Centre for Transformative Innovation

Global Prosperity Through Knowledge and Innovation

SWINBURNE UNIVERSITY OF TECHNOLOGY

INNOVATION = IDEAS + CHANGE

The Additionality of R&D Tax Policy in Australia

Russell Thomson and Ahmed Skali

Centre for Transformative Innovation

February 2016

Executive Summary

The aim of this report is to provide estimates of the rate of additionality associated with R&D tax subsidies in Australia. In contrast with international evidence, several statistical studies published previously have failed to confirm that research and development (R&D) investment by Australian firms is responsive to tax subsidies. This study uses company-level data from the Australian Bureau of Statistics (ABS), which has recently been made available for research purposes. The dataset comprises information from company Business Income Tax returns and Business Activity Statements provided to the Australian Taxation Office, as well as information collected by the ABS from their Business Expenditure on Research and Development survey. The data covers the period 2005 to 2012 and is far more comprehensive than any data that has previously been available. Both the R&D Tax Concession and R&D Tax Incentive policies are considered, referred to collectively as R&D tax subsidies.

The data reveal that the average R&D active firm which claims an R&D tax subsidy invests statistically significantly more in R&D than a 'similar' R&D active firm which does not claim a tax subsidy. This difference can be interpreted as the causal effect of tax policy under the assumption that unobservable factors that determine R&D investment do not also influence firms' decision to claim the tax subsidies.

While the report applies several methods to estimate additionality, the introduction of the R&D Tax Incentive policy in 2012 provides an opportunity to undertake difference-in-difference analysis, which is a stronger basis for establishing causality. Difference-in-difference analysis rests on the assumption that, even though claiming and non-claiming firms exhibit a different level of R&D investment, they exhibit the same trend over time.

We conclude that R&D tax policy analysis should consider plausible additionality in the range of 0.8-1.9. This range compares favourably with estimates from other countries. Further analysis may be desirable to improve the confidence and precision of estimates. Some suggestions for future analysis are offered within the report.

Acknowledgements

Staff at the Australian Bureau of Statistics and the Department of Industry, Innovation and Science made a substantial contribution to this report. We thank Malcom Jones and Antonio Balaguer and in particular Jared Holt who advised on details of the operation of the tax subsidy schemes and in interpreting firm level data from the Department of Industry, Innovation and Science and the Australian Tax Office. We gratefully acknowledge Diane Braskic and David Taylor at the ABS for making available the unique data, without which this analysis would not be possible. Thanks in particular to Tom Pougher and Adam Hill for their high level expertise in executing all required STATA code on the ABS servers. Alfons Palangkaraya and Beth Webster provided expert comments and technical advice. All errors remain the responsibility of the authors.

Introduction and summary of results

This report was commissioned by the Australian Government Department of Industry, Innovation and Science with the objective of measuring the level of R&D tax programme additionality in Australia. Additionality is the amount of additional R&D investment firms undertake for every dollar of tax revenue forgone.

International evidence suggests business investment in research and development (R&D) is responsive to tax subsidies. However, to date, evidence in the Australian context has been lacking. The two most comprehensive statistical studies on the additionality of R&D tax subsidies in Australia were unable to identify any statistically significant effect of tax subsidies on R&D investment. These are Thomson (2010) and Bureau of Industry Economics (1993). It has remained an open question as to whether these findings reflected shortcomings of the prior studies or some fundamental underlying structural feature of Australian industry or policy environment that renders tax policy less effective. The analysis presented in this report suggests the former and that in fact tax subsidies are effective in inducing additional R&D investment by Australian firms.

The analysis presented in this report uses new data from the ABS Expanded Analytical Business Longitudinal Database (EABLD). The data is considerably more comprehensive than has been used in previous analysis on the same question. The EABLD allows us to analyse almost the entire population of R&D-active firms for the years 2005 to 2012. Analysis considers both the R&D Tax Concession and the R&D Tax Incentive (which we jointly refer to as R&D tax subsidies). This study would not have been possible without the ongoing and invaluable support from staff at the Australian Bureau of Statistics in developing this important data resource.

The challenge of identifying the causal impact of R&D tax subsidies arises because all identical firms can access the same benefit from the tax incentive policy. Any statistical relationship between the benefits a firm receives from subsidies and the amount of R&D they perform tells us little about the effect of policy if the factors that determine benefits also influence their R&D investment strategy. This problem is known as simultaneity. For example, firms which do not perform R&D do not benefit from the schemes and therefore do not register. The problem of simultaneity is particularly acute for the R&D Tax Concession policy where incremental expenditure over and above the previous three-year average was eligible for a bonus concessionary rate.

We focus on the intensive margin, which is to ask: given that a firm invests in R&D, do tax subsidies influence the amount of R&D they perform? In principle, R&D tax incentives might also impact on firms' decision whether or not to do any R&D (called the extensive margin) but this is not assessed here. We present four statistical approaches, presented in decreasing order of how onerous the assumptions required for causal interpretation are. These are ordinary least squares; propensity score matching; difference-in-difference; and regression discontinuity design. The statistical approaches allow us to estimate the average effect of policy on those affected (i.e., treatment effect on the treated). We then undertake simple counterfactual analysis to estimate the additionality implied by the treatment affect.

We first use statistical approaches to compare R&D active firms that claim R&D tax subsidies with 'similar' R&D active firms which do not claim subsidies. Using ordinary least squares and matching estimators to control for observable firm attributes including industry, company turnover, wage bill and any benefits from government R&D grants, we find that claiming firms invest around 40 per cent more R&D than 'similar' firms which are not registered to receive the subsidies. This translates to an additionality of approximately $0.8-1.7 for every dollar of tax revenue forgone. This estimate can only be interpreted as the causal impact of tax policy if we assume that there are no unobservable factors that determine both R&D investment and also firms' registration status. *A priori* this assumption is plausible, but it is certainly not possible to rule out the possibility that such unobservable factors exist. Approximately 22 per cent of R&D active firms do not claim an R&D tax subsidy. Companies not claiming are either unaware or ineligible. For example, they may perform ineligible R&D activities, perform R&D for other Australian firms, or their R&D may be financed by other forms of government support and hence is ineligible for the scheme benefits.

The introduction of the R&D Tax Incentive policy in 2012 provides an opportunity to undertake difference-in-difference analysis which is a stronger basis for establishing causality. Difference-in-difference estimators do not rely on the assumption that there are no unobservable factors that determine both selection and R&D investment. Instead, difference-in-difference is based on what is known as the 'parallel trends assumption'. The parallel trends assumption states that, even though claiming and non-claiming firms exhibit a different level of R&D investment (and this may be driven by unobserved factors that determine the decision to claim) it is plausible that they exhibit the same trend over time. I.e., the assumption is that R&D investment by claiming and non-claiming firms move in parallel over time because they are subject to the same macro-economic conditions. Using the difference-in-difference estimator we find that the introduction of the R&D tax incentive led to a 14 per cent increase in R&D spending by the sample of firms claiming in both 2011 and 2012. This translates to an additionality of 1.9 dollars per dollar of tax revenue forgone for the sample of firms for which R&D data is available and that were claiming for the tax subsidy schemes in both 2011 and 2012. A falsification test shows that the two groups of firms do exhibit parallel trends between 2010 and 2011.

We also considered a regression discontinuity design based on comparing R&D investment marginally above and below the $20 million turnover threshold which determines whether firms are eligible for a higher rate of Tax Incentive (40 percent vs 45 percent). Regression discontinuity is, at least in principle, a very powerful method for identifying the causal effect of policy, however its application in this context appears to be somewhat inhibited by the small number of observations located near the threshold. The small number of observations is exacerbated as only one year of data was available at the time of writing. Using the regression discontinuity design, we do not find evidence of a significant effect of the step change in policy generosity. However, this may simply reflect the low number of firms close to this turnover threshold meaning the test is of inadequate power. It would be useful to revisit when more years of data are available.

There are a number of limitations to these estimates that should be acknowledged upfront. The assumptions behind each estimator are mentioned above. The analysis focuses on the intensive margin. The difference-in-difference estimates relate only to the firms that were claiming for the Tax Concession in 2011 and the Tax Incentive in 2012. We estimate the additionality implied by the statistical estimates of policy impact using counterfactual type analysis based on a number of simplifying assumptions. For example, we assume all R&D is eligible, and we do not model loss making firms' differential ability to benefit from the Incentive due to the refundable offset or time costs of money associated with carry-forward/backs. There is no strong reason to expect this would substantially change the estimated average additionality.

Background

What is 'additionality' and how does it relates to policy effectiveness?

