaluation is that we are able to isolate the impact due to Technology New Zealand assistance from the impact due to other types of government support for business development, such as assistance provided to the firms by New Zealand Trade and Enterprise (NZTE). Earlier evaluations have failed to take multi-agency assistance into account.

Firms that receive Technology New Zealand assistance are higher performing than the average New Zealand firms *even before they seek out R&D assistance*. Prior to receiving assistance, on average assisted firms are larger, have higher sales and capital intensity and more likely to be exporting goods and undertaking R&D than firms that do not receive assistance.

We find that *additional* impacts depend upon the type of R&D assistance provided to a firm. Firms that receive Capability Building assistance show significantly higher employment growth compared with matched unassisted firms. Most of this growth occurs at the start of R&D assistance and is still evident three years following first receiving assistance. We also estimate short term impact on sales and infer a positive *additional* impact on value-added. The ultimate outcome for most government business assistance schemes, including R&D funding like the Capability Building assistance, is to raise the productivity of New Zealand firms. Encouragingly, we see a significant *additional* impact on multifactor productivity four years after first assistance.

[3] This database provides information on how firms performed before, during and after they received Technology New Zealand assistance. It also contains all the economically significant firms in the New Zealand economy, so we can use the rich information in the LBD to find a similar group of controls firms. The sample for the study consists of all firms that first received R&D assistance between 2002 and 2008 (inclusive). Analysis outside this period was restricted by the available data; we require at least one year of outcome information following assistance and two years of data prior to assistance.

In contrast, we find no overall *additional* impacts of Project Funding, even on intermediate outcomes. When we pool both types of assistance and examine the influence of firm size and prior R&D activity on the results, the pattern is clear. We found significant *additional* impacts only for small firms and for firms that had not undertaken R&D two years prior to receiving their first assistance. We saw no positive *additional* impacts either for large firms or firms that were already undertaking R&D.

We conclude that Technology New Zealand has a significant positive *additional* impact when it is targeted at firms that are building capability; that are small and that have not previously undertaken R&D. These findings are consistent with findings in the recent literature on impacts of publicly funded business R&D.

1 Introduction

The first stage of the Cross Vote evaluation was completed in 2009. This evaluation was a proof of concept, focusing on one specific government programme administered by New Zealand Trade and Enterprise (NZTE): The Growth Services Range GSR (MED, 2009). The GSR report demonstrated that it was possible to measure the average impact of a government programme on firm performance using econometric techniques and the available New Zealand data[4]. Earlier evaluations had been primarily non-quantitative relying on case studies, interviews, surveys and monitoring data.

This report presents the second stage of the Cross Vote evaluation. Robust econometric techniques are applied to a different type of government assistance – grants and services aimed at increasing and enhancing R&D undertaken by firms. The R&D programmes evaluated in this report are part of Technology New Zealand (Tech NZ) and are administered by the Foundation for Research, Science and Technology (FRST). R&D grants and services from FRST are intended to lead to additional R&D expenditure by the firm. This is, in turn, expected to increase the economic performance of a firm over a longer time frame.

Another distinguishing feature of this report relative to the GSR report is the focus on how the impact of assistance varies across firms. Economic theory and evidence suggest that small and larger firms differ in the amount and nature of their innovation behaviour, including R&D. In order to design effective policy, therefore, it is important to understand how the impact of assistance varies across firms.

The main constraint is that we do not have suitable data on the R&D expenditure history for all firms. This means that we are unable to estimate the most appropriate outcome from Technology New Zealand programmes - whether or not receiving this assistance led to a higher level of R&D expenditure than would otherwise have been undertaken had the firm not received support (R&D additionality). We assess the impact of R&D assistance on firm sales, employment, labour productivity and multifactor productivity at zero to four year lags after a firm first receives assistance. A total of 555 assisted firms are included in our sample: the split by type of assistance is Capability Building (402 firms), Project Funding (111 firms), and both forms of assistance (42 firms).

This evaluation report focuses exclusively on the benefits of R&D to firms. The broader question of spillover benefits at the industry or economy level is not explored. Indeed, the methods that we use in this paper are less suited for broader spillover studies.

In the next section, we review existing empirical literature on impacts of R&D distinguishing between findings relating to private and publicly funded R&D. In section 3 we present an overview of Technology New Zealand assistance. Section 4 presents the method we adopt to remove selection bias. Section 5 describes the data and model variables. Results are presented in Section 6 and we conclude in Section 7.

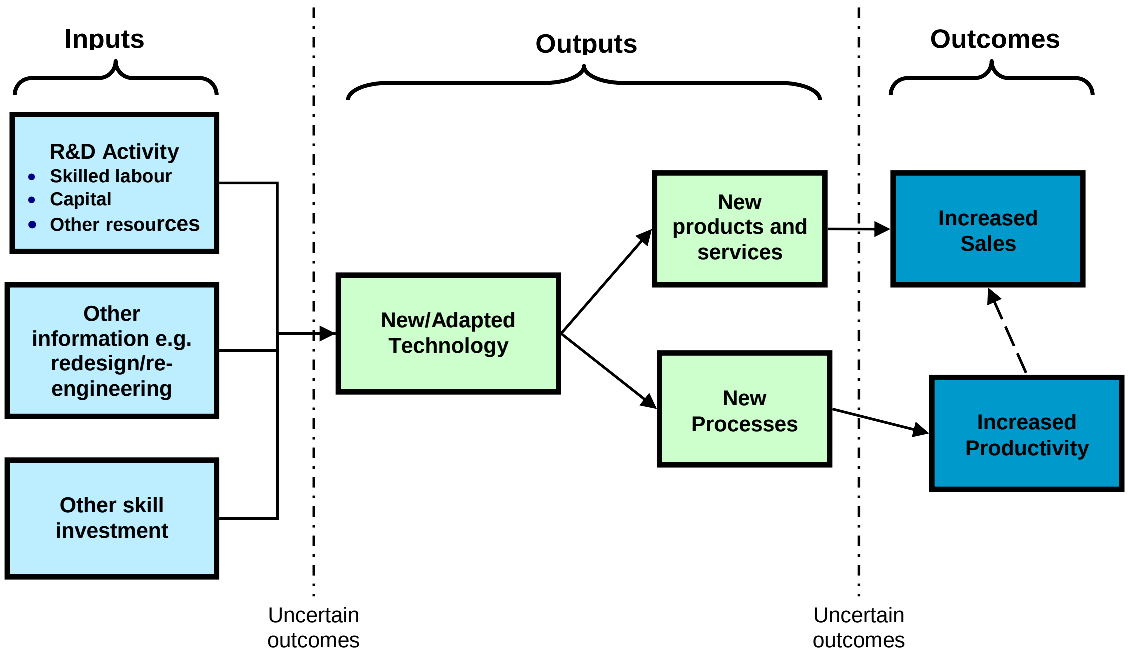
[4] The evaluation found that GSR support had a significant and positive mean impact on firm performance. GSR supported firms had higher sales and value-added relative to comparable firms. The findings were reported to the Minister.

2 Literature Review

Why do firms invest in R&D? It is a costly activity and the returns are uncertain. In short, firms invest in R&D to stay competitive, to earn future profits or merely to survive. R&D can generate new products, which can outcompete those of competitors or for which firms can charge a premium price. R&D can also generate cheaper or more efficient ways of producing products or services and delivering them to the market.

We outline the innovation process in firms, and R&D's place in it in Figure 2-1. R&D[5] is one of a number of activities firms undertake in order to innovate. In the figure we also include other information-creation activities, such redesigning and reengineering other firms' products and processes and other investments such as developing the skills of its workforce. These activities are undertaken with the intention of creating new technology (or adapting existing technology) in the form of new products and services or processes[6]. The intention of these innovations is to benefit the firm. New products and services aim to attract new customers and increase sales revenues. New production processes or organisational forms improve the productivity of the firm, this may have an impact on revenue if they enable the firm to offer its products and services at a lower price.

Figure 2-1: R&D and the Innovation Process



In some ways R&D investment is just another form of capital investment: an investment now in anticipation of future returns. However, the risk and uncertainty involved in R&D are much higher. Conventional fixed capital investments aim to

[5] OECD Frascati Manual
[6] The OECD Oslo manual divides innovation into (i) product innovation; (ii) process innovation; (iii) marketing innovation and; (iv) organisational innovation. For simplicity, we summarise these as new products/services and processes.
http://www.oecd.org/document/10/0,3746,en_2649_33723_40898954_1_1_1_1,00.html

increase future production capacity and the risk related to this type of investment is often low. Whilst the firm runs the risk that the capacity will not be required, this is a calculation about demand for existing goods and services. The markets for the entirely new or significantly-altered goods and services created by R&D are untested. The process of technological innovation is complex and risky. The rewards for successful innovation can be very high, but the majority of R&D projects fail. The investor who elects to invest in a R&D project risks a complete loss of capital. The few successful R&D projects must also pay for the projects that are unsuccessful or terminated early by the company.

2.1 The returns to R&D

It is now widely acknowledged that increases in productivity are the main source of long-run economic growth. As Krugman's famous quote goes: "productivity isn't everything, but in the long run it is almost everything"[7]. Most increases in productivity are due to innovation, i.e. either new products and services or a better use of input factors (process innovations). R&D activity is one of the most important input factors for innovation. It is also the most widely examined activity that influences innovation and hence productivity.

There are several econometric issues involved with measuring the returns to R&D[8]. Problems arise in the measurement of R&D output (innovation) and R&D inputs. Typically, it is difficult to directly measure changes in the quality of firms' outputs (this is because firm-specific price deflators are not available). A further complication is that R&D executed in one firm can affect the productivity performance of other firms. Theses spillovers may occur in the same industry or to firms operating in other industries, locally or abroad.

Griliches (1979, 1995, 1998) surveys the major progress made in using a production function approach to estimating the return to R&D. The most recent extensive review of production function estimates can be found in Hall, Mairesse, Mohnen (2010). They summarize the main results of empirical research on private and social returns to R&D. They find that: (i) rates of return of R&D are higher than for other factors, such as level of capital and human resources; (ii) the social returns are almost always higher than private returns; (iii) estimates of the rate of return of R&D vary, depending on whether they are measured at the level of the firm, the industry or the country.

Whilst the long-term objective of R&D (from a policy perspective) is its impact on productivity, many studies investigate its impact on intermediate outcomes. These include sales, value added and other related variables such as employment or exports (European Commission, 2010; López Acevedo and Tan, 2010) or patents (Piergiovanni and Santarelli, 2010). Studies that identify the time frame required for an R&D impact to be realised are rare (World Bank, 2010). There are a number of recent studies that are not included in the above mentioned surveys. Lööf and Heshmati (2006) performed a sensitivity analysis of different firm performance measures and found the same pattern of positive and significant effect of innovation on firm performance measures. Bogliacino and Pianta (2010) conclude that both technology adoption and R&D improve innovative performance of European companies. Benavente (2006) found that R&D and innovative activities are related to

[7] Krugman (1992), p. 9
[8] The surveys by Cerulli (2010), Abbring and Heckman (2006), Heckman and Vytlacil (2006a, 2006b) deal with the econometric issues arising when estimating the impact on productivity

firm size (and market power), but that R&D activity does not influence firm performance.

Fabling's (2008) study of R&D expenditure by New Zealand firms examined the determinants of a firm's decision to undertake R&D[9]. He found that the propensity to undertake R&D is positively influenced by access to Tech NZ funding, exporting history, larger market share, greater R&D intensity and concentration levels in the industry of affiliation, lower debt to equity ratio, high retained profits and past R&D activity. In contrast and rather unexpectedly, he finds that smaller firm size and lower prior profitability increases the likelihood of doing R&D, all other things equal.

The general conclusion of the literature is that, regardless of how performance is measured, private R&D activity positively and significantly affects firm performance.

2.2 The impact of publicly funded R&D – crowding out and additionality

Why do governments support R&D activities? The major reason is that R&D has some of the characteristics of a 'public good'. The value created by R&D projects cannot be secured completely by the investing firm. Once an idea has been generated, it can potentially be used by anyone. Unlike a piece of fixed capital – say a truck, which can be driven by only one person at a time – the results of R&D investment could benefit many others. Economists call this *non-rivalry*. For private firms, this creates a disincentive for them to undertake R&D investment – why create something if someone else gets the benefits? For society as a whole, this 'spilling over' of the knowledge is an important benefit. It is very difficult for the investing firm to prevent others from using the knowledge they have created. Economists call this *non-excludability*. Because of these knowledge spillovers, the social rate of return tends to exceed the private rate of return. This in turn leads to an underinvestment in R&D from the point of view of society as a whole.

Note, however, that there are also reasons for firms to appear to be *over*investing in R&D. R&D also benefits the firm by increasing their understanding of other advances in technology (what economists call their *absorptive capacity*) (Griffith *et al.*, 2003; Kneller and Stevens, 2006; Cerulli, 2010).

Another critical line of inquiry pertaining to R&D investment is the relationship between publicly and privately funded R&D and whether public subsidies crowd-out private investment in R&D. Crowding out or substitution occurs when a firm reduces its level of R&D investment as a result of the government R&D subsidy it receives. In the case of 100% crowding-out, the firm merely replaces the investment it was already going to make in R&D with the assistance provided by the government. Additionality occurs when the firm increases the R&D level it would have undertaken in the absence of the subsidy. Cerulli (2010) and Tanayama (2007) give a good overview of estimation methods, types of data, policy variables, and different econometric models in the context of crowding out and additionality

Surveying the evidence on publicly funded R&D, David, Hall and Toole (1999) observe that findings are ambivalent at best. They find that many estimates of impact are subject to a potential selection bias. This is, amongst others, because the most promising candidates for successful research projects are chosen by the funding organization to be recipients of subsidies. García-Quevedo (2004) presents results of

[9] Hall and Scobie (2006), Scobie and Eveleens (1986) estimate the contribution that R&D has made to productivity in New Zealand.

39 studies on evidence concerning the relationship between public funding of R&D and private R&D expenditure. The results tend to support complementarity over crowding-out between public and private R&D investments. That is, public R&D investments lead to higher private R&D investments (they 'crowd in'). .

Heshmati and Lööf (2005) suggest that whilst there are complementary effects of public R&D financing on private research expenditures, the only beneficiaries are small firms. Czarnitzki and Toole (2006) using a sample of German manufacturing firms show that R&D subsidies mitigate the effect of uncertainty and thereby increase business R&D investment. Gonzalez and Pazo (2008) analyze the effects of public R&D support in Spanish manufacturing firms. The main conclusions indicate absence of crowding-out and benefits mainly associated with small firms and those operating in low technology sectors that might not have engaged in R&D activities in the absence of subsidies. Garcia and Mohnen (2010) evaluate whether public support from central government spurs innovation in Austrian firms. They find evidence that central government support increases the intensity of R&D.

A recent New Zealand study by Johnson, Razzak and Stillman (2007) also investigated the relative impact of public versus private funding, but instead of focusing on R&D additionality they looked at the impact on labour productivity. They used panel data for 9 industries to estimate the impact of public and privately funded R&D on output per person on their own industry and the rest of the economy. They find privately funded R&D increases firm productivity in industries making the investment and across the economy, but publicly funded R&D (undertaken by public sector providers) has no impact.

The review presented in this section encompasses a great diversity of approaches to measures the effect of public funded R&D and has not arrived at definite conclusions.

2.3 Evaluating the impact of publicly funded R&D on outcomes

A separate branch of the literature focuses on the impact on firms receiving business support from a programme evaluation perspective. Cursory analysis often generates positive reports of a programme's impact. However, as Storey (2000) has noted, it is not uncommon for these positive reports to disappear under further scrutiny, when the performance of assisted firms are compared to unassisted firms. Note that the problem is not that firms receiving assistance do not do well following their grants. Rather, they are not doing any better on average than a group of similar firms drawn from the control group. Rigorous evaluations of these programmes typically found little or no impact on the ultimate outcomes of value-added or productivity. Some, however, have identified impacts on intermediate outcomes, such as employment growth or increased R&D expenditures (Storey, 2000 and OECD, 2007).

A recent World Bank report (2010) questions the earlier pessimistic econometric assessments of the impact of business support. The report notes that recent studies using improved methodologies and data generate more positive findings. The report included a review of nineteen rigorous impact evaluation studies from high and low incomes countries (including New Zealand – our 2009 GSR evaluation was reviewed as part of that study). In general, the reviewed studies found positive impacts on intermediate outcomes and mixed performance for longer term outcomes from a wide range of business support programmes.

The World Bank report describes five studies that reported impacts of R&D programmes (as opposed to more general SME support). All five studies find positive impacts on the levels of R&D as well as the *intensity* (R&D expenditure to total sales) following assistance (in the following countries: Argentina, Australia, Belgium, Brazil, Chile, and Turkey). The Turkish study (Özçelik and Taymaz, 2008) also found that small firms benefited more from public support than larger firms, even though larger firms did more R&D. However, there is little evidence for R&D programmes affecting final outcomes, such as sales or productivity. Four studies looked at the impact of R&D programmes on productivity (these studies were for Australia, Argentina, Brazil, Chile). All four studies found no effect. Two of the three studies that estimated the impact of R&D programmes on sales found no impact (Argentina and Brazil).

The authors then present the results of four new country studies of business assistance in Columbia, Mexico, Chile and Peru. These new studies use a consistent method to estimate impacts and one that is comparable to our own method. Two of those studies in Chile (Tan, 2009) and Mexico (Lopez-Acevedo and Tinajero, 2010) provide impacts for R&D programmes.

The Chile study finds strong mean impacts on sales, value-added, wages, labour productivity and export intensity for all SME programmes combined. However, the impact due to FONTEC's[10] technology programmes (which include R&D development and technology transfer) only show significant impact on export intensity and wages. The study reports highly significant impacts for a related FAT[11] programme that provides matching grants to fund technical assistance to address specific problems including marketing, product design, production processes, information systems and pollution control. The FAT impacts are seen on sales, value added, wages and labour productivity, but not on export intensity. How the effects of programme participation vary over time are also examined, although only for the combined impact of all SME programmes and not just R&D related ones. Interestingly, most impacts take over four years to become positive and significant. The impact continues to become stronger and more significant up to the last lag shown (11+ years since treatment).

In Mexico, the authors find strong evidence of impact on sales, value-added, employment (8-10%) and exports (25%) for all assistance delivered by the national science and technology agency (CONACyT[12]) and for the individual CONACyT programme called Fiscal Support and Technology Innovation. In terms of timing, the impact on outcomes for all SME programmes (not just R&D related programmes) only become significant after four years following the start of support.

2.4 Summary

Innovation is the main determinant of productivity (and hence economic) growth in developed economies. R&D expenditure is a major determinant of this.[13] The private rate of return for R&D is higher than for other investments and the social rate of return tends to be higher than the private rate, Hall, et al. (2010). This creates an incentive for firms to under-invest in R&D from the perspective of society as a whole. Because of this, governments intervene to stimulate R&D spending. It is difficult to calculate the impact of government R&D assistance because firms with a high

[10] FONTEC (*Fondo de Tecnología, Proyectos de Innovación Tecnológica)*
[11] FAT *Fondo de Asistencia Técnica*
[12] *Consejo Nacional de Ciencia yTecnología*—CONACyT This agency had a significant budget but limited coverage among firms.
[13] R&D is only one of many inputs into innovation. Other innovating activities include learning-by-doing and work reorganisation.
.

likelihood of benefiting from and undertaking R&D self-select into treatment. Because of this, simple studies tend to overstate the benefits of assistance. It is, therefore, important to use appropriate techniques including identifying a control group of similar firms. We return to this in more detail in section 4.

3 Overview of Government R&D Assistance

In this section, we describe the schemes that are the subject of this evaluation. It is important to understand the types of firms that receive assistance and how they compare with the general population. We compare the firms that receive Capability Funding and those that receive Project Funding with the population of unassisted firms over six important variables.

3.1 Technology New Zealand – background information

The R&D programmes included in this evaluation are known as Technology New Zealand (Tech NZ). The included programmes are listed in Table 3-1. Some of these programmes are no longer current. Also, the detailed objectives and implementation of most of these programmes have evolved over time. (A more detailed time line of Tech NZ programmes is included in Appendix 1.)

Tech NZ represents the bulk of publicly funded R&D assistance targeted directly to firms in New Zealand. New Zealand firms also receive indirect forms of government assistance through universities and Crown Research Institutes undertaking publicly funded R&D to assist long term industry needs. This type of indirect government assistance by public providers is not evaluated in this report[14]. We also do not evaluate the services provided to firms by Tech NZ staff, including the Global Expert scheme which helps businesses link to local and global R&D expertise.

The Tech NZ programmes are split into two categories: assistance to build R&D capability and assistance for R&D projects for firms with more highly developed R&D capability[15].

Table 3-1: R&D assistance provided by Tech NZ

Categories	Broad Description	Tech NZ programmes	Start Year
Project Funding	Support for R&D projects provided to businesses with potential for high growth	Technology for Business Growth (excluding some historical TBG schemes which are classified as Capability building)	1995
		Grants for Private Sector Research and Development	2001
		Technology Fellowships - Expert	1998
Capability Building	Support for R&D aimed at building R&D capability within a firm	TECHLINK	1998
		Technology Fellowships and Internships	1995

[14] The largest source of indirect funding to businesses in Vote RS&T between 2002 and 2008 was 'Research for Industry'. This funding was distributed primarily to Crown Research Institutes and universities. It also included funding for public-private partnerships known as research consortia. For context, the total Vote:RS&T allocated to this type of funding in 2008/09 year was $216M compared to the funding available for Technology NZ which was $51 M (The Estimates of Appropriations, Vote RS&T).

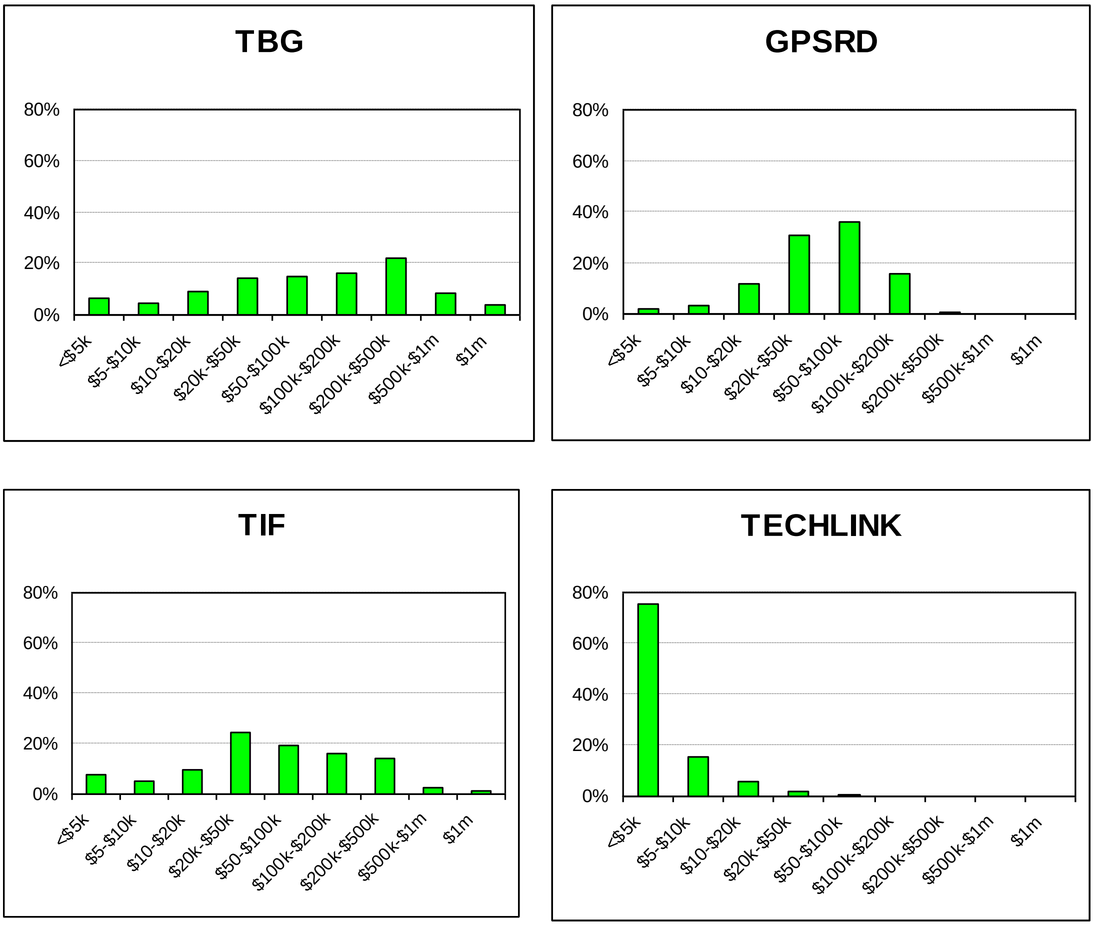
[15] These classifications were agreed by the Cross Vote Evaluation Steering Group in 2009. At that time, members of the group included representatives from MED, MoRST, FRST, NZTE and Treasury in 2009.

Funding for Tech NZ has grown from an initial value of $11.2M in 1996/97 financial year to $50.9M in 2008/09. For methodological and data availability reasons, this evaluation focuses on firms first receiving Tech NZ assistance between 2002 and 2008 (inclusive). Table 3-2 displays summary information and Figure 3-1 shows the distribution of grant funding for that period.

Table 3-2: Overview of Tech NZ: 2002 to 2008

	Total grant payments (millions $)	Number of grants[16]
Technology for Business Growth (TBG)	156.0	945
Grants for Private Sector Research and Development (GPSRD)	57.2	1086
Technology Fellowships (TIF)	38.8	747
TECHLINK	7.8	2850

Figure 3-1: Distribution of total grant payments to firms between 2002 and 2008



[16] Numbers in this and following tables have been randomly rounded to base 3 to protect confidentiality.

3.1.1 Technology for Business Growth (TBG)

This was the flagship programme for Tech NZ; it was the largest and longest running programme starting in the mid 1990s. Tech NZ has since been restructured: TBG has been disbanded, but similar projects are funded under a category called Project Funding. TBG operated as a discretionary grant. It targeted firms with potential for strong growth to enable them to move towards high-value, technology based products, processes and services. The objective of the scheme was to foster technological learning, knowledge application and the development of technology based human capital within firms and to increase the overall level of R&D undertaken by NZ firms.

The bulk of the funding over time has gone into research contracts which fund 50% of the costs of an R&D project. The average grant payment between 2002 and 2008 was $165,000. However, there is quite a wide spread in the total grant payments to firms over this period (see, Figure 3-1). The average size of a TBG grant has increased over time. This is partly as a result of the introduction of new schemes, such as Grants for Private Sector Research and Development which focuses on smaller grants and a new sub-scheme introduced within TBG, known as TBG Strategic in 2006. Under TBG Strategic, a firm makes a single application for a series of large R&D projects. TBG grants have been invested across a range of industries, particularly manufacturing and primary sector related industries.

3.1.2 Grants for Private Sector Research and Development (GPSRD)

GPSRD was established in 2001 and was disestablished in 2008 with the introduction of a R&D tax rebate, which itself lasted for just one year. The scheme was intended as a first step into R&D activities. The grant was targeted at smaller firms with turnover of less than $50 million. GSPRD grants provided up to one third the cost of an R&D project, with a maximum value of $100,000. The objectives were similar to TBG; the main differences were related to the upper threshold of grant value, lower subsidy and maximum firm size. The average grant size between 2002 and 2008 was $52,700. The average grant size did not change significantly over time. The distribution of payments is less spread out than for TBG (see, Figure 2-1) because of the upper threshold of $100,000. However, some firms have had more than one GPSRD, so there are a few firms in the $200,000-500,000 band.

3.1.3 Technology for Industry Fellowships (TIF)

TIF provides fellowship payments to senior undergraduate and graduate students to undertake a R&D project within a company. Typically, this project will be part of a thesis. The TIF Expert scheme provides funding to bring suitable experts in to a firm to assist with an R&D project. The objectives of TIF were: to create new or enhance existing Research, Science & Technology capabilities within firms; to foster connections between firms and existing research providers and; to increase researchers' appreciation of the commercial focussed R&D environments. These types of fellowships are now funded under Tech NZ Capability Funding. The average contract size was between 2002 and 2008 was $51,900, but Figure 2-1 shows a wide spread in total grant funding to firms. Some large firms access multiple fellowships leading to large payments ($500,000 or more) over this period. Around 67% of this expenditure went to post graduate students.

3.1.4 TECHLINK

This assistance programme was designed to create awareness of, and facilitate access to, technology and technological capabilities that are new to firms. It aimed to improve access to information about public and private suppliers of technology and technological services, both within NZ and overseas. It involved several different activities, two of which are within scope for this evaluation: Technet and SmartStart. Technet was an information service designed to enable research organisations to respond to technological information requests at low/no cost to the requesting firm. The scheme essentially subsidised fees up to a maximum value of $5,000 per request (previously $2,000). SmartStart provided funding of up to $25,000 per project (previously $5,000) to an applicant firm to enable then to hire a consultant on a technical innovation project. This funding was on a 50:50 basis, i.e., the applicant firm had to front up half the cost of the project. The average contract was small $2,700 and over 75% of firms have received less than $5,000 from the scheme between 2002 and 2008.

3.1.5 Summary by R&D categories

Table 3-3 summarises the policy rationale; types of activities; selection processes; and expected outcomes of the individual Tech NZ programmes into the two broad categories of assistance used in this evaluation – Capability Building and Project Funding.

The expected long term outcomes for both types of assistance reflect the objectives of Tech NZ: enhancement in business performance at the firm, industry and economy level through increased private sector R&D. However, it is reasonable to expect that there will be differences in the short term outputs and intermediate outcomes of the two different types of assistance. Certainly, both are expected to build R&D capability in the short term. However, project funding, in particular, is also expected to result in more tangible outputs, such as new or improved products, processes and/or services.

Both categories of assistance schemes target a wide range of firms at different stages of their life cycle - from early stage to maturity. The distinguishing characteristic between the two categories is the type of activity funded, not the type of firm. There is an additional emphasis on targeting firms with potential for high growth with Project Funding. This means that a mature firm may engage in capability building in a new area with a goal of increasing their understanding and technological awareness. A start up company may apply for and receive significant project funding if it can demonstrate (amongst other things) that the idea and has potential to general significant future revenue for the firm.

Table 3-3: Summary of R&D assistance

	CAPABILITY BUILDING ***Technology Industry Fellowships*** ***Techlink** (Technet and SmartStart only)*	**PROJECT FUNDING** ***Grants for Private Sector Research and Development*** ***Technology Business Growth*** ***TIF Expert***
Problem to be solved/market failure	• Perception of R&D capability deficit in firms generally • Perception that linkages with universities (and other knowledge institutions) are too low.	• New Zealand firms under-invest in R&D • This may reflect a perception (or reality) that wider returns to society from privately funded R&D generally exceed private returns
Inputs/Activities	Examples include: • Involving young scientists, technicians and engineers in research and development projects • Hosting Masters and PhD students in firms • Up to $5k for research organisations to provide consultancy services to firms • Up to $25k for (business) consultant on a 50:50 basis on technical innovation project	• Co-funding R&D projects • Including engaging experts in R&D and commercialisation projects
Selection criteria	• Firms are targeted both at early stage to give them the tools they need to succeed in R&D, and at the mature stage to help them exploit emerging areas.	• Firms range from start up to established competitors across a range of sectors • Firms have a potential for high growth
Expected Outputs & intermediate outcomes	• Increased awareness of, and access to, technology and technological capabilities that are new to firms. • an increased awareness and understanding of the value that technological innovation can deliver to their businesses • enhanced level of scientific and technology-based human capital in participating firms	• Firms increase/begin R&D • Firms enter new globally competitive markets • Firms build R&D capability and absorptive capacity • Firms develop new technologies, products, processes or services
Expected Outcomes	• Higher profitability through high value products, processes, services. • Higher industry or economy-wide behaviour (e.g. R&D, exporting, productivity etc) • Positive spillovers (knowledge and market spillovers)	

3.2 Assisted and non-assisted firms

Firms that receive government assistance are on average higher performing than the average New Zealand firm, even prior to receiving assistance (MED, 2009; Statistics NZ, 2010). To illustrate this point, Figure 3-2 shows the distribution of firm variables for three different groups of firms: firms that received R&D assistance (split by the type of assistance: Capability Building and Project Funding), and firms that received no government assistance from NZTE or FRST. We include plots[17] of the four performance variables that we consider in this evaluation: log sales, log total employment, log labour productivity and multifactor productivity (MFP), and also show log value-added and the capital labour ratio[18]. All industries (two-digit ANZSIC) and year observations are pooled together with industry-year averages removed. The distributions for firms receiving government assistance are shown in the year prior to their first year of participation in any Tech NZ programme.