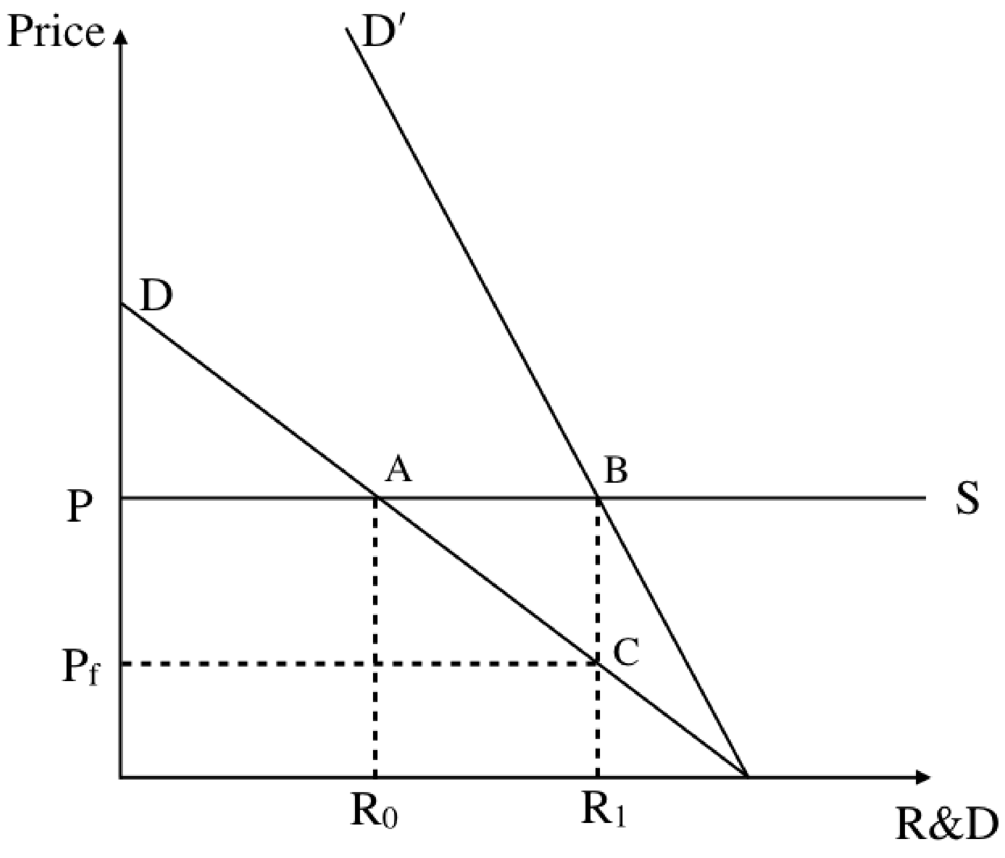
Additionality is the amount of R&D invested for every dollar of tax revenue forgone which can be written as:

$$\text{Additionality} = \frac{\text{R\&D}_{1|1} - \text{R\&D}_{1|0}}{\text{T}_{1|0} - \text{T}_{1|1}}$$

Where $\text{R\&D}_{1|1}$ amount of R&D performed by the firms which claim the tax subsidy (the 'treated' group) and $\text{R\&D}_{1|0}$ is denotes the amount of R&D that would hypothetically be invested by the same group of firms in the absence of tax subsidies. Analogously, $\text{T}_{1|1} - \text{T}_{1|0}$ is the amount of tax revenue forgone due to the policy (which is the negative of the change in the firms' tax liability).

Figure 1 provides a graphical representation of how R&D tax subsidies impact on the amount of R&D investment and what we mean by additionality. The x-axis is the amount of R&D activity and the y-axis reflects the price. Figure 1 applies to all R&D activity, but for illustrative purposes, we can think of Figure 1 as depicting the market for scientists (the number of scientists employed and their wage, respectively). The supply curve is denoted by S and we depict this as flat (entirely elastic) though it may be upward sloping, for example if the number of scientists and technicians are limited (see Thomson and Jensen 2013). The demand curve, the amount of R&D demanded by firms in the absence of any tax subsidy is denoted by D. The market equilibrium when firms demand a quantity of R&D equal to R_0 at a price of P is at point A. An ad valorem tax subsidy paid on firms R&D investment pivots the demand curve outwards. The new equilibrium is at point B, where firms demand a quantity of R&D equal to R_1. At the new equilibrium firms pay P_f and the government pays the difference $(P - P_f)$. We define additionality as the additional R&D per dollar of tax revenue forgone. In Figure 1, the additional R&D induced is given by the area bounded by the points R_0R_1BA. The cost to government in terms of revenue forgone is given by the area bounded by the points PP_fCB.

Figure 1. Graphical Illustration of the impact of R&D tax incentives



The R&D Tax Incentive is an ad valorem (percentage or proportional) subsidy and as such, the more firms spend on R&D, the more benefit they receive (and correspondingly the greater the tax revenue forgone). For example, with a 10 percent subsidy, there are 10 cents revenue forgone for every extra dollar of R&D performed, by policy design. On the chart, this would be represented as a shift outward in the R&D demand curve for a fixed subsidy. In order to estimate the additionality that is caused by a subsidy, it is necessary to have exogenous variation in the rate of subsidy either between firms or industries or over time. In practice, most firm level data reflect a great deal of variation in R&D expenditure between firms, and little or no exogenous variation in subsidy level (or rate). The empirical challenge is to isolate this variation in subsidy and control for variation related to changes in demand for R&D.

Additionality is defined in gross terms. An additionality of 0.7 means private firms only increase their spending by 70 cents for every dollar the government gives them; 30 percent of private spending that was already happening has been displaced by the government subsidy. An additionality of 1 means the government gives firms $1 and they spend it on R&D – so there are no private investments displaced by government spending. The same gross investment on R&D could be achieved via spending on intra-mural or higher education R&D. In this case, with an additionality of unity (ignoring administrative costs), tax incentives provide a means for harnessing market forces to allocate the spending on R&D. That is, in the case of tax incentives, government resources are allocated and spent by private firms in contrast to government or higher education R&D, which must be allocated by other means. There are arguments as to the efficacy of government allocation of R&D spending but these are outside the scope of this report. An additionality above unity implies that policy is leveraging more private spending than it is costing government in terms of forgone revenue. The magnitude of the additionality depends on the slope of the R&D demand and supply curves.

In this report additionality does not take into account potential additional tax revenue from firms that have higher future taxable income due to the increased R&D investment on account of the policy. Finally, it is vitally important to bear in mind that inducing additional R&D is not an end in itself. The rationale for subsidising R&D is to induce positive spill-over benefits to other firms and consumers. If left to themselves, for-profit organisations will under-invest in R&D and thereby forgo welfare-enhancing spill-over benefits. Sound theory and extensive empirical evidence suggest each dollar of R&D investment makes a contribution to the material well-being of Australians considerably greater than one dollar.

Australian R&D tax Policy

Tax subsidies for R&D were first introduced in Australia with the introduction of the R&D Tax Concession in 1985. The Concession provided an allowance of 150 percent; that is, firms could deduct from their taxable income 150 percent of the value of their eligible R&D expenditure. Since its inception, the scheme has undergone a number of reforms. Salient features of the scheme within the time period analysed are outlined below and further details about historical aspects of the policy can be found in Thomson (2010). A chronology of important reforms is discussed below and these are summarised in Table 1.

The Tax Concession scheme underwent a major reform in 1996. The rate of deduction was cut from 150 per cent to 125 per cent of eligible expenditure and the scope of eligible expenditure was revised. An incremental scheme, known as the 175 per cent premium deduction, was introduced in 2001. Under the incremental scheme, firms could claim an additional 50 per cent deduction on the portion of expenditure exceeding average nominal expenditure over the prior 3 years. This was in addition to the 125 per cent deduction available on all R&D investment, meaning 'incremental' expenditure attracts a 175 per cent deduction in total. The rationale behind the bonus concession is to provide additional incentives while limiting deductions on infra-marginal R&D investment – i.e. investment that would have occurred in the absence of the Concession.

A small businesses tax offset scheme was introduced in 2001. Under the tax offset scheme, firms with a turnover of less than $5 million can claim the Concession as a tax offset (rebate) of 30c for each dollar of eligible R&D investment, provided the expenditure is between the floor ($20,000) and a maximum (cap) of $1 million. A special scheme for foreign contract R&D was introduced in 2007. Up until 2007, eligibility for the Concession depended on the resultant intellectual property being vested with the researching firm, which reduced the attractiveness of the scheme to an Australian affiliate of a foreign-owned firm (BIE 1993; ATO 2002).

The R&D Tax Incentive has been in place since the 2011/12 financial year and replaces the R&D Tax Concession. It comprises a 45 percent offset (rebate) for small companies (turnover less than $20 million) and a 40 percent offset (rebate) for large companies (turnover greater than $20 million). The 45 percent R&D tax offset is a refundable tax offset, which means that if a company's tax liability is reduced to zero, companies may be entitled to a refund of any unused offset amount. The 40 percent R&D tax offset is non-refundable, which means that companies cannot access a refund for any unused offset amount if their corporate income tax liability has been reduced to zero. However, any excess offsets may be carried forward for use in future income years.

The refundable offset has a potentially large impact on the effective relative generosity of the policy for companies which have no taxable profit. If all R&D is expensed, a company with a positive tax liability is only

15 percentage points better off with the Tax Incentive scheme. In contrast, for a company with no tax liability the policy reduces the after tax cost of R&D by a full 45 percent.

Under the R&D Tax Incentive scheme the following expenditures are excluded from receiving the tax subsidies:

1. Expenditure that is not at risk
2. Core technology expenditure
3. Expenditure included in the cost of a depreciating asset (decline in value notional deductions may apply however)
4. Expenditure incurred to acquire or construct a building (or part of a building or an extension, alteration or improvement to a building).
5. Expenditure incurred for interest payable to an entity
6. Expenditure incurred to an associate in a year, but not paid in that year

Other tax policy reforms, not directly linked to R&D investment, can also affect the efficacy of tax subsidies. Importantly, the dividend imputation system acts to dilute the impact of the R&D Tax subsidies because it can lead to 'clawback of the R&D subsidy to companies through the taxation of their shareholders' (BIE, 1993). The dividend imputation system was introduced in 1989 and it aims to avoid the double taxation of company profits when they are paid out to shareholders. Under the dividend imputation system, firms are eligible for franking credits commensurate with the company income tax they pay. Franking credits are allocated to shareholders with dividend payments and effectively reduce personal income tax liabilities by the amount already paid by the company. There is some evidence that firms respond less to R&D tax incentives when they operate in a country that also has a dividend imputation system (Thomas *et al*., 2003). Australia is one of only a handful of countries to allow dividend imputation and this has been proposed as a reason that R&D tax incentives may be less effective here (BIE 1993; Thomson 2010).

Table 1. History of the R&D Tax Subsidies in Australia

Year	Policy Event
1985	R&D Tax Concession established Available to Australian companies Enhanced deduction of 150 per cent on R&D expenditure, resulting in a benefit of 23 cents in the dollar (corporate tax rate was 46 per cent)
1987	Corporate tax rate increased to 49 per cent, resulting in an increased benefit of 24.5 cent in the dollar
1988	Corporate tax rate reduced to 39 per cent, resulting in a reduced benefit of 19.5 cents in the dollar
1993	Corporate tax rate reduced to 33 per cent, resulting in a reduced benefit of 16.5 cents in the dollar
1995	Corporate tax rate increased to 36 per cent, resulting in an increased benefit of 18 cents in the dollar

Year	Policy Event
1996	Enhanced deduction rate was reduced from 150 to 125 per cent, resulting in a reduced benefit of 9 cents in the dollar (corporate tax rate was 36 per cent)
2001	Corporate tax rate reduced to 30 per cent, resulting in a reduced benefit of 7.5 cents in the dollar Introduction of the 175 per cent Premium (Incremental) Tax Concession for additional investment in R&D Introduction of a refundable R&D Tax Offset for small companies in tax loss that undertake R&D, enabling them to 'cash out' their R&D tax losses
2007	Introduction of the 175 R&D International Premium, designed to encourage additional R&D investment in Australia by firms in which the IP is held by an overseas company in the same enterprise group
2011	R&D Tax Incentive replaces the R&D Tax Concession Available to companies that are resident in Australia for tax purposes, and foreign companies in certain circumstances Refundable 45 per cent tax offset available to companies with turnover of less than $20 million, providing a benefit of 15 to 45 cents in the dollar for these companies Non-refundable 40 per cent tax offset available to other companies, resulting in an benefit of 10 cents in the dollar for these companies
2015	$100m R&D expenditure threshold introduced. Companies expending more than $100m on R&D can receive a tax offset at the corporate tax rate for the R&D expenditure in excess of $100m

Source: Department of Industry, Innovation and Science.

Evidence of Additionality

Most existing studies on the effects of tax policy on private sector R&D have taken one of two approaches: cross-country or firm-level (within-country) analysis. Cross-country analysis exploits variation in policy between jurisdictions, and as such aims to disentangle contemporaneous macroeconomic events (Bloom *et al.,* 2002). These studies have found an elasticity ranging from 15 per cent in the short run to about unity in the long run (see Guellec & Van Pottelsberghe, 2003; Falk, 2006). An approach that has been used to evaluate the effect of fiscal incentives using firm-level data is to estimate an investment demand equation with policy shift dummies (Eisner *et al.,* 1984; Bernstein, 1986; Thomas *et al.,* 2003). This approach does not provide a strong basis for identification as it is difficult to separate the effects of tax policy from other changes over time. Using this approach, Eisner *et al.* (1984) failed to observe a significant effect of the tax subsidy in the USA. A second approach using firm level data is to model R&D investment on firms' effective benefits from the prevailing tax policy in a single country. Since tax policy treats all equivalent firms the same way, variations in firms' effective benefits from tax subsidies essentially arise due to differences between firms, typically differences in firms' profit status and historic R&D investment. Unfortunately, from a statistical perspective, these generally depend on the firm's current choice of R&D investment (Hall and van Reenen 1999). Results from firm-level analyses have varied widely, with estimates of the short-run elasticity between 0.07 and 0.85, and a long-run elasticity ranging of about unity (Hall, 1992; Dagenais *et al.,* 1997). A summary of estimates from salient papers is provided in Table 2.

Australian R&D tax policy has been subject to a number of studies. Survey evaluations of the Australian R&D Tax Concession found that while the majority of beneficiaries of the policy describe it favourably, approximately 30 per cent concede that their R&D endeavours would be neither smaller nor have been completed at a slower rate in the absence of the programme (DITR, 2005, 2007a). However, the limitations of basing conclusions on subjective survey results are well-known. A comprehensive assessment of the Australian R&D Tax Concession which reports both survey data as well as analysis of firm financial data was undertaken in 1993 by the Bureau of Industry Economics (BIE, 1993). Data used for the statistical analysis include a mix of firms that are registered to receive the credit and other firms, with observably similar characteristics, that are not registered to receive the credit. The data suggest a modest effect over the year the policy was introduced, but not over longer periods and the report cautions that this observed increase may simply be due to reclassification of existing expenditure. The oft-cited inference of the report, namely that the Concession induces between $0.6 and $1 of additional R&D for each dollar of forgone revenue, rests primarily on subjective survey responses (see p. 155).

A more recent, comprehensive evaluation of R&D tax policy in Australia also found no identifiable impact. Thomson (2010) considers an unbalanced panel of financial data of approximately 500 large Australian firms between 1990 and 2005. The role that cost of capital plays in R&D investment decisions is investigated. The measure of cost of capital incorporates both a financial cost (imputed cost of capital derived from a CAPM model) and the impact of the R&D Tax Concession. However, only time series variation in tax policy was used because the author did not have access to firms' actual tax claims or registration status. R&D investment is not found to be impacted by the measured cost of capital.