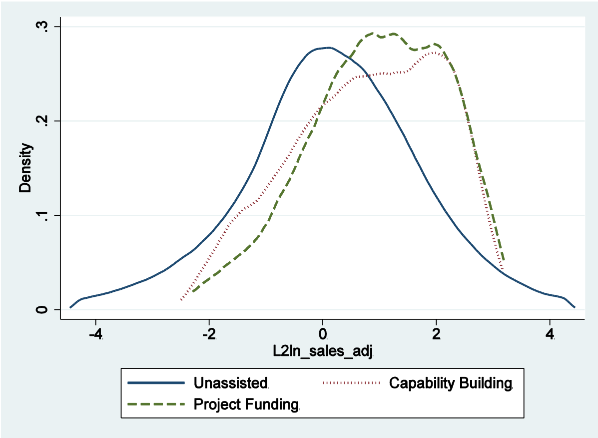
We see that firms that seek and receive Tech NZ assistance are, in general, higher performing than unassisted firms; they have higher sales, employment, capital-labour ratios and labour productivity compared to the rest of the population of firms that did not receive any government R&D assistance. Assisted firms appear to have slightly lower MFP than unassisted firms. Interestingly, there does not appear to a large degree of differentiation between firms that receive Capability Building and Project Funding assistance, at least in the year prior to first participating in a Tech NZ programme.

There are other ways in which assisted firms may differ from the average New Zealand firm. For example, if only firms with potential for high growth receive Project Funding assistance, then the evaluation will tend to overstate the impact of the assistance if a comparison is made with the remainder of the business population. This is an example of *selection bias* in the impact estimate. The appropriate comparison group would be firms that also have the potential for high growth, but have not received assistance.

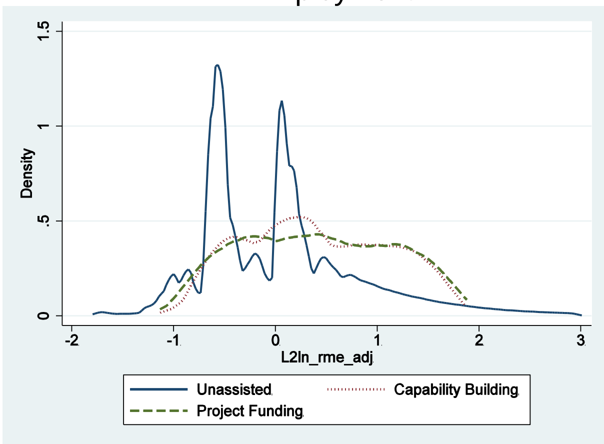
[17] The x-axes have been restricted to protect confidentiality.
[18] We only include those firms that are used to estimate the impact of receiving R&D assistance.

Figure 3-2: Kernel density plots of firm variables by assisted status

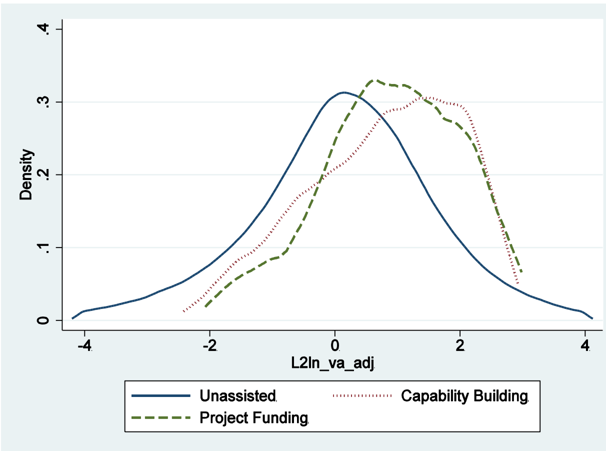
A: Sales



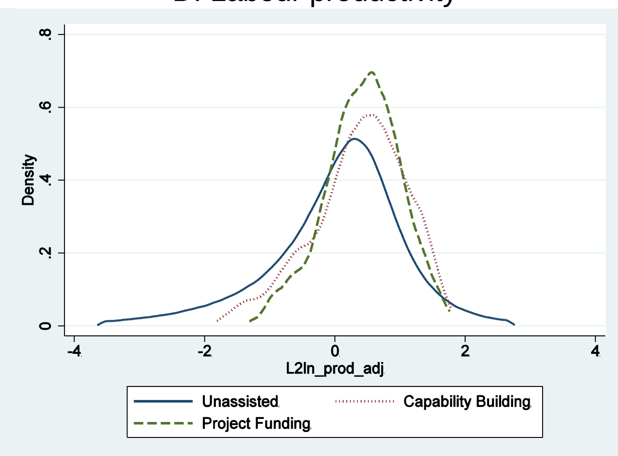
B: Employment



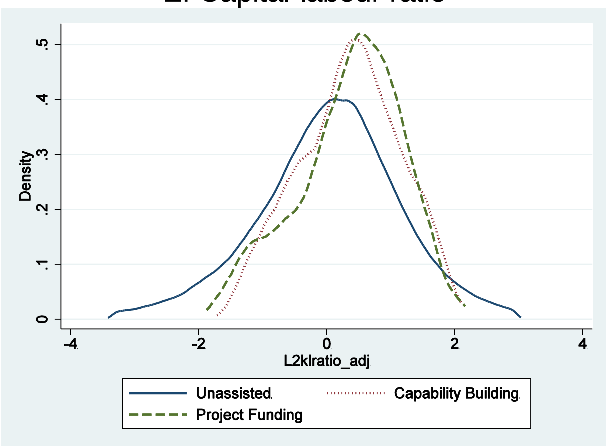
C: Value added



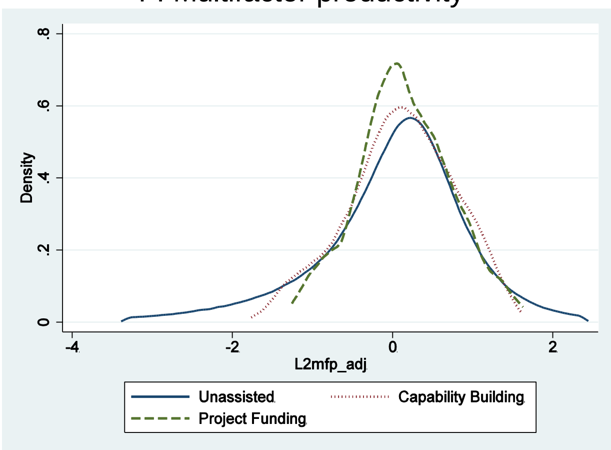
D: Labour productivity



E: Capital-labour ratio



F: Multifactor productivity



3.3 Existing evidence of the impact of Technology NZ Schemes

There have been a number of evaluations of Tech NZ programmes and individual sub-schemes over the years using traditional evaluation methods, including interviews and/or surveys of firms that received Tech NZ assistance. In this section, we review these previous evaluation findings although they are not directly comparable to this evaluation due to the differences in method. We highlight evidence from two evaluations in this section and include summaries of related material in Appendix 2. The first and most comprehensive evaluation of Tech NZ was commissioned by MoRST[19] then undertaken by Infometrics in 2001 (Infometrics, 2001). It reached the following conclusions relating to impact**:**

- Tech NZ was making significant progress in meeting its objectives. Tech NZ's contribution could be best characterised as performance enhancing rather than as the critical factor in initiating the type of firm behaviour the scheme is aimed at.

- One of the prime benefits of the Tech NZ Scheme is encouraging a deepening and broadening of the relationship between business and public and private sector research providers.

- Over the period 1995/96 - 1999/2000 Tech NZ has invested almost $93m in assisting firms undertake R&D for business growth. The estimated direct multiplier effect of Tech NZ funding on firms' turnover lies between three and four. That is, the lift in turnover that managers regarded as being directly related to the $55m worth of TBG funding they received between 1995/96 and 1998/99 was in the order of $180m. When the results for both TBG and GrIF[20] are combined for the period 1995/96-1999/2000, companies reported that over the last three years Tech NZ has been directly responsible for a $335m increase in turnover and the creation of 2,134 new jobs.

A subsequent recent evaluation was commissioned by FRST and undertaken by Infometrics (2009). It focused on a relatively small number of firms (28) that received significant amounts of Tech NZ funding over the previous decade. Infometrics concluded the following:

- TechNZ lifted the performance of the interviewed companies significantly above where they would otherwise have been. Smaller firms enjoyed a larger proportional benefit from Tech NZ than larger firms.

- Interviewed firms attributed an average lift in sales of 19.8% and export earnings of 18.2% directly to Tech NZ. Over this period, firms received a total of $39.5m from Tech NZ; the authors estimate a lift in sales of $509m with a discounted benefit cost ratio reported as 12.9. However, the authors did note that a more robust calculation requires econometric evaluation to compare the performance of TechNZ firms with a group of similar firms that did not receive the assistance.

- Other reported benefits included improvements in production processes, which enhance the competitiveness of the firm through lower product prices. Firms also noted other benefits including: brand positioning; skill retention and recruitment; addition of R&D capacity; and credibility in the market which have

[19] Ministry of Research, Science & Technology until 1 February 2011.
[20] GrIF – an earlier name for Technology Fellowships to undergraduate and postgraduate fellowships

allowed collaboration with, or sale to, large overseas companies that have aided development of new technologies.

- While some respondents believed that particular R&D would not have gone ahead without government funding, others noted that it would have gone ahead but at a reduced level and scope and over a longer period of time. Other firms noted it may have still gone ahead but only with venture capital funding, which firms believe would eventually result in a future sale of the firm to overseas, or it would be privately funded resulting in higher levels of debt and/or asset sales.

To summarise, existing evaluation evidence suggests that Technology NZ assistance has greatly benefited participating firms and resulted in increased R&D and improved firm performance. The main issue with these estimates is that in order to establish the counterfactual, they rely on judgements of interviewees as to what would have occurred had the funding not been available. However, these types of evaluations often provide overly positive estimates of a programme's impact due to the presence of selection bias (Storey, 2000). This current evaluation is the first econometric evaluation of the impact of Tech NZ which addresses these issues. None of the previous evaluations applied rigorous quantitative techniques to measure the net impact of assistance on firm performance by comparing the performance of assisted firms with the performance of a comparable control group of other firms.

4 Method

In this evaluation we use a combined propensity score matching and difference-in-difference approach. This allows us to take advantage of the strengths of both methods. The matching method matches assisted firms with similar, unassisted firms from the rest of the population on the basis of observable characteristics. This allows us to take advantage of the size and scope of our dataset, both in terms of the large number of firms that are potential controls and the range of firm characteristics prior to receiving assistance. The difference-in-differences aspect of our approach allows us to take some account of unobservable aspects of firms that are constant over time – such as its management capability or essential business model.

4.1 The Evaluation Framework

In this evaluation, we wish to assess the direct impact of receiving R&D assistance on the performance of firms that received the assistance. At the heart of evaluation is the following: In seeking to know the impact of a programme on a firm, we wish to compare what happens if they receive government assistance (in the language of the literature: receive the treatment) to what would happen otherwise. If we call the first Y^1 and the second Y^0, then the *treatment effect* for each firm i at any time t is defined as the difference between its potential outcomes:

$$\text{(1)} \qquad \alpha_{it} = Y^1_{it} - Y^0_{it}$$

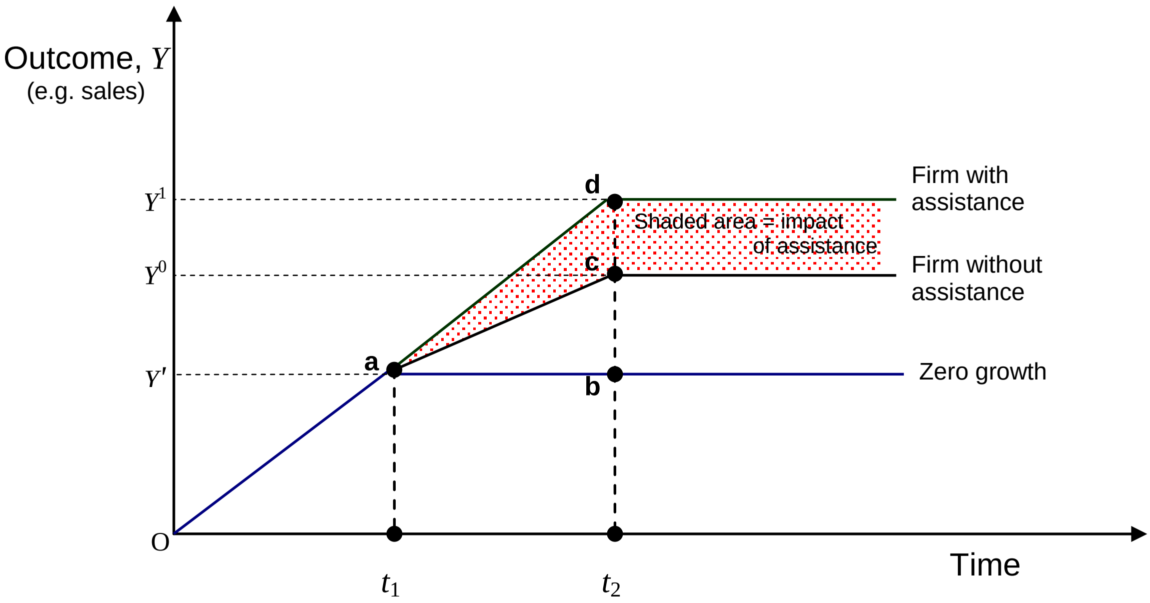
where the outcomes of interest might be intermediate outcomes, such as increases in a firm's R&D activity or final outcomes such as improvements in productivity. The fundamental evaluation problem arises because we cannot observe both what would happen if the firm received assistance (Y^1) and what would happen if it did not (Y^0). The outcome that we do not observe is called the 'counterfactual'.

We set out the core evaluation issue in Figure 4-1. Consider a firm that produces at **a** prior to assistance (at time t_1). After receiving assistance (at time t_2), the firm's sales rise until it produces at point **d**. One simple way to measure the impact of the assistance would be to compare the firm before (**a**) and after (**d**) assistance. This is the same as assuming that the firm would not grow (i.e. it would have been at **b** at time t_2). If we did this, we would infer that the impact was measured by the distance **bd**. That is, it is the assistance increased sales by Y^1 - Y'.

However, this ignores what was happening to the firm already (as well as the other changes that affected the firm since assistance). We can see from the figure that the firm was already on an upward sales path. Indeed, if the firm had maintained its pre-assistance trajectory, it would have ended up at **d** anyway. The difference between a zero impact and **db** in our figure is quite significant.

If somehow we knew that the firm would have actually ended up at **c** if it had not received assistance, we could clearly identify the impact as the distance **dc**. At time t_2, the additional sales the firm enjoyed as a result of receiving assistance is Y^1 - Y^0. The total additional sales enjoyed by the firm is the shaded area between the two lines describing what happened after the firm received assistance and what would have happened if it did not receive assistance.