Table 2. Overview of selected previous elasticity estimates

Authors	Policy measure	Specification	Country	Obs.	Price elasticity	Additionality (approx.)†
BIE (1993)	Dummy	R&D demand (levels).	Australia	1,400	Insignificant	0
Thomson (2010)	UCRD	R&D demand. (PA)	Australia	2,025	Insignificant	0
Lokshin and Mohnen (2007)	UCRD	R&D stock demand.	Netherlands	2,615	-0.27 (SR)	0.37
					-0.39 (LR)	0.50
Mulkey and Mairesse (2013)	UCRD	R&D demand (ECM)	France	10,850	-0.40 (LR)	0.51
Koga (2003)	UCRD	R&D demand (levels)	Japan	5,738	-0.68	0.80
Dagenais et al. (1997)	UCRD	R&D stock demand (PA)	Canada	4,859	-0.07 (SR)	0.11
					-1.09 (LR)	1.05
Harris *et al.* (2009)	UCRD	R&D demand (static and dynamic models).	Northern Ireland	2,063	-0.21 (SR)	0.23
					-1.40 (LR)	1.35
Parisi and Sembenelli (2003)	UCRD	R&D demand	Italy	4,356	-3.27	1.7
Hall (1993)	Credit rate	Euler equation	US	9,167	-0.80-1.50 (SR)	2.0
					-2-2.7 (LR)	N/A
Guellec and Pottelsberghe (2003)	Tax component of UCRD	R&D demand. (PA)	Cross country	199	-0.28 (SR)	0.37
					-0.31 (LR)	0.41
Falk 2006	Tax component of UCRD	R&D demand. (PA)	Cross country	92	-0.22 (SR)	0.30
					-0.84 (LR)	0.89
Bloom *et al.* 2002	UCRD	R&D demand. (PA)	Cross country	179	-0.16 (SR)	0.23
					-1.10 (LR)	1.06
Thomson and Jensen (2014)	Tax component of UCRD	R&D labour demand (PA & ECM).	Cross country	373	-0.19-0.32 (SR)	0.27-0.42
					-1.30-3.3 (LR)	1.18-1.83
Wilson 2009	UCRD	R&D demand. (PA)	US states	365	-1.26-1.43 (SR)	1.19
					-2.29-2.58 (LR)	1.64

Notes: papers ordered by long run elasticity estimate. Abbreviations: Policy measure: UCRD user cost of R&D. Specification: partial adjustment (PA), error correction model (ECM), no dynamics modelled (levels); Price elasticity: LR long run, SR short run. Additionality except in the case of Hall 1993, these are approximated using $\frac{dR}{d(sR)} = \frac{\eta}{1-s-\eta s}$.where s is unity less after tax cost and η the elasticity of R&D with respect to tax-price (see Thomson forthcoming). Approximated at the hypothetical margin where R&D is expensed (s given by unity less corporate income tax rate using the midpoint of sample corporate income tax rates in the absence of sample weighted average).

Data

The data used for this study are the most comprehensive that have been available to researchers looking at the Australian context to date. The data for this study is from the ABS Expanded Analytical Business Longitudinal Database (EABLD). We restrict our attention to enterprise groups for which data for wage bill and sales are available.

The main variable of interest is business expenditure on R&D from the ABS *Business Expenditure on R&D survey* (BERD). The business expenditure survey uses standard consistent definition of R&D activity. Between 2005-06 and 2011 to 2012 the Survey of R&D, Businesses aimed to be a complete enumeration of businesses within the Australian business sector (i.e. all businesses and the private non-profit institutions mainly serving them) with intramural expenditure on R&D of $100,000 or more during the reference period. R&D investment data cover approximately 5000-6000 firms per year prior to 2012 and for approximately 2500 firms in 2012 after the shift to the sample approach.

Note that it is not possible to use registered or claimed R&D expenditure since the definition of eligible R&D under each scheme has been revised at various points of policy reform (including over the transition to the R&D Tax Incentive) and varied with policy. Our analysis is therefore based on those firms for which data on R&D investment is available in the BERD survey. Table 3 shows that the number of R&D-performing firms is very similar across the three sources, such that the BERD survey is very likely to pick up a large and representative portion of R&D-performing firms. Table 3 displays the number of firms for which we have R&D data for the last three financial years from each source. For brevity, we show data from the last three financial years only but the same trends are visible across the entire time coverage of the dataset (financial years 2005 to 2012).

Table 3. Number of Businesses for which R&D Data is available, by Source. Table shows Panel (a). All Businesses.

Financial Year	BERD	Dept. Industry	Company tax return
2009/2010	5472	7907	6731
2010/2011	5825	8398	7267
2011/2012	2671	9072	7303

Claiming and non-claiming firms

As in the case of the BIE (1993) study, several methods applied in this report involve comparing firms which claim R&D tax subsidies with those that do not. It is important to consider whether this is a valid comparison. We begin by providing a statistical overview of the two groups. For the period 2005 to 2012, 22 percent of R&D active firms do not claim any R&D tax subsidy. Companies not claiming are either unaware or ineligible. Survey evidence suggests that many firms remain unaware of R&D support programs even many years after they are introduced (Thomson and Webster 2012). There are a number of reasons that firms may be ineligible to claim the tax subsidy. First, not all R&D activities are eligible. For example, some R&D activities are not eligible such as software development and social science research. R&D financed by other Australian firms is not eligible. Lastly, clawback provisions act to prevent companies receiving a benefit on amounts received through other sources of government support. Although companies would be eligible in these instances, they may opt not to claim under the programme as it is more beneficial to pursue other funding sources (such as government grants). Table 4 shows a breakdown of firms by claiming status and grant recipient status.

Table 4. Claiming Status for R&D tax subsidies and other forms of government support

	Claiming	Not Claiming
Grants > 0	5,816	3,181
Grants = 0	24,757	1,288

Table 5 shows the distribution of surveyed firms across the two schemes over time. Over the observation period of 2005 to 2012, the number of firms claiming the Concession appears to rise steadily from 2,969 in 2005 to 4,597 in 2011. In addition, the proportion of R&D active firms, not claiming the subsidy decreased in the 6 years to 2011 (from 0.29 in 2005 to 0.16 in 2011). The pattern of increasing policy uptake could be driven by several factors, though it is consistent with a process of learning and adoption as non-claiming firms learn about the policy and begin to claim it. Because the BERD became a survey of a sample of firms in 2012, we do not have information on all R&D-performing firms in 2012.

Table 5. R&D Active Firms Claiming Concession, Incentive or Neither.

Financial Year	Claim Concession	Claim Incentive	Not claim	Total	Not Claim / Total
2005	2,969	0	1,195	4,164	0.29
2006	3,225	0	969	4,194	0.23
2007	3,308	0	908	4,216	0.22
2008	3,630	0	885	4,515	0.20
2009	3,924	0	871	4,795	0.18
2010	4,241	0	889	5,130	0.17
2011	4,597	0	868	5,465	0.16
2012*	368	1,646	519	2,533	0.20
Total	26,262	1,646	7,104	35,012	0.20

Notes: Data includes firms at the enterprise group level with non-zero R&D spending (BERD survey) and non-missing turnover and wage data (BAS survey). *: based on a sample survey only.

Table 6 shows that, while non-claiming firms are typically smaller than claiming firms on average, the distributions of covariates within each group display such a wide spread (as the standard deviations are very large relative to the means), which gives the algorithm a large variety of firms to pick matches from. It is interesting to observe that while the R&D spend for non-claiming firms is smaller on average, such firms are similarly R&D intensive in terms of R&D per turnover or R&D per wage bill.

Table 6. Summary Statistics

Variable	Claiming	Not Claiming
R&D Expenditure [standard deviation]	$ 3,749 [24,614]	$ 1,411 (3,750]
Turnover [standard deviation]	$ 318 million [2.96 billion]	$ 81.5 million (373 million]
Wages [standard deviation]	$ 27.9 million (201 million]	$ 12.3 million [54.9 million]
Assets [standard deviation]	$ 969 million [17 billion]	$ 48.1 million (358 million]
Profits [standard deviation]	$ 39.4 million (480 million]	$ 2 million [33.9 million]

Ordinary least squares analysis

The first approach is a conventional linear regression model estimated using ordinary least squares (OLS). This method allows us to identify if there is a correlation between receiving the subsidy and R&D outcomes while holding constant some other observable firm attributes. The OLS model is:

$$ln(R\&D\ exp)_{it} = \alpha + \ \beta\ R\&D\ tax\ credit_{it} + \ X_{it}\ \delta + \ v_{it} \qquad (1)$$

Equation (1) represents a linear relationship between R&D investment by firm *i* and year *t* and firm-level attributes *X*, a stochastic error term *v*, and a dummy variable *R&D tax credit* set equal to 1 if firm *i* claims an R&D tax subsidy and zero otherwise. We can interpret β as the causal effect of tax policy on R&D investment under the assumption that no unobservable factors (factors not included in the model) influence both the amount of R&D performed and also the firms' propensity to register for the subsidies.