Figure 4-1: Defining a counterfactual



Because when we conduct evaluations we do not observe the counterfactual, we have to somehow estimate it. One way to do this is to find a suitable comparison group of firms and compare the outcomes of the firms receiving assistance with those of the control group. However, we cannot simply compare a group of firms receiving assistance with another random group selected from the business population. As we have seen in section 3.2, firms that receive government assistance are on average higher performing than the average New Zealand firm, even prior to receiving assistance (see also MED, 2009; Statistics NZ, 2010). Therefore, a simple comparison of outcomes between assisted and non assisted firms would reveal a spuriously high treatment effect for receiving R&D assistance because it would also include pre-existing differences in firms' outcomes (compare the distributions of firms in Figure 3-2).

Techniques to remove selection bias

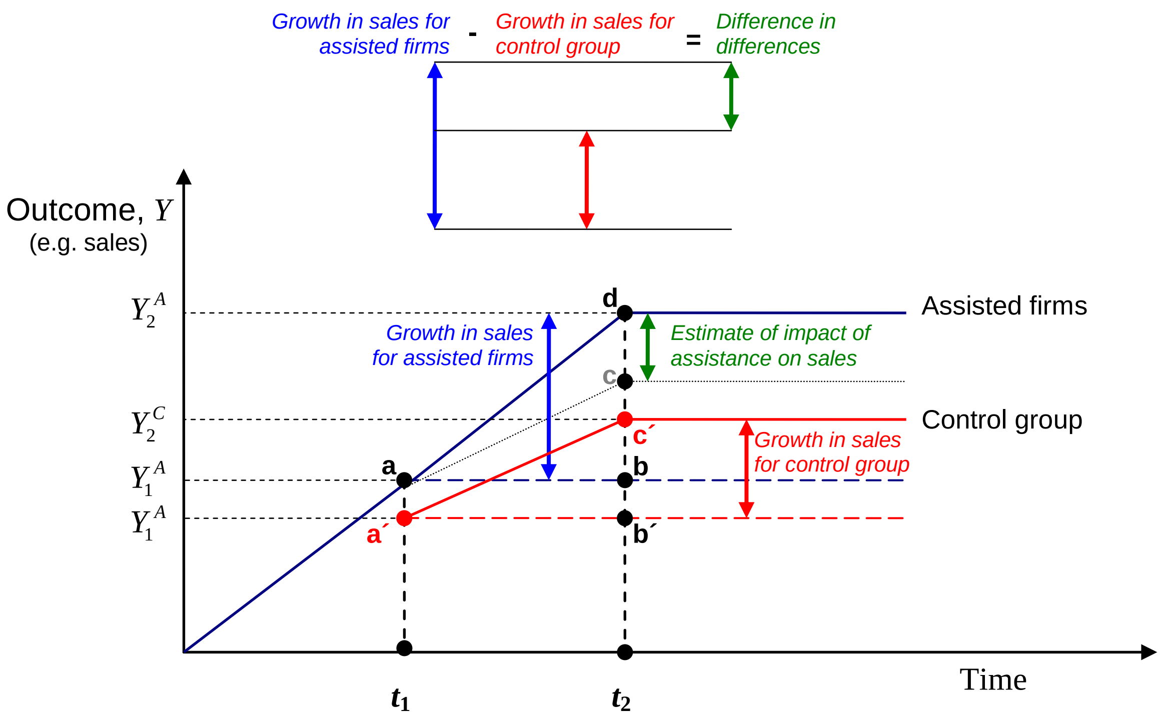
A range of empirical techniques are available to estimate the impact of receiving assistance in the presence of selection bias. These are considered in some detail in MED (2009). The simplest strategy is to use ordinary least squares (OLS) regression with appropriate control variables to account for the pre-existing differences between assisted and unassisted firms. That method links a firm's outcome Y (such as sales of productivity) to a range of observed firm characteristics $\mathbf{X}$ (such as the firm size or industry grouping), and to whether or not the firm received Tech NZ assistance, i.e.:

$$(2) \qquad Y_{it} = \boldsymbol{\beta}\mathbf{X}_{it-1} + \alpha_{it} D_{it} + \varepsilon_{it}$$

where $\mathbf{X}_{it\text{-}1}$ is a vector of pre-existing firm characteristics or control variables for firm i at time t. D_{it} is a treatment variable indicating whether a firm received Tech NZ assistance and ε_{it} is the residual term. In theory, the average treatment effect (or more correctly, the average treatment effect on the treated) could be obtained from OLS regression on equation (2) with the coefficient on the treatment indicator providing the average treatment effect estimate. Any systematic differences between the two groups other than those due to control variables are then attributed to the treatment, in this case participation in a government R&D programme. This approach relies on a good source of firm data relating to financial performance and other firm characteristics.

There are a few issues with this approach. It assumes that we can observe all the important differences between treated and untreated firms, and that we understand how the outcomes of a firm are related to these observed characteristics. However, there could still be systematic differences between the assisted and unassisted firms even after adjusting for all observed firm characteristics. For example, it would be hard to find one variable within a database containing administrative and survey records that could account for the *quality* of the R&D staff or management attitude to risk for every firm. These characteristics would be unobserved, but they are likely to be important factors in motivating a firm to undertake R&D (and hence seek government assistance) and driving improvements of firm performance.

Figure 4-2: Defining a counterfactual - difference in differences



One simple way to isolate the true treatment effect in the presence of unobserved differences is to use '*difference-in-differences*'. This is illustrated in Figure 4-2. We have seen that we cannot simply look at the assisted firms before treatment (t_1) and afterwards (t_2) and ascribe any change to the scheme as there are many reasons why a firm's performance might improve or decline from one period to the next. Such calculations attribute any change in performance wholly to the assistance. The *difference-in-difference* estimator on the other hand looks at changes in time before and after assistance for two groups: the group of firms receiving assistance and a control group. The impact of the assistance equals the difference in the changes, or 'difference-in-differences'. In comparing firms before and after treatment, it assumes that the treated and control groups would grow and perform in the same way in the absence of assistance. Any remaining changes are attributed to the assistance.

A key advantage of this approach is that firms to not have to be starting from the same point. Even if we have a control group that looks identical to our assisted firms, there may still be a difference, due to unobserved factors. In Figure 4-2, the assisted firms start at **a**, whereas the unassisted firms start at **a'**. We look at the difference between assisted and control firms before assistance (the distance **aa'** in the figure) and compare this to the difference between assisted and control firms after assistance (the distance **cc'**). The difference between the *before* difference and the *after* difference is the estimate of the impact of assistance.

More sophisticated versions of the difference in difference regression approach have been used to isolate the impact of a business support programme in the presence of selection bias (see MED,2009 for a New Zealand application and World Bank,2010 for international examples). However, in recent years the consensus approach for evaluating business support programmes is to use matching methods combined with differencing-in-differencing (World Bank, 2010).

4.2 Matching Methods

Matching estimators work by matching assisted firms with firms or groups of firms that do not receive assistance, based on the observed firm characteristics. In practice, it is more typical to use a matching index, such as the propensity score (Rosenbaum and Rubin, 1983). There are two main stages to this *Propensity Score Matching* (PSM) technique.

In the first stage we select a control group of firms from the population of untreated firms. This involves predicting the probability of a firm receiving treatment based on their pre-treatment characteristics, such as the firm's employment, their industry group and growth in performances variables. This participation model is then used to choose firms in the control group that have a similar probability of receiving treatment (i.e. have similar 'propensity scores') as those firms that actually did receive treatment. Unassisted firms that have very different probabilities of receiving assistance are not included in the control group.

In the second stage we calculate the average impact of receiving R&D assistance by comparing the average outcomes of the assisted firms to the average outcomes of the control group. As we have noted above, in fact we go one step further than many analyses using PSM: we compare the changes in outcomes for assisted firms with the average changes of unassisted firms to reduce the bias associated with unobserved variables (Heckman, Ichimura, and Todd, 1998 and Heckman, Ichimura, Smith and Todd, 1998). The changes are measured from the year prior to a firm receiving assistance.

The matching method assumes any bias associated with differences in the treated and untreated groups can be removed by conditioning on the propensity score. It involves two important assumptions. The first, known as "unconfoundedness", states that there are no unobserved characteristics that influence potential outcomes and the probability of treatment; the second is that the distributions of characteristics are similar for the treated and control firms so that there are control firms available to be matched with each treated firm ("overlap"). The "unconfoundedness" assumption maintains that assignment to treatment is essentially random after conditioning on all observed control variables (or on our case, the propensity score). This assumption will be violated if the control variables include any variables that are themselves affected by treatment - that is why we use characteristics in the year prior to receiving assistance in the participation model.

There are a number of options available for the matching algorithm in the second stage (e.g. Caliendo and Kopeinig, 2008). All use a weighted sum of the differences in outcomes between treated firms and control firms, but differ in number of control firms included in the comparison as well as the assigned weightings. The simplest method selects the nearest firm to each treated firm from the population of untreated firms based on the most similar propensity score value - this is known as the nearest neighbour method. In this case only one untreated firm is matched to each treated firm and the difference in outcomes for each matched pair is averaged across all matched pairs to obtain the treatment effect. This is a suitable technique when the number of available comparison firms is low, however there is a risk of poor matching when the closest firm is far away. Other matching techniques are more suitable when there are a lot of comparable untreated firms because they take advantage of the extra information available when there are multiple potential control firms.

Our preferred method uses radius matching with replacement[21]. The radius matching method selects all untreated firms with propensity score values within a specified distance (radius) to a treated firm's propensity score. Each treated firm is only matched to firms in the same industry and year. The individual treatment effect is the difference between the treated firm's change in outcomes and a weighted sum of the matched untreated firms' changes in outcomes (with weighting equal to the inverse number of untreated firms within each propensity score radius). The average treatment effect is the average of all the individual treatment effects, pooled across all years and industries. Standard errors are calculated by bootstrapping across both stages of the estimation: the probit matching model and the calculation of the treatment effect. The bootstrap samples are drawn independently across four groups based on treatment status and the availability of the future outcome.

We check the quality of the match by comparing the differences in mean values of the pre-treatment control variables for treated and untreated groups. This is known as testing the balancing hypothesis. If the mean characteristics are significantly different then the balancing assumption is violated and the participation model needs to be refined by including additional variables or reducing the size of the matching radius. In our case, we ensure that all pre-treatment matching variables and all pre-treatment values of outcome variables were balanced at the 5% significance level. The pre-treatment year is defined as the year prior to a firm first receiving Tech NZ assistance. The propensity score radius is adjusted to include as many untreated firms as possible whilst still satisfying the balancing hypothesis.

One of the advantages of the matching methods is that we do not need to specify a functional relationship between the outcome, such as productivity measures, and the factors that influence it. This is particularly advantageous when considering the impact of receiving R&D assistance on firm performance, due to the complex ways in which a firm may benefit by undertaking an R&D project.

One complication discussed in the programme evaluation literature is the time frame required for any impact to be realised from undertaking a new R&D programme. The only observational studies with sufficiently long panel data to examine the time dependent impact suggest significant benefits may not be seen until many years after first undertaking the project (World Bank, 2010). On the other, there are many

[21] For another example of this method, see Fabling and Sanderson (2010). Our code is also based on Fabling and Sanderson's code.

examples in the returns to R&D literature (see Section 2.1) of immediate positive benefits from firms undertaking R&D. It is unclear why the impact due to publicly funded R&D programmes takes so much longer to appear than impact from privately funded R&D discussed in the returns to R&D literature. One reason could be the mix of public R&D: more ‘research’ (blue skies type) versus less ‘development’ (close-to-market development).

Our dataset allows us to track outcomes between assisted and matched control firms for up to four years following a firm’s year of entering into an R&D programme. The treatment effect is calculated by comparing the growth in outcomes between the assisted firms and the matched control firms. The comparison is made at each year subsequent to the first year of receiving R&D assistance (treatment year) and the growth is measured from the year prior to the treatment year.

The primary methodological issue is to overcome the selection bias apparent in Figure 4-2, i.e., that firms that seek Capability Building or Project Funding are likely to have better than average performance regardless of whether they received government assistance for R&D. Fortunately, we have a rich dataset to allow for a wide range of characteristics to be incorporated in the participation model. This is discussed next.

5 Model, Data and Variables

In this section, we describe the details of our analysis. We set out the specific models we use, the data we use to conduct the analysis, describe the sample of firms and outline the variables that appear in our model.

5.1 The three models

To recap, our analysis uses a propensity score matching approach. We predict the probability of receiving R&D assistance using a probit regression model based on characteristics prior to assistance. Our choice of matching variables is based on the Tech NZ programme selection criteria and evidence from the literature, especially Fabling (2008). We discuss the variables in section 5.4.

An important aspect of this evaluation is our analysis of *treatment heterogeneity*. We investigate how the impact of assistance varies across schemes and firms. Schemes are designed with different outcomes or recipients in mind and firms respond to and benefit from assistance in different ways.

This focus requires us to consider different sets of firms to isolate particular impacts. Note that R&D assistance is not the only assistance businesses in New Zealand may receive from government. In order to remove any bias from our results caused by the impact of other business assistance, we focus our analysis on firms that only received funding from Vote: RS&T[22].

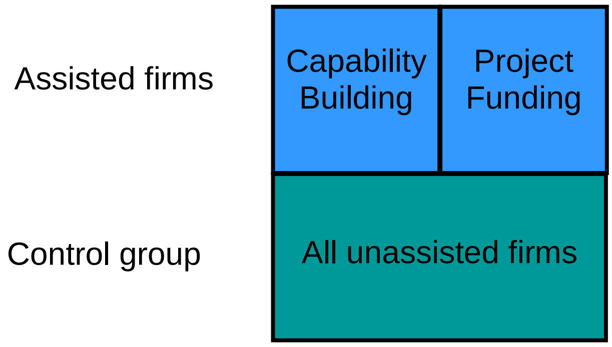
Model 1 – Comparing Capability Building and Project Funding

With our first model, we investigate the individual impacts of Capability Building and Project Funding assistance. As we have seen from section 3, these programmes each have a different focus. Capability Building focuses on growing firms' R&D capability. Project Funding focuses on assisting firms that already have that capability undertaking R&D projects. Because of this, the two sets of programmes would be expected to have different impacts (particularly on intermediate outcomes and the mechanisms whereby ultimate outcomes would be influenced).

In our first model, we divide firms into three groups: Those that received Capability Funding, those that received Project Funding and those that received no government assistance at all (see Figure 5-1). Because the focus is on identifying each programme's individual impact, we exclude firms that received both from the sample in this model.

[22] Firms that receive assistance from FRST and NZTE will be examined in a future module of the Cross Vote evaluation. This report focuses solely on Vote: RS&T because we wish to understand the impact of receiving particular types of assistance without the complication of interactions with other forms of business support.

Figure 5-1: Model 1 – Capability Funding and Project Funding

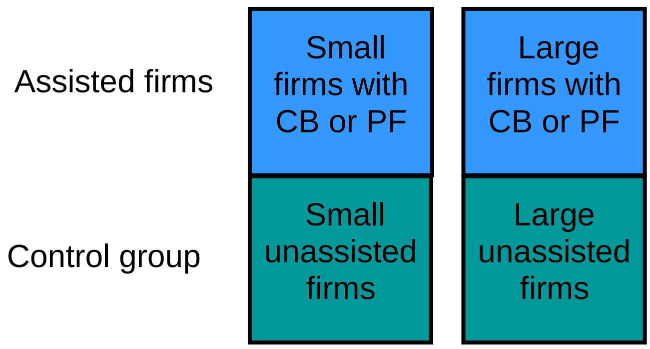


Model 2 – Comparing the impact of assistance by firm size

We might also expect the impact of assistance may vary is by firm size. Larger firms may be at different stages of their development and also gain from economies of scale. An important aspect of economies of scale is the ability specialise and to conduct potentially resource-intensive activities such as R&D. There is also literature that suggests that larger firms are more likely to conduct particular types of R&D, Coombs and Georghiou (2002).