Table 7 displays the results of the OLS estimates of firm level R&D investment. Column (1) indicates that, on average across all years and all firms considered, firms which received a Tax Incentive or Concession spent approximately 50 percent more on R&D than firms that did not claim an R&D tax break.[*] This difference is statistically significantly different from zero at the 1 per cent level, meaning that the observed difference is less than 1 per cent likely to be due to chance. We therefore reject the

---

[*] The interpretation of the coefficient on dummy variables when the dependent variable is in logarithmic form has drawn some discussion. Let *c* denote the coefficient estimated on a dummy variable in such a case. Here, we follow the traditional interpretation that when the dummy variable switches from 0 to 1, the dependent variable increases by 100 * *c* percentage points. Halvorsen and Palmquist (1980) propose a correction that estimates the effect on the dependent variable to be 100 * [exp(*c*) – 1]. Kennedy (1981) proposes a further correction that takes into account the variance of *c*. In Kennedy's correction, the effect of interest is 100 * [exp(*c* – ½ var(*c*)) – 1]. Most recently Krautmann and Ciecka (2006) show that both the Halvorsen and Palmquist (1980) and the Kennedy (1980) corrections may be misleading

null hypothesis that there is no association between R&D investment and receiving an R&D tax break. This conclusion holds true for both the Concession (columns 1-3) and the Incentive (columns 4-5). As expected, the effect of the Incentive is considerably higher for small firms with zero profits (column 5). However, the effect is smaller for both small firms (column 2) and firms not paying franked dividends (column 3). We cannot explain these results. Nonetheless, overall we document a robust significant relationship between R&D tax subsidies and R&D expenditure using OLS.

We highlight that the 1993 study by the Bureau of Industry Economics followed a similar estimation strategy and did not report a robust significant difference between these groups, controlling for other factors. Results using OLS are similar to those reported below using matching estimators which are discussed in greater detail below. As such, we do not report the additionality for the OLS results separately. The additionality estimated using matching is presented in the next section.

Table 7. Ordinary Least Square Estimates. Dependent variable: ln R&D Investment (BERD).

	Tax Concession (1)	Tax Concession small firms (2)	Tax Concession. No franked dividends (3)	Tax Incentive (4)	Tax Incentive small firms, no profit (5)
Treated' (claiming subsidy dummy)	0.508***	0.364***	0.405***	0.193**	0.924***
	(0.0189)	(0.0194)	(0.0213)	(0.0758)	(0.176)
Other government finance (e.g., grants)	0.156***	0.160***	0.151***	0.149***	0.139***
	(0.00361)	(0.00362)	(0.00388)	(0.0151)	(0.0250)
Turnover	0.141***	0.0196***	0.108***	0.140***	-0.00776
	(0.00337)	(0.00299)	(0.00339)	(0.0133)	(0.0145)
Wages	0.0457***	0.0669***	0.0472***	0.0622***	0.0977***
	(0.00258)	(0.00296)	(0.00285)	(0.0112)	(0.0136)
Industry controls	Y	Y	Y	Y	Y
Observations	32,354	24,810	25,191	2,147	699
R-squared	0.284	0.178	0.235	0.276	0.225

Notes: *** significant at 1 percent. Round parenthesis denotes number of observations.

Propensity score matching

Propensity score matching provides a potentially stronger basis for evaluating program effectiveness than OLS. Propensity score matching involves matching firms that claim tax subsidies with similar firms that do not. Similar to OLS, the results from the matching analysis can only be interpreted as causal if are no unobserved factors (factors not included in the matching algorithm) which determine treatment and also determine R&D investment. However, unlike OLS, matching estimates essentially only make comparisons between 'similar' firms, which reduces the potential for unobserved variables to influence the result. Because matching focuses on comparable firms, firms that are very dissimilar from all others are only given a small weight in the final result, whereas with OLS, all observations are weighted equally.

Let Y_{1i} denote the outcome (R&D investment or human resources devoted to R&D) for firm *i* if it receives the treatment and let Y_{0i} denote the outcome for the same firm *i* if it does not receive the treatment. The effect of the treatment would therefore be Y_{1i} - Y_{0i}. Of course, in the real world, we never get to observe both Y_{0i} and Y_{1i}, since each firm *i* either receives the treatment or does not, but cannot both receive and not receive the treatment at the same time. We therefore need a method for the imputation of these missing outcomes; for this, we rely on the propensity score matching estimator. This method first computes, for each observation, a propensity score, which is the likelihood that the observation receives the treatment, conditional on its pre-treatment characteristics. Rosenbaum and Rubin (1983) formally define the propensity score as:

$$p(X) = \Pr(Treatment = 1 \mid X) \ = E(Treatment \mid X) \qquad (3)$$

Equation 3 states that the probability of treatment, *p(X)*, is equal to the probability that the treatment is received by an observation with characteristics *X*, and also equal to the conditional mean of *Treatment* given some values for *X*, which is referred to as *E(Treatment | X).* If the propensity score is known, then we calculate the average treatment effect on the treated as:

$$\beta = E\ [\ E\ \{Y_{1i}|D_i = 1, p(X_i)\} - E\{Y_{0i}|\ D_i = 0, p(X_i)\}|D_i = 1] \qquad (4)$$

Where β, the average treatment effect for the treated, is the net effect of R&D tax subsidies on firms which receive them, *D* is a dummy variable denoting whether firm *i* has received the treatment or not,

Y_{1i} is the R&D outcome for firm *i* if it receives the treatment (Incentive or Concession), and Y_{0i} is the R&D outcome for firm *i* if it does not receive the treatment.

The result is β, the average treatment effect on the treated, which informs us on what the net effect of the policy is. The key strength of propensity score matching is that, for a given propensity score, the assignment to treatment or control is essentially random, which is of central importance for causal questions (see Becker and Ichiro, 2002). Importantly, we only match treated firms to untreated firms within the same two-digit industry code, which allows us to account for all industry-specific factors.

We compute the propensity score based on several dimensions: industry, turnover size, the wage bill and receipt of a government grant (R&D financed by State or Commonwealth Governments). In practice, this means that we are comparing R&D investment for firms which receive tax subsidies and firms which do not, with both types of firms being equally likely to be treated (as the propensity score, or probability of treatment, is the matching variable). We also only match firms within the same industry, which ensures that we are not matching, say, an aerospace engineering firm to a textile production firm simply because their turnovers, wages and R&D grants are similar. Intuitively, we would expect the two firms to be very poor counterfactuals for each other, despite being similar along other observable characteristics. Therefore, the within-industry matching allows for a stronger explanatory power of the matching estimates.

To implement the exact matching on industry and year, we first use the coarsened exact matching method of Iacus, King and Porro (2012) to prepare the sample. We then implement a standard propensity score matching procedure with bootstrapped standard errors. Table 8 displays the results obtained with propensity score matching estimation when R&D investment is the dependent variable. The *Treatment* variable is significant in all specifications. The parameter estimates on *Treatment* suggest an average treatment effect of 43.8 percent for the tax Concession sample (column (1), which is slightly smaller than the average treatment effect obtained with OLS estimates (which was about 50 percent). Columns (2) present the results for small firms separately, defined here as firms with a turnover below 20 million. As observed previously, firms which do not pay franked dividends benefit more from tax subsidies and it is anticipated that they will exhibit greater policy response. However, this is not borne out by the data. As can be seen in column (3), the estimate for firms without franked dividends is marginally smaller than for the full sample. We interpret this as cautious support for the hypothesis that any efficacy of tax policy is not substantively diminished by the existence of the dividend imputation system. Column (4) presents the estimates for the impact of the Incentive policy in 2012 only. This is not significant at conventional levels though the coefficient is of similar magnitude to the OLS results and the lack of significance may reflect the lack of precision due to the smaller sample, which is supported by the difference-in-difference results presented in the next section. The results in column (5) cover the sample of firms that we anticipate benefiting the most from the R&D Tax Incentive – small firms with no profits. These firms receive a refundable offset of 45 percent as compared to no deductions at all in the absence of policy. The estimated treatment effect for these firms is considerably larger than the other samples.

Overall the variation between samples are not large and do not provide a great deal of additional insight into the effect. In light of the limitations of the matching approach we caution against reporting separate additionality values for each group of firms (small, no franked dividends etc). We are not aware of any strong a priori case that the Incentive and Concession policies should differ in their rate of additionality except in so far as they may induce different types of firms to claim.

Table 8. Matching results: treatment effect. Dependent variable: ln R&D Investment (BERD).

	Concession (1)	Concession Small firms (2)	Concession No Franked Dividends (3)	Incentive (4)	Incentive Small & no profit (5)
Treatment	0.438***	0.358***	0.353***	0.153	0.823***
	[0.026]	[0.0292]	[0.0307]	[0.109]	[0.248]
Obs.	32,354	24,788	25,182	2,147	670
Untreated	6,553	5,066	5,331	515	64

Notes: *** significant at 1 percent. Round parenthesis denotes number of observations.