In this model, we divide both the group of assisted firms and unassisted firms by size (in terms of employment). Our split point is chosen so as to split the group of assisted firms in half[23]. Because this reduces the sample size of our assisted firms, we pool the Capability Building and Project Funding recipients into one group. This means we can also include firms that receive *both* Capability Building and Project Funding. This is set out schematically in Figure 5-2. This means that in our analysis, we do two comparisons. In the first, we compare small firms receiving Capability Building and/or Project Funding assistance with small firms receiving no government assistance. In the second, we compare large firms receiving either type of assistance with large firms receiving no government assistance.

Figure 5-2: Model 2 – Variations in impact by firm size



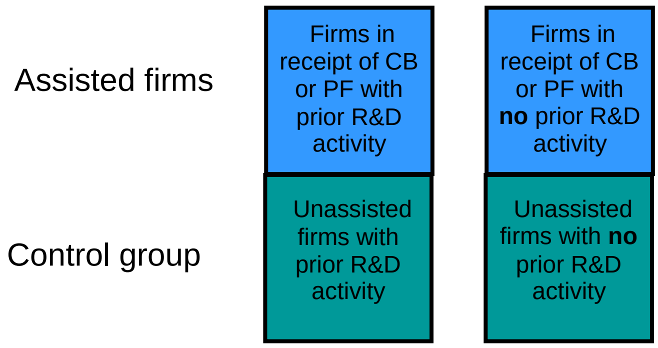
[23] This means that small firms are defined as having employment of less than 6.2. Our measure of employment is the average over the years of the number of employees in each month and so need not be an integer. For more on variables, see section 5.4 below.

Model 3 – Comparing the impact of assistance by previous R&D activity

Another important dimension over which we might expect the impact of assistance to vary is whether firms had previously conducted R&D or not. The ability to benefit from some types of funding will be higher when a firm has already done some R&D previously as they already have the systems and capability in place. Indeed, Project Funding is aimed at firms with existing R&D capability. One would expect these firms to have conducted some kind of R&D activity previously. Similarly, one would expect firms that had not previously conducted R&D to have lower R&D capability and benefit more from Capability Building programmes.

In Model 3, we split the sample into firms that have undertaken any R&D in the two years prior to first receiving R&D assistance. We then compare firms in receipt of Capability Building and/or Project Funding assistance with firms receiving no government assistance (see Figure 5-3).

Figure 5-3: Model 3 – Variations in impact by previous R&D activity



5.2 The prototype Longitudinal Business Database

The data for the analysis in this report comes from Statistics New Zealand's prototype Longitudinal Business Database (LBD). The LBD contains business-related data for financial years 2000 to 2008 from a number of sources. The main unit of analysis is the 'enterprise level', where the enterprise is defined as a business or service entity operating in New Zealand. The spine of the LBD is the Longitudinal Business Frame (LBF) which records firm characteristics and changes in these characteristics over time. The LBF is able to identify the predominant industry affiliation of a firm (ANZSIC code), foreign ownership interests and firms' connections through some kind of reporting arrangement.

Several administrative data sources are also attached to the LBF. These include Goods and Services Tax (GST), tax returns (IR4), financial accounts (IR10), and aggregated Pay-As-You-Earn (PAYE) returns provided by the Inland Revenue Department (IRD) and Customs merchandise trade data. Several Statistics New Zealand business surveys are also attached, including the Annual Enterprise Survey (AES), which is the primary data source for calculating the National Accounts; the Business Operations Survey and the Research and Development Survey. All data in the LBD are annualised to firms' actual balance date, and then assigned to the closest year ending 31st March. The database continues to evolve over time. It is described in more detail in Fabling (2009) and Statistics NZ (2010).

The LBD also includes participation data for business assistance schemes administered by New Zealand Trade & Enterprise (NZTE) and Foundation for Research, Science and Technology (FRST), Te Puni Kōkiri (TPK) and New Zealand Venture Investment Fund. NZTE, FRST and TPK provided a list of firms that had received assistance with information on the duration and amount of assistance. These details were matched with GST numbers (where supplied) or probabilistically linked (on name and contact details) to the LBF. These records were matched where possible to firm records in the LBD with high matching rates: 92% of firms receiving NZTE assistance (excluding the Enterprise Training Programme) were matched and 77% of firms receiving Technology New Zealand programmes from FRST were matched. The slightly lower matching rates for FRST reflects the longer duration of those programmes as the historical records are harder to match than recent records.

5.3 The evaluation sample

Table 5-1 shows the number of firms that first received R&D assistance between 2002 and 2008 distributed by type of assistance and year of entry into a government R&D programme. The number of new entrants in all categories trends down between 2002 and 2008. This is associated with an increase in the mean grant size (not shown) as the total available funding increased over this period. About 66% of all assisted firms (receiving 39% of the total amount dispersed) received either Capability Building or Project Funding. About 25% of all assisted firms (receiving roughly half the total amount dispersed in this period) also received assistance from NZTE. We exclude these firms from this evaluation as discussed previously.

Table 5-1: Number of firms receiving R&D assistance by year of entry and type of assistance.

	Firms receive R&D assistance only			Firms receive R&D and NZTE assistance	Total
Year of first R&D assistance	Capability Building	Project Funding	Both types of assistance		
2002	309	60	57	120	546
2003	249	108	45	93	495
2004	255	63	36	141	495
2005	186	57	21	102	363
2006	147	39	18	87	291
2007	144	54	18	99	318
2008	126	45	9	105	282
Total number of firms	1,413	426	207	750	2,796
Share of total number of firms	51%	15%	7%	27%	100%
Share of total dollars dispersed	6%	33%	13%	48%	100%

The population is drawn from "private for profit" firms and excludes households, ANZSIC division M (Government Administration and Defence) and firms located offshore. Only firms that are considered to be economically active[24] are included;

[24] Defined by a number of criteria, including non-zero GST sales/purchases; RME and selected IR10 variables

firms not assigned an ANZSIC industry classification are dropped. We only include treated and untreated firms for which we have a full set of data to calculate matching variables in the pre-treatment year. Because our matching model includes growth variables (see next section), we require data two years prior to a firm first receiving assistance. The LBD starts in 2000 so we can only examine the impact on firms that first receive R&D assistance from 2002 onwards. Table 5-1 shows that numbers of firms in the evaluation sample by treatment status. A large share of treated firms is dropped, primarily because they have zero total employment in the two years preceding their first year of government R&D assistance.

5.4 Model variables

This section discusses outcome and matching variables used in the evaluation. A list of all variables and their definitions is included in Appendix 3. We also show summary statistics for these variables by treatment status.

In this evaluation, we estimate the impact of receiving R&D assistance for four different outcome variables: log of sales, log of employment, log of labour productivity and MFP.

There are three sources of information relating to R&D. The first are two business surveys containing high quality information on R&D expenditure: the biennial national R&D survey and the annual Business Operations Survey. However, both of these are surveys of a sample of firms from the population, they were not designed for this type of evaluation. Because of this, they do not allow us to track the R&D activity of a sufficient number of firms receiving government R&D assistance and compare them to a control group of similar surveyed firms[25]. This means that the surveys are not useful as an outcome variable. Because of this, we are unable at this stage to use the LBD to determine whether *R&D* additionality occurs as a result of Tech NZ assistance.

The third source of information on R&D is the IR10 Financial Accounts form submitted to Inland Revenue. Whilst IR10 derived R&D expenditure does not concord well with the higher quality data from the surveys, this is likely to be because one of the major components of R&D expenditure (salaries and wages) are accounted for separately in the tax data (Fabling, 2008). Fabling (2008) concludes that the IR10 measure is sufficiently accurate to use as a binary variable, i.e. as an indicator that a firm performed R&D or not. That is to say, firms that report any expenditure in this category of the IR10 form do conduct R&D.

In light of the above, we construct a binary R&D indicator derived from all three sources for use as a matching variable. Firms are recorded as having previously undertaken R&D if they were recorded as conducting R&D in any of the three

[25] The Business Operations Survey is most suited to our task because it is an annual survey and represents a random sample of the population of firms (albeit only with firms with employment of 6 or more people). In contrast, the R&D survey is targeted at known R&D performers and receipt of Tech NZ assistance leads to a higher chance of being sampled in future R&D surveys. This could potentially lead to positively biased treatment effects. There is also a large panel element in the BOS survey - all respondents to BOS in 2005 continue to be sampled. However, the BOS has only been running annually since 2005. We explored if a subset of firms sampled in the BOS could be used to estimate whether R&D assistance resulted in additional R&D expenditure following assistance. However, the numbers of Tech NZ firms and suitable control firms with BOS responses were too small to provide conclusive results.

sources in the year preceding their first assistance or the previous year. For more on this, and other variables, see Appendix 3.[26]

We wished to include lagged outcomes variables as matching variables in the probit model to ensure that we compare treated and matched control firms with similar levels in sales, employment, labour productivity and MFP prior to estimating the treatment effect on those outcomes.

In order to remove bias in the treatment effect due to pre-existing differences in outcomes, we include pre-assistance levels of some of the outcomes measures. Because these are highly correlated with each other, we do not include them all in the probit model (after some experimentation we did not include sales and labour productivity in our probit model). To ensure the robustness of our results, we did check that all four lagged outcome variables were balanced at the 5% significance level.

One of the selection criteria for Tech NZ project funding is that firms have a potential for high growth. We use lagged growth in firm performance variables (employment, MFP) as a proxy for this criteria. It does not seem unreasonable that funding agencies use current firm growth to determine whether they believe a firm will grow strongly in the future and that firms experiencing high growth might seek government assistance to undertake new or enhanced R&D projects. Including the growth variables comes at a cost, however- we lose an additional year of data.

We also expect a positive relationship between a firm's exporting history and seeking Tech NZ assistance based on the expected outcomes of some Tech NZ programmes. Furthermore, over 40% of firms receiving Capability and Project Funding were goods exporters in the year prior to first receiving Tech NZ assistance; this compares to less than 5% of firms that were goods exporters in the total population[27] (Statistics NZ, 2010). We include two binary indicators for exporting in the year prior to treatment[28]: one for manufacturing exporters and the other for non manufacturing exporters. Dual binary variables are required because exporting activity is measured using trade merchandise data. The export binary variable is likely to be a good performance measure for the manufacturing sector (where firms tend to be involved in merchandise exports), but less so in non-manufacturing industries which predominantly export services.

Firm size may also influence the decision to seek government R&D assistance. Figure 3-2 shows that assisted firms are larger than the average firm in the

[26] We considered using this combined binary indicator as an outcome variable instead of R&D expenditure. However, we found that the IR10 data underestimates R&D activity in cases where we know that a firm received Tech NZ payments and is therefore undertaking R&D, but the IR10 data shows no activity. The BOS and R&D survey measures are more likely to report accurate indicators in these cases. The measurement error in the combined binary indicator is also related to whether a firm is treated or not. If a firm is treated (receives Tech NZ) then it is more likely to be sampled in future R&D surveys. Since the R&D survey is a more accurate measure of R&D activity than IR10, the firm may show up subsequently as starting to undertake R&D, even though it may have been doing R&D all along but just not reporting it in IR10 forms. This would lead to a positive bias in the treatment effect. We might exclude the R&D survey from the combined measure and consider combining only BOS and IR10 data. However, if receiving Tech NZ has a positive impact on employment, then the firm will grow after receiving treatment and the larger it grows, the more likely it will exceed the BOS sampling threshold of 6 people. Again, the firm might look like it just started doing R&D simply because it was now more accurately measured.

[27] Businesses were restricted to the following industries: agriculture, forestry and fishing; manufacturing; wholesale trade; retail trade; transport, postal, and warehousing

[28] We experimented with exporting dummies involving longer exporting histories, however the probit model results were relatively insensitive to the choice of dummy variable.

population so this might lead us to expect that larger firms receive R&D assistance. However, Fabling (2008) found that smaller firms have an increased likelihood of undertaking R&D so we have no clear view on the relationship between size and receiving government R&D assistance. There is a wide range of firm sizes in the treated sample, for both Capability Building and Project Funding assistance. We therefore also include a squared term to account for the possibility that participation is nonlinearly related to firm scale.

We expect firms with higher levels of capital will be more likely to apply for an R&D grant. Since we are already including a measure of scale with employment, we use the capital intensity (the ratio of capital to labour) as a matching variable. Hall and Ziedonis (2001) argue that firms with large sunk costs respond strategically to an environment by placing more emphasis on innovations through expansion. This suggests a positive relationship between capital intensity and treatment. This is supported by Figure 3-2, which shows that firms receiving government R&D assistance have higher levels of capital intensity compared to the untreated population, at least in the year prior to first receiving assistance. We also include growth in capital intensity as it seems possible that firms increasing their investment in capital intensity may be gearing up to undertake R&D.

Other matching variables include the age of the firm and dummy indicators for whether or not it is foreign owned, and whether or not the firm is a single entity or is in a group and associated with other firms through some kind of reporting arrangement (e.g. a manufacturing firm might be associated with a head office). All foreign owned firms are assumed to be in groups. We believe these characteristics may affect a firm's decision to seek Tech NZ assistance or be granted assistance by the funding agency but we have no clear view on the sign of that relationship or whether it is significant.

We pool all observations across industries and years, but include industry (2 digit ANZSIC) and year dummies to account for changes in the macroeconomic climate that might influence participation and funding decisions[29]. We remove industry specific annual averages (at the 2 digit ANZSIC level) from all continuous variables (outcome and matching variables) prior to estimation. Our interest lies in estimating the impact on firm performance that is solely due to government assistance; this impact is likely to be swamped by year to year variations in performance due to external factors that are common to industry groupings. We also dropped all outliers in the distribution of changes in our outcome variables as these can seriously skew mean treatment effect when sample sizes are small.

[29] We did not have sufficient memory to use industry-year dummies for the whole dataset. However, analysis involving subsets of the data showed that the two models (separate industry and year dummies and industry-year dummies) were not statistically different.

6 Results

6.1 Matching model results

The results of estimating the matching model of Capability Building and Project Funding are set out in Table 6-1. Matching is based on predicted probabilities from a probit regression of the treatment variable on characteristics in the previous year. The treatment variable relates to first time receipt of Capability Building or Project Funding assistance. To save space, the coefficients for the industry and year dummies are not shown.

The coefficients on employment, capital intensity, exporting and R&D activity are significant and have the expected signs. Larger firms and firms with higher capital intensities have a higher likelihood of receiving R&D assistance. There is also a significant nonlinear dependence on firm size so that the probability of receiving R&D assistance doesn't continue to increase with firm size. Firms that export goods are also more likely to receive assistance – the coefficients are similar whether the firm is in a goods exporting industry (*manu_goods_export*) or not *(non_manu_goods_export)*. R&D activity in the two years prior to first time assistance is also a strong predictor of receiving R&D assistance. These results confirm our expectations based on Figure 4-2 that higher performing firms self-select (or are preferentially selected by funding agencies) into Capability Building and Project Funding assistance.

There is no evidence of firms gearing up prior to undertaking a government R&D project. Growth rate variables are not statistically significant, except in the case of firms seeking Capability Building assistance, where lower growth rates in MFP increase the likelihood of receiving assistance, all other things equal. Younger firms are also more likely to receive Capability Building assistance. Foreign ownership and group status only impacts on the probability of receiving Project Funding; foreign owned firms are less likely, and firms in groups more likely, to receive Project Funding.

Table 6-1: Probit model results: The probability of receiving R&D assistance by type of assistance

	Capability Building	**Project Funding**
Employment *(ln_rme)*	0.278*** [0.028]	0.283*** [0.05]
Employment^2 *(ln_rme_squared)*	-0.022*** [0.007]	-0.044*** [0.012]
Change in employment *(Δln_rme)*	0.05 [0.059]	0.139 [0.098]
Multi-factor productivity *(mfp)*	0.03 [0.021]	0.033 [0.039]
Change in MFP *(Δmfp)*	-0.047* [0.025]	-0.058 [0.053]
Capital intensity *(klratio)*	0.081*** [0.016]	0.080*** [0.027]
Change in capital intensity *(Δklratio)*	-0.014 [0.028]	-0.01 [0.056]
Firms in group *(in_group)*	0.073 [0.058]	0.158* [0.084]
Goods exporting industry *(manu_goods_export)*	0.321*** [0.073]	0.386*** [0.115]
Other exporting industry *(non_manu_goods_export)*	0.311*** [0.072]	0.373*** [0.12]
Firm age *(ln_age)*	-0.004** [0.002]	0.003 [0.002]
R&D activity *(R&D_ind)*	0.351*** [0.05]	0.429*** [0.079]
Foreign owned firms *(foreign_owned)*	-0.121 [0.094]	-0.367** [0.163]
Pseudo R^2	**0.173**	**0.208**
N treated firms	405	111
N control firms	176,532	118,446

- Robust (clustered on firm) standard errors in brackets (*, **, *** refer to significance levels of 10%, 5% and 1% respectively);
- 2 digit industry and year dummies were included in the model but are not shown;
- Low values of PseudoR^2 are typical with probit and logit models; this measure is not like the R^2 for ordinary least squares regression.
- Firms with non-finite values of matching variables are dropped from the model.