We estimate representative additionality implied by our statistical estimate of the treatment effect for both the Concession and the Incentive scheme. While the estimated treatment effect of the Incentive scheme is only significant at 16 percent, we argue the magnitude has some illustrative value, particularly in the context of the significant difference-in-difference result, the OLS result and that the scheme appears to have a strong effect on the subsample used in column (5). We apply a simple counterfactual analysis using ABS BERD data to calculate the approximate additionality implied by the treatment effect reported above. Details of the method are outlined below.

The definition of the average treatment effect on the treated is that R&D expenditure in treated firms is β percent larger than the amount of R&D expenditure in untreated firms. The counterfactual R&D (what the R&D would have been in the absence of the policy) can be written as:

$$\mathrm{R\&D}_{1|0} = \frac{\mathrm{R\&D}_{1|1}}{(1+\beta)} \tag{5}$$

We estimate the tax revenue forgone as follows. For the R&D Tax Incentive note that the tax revenue forgone is given by:

$$\mathrm{T}_{1|0} - \mathrm{T}_{1|1} = \mathrm{OFFSET} \times \mathrm{R\&D}_{1|1} - \frac{\mathrm{CTR}}{1+\beta}\mathrm{R\&D}_{1|1} \tag{6}$$

where T are tax liabilities R&D is NPV of eligible R&D expenditure; CTR is the corporate tax rate; and, OFFSET is the value of the tax offset given by the R&D Tax Incentive program (either 40 percent or 45 percent). Using the equation (5) we can write:

$$\mathrm{T}_0 - \mathrm{T}_1 = \left(\mathrm{OFFSET} - \frac{\mathrm{CTR}}{1+\beta}\right) \times \ \mathrm{R\&D}_{1|1} \tag{7}$$

We estimate tax revenue forgone for each firm in the sample using R&D data from the BERD making the simplifying assumption that all R&D is eligible. We do not model differences in firm's ability to benefit from the Incentive due to lack of taxable profits, the refundable offset or time costs of money associated with carry-forward/backs. Time costs associated with allowable depreciation rates for capital type R&D expenditure is also not modelled. The implication of these assumptions is minimised since we focus on the difference in tax liabilities – the same assumptions are applied to the no policy case (the counterfactual with 100 percent deduction at 30 percent corporate income tax rate) and the policy case. Using ATO data could potentially improve these estimates, but the potential for incomplete data would need to be carefully considered and accommodated (since firms can carry forward and back claims and update their tax position ex-post). Carry forwards also introduces the complexity of discounting revenue forgone.

An analogous estimate for the R&D tax Concession shows that

$$\mathrm{T}_0 - \mathrm{T}_1 = \mathrm{CTR}\ \left[\left(\frac{1.25\ \beta + 0.25}{1 + \beta}\right) * \mathrm{R\&D}_{1|1} + 0.5\mathrm{INC}\right] \tag{8}$$

Where $\mathrm{INC} = \max\left\{\left(\mathrm{R\&D}_{1|1} - \frac{1}{3}\sum_{t-1}^{t-4}\mathrm{R\&D}_{1|1}\right), 0\right\}$ is the component of R&D eligible for the incremental Concession (expenditure above a 3 year lagged moving average). For tractability we assume that INC is independent of treatment.

We arrive at an estimated additionality for the R&D tax Incentive Policy of approximately 0.8 dollars of additional R&D per dollar of revenue forgone. For the Concession, the estimated policy impact suggests an additionality of 1.7.

Difference-in-difference

The R&D Tax Incentive, introduced in 2012, is somewhat more generous than the R&D Tax Concession it replaced. The Tax Incentive comprises a 45 percent offset (rebate) for small companies (turnover less than $20 million) and a 40 percent offset (rebate) for large companies (turnover greater than $20 million). Under the Concession scheme firms could deduct 125 percent of eligible R&D spending and an additional 50 percent of expenditure over and above the average of the past three years (with a corporate income tax rate of 30 percent in 2011). For a hypothetical large firm increasing nominal R&D spend by 5 percent per year, the Incentive policy reflects an increase from about 8.9 cents on the dollar to 10 cents on the dollar. This figure is higher for small firms and firms that do not increase their R&D spend and smaller for firms that typically increase their R&D spend more than 5 percent per annum.

The policy change allows us to implement a difference-in-difference estimator. The difference-in-difference approach can provide a substantially stronger basis for evaluating the causal effects of policy than either propensity score matching or OLS. Difference-in-difference estimators do not rely on the assumption that there are no unobserved factors which determine both selection and R&D investment. Instead, difference-in-difference is based on what is known as the ‘parallel trends assumption’. The parallel trends assumption states that, even though claiming and non-claiming firms exhibit a different level of R&D investment (and this may be determined in part by unobserved factors which also determine the decision to register) it is plausible that they exhibit the same trend over time. That is, the assumption is that R&D investment by claiming and non-claiming firms move in parallel over time because they are subject to the same macro-economic conditions.

The difference-in-difference method reflects the change in outcome variable (R&D) exhibited by the treated firms over and above the change in outcome variable exhibited by the control group. In this case, the treated sample consists of 1256 firms which claimed the Concession in 2011 and the Incentive in 2012. The control group consists of 206 R&D active firms which do not claim any tax subsidy in either 2011 or 2012. Denoting R&D expenditure by firms in the control group by $\mathrm{R\&D}_{0|2011}$ and $\mathrm{R\&D}_{0|2012}$ and R&D expenditure by the treated group in 2011 and 2012 by $\mathrm{R\&D}_{1|2011}$ and $\mathrm{R\&D}_{1|2012}$, respectively, then the difference-in-difference estimator can be written as:

$$\left(\mathrm{R\&D}_{1|2012} - \mathrm{R\&D}_{1|2011}\right) - \left(\mathrm{R\&D}_{0|2012} - \mathrm{R\&D}_{0|2011}\right) \qquad (9)$$

For statistical inference, it is straightforward to derive the difference-in-difference estimate using a regression model given by:

$$R\&D_{it} = \beta_0 + \beta_1 Registered + \beta_2 Y2012 + \beta_3 (Registered \times Y2012) + u \qquad (10)$$

Where *Registered* is a dummy for the firms registered for tax subsidies in both 2011 and 2012. β_1 reflects the average difference in R&D spending between registered and unregistered firms in both years, *Y2012* is a period dummy and is equal to 1 in 2012 and 0 in 2011. The coefficient β_2 reflects the average growth in R&D between periods. The coefficient of interest is β_3 (the interacted term) which can equivalently be retrieved from a model of the form:

$$\Delta R\&D_i = \beta_3 Registered + \varepsilon \qquad (11)$$

The latter model reflects the first difference transformation of equation (10) thereby controlling for individual fixed effects. Controlling for individual attributes does not impact on identification of the coefficient of interest, but can increase the efficiency (Angrist and Pischke 2009). Results for the estimates are presented in table 9 below; column 1 presents baseline result (equation 11) and in column 2 additional time varying firm-level controls are added. These indicate that the transition from the Concession to the Incentive policy led to an increase in R&D spending of around 13 per cent for those firms which transitioned in 2012 and is statistically significant at the 5 per cent level.

Table 9. Difference-in-difference estimates. Dependent variable: growth in R&D expenditure

	(1)	(2)
Firms receiving R&D tax subsidies (Concession in 2011 and Incentive in 2012)	0.136**	0.126**
	(0.0560)	(0.0558)
Growth in turnover		0.0246**
		(0.0114)
Growth in wages		0.0350***
		(0.0125)
Grant		0.0424***
		(0.0112)
Observations	1,462	1,462
R-squared	0.004	0.026

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The difference-in-difference results suggest that the introduction of the more generous R&D tax Incentive policy led to a 13.6 percent increase in R&D spending by the sample of firms registered in both 2011 and 2012. Using an analogous counterfactual type approach as described in the previous section we estimate the policy impact translates to 1.9 dollars of additional R&D invested per dollar of tax revenue forgone for the sample of firms. In this case, we use the difference between the estimated counterfactual R&D in 2012 (see equation 5) and recorded R&D in 2011 as a proxy for the share of R&D eligible for the augmented 175 percent Concession rate.

Observe that the estimate of 1.9 is considerably higher than the additionality for the same program estimated using the matching approach (which was 0.8 and not significant). We have no immediate explanation for this difference. It may simply reflect the lack of precision with which the treatment effect is estimated using matching. We also note also that the sample used for difference-in-difference include only firms which have R&D expenditure recorded in both 2011 and 2012 and omits firms which transition from claiming to not-claiming status (and visa-versa). We tentatively suggest that the difference-in-difference provides more confidence that the effect is causal, however, since the data used to derive the estimate exclude many claiming firms, we cannot claim that this is representative of the effect on all claiming firms. It would be valuable to investigate this difference more deeply, possibly including undertaking matching before performing the difference-in-difference estimates.