6.2 Causal estimates of the impact on firm performance

The matching models show that the performance of assisted firms is higher than the average New Zealand firm, even before the assistance begins. The question remains whether the R&D assistance results in any additional impact on firm performance. We obtain causal estimates of the effect of R&D assistance on firm performance by using the estimated propensity scores from the matching model to match assisted firms to comparable control firms, and then compare the changes in firm performance between treated and matched control firms.

Table 6-2 to Table 6-4 present the results for our three different model specifications. The tables show the causal treatment effect estimates and their errors, the numbers of treated and control firms[30] used in the estimates and the share of treated firms dropped in the radius matching process because there was no overlap with similar untreated firms. Statistically significant coefficients are shown in bold.

Model 1 – Comparing Capability Building and Project Funding

Our main estimates show the impacts of receiving Capability Building and Project Funding assistance separately (Table 6-2). We see that Capability Building assistance has a positive and sustained impact on employment (RME). The coefficients are around 5%, meaning that on average, firms that received Capability Building assistance subsequently grew their employment to be about 5% higher than similar matched firms over the same period. The impact was evident up to three years following a firm first receiving Capability Building assistance. Most of the differential employment growth happens at the start of the assistance with only a small increase after three years (from 4.7% to 6.7%). The lack of significant impact on RME after four years may partially reflect the decline in sample size and the corresponding increase in standard errors. However, the lack of significant impact after two years is difficult to explain. There is a decline in sample size between one and two years, however the impact is significant after three years and the sample is even smaller then. This pattern may be linked to the intermittent nature of R&D activity particularly for firms that are just starting build R&D capacity.

There is a short term impact on sales one year after first receiving Capability Building assistance but no impact for later years (although the coefficients are positive they are not statistically significant). There is no impact on labour productivity (LP) although the coefficient at lags of four years is getting close to becoming significant. If the differential growth in value-added between treated and matched control firms remained constant, then the significant difference in employment growth might lead to negative values of labour productivity. In fact, labour productivity coefficients are positive although not significant, implying that value-added must have also increased although not so much that we see significant impact on labour productivity. There is no significant impact on multifactor productivity (MFP) for the first three years following the first year of assistance. However, we do see a significant positive impact on one of our final outcomes, MFP, at four years following first receiving Capability Building assistance.

The table shows a large reduction in the number of observations from zero lag to lags of four years. Most of this reduction in data is a reflection of our relatively short

[30] These number of treated firms used in the estimation are fewer than the numbers shown in Table 5.1 because they have missing values for matching variables in the year prior to treatment. For example, about 35% of firms are dropped because they have zero employment in the year prior to employment.

time series, resulting in a smaller number of possible observations at lags of four years compared to no lag. However, some of this reduction will be due to firm attrition. It is possible that our treatment effect estimates are affected by a change in composition of treated firms over time, e.g. if high performing firms are more likely to survive then our estimates at longer time lags may be positively biased due to attrition of weaker firms. To test this, we repeated the analysis using a common sample that only included firms that were present in all years in order to untangle changes in the composition of the assisted firms over time from within-firm changes in performance. The common sample results showed the same time dependence in impact on MFP as the full sample, there is no statistically significant impact until four years after first receiving assistance. This suggests that attrition bias is not the cause of the increase in significance for MFP at later years. The evidence of a significant long term impact on MFP from Capability Building is encouraging because higher firm productivity is a final rather than an intermediate outcome. MFP could be improved by firms adopting better business practices or utilising resources in more efficient ways as a result of receiving R&D assistance. If this is what is happening then we would expect to see even higher returns in the future.

Moving to Project Funding assistance (right hand side of Table 6-2), we see no causal effects on any of firm performance measures at any time lag. Most of the employment coefficients are positive but not significant. All the productivity coefficients are negative and not significant. The results seem counterintuitive - Project Funding involves large sums of money and is directed to firms that are embarking on significant R&D projects that have been found to produce tangible results (e.g., Infometrics, 2009). Yet we measure no impact on any firm performance measures for up to four years following project approval. This does not mean that the R&D projects undertaken as a result of receiving assistance have been unsuccessful. Based on previous evaluation evidence of Tech NZ it is highly likely that the projects improved the performance of firms following receipt of the grant. However, our results suggest that a comparable group of firms would have had similar improvements in firm performance (possibly as a result of undertaking privately funded R&D) regardless of whether they received Project Funding assistance.

Why do we see significant impacts for Capability Building assistance but not Project Funding? Is it related to the types of firms that receive Capability Building, e.g. because firms are less likely to have undertaken R&D prior to receiving Capability Building? We examine this question in our next two specifications. We also examine the possibility that the lack of significance is associated with the smaller sample size for Project Funding (about 30% of the Capability Building sample size).

For our next two specifications we pool both types of assistance to increase our sample size and examine the influence of firm size and prior R&D activity on our estimates. (We can now include the firms that received both Capability Building and Project Funding assistance, which we previously excluded to get a clear picture of the separate impacts). To do this, we need to assume that the probability of receiving assistance and the time dependent impact on firm performance does not depend on the type of R&D assistance. We see some justification for this assumption in the similarity of firm characteristics prior to receiving either Capability Building or Project Funding assistance (Figure 3-2) and in the similarity of the matching models (Table 6-2).

Table 6-2: Results for Model 1 – The causal effect of R&D assistance on firm performance by type of assistance

	Capability Building					Project Funding				
	Begin treatment	*Continued treatment*				*Begin treatment*	*Continued treatment*			
	Approval Year	Year 1	Year 2	Year 3	Year 4	Approval Year	Year 1	Year 2	Year 3	Year 4
SALES	0.043	**0.084****	0.081	0.111	0.106	-0.021	0.015	-0.058	-0.060	-0.057
	[0.03]	[0.039]	[0.053]	[0.072]	[0.081]	[0.05]	[0.066]	[0.125]	[0.143]	[0.157]
N treated	351 (0.13)	348 (0.13)	306 (0.13)	255 (0.12)	201 (0.14)	99 (0.11)	96 (0.11)	84 (0.13)	72 (0.14)	60 (0.13)
N control	176532	173478	142428	118557	97671	118446	110163	94749	86964	72573
RME	**0.047****	**0.058***	0.018	**0.067***	0.047	0.011	0.011	0.006	0.023	-0.101
	[0.02]	[0.033]	[0.048]	[0.039]	[0.046]	[0.044]	[0.079]	[0.099]	[0.089]	[0.109]
N treated	339 (0.13)	330 (0.13)	285 (0.14)	237 (0.14)	186 (0.16)	96 (0.14)	90 (0.14)	75 (0.14)	63 (0.13)	54 (0.14)
N control	167313	154143	124212	100857	83337	108159	97755	83076	71496	52911
LP	0.006	0.046	0.034	0.021	0.114	-0.009	-0.052	-0.053	-0.053	-0.041
	[0.045]	[0.043]	[0.062]	[0.065]	[0.078]	[0.081]	[0.128]	[0.106]	[0.106]	[0.096]
N treated	318 (0.14)	315 (0.15)	273 (0.13)	219 (0.14)	168 (0.16)	93 (0.11)	87 (0.12)	66 (0.12)	63 (0.13)	51 (0.11)
N control	147525	139296	108855	87915	71334	99720	83787	67032	60198	42978
MFP	0.008	0.058	-0.002	0.037	**0.151****	-0.089	-0.072	-0.169	-0.195	-0.019
	[0.047]	[0.046]	[0.065]	[0.071]	[0.061]	[0.079]	[0.102]	[0.116]	[0.123]	[0.107]
N treated	297 (0.14)	291 (0.14)	243 (0.14)	201 (0.13)	159 (0.13)	78 (0.19)	69 (0.21)	54 (0.22)	51 (0.19)	42 (0.24)
N control	138897	123273	95001	75474	60864	89436	72261	57564	46893	38916

Notes

Difference in difference estimates comparing growth in outcomes between assisted firms and a matched sample of firms. Growth is measured from the year prior to receiving assistance to the outcome year. We use radius matching with replacement and a propensity score radius of 0.0003 for the Capability Building and 0.001 for Project Funding. Treated firms are only matched to firms in the same 2 digit industry and year. Individual firm treatment effects are averaged across all industries and years. All pre-treatment matching variables and pre-treatment performance variables are balanced at 5% significance level. Bootstrapped errors in brackets (*, **, *** refer to significance levels of 10, 5 and 1% respectively).The number of treated and control firms used in each estimate are also shown. The share of treated observations dropped due to falling outside the propensity score radius is shown in brackets beside the number of treated firms.

Model 2 – Comparing the impact of assistance by firm size

Table 6-3 shows the influence of firm size on impact estimates. We split the sample of all assisted firms into two equal groups based on total employment (RME). The split occurs at RME=6.2[31]. There is a clear pattern from our analysis: we see some positive and significant impacts on firm performance for the small firms, but no impact for large firms. In fact, we see significant *negative* impacts on productivity at two time lags for the large firm group. For firms in the small size group, we see differential growth in employment, labour productivity and MFP after four years between assisted and unassisted firms. The estimates are not significant at shorter time lags except for employment, but coefficients are positive from lags of one to three years for employment and LP. In contrast, all the productivity coefficients are negative for the large firm group although employment coefficients are positive. The lack of significance in the large firm results is not likely to be due to small sample size issues in this specification.

[31] The numbers of firms in the small and large group are equal prior to matching, however many of the small firms did not have data for some of the matching variables and were dropped in the matching model. This is why Table 6.3 shows more firms in the large firm group compared to the small firm group.

Table 6-3: Results for Model 2 – The causal effect of R&D assistance on firm performance by Firm size

	Small firms (employment < 6.2)					**Large firms** (employment ≥ 6.2)				
	Begin treatment	*Continued treatment*				*Begin treatment*	*Continued treatment*			
	Approval Year	Year 1	Year 2	Year 3	Year 4	Approval Year	Year 1	Year 2	Year 3	Year 4
SALES	0.01 [0.037]	0.044 [0.063]	0.054 [0.068]	0.078 [0.14]	0.184 [0.133]	0.018 [0.021]	0.030 [0.027]	0.048 [0.05]	0.088 [0.06]	0.014 [0.099]
N treated	186 (0.07)	183 (0.06)	162 (0.07)	138 (0.08)	108 (0.08)	279 (0.15)	279 (0.16)	249 (0.15)	210 (0.14)	177 (0.16)
N control	123183	122235	111819	93711	78945	15291	15282	11790	10212	7695
RME	**0.051**** [0.023]	0.032 [0.048]	0.028 [0.053]	0.085 [0.066]	**0.125*** [0.069]	0.009 [0.018]	0.023 [0.027]	0.003 [0.043]	0.021 [0.047]	-0.079 [0.061]
N treated	180 (0.08)	186 (0.06)	150 (0.06)	126 (0.09)	105 (0.08)	279 (0.15)	279 (0.16)	246 (0.15)	204 (0.14)	168 (0.14)
N control	120765	124368	100779	81234	66510	15306	15306	11577	9669	7284
LP	-0.003 [0.059]	0.039 [0.072]	0.044 [0.09]	0.044 [0.116]	**0.202**** [0.104]	-0.036 [0.035]	-0.045 [0.039]	-0.056 [0.039]	**-0.106*** [0.061]	-0.001 [0.063]
N treated	162 (0.07)	162 (0.07)	135 (0.08)	111 (0.08)	87 (0.06)	276 (0.16)	279 (0.15)	237 (0.15)	201 (0.14)	162 (0.14)
N control	107073	106974	87744	68826	55224	14949	14955	11163	9327	6939
MFP	-0.023 [0.065]	0.04 [0.059]	-0.059 [0.096]	0.073 [0.11]	**0.225*** [0.122]	**-0.057*** [0.035]	-0.012 [0.051]	-0.06 [0.066]	-0.074 [0.064]	0.03 [0.08]
N treated	153 (0.07)	147 (0.08)	120 (0.07)	99 (0.11)	81 (0.07)	252 (0.17)	249 (0.18)	207 (0.18)	183 (0.16)	138 (0.15)
N control	102285	95856	77430	59541	49683	13998	13545	9720	7755	6048

For notes see Table 6-2

Model 3 – Comparing the impact of assistance by previous R&D activity

Small firms appear to benefit more from R&D assistance than large firms, at least in the four years following their first assistance. Another factor that might significantly influence how much benefit a firm receives from assistance is whether or not they have previously undertaken R&D. This is examined in Table 6-4. We see no significant impact for firms that had undertaken R&D in the two years prior to receiving their first grant. In contrast, we do see some impacts for firms that had not previously undertaken R&D in employment growth and MFP. One of the problems with interpreting Table 6-4 is that we believe that many firms that undertake R&D are under-reporting this activity in their taxation (IR10) forms that have been used as a data source for this study. This means that there will be an unknown number of firms in the ‘no prior R&D’ group that are actually doing R&D in the two years before receiving their first grant and this may be weakening the impact estimates if firms receive maximum benefit from starting to do R&D for the first time. (We are reasonably confident that firms in the prior R&D group are correctly identified as doing R&D so the difficulty in interpretation lies with the left-hand side tables only).

Table 6-4: Results for Model 3 – The causal effect of R&D assistance on firm performance by prior R&D activity

	No Prior R&D					Prior R&D				
	Begin treatment	*Continued treatment*				*Begin treatment*	*Continued treatment*			
	Approval Year	Year 1	Year 2	Year 3	Year 4	Approval Year	Year 1	Year 2	Year 3	Year 4
SALES	0.023	**0.084***	0.08	0.064	0.093	0.013	-0.006	-0.101	0.047	-0.194
	[0.027]	[0.046]	[0.051]	[0.068]	[0.072]	[0.055]	[0.068]	[0.149]	[0.124]	[0.156]
N treated	381 (0.09)	375 (0.09)	330 (0.09)	279 (0.08)	219 (0.1)	114 (0.16)	114 (0.16)	99 (0.18)	78 (0.21)	69 (0.23)
N control	178833	174204	147510	124716	101424	3267	3222	2619	1929	1578
RME	**0.041****	**0.062****	0.038	0.04	-0.014	0.05	-0.003	-0.025	-0.05	-0.179
	[0.019]	[0.03]	[0.04]	[0.039]	[0.052]	[0.037]	[0.07]	[0.077]	[0.086]	[0.133]
N treated	369 (0.09)	357 (0.1)	306 (0.1)	252 (0.11)	204 (0.12)	111 (0.18)	114 (0.17)	93 (0.21)	75 (0.22)	69 (0.21)
N control	168708	153432	127734	105195	85641	3153	2976	2019	1782	1443
LP	-0.032	-0.024	-0.028	-0.046	0.096	-0.053	-0.074	0.022	-0.088	0.003
	[0.041]	[0.041]	[0.046]	[0.058]	[0.069]	[0.077]	[0.104]	[0.097]	[0.154]	[0.149]
N treated	348 (0.1)	336 (0.1)	285 (0.1)	234 (0.11)	183 (0.12)	105 (0.19)	111 (0.16)	90 (0.19)	75 (0.19)	63 (0.19)
N control	147672	134328	110181	89898	71451	2928	2796	1653	1617	1296
MFP	-0.047	-0.01	-0.055	-0.028	**0.131***	-0.104	-0.037	-0.001	-0.074	0.071
	[0.036]	[0.054]	[0.064]	[0.066]	[0.082]	[0.096]	[0.085]	[0.099]	[0.139]	[0.144]
N treated	318 (0.11)	306 (0.11)	255 (0.11)	210 (0.11)	165 (0.11)	93 (0.18)	96 (0.2)	78 (0.19)	69 (0.21)	57 (0.14)
N control	139812	118242	98124	77919	62535	2166	2331	1428	1434	1098

For notes see Table 6-2

6.3 Comparison with past evaluations of Technology New Zealand

At this stage it is natural to ask how these recent findings fit in with previous evaluations of Tech NZ based on self reported impacts on a sample of recipient firms. We expect there will be some differences in conclusions which are solely due to sample differences and different periods of analysis. For example, the most recent Infometrics (2009) evaluation which surveyed 28 firms that had received significant levels of funding over the previous decade. It is likely that several of the firms that were interviewed in that study are not part of our analysis because they may also have received funding from NZTE or they received their first grants prior to 2002. We focus on the more recent past evaluations and summarise some relevant points in Table 6-5.

Previous evaluations report an increase in R&D capability as a result of receiving Tech NZ assistance. Firms surveyed in the Infometrics study (2009) mentioned that R&D would not have occurred, at least at the same level, without assistance. This is consistent with R&D additionality, but it is not an actual measure because it is based on self-reported performance. Technology NZ performance reports show increases in the average R&D expenditure following contract completion, but much of this increase may have occurred anyway not just as a result of receiving Technology Business Growth (TBG) assistance.

In this study, we focus on whether the assistance actually improved the performance of the firm. We might expect any significant increases in R&D activity and/or capability to be evident in changes in employment levels. We measure no impact on employment for Project Funding for up to four years following the first year of assistance. This appears to be inconsistent with the very positive findings from previous TBG evaluations (although of course additional R&D activity and/or expenditure could have occurred with no additional employment growth). However, it is unclear what benefits to the firm are if it does not grow or become more productive. We do see increases employment for Capability Building assistance and this is consistent with previous findings from the TIF evaluation which found that fellowships have created new R&D capability and enhanced a firm’s appreciation for undertaking R&D.

Previous evaluations did not identify or quantify the counterfactual. They found very positive impacts on sales, with quantitative estimates ranging from on average increase in 7% to 29% due to Tech NZ assistance. The highest impact of 29% is at 18 months after completion of TBG projects and is measured from the start of the TBG grant. Depending on the duration of the funding, this could be two or more years on since first receiving assistance[32]. This result is much more positive than our estimates which show no impact on sales, except for firms receiving Capability Building assistance and for firms that did no prior R&D two years before their first assistance (and then only in the first year after approval). This is not surprising as the TBG estimate is a before/after measure, i.e. it measures what happened as after receiving a TBG. We saw in section 4 how this might severely overstate the impact. It does not compare the performance of TBG firms with similar firms that received no assistance. It is not that TBG firms did not develop new products, processes or services and generate excess sales; it is clear that they do. However our analysis suggests that they would have done that anyway and attributing the entire change in sales to Tech NZ assistance leads to overestimates of sales impact.

The Infometrics (2009) evaluation goes one step further and asks firms to estimate the impact attributable to Tech NZ assistance. This leads on average to a slightly lower estimate on the average impact of sales of 19.8%. This is again significantly higher than our estimate

[32] Around 85% of firms receiving Project Funding in our evaluation sample had received their total grant within 2 years of approval.

and we believe it is biased high due to the inherent uncertainty in the method of estimation and the small sample size.

6.4 Comparison with other econometric evaluations of R&D support

As we noted in section 2, there are only a handful of studies that have been able to quantify impacts on firm performance due to government funded business support using robust econometric techniques. Even fewer of those studies focus on government R&D assistance. Similar to those studies (World Bank, 2010) we find the strongest evidence for impact on outcomes such as employment growth rather than productivity (as a result of receiving Capability Building assistance). The impact is restricted to small firms and firms that had not undertaken R&D in the two years prior to receiving first assistance.

Three out of five of the previous studies that included sales as a performance measure found no significant impact from R&D programmes. Similarly, we found an immediate but not sustained impact on sales. All of the studies that looked at impact on productivity found no impact due to R&D assistance (although there were impacts on productivity due to other types of business support). This is similar to our findings related to Project Funding. However, we have measured a positive and significant impact due to Capability Building at fours year following the start of a project. We found positive impacts on MFP to be associated with smaller firms and those firms that had not undertaken R&D prior to the first project. This is a more positive finding than those recent studies with regard to R&D assistance.

The Chile and Mexico studies also examined the effects of timing of assistance on firm performance although this was in relation to all forms of SME support combined and not just R&D support. Both studies find that impacts may take up to four years to materialise and impacts can continue to increase for many years following that. The authors of the synthesis report (World Bank, 2010) conclude that long time lags may partially explain why so previous studies have found little significant impacts. We could apply that argument to explain why we did not find any significant impacts on firm performance due to Project Funding; perhaps significant impacts will be evident when this analysis is repeated again in a few years.

On the other hand, it is puzzling that the ‘returns to R&D’ literature discussed in the Literature review is full of examples of significant immediate or short term impacts due to R&D including on productivity. It is true that many of these studies may relate to privately funded R&D programmes and these might be quite different in nature to publicly funded programmes evaluated here. The different temporal patterns in impact due to private versus public funding needed to be explored further.

Table 6-5: Comparison with previous evaluations

	Previous Tech NZ evaluations	This evaluation
Increases in R&D capability and expenditure following assistance	*Infometrics 2009 survey of 28 TBG firms:* Some firms report R&D would not have gone ahead without assistance, others report R&D would have gone ahead but at a reduced level *TBG Performance Report of completed contracts (2006/07):* Average R&D expenditure increased by 37% in the 18 months since the completion of funded TBG projects *TBG Intellectual Property Survey (2003):* 65% of 114 TBG firms increased their capability to undertake future R&D *TIF evaluations (2001,2004):* Fellowships created new R&D capability; firms have gained a higher appreciation of R&D projects *GPSRD 2004:* The overall trend showed a decline in R&D spend following assistance. Some evidence relating to the intermittent nature of R&D for small firms.	We are unable to measure the impact of assistance on R&D activity or expenditure due to data constraints. However, we do measure changes in another intermediate outcome, employment, and we expect that some employment growth may be linked to an increase in R&D capability. We are able to attribute significant employment growth following assistance to Capability Building assistance, but not Project Funding. This impact is only significant for small firms and for those that had not undertaken R&D in the two years prior to receiving their first grant.
Impact on sales and productivity	*Infometrics 2009 survey of 28 TBG firms:* Tech NZ has lifted the performance of companies above where they would otherwise be. Smaller firms enjoyed a larger proportional benefit. Average increase in sales of 19.8% due to assistance and a discounted benefit cost ratio of 12.9. Average increase in export earnings of 18.2% due to assistance *TBG Performance Report of completed contracts (2006/07):* Average increase in turnover of 30% in 18 months since completion of TBG with on average revenue generated of $4.4 m per million dollars invested in TBG. One in 7 firms report an increase of over 200% in export earnings in 18 months since the completion of TBG projects. *TBG Intellectual Property Survey (2003):* 84% of firms had additional revenue generated from new products processes and services. *GPSRD 2004:* Average growth in sales of 7% or more due to GPSRD	We are able to attribute significant growth in sales and multifactor productivity following assistance to Capability Building assistance, but not Project Funding. The benefit is restricted to small firms and those firms that had not undertaken R&D in the two years. We find immediate (1 year) impacts on sales but these are not sustained. We find longer term impacts on multifactor productivity and in some cases labour productivity.

7 Conclusions

The main results of this evaluation are presented in Table 7-1. Firms that receive R&D assistance are higher performing than the average New Zealand firm. Firms are larger, have higher sales and capital intensity and more likely to be exporting goods and undertaking R&D even before they seek out R&D assistance. Failure to take this into account when assessing the impact on firm performance due to assistance will result in biased estimates. We reduce the selection bias by matching firms that have received assistance with comparable unassisted firms, and by comparing the changes in performance of the assisted and unassisted groups before and after receiving the assistance. Our method is similar to the current best practice methods used in recent international studies (World Bank, 2010).

We assess the impact on sales, employment, labour productivity and multifactor productivity of firms receiving R&D assistance relative to matched unassisted firms. Ideally, we would like to assess the impact of R&D assistance on R&D additionality, i.e., whether R&D assistance has resulted in the firm investing in R&D over and above the level it would have done without assistance. Following that we would like to show a link between improved R&D activity and improved final outcomes. Unfortunately, we do not have sufficiently accurate and comprehensive information on the temporal history of R&D expenditure or activity to do this now. We require a longer history of firm responses from the Business Operations Survey and/or Research and Development Survey before we are able to assess the impact of R&D activity. This will not be available for a few more years.

We use three different models to examine the impact of government R&D assistance. Our main model looks at the impact of Capability Building and Project Funding separately, in order to distinguish whether impacts depend on the type of assistance provided to a firm. We see that they do. Firms that receive Capability Building assistance show significantly higher employment growth compared to matched unassisted firms. Most of this growth occurs at the start of R&D assistance and then grows only slightly after that till three years following first receiving assistance. Still with Capability Building, we see a short term impact on sales and we infer a positive impact on value-added because labour productivity does not become negative although labour has increased. However, our most encouraging result is the impact on multifactor productivity four years following first assistance because this is an ultimate outcome for government assistance. If this impact is due to firms using resources more efficiently or adopting better business strategies and/or practices then we should expect to see the impact continue to be positive at longer lags.

In contrast, there are no impacts for Project Funding even on intermediate outcomes. We found this counterintuitive because we know that Project Funding involves larger dollar amounts compared to Capability Building. In order to understand this result better, we pooled both types of assistance and examined the influence of firm size and prior R&D activity on the results. We only found impacts for small firms and firms that had not undertaken R&D two years prior to receiving their first assistance. We saw no positive impacts for large firms and no positive impacts for prior R&D performers. Our results show that Technology New Zealand has a significant positive impact when it is targeted at firms that are building capability; that are small and that have not previously undertaken R&D.

Table 7-1: Main findings

Selection bias	Characteristics of assisted firms compared to all firms before receiving assistance • Higher sales • Higher employment • Higher labour productivity • Slightly lower multi factor productivity • Higher value added • Higher capital-labour • Do export • Perform R&D
Capability Building assistance	• 8.4% increase in sales only for one year after first receiving assistance • 4.7% - 6.7% increase in employment after three years • 15% increase in multi factor productivity after four years
Project Funding assistance	• No impact
Large firms[1, 2]	• - 10.6% drop in labour productivity after three years • - 5.7% drop in multi factor productivity during approval year
Small firms[1, 2]	• 5% - 12.5% growth in employment • 20% increase in labour productivity after four years • 22.5% increase in multi factor productivity after four years
Firms that had undertaken R&D[2]	• No impact
Firms that had not previously undertaken R&D[2]	• 8.4% increase in sales only for one year after assistance • 4% - 6% increase in employment in the first two years after assistance • 13% increase in multi factor productivity after four years

[1] Small firms < 6.2 employees.
[2] Capability and Project funding are pooled.

How does this compare with other evaluation evidence? Previous evaluations of Technology New Zealand using traditional methods such as surveys or case studies of recipient firms find positive impacts. It is clear that these projects result in new or enhanced products, processes and services and sales and exporting revenue for firms grow following completion of the grants. The question is whether the firms grow any faster than they would have done without assistance. The answer appears to be no, at least over four year lags that we are able to measure. However, it is not unusual for econometric studies to find less positive impacts than traditional surveys. International econometric studies that also looked at R&D programmes found little evidence of short term impact on final outcomes, although they did see an impact on intermediate outcomes such as wages and export intensity. None of these studies found any impact on productivity due to R&D support. One explanation for this is that the impacts are yet to materialise. There is support for this explanation in previous studies that found impacts due to SME support could take between four to eleven years to become significant. Yet, the ‘returns to R&D’ literature clearly demonstrates that short terms impacts due to R&D activity on productivity are possible. Why then the differing timing in returns from publicly supported R&D projects? This analysis needs to be repeated in a few more years to see whether there are any significant impacts on firms receiving Project Funding.

A lack of significant impact on participants in a government programme does not necessarily mean that government money is wasted. There is potential for spillover benefits, even in cases where public programmes have an average negative impact on recipients. For example, unassisted firms may observe the failure of a government funded R&D project and decide not to undertake a similarly risky project themselves, possibly resulting in net savings to the New Zealand economy. This is unlikely to be occurring here, given the overwhelming positive findings from previous evaluations of Technology New Zealand. Another argument could be that R&D projects have been so successful that spillovers have occurred immediately so that our group of matched control firms already includes firms that have benefited by knowledge. We find this unlikely. One concern is that we have not identified firms that benefit in an indirect manner from other publicly funded projects, such as, e.g., when firms are engaged in partnerships with Crown Research Institutes of universities. If these firms are included in the matched control group then we will underestimate the impact of direct assistance. However, the treated firm is also likely to include some of these indirectly assisted firms and so the direction of bias is unclear. Also, the number of unassisted firms is very large; we think it is unlikely that the indirectly assisted firms could skew the results so that all coefficients for Project Funding, for large firms and prior R&D performers are insignificant. However, it is important that we attempt to address this deficiency in the LBD by included information about firms that are known to be linked with public providers.

8 Bibliography

Abowd, J., Creecy, R., and Kramarz, F., (2002), 'Computing Person and Firm Effects Using Linked Longitudinal Employer-Employee Data', Technical Papers 2002-06, Longitudinal Employer-Household Dynamics, Center for Economic Studies, U.S. Census Bureau.

Bogliacino, F. and Pianta, M. (2010), *Profits, R&D and Innovation: a Model and a Test*, IPTS working paper Corporate R&D and Innovation - No. 05/2010

Caliendo, M. and Kopeinig, (2008). 'Some practical guidance for the implementation of propensity score matching' *Journal of Economic Surveys,* Blackwell Publishing, vol. 22(1), pages 31-72, 02.

Centre for Advanced Engineering, (2001). 'An Evaluation of the TIF Training Environment', An evaluation report prepared for Foundation for Research Science and Technology. http://www.frst.govt.nz/library/evaluations/business-support-schemes/TIFtraining

Cerulli, G. (2010), 'Modelling and Measuring the Effect of Public Subsidies on Business R&D: A Critical Review of the Econometric Literature', *Economic Record*, 86: pp. 421–449. doi: 10.1111/j.1475-4932.2009.00615x

Coombs, R. and L. Georghiou (2002), 'Research and Development: A New "Industrial Ecology"', Science, Vol. 296 no. 5567 p. 471

David, P., Bronwyn H. Hall & Andrew A. Toole, (1999), 'Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence', NBER Working Papers 7373, National Bureau of Economic Research, Inc

European Commission (2010), *European Innovation Scoreboard 2009*

Fabling, R., (2008), 'Will a BERD model fly? Estimating aggregate R&D expenditure using a micro model', Draft paper prepared for ESAM'08, Wellington. http://www.nzae.org.nz/conferences/2008/110708/nr1215389596.pdf

Fabling, R., (2009), 'A Rough Guide to New Zealand's Longitudinal Database', Global COE HiStat discussion paper series 103. Tokyo: Hitotsubashi University. http://gcoe.ier.hit-u.ac.jp/CAED/papers/id225_Fabling.pdf

Fabling, R. and A. Grimes, (2009b), 'The suite smell of success: Complementary personnel practices and firm performance', Reserve Bank of New Zealand Discussion Paper, DP2009/13.

Fabling, R and L. Sanderson, 2010, 'Exporting and performance: Market entry, expansion and destination characteristics', Reserve Bank of New Zealand, Discussion Papers, DP2010/07

Griffith, R., s. Redding and J. Van Reenen, (2003), 'R&D and Absorptive Capacity: Theory and Empirical Evidence', *Scandinavian Journal of Economics*, 105.1, pp. 99–118.