Recall that the assumption underlying the difference-in-difference approach to policy evaluation is that the trends in R&D expenditure by treated and untreated firms would move in parallel over time, in the absence of policy change. To provide some empirical support to this proposition we undertook a falsification test using data from the same sample of firms over the 2010 to 2011 period – that is, the years immediately prior to the policy shift. The falsification test effectively involves estimating the same model using the data for the same firms in the year that no policy shift occurred was introduced. The result indicates that the groups of firms do exhibit parallel trends between 2010 and 2011 (the coefficient on the interacted term is insignificant when the prior year data is used). This increases our confidence in the parallel trend assumption and therefore in interpreting our result as causal is valid.

Regression discontinuity design

Our final approach uses a regression discontinuity design (see for example Imbens and Kalyanaraman, 2012; Calonico *et al.,* 2014). Given an appropriate data and policy context, regression discontinuity design can provide the strongest method for establishing causality of the methods presented in this report. The R&D Tax Incentive has a discontinuity for firms with a turnover above $20 million – firms with annual turnovers over $20 million are eligible to claim a 40 percent non-refundable tax offset, while firms with turnovers below $20 million are eligible to claim a 45 percent refundable tax offset. The idea behind the regression discontinuity design we setup is that firms which are just above and just below the $20 million cut-off are highly likely to be very similar in all respects other than in the benefit they get from tax subsidies. Regression discontinuity designs have recently become popular in economics, as the discipline's focus has shifted towards quasi-experimental methods. The central idea behind regression discontinuity design is that the assignment to treatment (in this case, the size of the R&D tax offset) is determined by whether a "running variable" exceeds a known cut-off point. A key advantage of regression discontinuity designs is that they are relatively free of assumptions, including the assumption of random assignment. This makes regression discontinuity designs potentially more credible than other quasi-experimental methods such as difference-in-differences estimation or instrumental variables approaches. Lee (2008) shows formally that regression discontinuity estimates are unbiased and consistent within the neighbourhood of the cut-off as long as participants cannot precisely manipulate their position vis-à-vis of the threshold. In this context, this means that, as long as firms cannot precisely manipulate their reported turnover to fall under the $20 million cut-off, the estimates will be consistent and unbiased. Turnover is difficult for firms to exercise any control over to qualify for the higher rate. In contrast, taxable profit is amenable to various claimable investments, depreciation schedules used over fixed assets, as well as interest repayments which vary depending on financial structure.

The cut-off we consider is a turnover of $20 million per annum. As per ATO guidelines, firms with annual turnovers below $20 million receive a 45 percent refundable tax offset, while firms above the cut-off receive a 40 percent non-refundable tax offset. Specifically, we estimate:

$$\ln(R\&D\ expenditure)_i = f(Turnover)_i + \gamma\ Above\ Cut\ Off_i + u_i \tag{12}$$

where *Above Cut Off* is a dummy variable set equal to 1 if firm *i* has a turnover greater than $20 million, *u* is a stochastic error term, and *f(Turnover)* is a n^{th} order polynomial. In this study, we follow the convention in the statistical literature and use a first order polynomial. This convention reflects the view that real world data is well approximated *locally* by linear patterns. Of course, we do not expect relationships between two given variables to be linear over the entire ranges of both variables. However, within small neighbourhoods around known points of interest (i.e., locally to the cut-off), we would expect real world processes to be well captured by linear patterns. In effect, we run a linear regression on both sides of the cut-off point, and we allow the coefficients estimated in the regression to be different on each side of the threshold. That is, we specify *f* as:

$$f(TO)_i = \alpha + \beta_1\ Above_i + \beta_2\,(TO_i - c) + \beta_3 * Above_i * (TO_i - c) + v_i \tag{13}$$

where *c* is the cut-off point ($20 million), *TO* and *Above* are shorthand notations for *Turnover* and *Above Cut Off* respectively, and *v* is a stochastic error term. We estimate equation (12) while specifying *f (Turnover)* as dictated by equation (13) to obtain the average causal effect on R&D investment of getting a 45 percent tax offset relative to getting a 40 percent tax offset.

We apply a regression discontinuity design to the annual turnover threshold of $20 million. Under the R&D Tax Incentive policy, firms with a turnover below 20 million are eligible to benefit from an offset that is five percentage points higher than those with a turnover above 20 million. We exploit this strict cut-off point as a chance to compare firms which receive higher R&D tax subsidies (the firms below the threshold) to firms with a comparatively lower tax break (the firms above the threshold). We exploit the fact that the firms immediately below and above the threshold vary smoothly in all their characteristics across the threshold, with the exception of treatment status. This is so because the treatment status is itself a well-defined function of the threshold: firms with turnovers below $20 million know for certain that they will be receiving the higher tax incentive, while firms above it know for certain that they will be receiving the lower tax incentive. Equations (12) and (13) above lay out the specifics of the econometric model we estimate.

Table 10 displays the results. For the baseline sample in Column (1), the model finds no statistically significant difference in R&D expenditure between firms below the $20 million cut-off and firms above the cut-off. As such, and perhaps surprisingly, we find no evidence that firms which receive a smaller offset perform any less R&D as a result. In columns (2) to (5), we experiment with alternative dependent variables, including the stock of R&D, R&D person-years and R&D intensity measured both as R&D expenditure per $1,000 of turnover and R&D expenditure per $1,000 of wages. We do not find a significant result in any of these specifications. As a robustness test, we considered log transforming the data which reduces dispersion, however this did not change the result.

In sum we are unable to observe a significant impact of the difference in the incentive rate between 40 and 45 percent. It is possible that whatever impact the difference has is too small to be observable. However, the number of observations used in the regression discontinuity design is not very large. Goldberger (1972) observes that in order to generate the same explanatory power as a randomized controlled trial, which is the best scientific method for causal inference, regression discontinuity designs need 2.75 times as many observations. We can therefore think of the results below as equivalent to being obtained from a randomized controlled trial with approximately 16 observations. The small sample size may therefore be driving the absence of a result. Performing the analysis again when the 2014 BERD survey results become available may help reconcile this issue.

Table 10. Regression Discontinuity Estimates, Dollar Scale.

Dependent Variable:	ln(R&D investment) (1)	ln(R&D stock) (2)	ln(Human resources devoted to R&D) (3)	R&D expenditure per $1,000 of turnover (4)	R&D expenditure per $1,000 of wages (5)
Treatment	0.191	-0.793	-0.053	0.051	0.034
	[0.730]	[0.760]	[1.120]	[0.061]	[0.210]
Upper & Lower Cut-Offs (millions)	4	4	4	4	4
Observations	43	38	43	43	43

*** p<0.01, ** p<0.05, * p<0.1. Regression discontinuity estimates with first-order polynomial (local linear regressions). Upper & Lower Cut-Offs of $4 million mean the local linear regressions are estimated in the $16-20 million window and in the $20-24 million window. The number of observations is the combined number of observations from both windows.

Conclusion and future directions

Estimating the additionality for R&D tax policies is an empirically difficult task. The fundamental difficulty is a feature of the schemes themselves which is difficult to overcome even using comprehensive data that was available for this study. As a general observation, there exists little truly exogenous variation in policy benefit between firms; and, the prospect of identifying a valid and comparable control group (group of non-benefiting firms) is limited. Nonetheless, the availability of the comprehensive firm level data from the EABLD, made possible through new initiatives of the ABS, has allowed us to make important inroads in understanding the efficacy of the R&D tax subsidies in Australia.

We report a significant difference in R&D spending between firms that benefit from the tax subsidies and those that do not, controlling for other observable firm level characteristics comprising industry, turnover, wages and participation in other forms of government support. The most compelling evidence of a causal effect of policy comes from the difference-in-difference estimates. These suggest that firms which were claiming the R&D tax Concession in 2011 and benefited from the more generous R&D Tax Incentive in 2012 increased their R&D spending by approximately 14 percent.

The analysis presented in this report suggests that R&D tax policy review, evaluation or reform should apply a benchmark additionality in the range of 0.8–1.9, observing that the results from our preferred approach fall toward the upper end of this range. Our estimated additionality falls within the range provided by the international literature and is quite close to Hall's (1993) seminal estimate that the US R&D tax credit in the 1980s induced around 2 dollars of additional R&D for every dollar of tax revenue forgone. In the estimates presented in this report, some firms in the sample had been claiming for many years, whereas others may be claiming for the first time. As such, the estimate can be thought of as a weighted average long-run and short-run effect.