Hadfield, T, (2003), 'Intellectual Property Survey (TBG-funded firms)', An evaluation report prepared for the Foundation for Research Science and Technology http://www.frst.govt.nz/library/evaluations/business-support-schemes/ipsurveyTBG

Hall, B. H., J. Mairesse and P. Mohnen, (2010), 'Measuring the Returns to R&D', UNU-MERIT Working Paper Series 006, United Nations University, Maastricht Economic and Social Research and Training Centre on Innovation and Technology

Hall, Bronwyn H. & Rosemarie Ziedonis, (2001), 'The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995', *Rand Journal of Economics*, 32. 1. pp 101-128.

Hall, Julia, Grant M Scobie (2006) 'The Role of R&D in Productivity Growth: The Case of Agriculture in New Zealand: 1927 to 2001' New Zealand Treasury Working Paper 06/01

Heckman, James, Hidehiko Ichimura, Jeffrey Smith & Petra Todd, (1998), 'Characterizing Selection Bias Using Experimental Data', *Econometrica*, vol. 66(5), pages 1017-1098, September.

Heckman, James J, Ichimura, Hidehiko & Todd, Petra E, (1998), 'Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Programme', *Review of Economic Studies*, vol. 64(4), pp. 605-54.

Infometrics Ltd, (2001) in association with Decision Research Ltd, "Evaluation of Technology New Zealand", A report prepared for Ministry of Research, Science and Technology http://www.morst.govt.nz/Documents/publications/evaluations/TechNZ-Evaluation.pdf

Infometrics Ltd, (2009), 'Evaluation of TechNZ', A report prepared for the Foundation for Research, Science and Technology. http://www.frst.govt.nz/files/TechNZ%20Evaluation.pdf

Johnson, Robin & W. A. Razzak & Steven Stillman, (2007), 'Has New Zealand benefited from its investments in research & development?', Applied Economics, vol. 39(19), pp 2425-2440.

Kneller, Richard, & Philip Andrew Stevens, (2006), 'Frontier Technology and Absorptive Capacity: Evidence from OECD Manufacturing Industries', *Oxford Bulletin of Economics and Statistics*, vol. 68(1), pp. 1-21.

Krugman, Paul (1992), 'The Age of Diminished Expectations: US Economic Policy in the 1980s', MIT Press, Cambridge

Lööf, Hans & Almas Heshmati, (2006), '**On the relationship between innovation and performance: A sensitivity analysis**', Economics of Innovation and New Technology, vol. 15(4-5), pages 317-344, June.

Lopez-Acevedo G. and M. Tinajero (2010), 'Mexico Impact evaluation of SME programs using panel firm data', Policy Research Working Paper 5186, The World Bank.

MED, (2009), 'Evaluation of the Growth Services Range: Statistical analysis using firm-based performance data," Ministry of Economic Development. http://www.med.govt.nz/templates/MultipageDocumentTOC 40617.aspx

OECD (2007), 'OECD Framework for the Evaluation of SME and Entrepreneurship Policies and Programmes' – ISBN 978-92-64-04008-3

Outcome Management Services, (2005), 'Evaluation of the Techlink Programme', An evaluation report prepared for the Foundation for Research, Science and Technology. http://www.frst.govt.nz/library/evaluations/business-support-schemes/techlink

Özçelik, Emre & Taymaz, Erol, (2008), 'R&D support programs in developing countries: The Turkish experience', *Research Policy*, 37(2), pp. 258-275.

Piergiovanni, R. and Santarelli, E. (2010), *The More You Spend, the More You Get? The Effects of R&D and Capital Expenditures on the Patenting Activities of*

Biotechnology Firms, IPTS working paper Corporate R&D and Innovation - No. 06/2010

Rosenbaum, Paull and Rubin, Donald, (1983), 'The central role of the propensity score in observational studies for causal effects', *Biometrika*, 70(1), pp. 41-55 doi:10.1093/biomet/70.1.41

Scobie, G and W. Eveleens (1986), Agricultural Research: What's it Worth?, Research Paper no 1/86, Economics Division, MAF, Hamilton

Statistics NZ (2010): de Beer, Y, Greet, P, & Morris, M. 'Business participation in government assistance programmes', Wellington: Statistics New Zealand

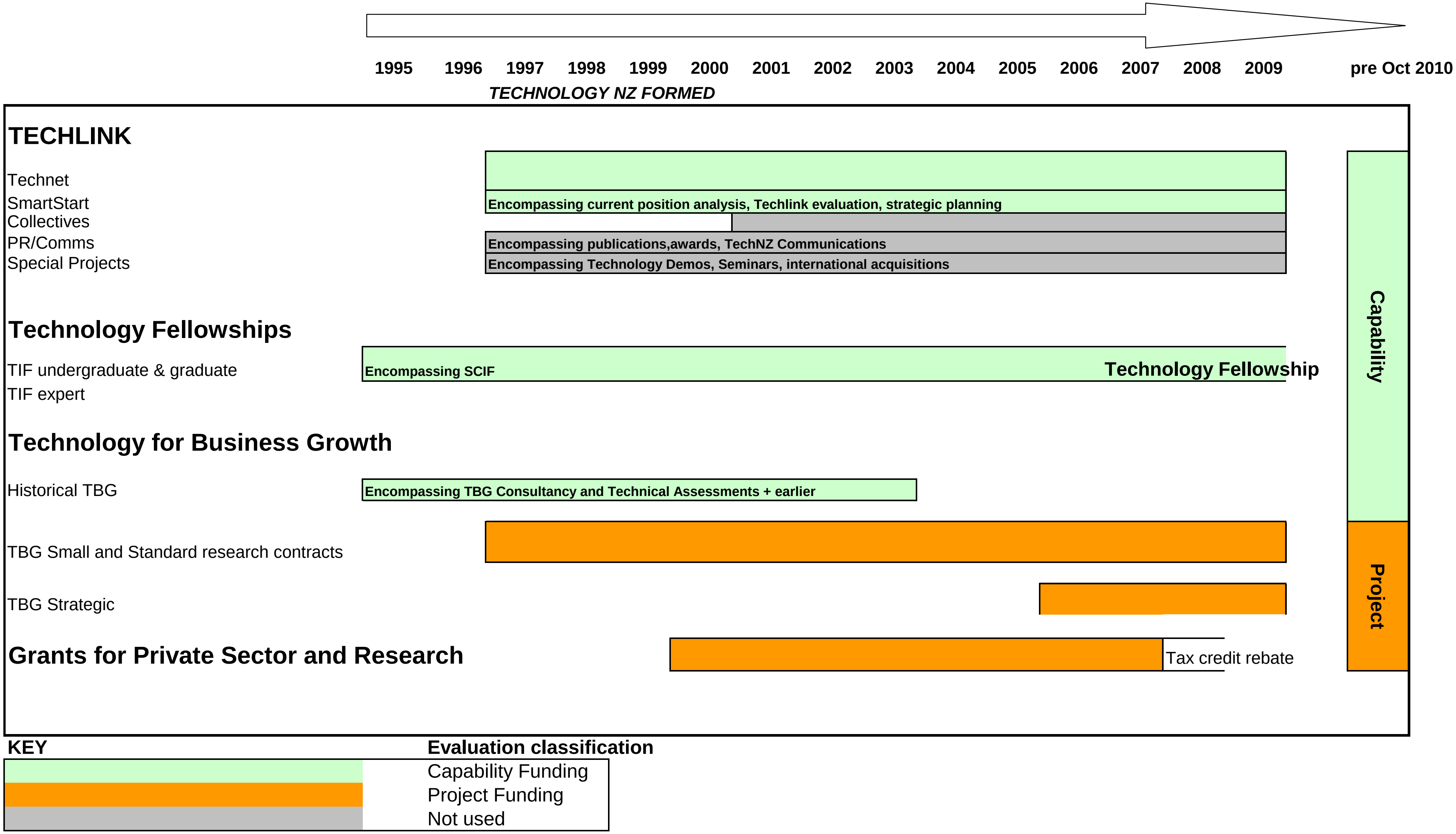
Storey, D., (2000), 'Six Steps to Heaven: evaluating the impact of public policies to support small businesses in developed economies', in Landstrom H and Secton D.L.(eds) *Handbook of Entrepreneurship,* Blackwells, Oxford, pp 176-194.

Tan, H. (2009), 'Evaluating SME support programs in Chile using panel firm data', Policy Research Working Paper 5082, The World Bank.

World Bank (2010), 'Impact Evaluation of SME Programs in Latin America and Caribbean', Edited by G Lopez-Acevedo and H. Tan, 2010 http://www.iadb.org/intal/intalcdi/PE/2010/05674.pdf

Appendices

Appendix 1: Technology New Zealand programme time line



Appendix 2: Additional evidence from previous evaluations of Tech NZ

A2.1 Other TBG evaluations and surveys

An Intellectual Property survey of 114 TBG funded firms in 2003 commission by FRST (Hadfield, 2003) found the following:

- 65% believed that TBG projects increased their capability to undertake future R&D;
- 90% of firms said that TBG projects resulted in new products, processes or services,
- 84% of firms indicated that additional revenues were generated by those products, processes or services.
- 75% of 149 projects involved collaboration with an external research provider

More recently, FRST has surveyed firms that have completed TBG contracts at 18 months after completion of each contract (for contracts over $50,000). The results for 51 companies are summarised in a TBG Performance Report for 2006/07[33] (based on a 75% response rate). The main outcomes are:

- Firms average turnover increased by 29% since the beginning of the TBG contracts to 18 months post completion
- One in five companies reported an increase of over 200% in turnover
- One in seven firms reported an increase in of over 200 percent in export revenues.
- The average research and development expenditure increased by 37%
- One hundred and twenty-seven new or improved products, processes or services resulted from 45 TBG projects.
- Current annual revenue from the technology developed was estimated at $4.4 million per million dollars invested in TBG grants, and over 70% of the revenue was reported from exports

A2.2 GPSRD evaluations

There has been one evaluation of GPSRD in 2004. It found that:

- Most firms reported that GPSRD projects were instrumental in growing sales 7% or more, although 150 firms reported no growth or contraction in the market.
- The overall trend showed a decline in R&D spend following GPSRD: "Anecdotal evidence showed that R&D for small firms was a cyclical process of 2-3 years rotation and that when a new product came to the end of its life the cycle begins again"

[33] http://www.frst.govt.nz/files/TBG_Performance_report.pdf

- Firms cited increased capability and high commercial success rates associated with GPSRD grants.

A2.3 TIF evaluations

There is some evidence relating to the impact of TIF student fellowships, however there is none available for TIF Expert. The three sources of evaluation evidence are the 2001 Infometrics evaluation described in the main text, "An Evaluation of TIF training environment" in 2001 based on interviews with 10 companies selected for their track record in employing students (Centre for Advanced Engineering, 2001) and a MoRST discussion paper based on a number of informal client interviews in 2004[34]. The summary findings are:

- TIF fellowships are creating new science and technological capability within firms. From the perspective of firms, employment spillovers were identified as the most important contributor of overall capability development (There is anecdotal evidence that students participating in TIF later find employment with the firm)
- The 2001 Infometrics evaluation found that TIF had made a significant contribution to building individual firms' experience and appreciation of R&D projects and raising the general quality of their business practices.
- MoRST interviews with firms found that on the whole firms were very positive about the TIF scheme and saw benefits to themselves as well as developing the skills of TIF students. There were many examples of TIF fellows contributing to the commercial outcomes of the business.
- The biggest issue was the time it took to mentor and manage students. The other evaluations identified this too particularly in the case of undergraduate placements. Masterate level students delivered outcomes appropriate with the product development cycle. The best results came from those firms that used graduates to undertake background research that was not time critical and where there was high quality backup from the university.

A2.4 TechNet evaluations

The TechNet and SmartStart components of TECHLINK were evaluated in 2005 (Outcome Management Services, 2005). The evaluation did not address whether the scheme was effective in terms of achieving is objectives. However, the evaluation found that:

- Technet and SmartStart were providing support consistent with their goals, e.g. they were providing support to reduce the financial costs for firms wishing to access technology appraisal services or access to technological expertise.
- SmartStart and TechNet are well regarded by firms receiving this assistance.

[34] Knowledge Transfer through people transfer, MoRST discussion paper, July 2004.

Appendix 3: Outcome and matching variables

Table A3.1 Description of variables

Variable	***Description***
ln_sales	Log of Sales of goods and services are sourced from Business Activity Indicator database (based on Goods and Services Tax (GST) data from the Inland Revenue Department). GST data also includes government grants and subsidies (except where these are intended for overseas use for international development). We have subtracted all government grant payments from GST sales records.
ln_rme *ln_rme_squared*	Log of Employment *ln_rme* : Employment data are from aggregated Pay-As-You-Earn (PAYE) data from Inland Revenue Department (IRD). Employment is measured using an average of twelve monthly PAYE employee counts in the year. This is known as Rolling Mean Employment (RME). It includes an annual count of working proprietors. A squared term *ln_rme_squared* is included.
Δln_rme	Growth in *ln_rme*
ln_prod	Log of labour productivity where labour productivity is defined as Value-added divided by rolling mean employment. Value-added is calculated from GST sales less purchases and expenses (adjusted to exclude GST).
MFP	Multifactor productivity (MFP) is calculated as the residual of a regression of value-added on employment and capital using industry specific coefficients. Sales less purchases and expenses (adjusted to exclude GST). Capital data are described below.
ΔMFP	Growth in *MFP*
klratio	Capital-labour ratio (ln K –l n RME) where K is capital services. Capital services data are derived from Annual Enterprise Survey and IR10 data following the method described in Fabling and Grimes, 2009b.
Δklratio	Growth in *klratio*
age	Calculated from the birthdate in the Longitudinal Business Frame and adjusted where earlier observations in GST returns or government assistance records occur.
rd_ind	This is a mixed source indicator of R&D activity. It equals 1 if any of the following are true in the current or preceding year (the variable takes a value of 0 otherwise): • A firm reports that they undertake R&D in Statistics New Zealand's Research and Development Survey • A firm reports that they undertake R&D in Statistics New Zealand's Business Operations Survey • The R&D variable sourced from IR10 is greater than 0.
foreign_owned	Equals 1 if the firm is owned or controlled by a non-resident and 0 otherwise. This variable is based on an IR4 response. If missing, the variable is coded as 0.
in_group	Equals 1 if a firm is associated with other firms via a group top reporting arrangement. Single entity firms are coded as 0. All foreign owned firms are coded as 1. Groups are identified using code developed by Abowd,Creecy and Kramarz (2002) method.
manu_goods_export	Equals one if the firm is a manufacturing firm and the value of revenue from exporting goods is greater than zero. It is zero otherwise. Exports are sourced from Customs trade merchandise data.
Non_manu_goods_export	Equals one if the firm is not a manufacturing firm and the value of revenue from exporting goods is greater than zero. It is zero otherwise. Exports are sourced from Customs trade merchandise data.
industry	Industry dummies are based 2 digit Australian New Zealand Standard Industry Classification 96.

Table A3.2 Summary statistics by treated status

	Capability Building				Project Funding			
	Treated		Untreated		Treated		Untreated	
	mean	sd	mean	sd	mean	sd	mean	sd
ln_rme	1.419	1.481	0.174	0.879	1.421	1.297	0.170	0.876
ln_rme_squared	4.201	7.179	0.802	2.106	3.685	4.470	0.796	2.051
Δln_rme	0.078	0.389	0.014	0.312	0.101	0.373	0.011	0.307
mfp	0.121	0.928	0.080	0.949	0.133	0.741	0.079	0.936
dmfp	-0.073	0.788	0.021	0.836	-0.095	0.715	0.017	0.852
klratio	0.482	1.061	0.044	1.105	0.470	0.978	0.057	1.073
Δklratio	0.003	0.596	-0.003	0.684	-0.022	0.550	0.001	0.670
age	4.248	13.422	2.274	8.949	8.450	18.195	2.204	9.161
rd_ind	0.209		0.025		0.270		0.023	
foreign_owned	0.059		0.005		0.027		0.005	
in_group	0.259		0.032		0.297		0.032	
manu_goods_export	0.163		0.009		0.237		0.009	
non_manu_goods_export	0.142		0.020		0.158		0.024	