There are a number of ways that the analysis covered in this report could be extended in order to improve precision and confidence. These are outlined below.

- Estimated change to tax revenue forgone could potentially be improved by using ATO data to estimate tax revenue forgone under each scheme. In the analysis above, estimates of the average treatment effect of R&D tax subsidies are converted to additionalities using a method based on BERD data and described in the text.

- The statistical estimate of the average treatment effect derived from propensity score matching approach could be improved through a more systematic and comprehensive sensitivity analysis relating to the design of the matching algorithm.

- Deeper analysis of the transition to the incentive policy provides important potential to improve the accuracy of estimates and confidence in the result. It may be valuable to consider the applicability of continuous treatment models, which allow for the fact that the policy shift affected some firms more than others. The difference-in-difference estimates can be improved by applying a matching procedure to the sample of non-claiming firms to those claiming firms that transition from the Concession to Incentive policy before undertaking the difference-in-difference regression. In our view, this would provide the best possible evaluation given the data currently available.

- When company R&D (BERD) data for the year 2014 (and 2013) are available it would be valuable to re-visit and re-estimate the regression discontinuity design. The regression discontinuity design as applied here uses the $20 million threshold feature of the Incentive policy and therefore is based on only one year of data for a newly introduced program and would greatly benefit from longer data coverage.

- A powerful approach to evaluate tax subsidies in Australia would be via a policy experiment. One option would be to provide a larger incentive than is currently allowable to a randomly selected group of firms. With appropriate study design it would be possible to provide such a credit to perhaps as few as 50 firms. While an approach would be very expensive as compared to this small study, the expense would likely amount to only a fraction of a percent of the total annual program costs and would generate unprecedented insight into the efficacy of tax policy for the purpose of stimulating R&D investment. Results would be of both domestic and international relevance.

References

Angrist, J and Pischke, J (2009), Mostly Harmless Econometrics, Princeton University Press

ATO (2002a), Information Sheet – R&D Tax Concession Core Technology for R&D. Australian Taxation Office, Canberra.

ATO (2002b), R&D Tax Concession Information Sheet – 'On Own behalf' Provisions. Australian Taxation Office, Canberra.

ATO (2006), You and Your Shares. Australian Taxation Office, Canberra.

Becker, S.O. and Ichino, A. (2002), 'Estimation of Average Treatment Effects Based on Propensity Scores', The Stata Journal, 2, 358-377.

Bernstein, J. (1986), 'The Effect of Direct and Indirect tax Incentives on Canadian Industrial R&D investments', Canadian Journal of Economics, 12, 438–48.

BIE (1993), Research Report 50. R&D, Innovation and Competitiveness: An Evaluation of the Research and Development Tax Concession. Bureau of Industry Economics, Canberra.

Bloom, N., Griffith, R. and Van Reenen, J. (2002), 'Do R&D Tax subsidies Work? Evidence from a Panel of Countries 1979–1997', Journal of Public Economics, 85, 1–31.

Calonico, S., Cattaneo, M.D. and Titiunik, R. (2014), 'Robust Data-Driven Inference in the Regression-Discontinuity Design', The Stata Journal, 14, 909-946.

CIE (2003), 'Review of the R&D Tax Concession Program Canberra', Prepared for the Department of Industry, Tourism and Resources by Centre for International Economics.

Dagenais, M., Mohnen, P. and Therrien, P. (1997), Do Canadian Firms Respond to the Fiscal Incentives to Research and Development. Scientific Series. Centre Interuniversitaire de Recherche en Analyse des Organisations (CIRANO), Montreal.

DITR (2005), The R&D Tax Concession – Impact on the Firm. Department of Industry Tourism and Resources, Canberra.

DITR (2007a), How R&D Assistance How R&D Assistance Influences Company Behaviour. Department of Industry Tourism and Resources, Canberra.

Eisner, R., Albert, S.H. and Sullivan, Martin A. (1984), 'The New Incremental Tax subsidy for R&D: Incentive or Disincentive?', National Tax Journal, 37, 171–84.

Falk, M. (2006), 'What Drives Business Research and Development (R&D) Intensity Across Organisation for Economic Co-Operation and Development (OECD) Countries?', Applied Economics, 38, 533–47.

Goldberger, A.S. (1972), 'Selection Bias in Evaluating Treatment Effects: Some Formal Illustrations', Discussion Paper No. 123, University of Wisconsin Institute for Research on Poverty, Madison, WI.

Guellec, D. and Van Pottelsberghe, B. (2003), 'The Impact of Public R&D investment on Business R&D', Economics of Innovation and New Technology, 12, 225–43.

Hall, B. (1992), 'R&D Tax Policy During the Eighties: Success of Failure', Working Paper No. 4240, NBER, Cambridge, MA.

Halvorsen, R., and Palmquist, R. (1980), 'The Interpretation of Dummy Variables in Semilogarithmic Equations', The American Economic Review, 70, 474–475.

Harris, R., Li, Q.C. and Trainor, M. (2009), 'Is a higher rate of R&D tax subsidy a panacea for low levels of R&D in disadvantaged regions?', Research Policy 38: 192–205.

Iacus, S. M3, King G. and Porro, G. (2012), 'Causal Inference Without Balance Checking: Coarsened Exact Matching', Political Analysis, 20, 1-24.

Imbens, G. and Kalyanaraman, K. (2012), 'Optimal Bandwidth Choice for the Regression Discontinuity Estimator', Review of Economic Studies, 79, 1-27.

IR&D Board (2004), Overseas Research and Development Activities Guidelines 2004. Industry Research and Development Board, Canberra.

IT 244 (1987), Taxation Ruling No. IT 2442. Income Tax: Concession for Eligible Research and Development Expenditure. Commissioner of Taxation, Australia.

Kennedy, P. E.. (1981). 'Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations' The American Economic Review, 71, 801–801.

Koga, T. (2003), 'Firm Size and R&D Tax Incentives.' Technovation, 23, 643-648.

Krautmann, A.C. and Ciecka, J., (2006), 'Interpreting the regression coefficient in semi-logarithmic functions: A note', Indian Journal of Economics and Business, 5, 121-125.

Lattimore, R. (1997), 'Research and Development Fiscal Incentives in Australia: Impacts and Policy Lessons', in Lattimore, R. (eds), Policy Evaluation in Innovation and Technology: Towards Best Practices. OECD, Paris; 91–134.

Leuven, E. and Sianesi, B., (2003). 'PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing'. http://ideas.repec.org/c/boc/bocode/s432001.html.

Lokshin, P. and Mohnen, P., (2007), 'Measuring the effectiveness of R&D tax subsidies in the Netherlands', United Nations University Merit Working Paper.

Maddala, G.S. and Wu, S., (1999), 'A comparative study of unit root tests with panel data and a new simple test', Oxford Bulletin of Economics and Statistics, 61, 631-652.

Mansfield, E. (1986), 'The R&D Tax subsidy and Other Technology Policy Issues', The American Economic Review, Papers and Proceedings, 76, 190–4.

Mulkay, B. and Mairesse, J. (2003), 'The Effect of the R&D Tax subsidy in France', EEA-ESEM Conference; 20–24 August 2003, Stockholm, Sweden. Available from: http://www.eea-esem.com/eea-esem/2003/prog/viewpaper.asp?pid=2250

Parisi, M. L., & Sembenelli, A. (2003), "Is private R & D spending sensitive to its price? Empirical evidence on panel data for Italy", Empirica, 30, 357-377.

SFPAC (Senate Finance and Public Administration Committee) (1999), Senate Finance and Public Administration Committee. Inquiry into Business Taxation Reform. Chapter 7. Parliament of Australia, Canberra.

Thomas, D., Manly, T. and Schulman, C. (2003), 'An International Investigation of the Influence of Dividend Taxation on Research and Development Tax subsidies', The Journal of the American Taxation Association, 25, 35–54.

Thomson, R. (2010), 'Tax Policy and R&D Investment by Australian Firms', The Economic Record, 86, 260–80.

Thomson, R. and Jensen, P.H. (2013), 'The Effects of Public Subsidies on R&D person-years: Evidence from OECD Countries', National Tax Journal, 66, 281–310.

Thomson, R., (forthcoming), The effectiveness of R&D tax credits*, Review of Economics and Statistics*

Wilson, D.J. (2009), 'Beggar Thy Neighbour? The In-state, Out-of-state, and Aggregate Effects of R&D Tax subsidies', Review of Economics and Statistics 91, 431–436.