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Tax Policy and R&D Investment by Australian Firms

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Abstract

This paper examines the determinants of investment in R&D by Australian firms, with a focus on the role of tax policy. The analysis considers an unbalanced panel of financial data of about 500 large Australian firms between 1990 and 2005. The principal result is that no evidence can be found that the user cost of R&D is an important determinant of firm R&D investment decisions. A corollary is that there is no evidence that tax incentives are an effective policy tool. Growth in sales is found to be the primary determinant of R&D investment, which is interpreted as evidence of the central role of demand conditions.

JEL classification: O32, H25, H32

Key words: R&D investment, R&D tax policy, innovation policy, Australian R&D

1. Introduction

Existing empirical evidence of the effectiveness of R&D tax incentives, based predominantly on US and Canadian experience, is mixed. Estimates of the elasticity of R&D with respect to tax price have varied considerably – ranging from unobservable (Eisner 1984) to -2.7 (Hall 1992a). However, some have argued that anecdotal evidence does not support the efficacy of R&D tax incentives. Regarding the US experience, a senior correspondent from BusinessWeek describes his experience speaking, off the record, with corporate executives (Gleckman 2006):

> *In 20 years , I've never had a single corporate executive from the pharmaceutical industry or the high tech industry, or anyplace else tell me that they have done a dime's worth of research that they otherwise wouldn't have done as a result of the R&D credit. They spend lots of time and effort reallocating costs so they can take advantage of the credit, but they don't actually do any more research.*

This paper aims to contribute to better understanding this important policy question based on the analysis of a unique dataset of large Australian firms. The analysis is based on a simple neoclassical framework, augmented with controls for other factors including firm size and liquidity. The principal variable of interest is the user cost of R&D (UCRD), which incorporates national tax policy and firm level financial cost of capital. In contrast, previous research has generally utilised a measures based on the realised effective value of tax incentives.

The main result of this study is that no evidence can be found that the cost of capital is an important determinant of R&D. A corollary is that there is no evidence that tax incentives are an effective policy tool. As regards to other determinants, analysis presented in this paper firms that are experiencing growth in sales generally invest more in R&D. Growth in sales is interpreted as a signal of future profitability and output demand. This is consistent with the suggested importance of 'demand pull' in directing innovation (Scherer 1982) and the notion of induced innovation attributable to Hicks (1932).

The paper is organised as follows: section 2 describers R&D tax policy in Australia, including a history of important policy reforms. Section 3 outlines and reviews existing literature on the efficacy of R&D tax policy, both in Australia and overseas. Section 4 outlines the methodology and approach adopted in this paper. The construction of data is outlined in section 5. Results and analysis are presented in section 6, beginning first with an overview of macroeconomic trends before proceeding to the regression analysis. Section 7 concludes.

2. The R&D Tax Concession in Australia

In 2005-06, 6,295 firms spending $9.2b on R&D shared in $425m distributed benefits from the R&D tax concession (IA 2007). In the same year total business expenditure on R&D (BERD) in Australia amounted to $10.1b (ABS 2007a) suggesting a great proportion of R&D undertaken by businesses in Australia is supported by the incentive. Under the policy firms are able to deduct 125% of eligible R&D expenditure from taxable income. Firms can also claim an additional 50% on incremental expenditure over and above their average nominal expenditure in the previous three years. Eligible expenditure includes wages and other overheads directly related to R&D including the amortization of machinery and equipment.

The definition of eligible expenditure is similar to the activities defined in the *Frascati Manual* (OECD 2002a).[1] To be eligible for the scheme firms must be registered with Innovation Australia (formerly the Industry Research and Development Board). The minimum eligible expenditure is $20 thousand and up to 10% of total expenditure can be undertaken abroad. A condition of eligibility is that the R&D must be undertaken 'on own behalf', which excludes contract R&D (ATO 2002). Additionally, that technology generated must be exploited on "normal commercial terms", to the exclusion of arrangements whereby R&D is carried out by affiliates and provided free to the foreign parent (Lattimore 1997 p.94).[2]

Since its inception the scheme has undergone a number of reforms. Two major reforms occurred within the time period of this study. These natural experiments provide and opportunity to investigate the effectiveness of the tax concession. A chronology of important reforms is discussed below and these are summarised in Table 1.

The R&D tax concession was first introduced in 1985 at a rate of 150%. In November 1987, the treatment of R&D buildings was amended. Until this time, R&D buildings could be depreciated over 3 years on a straight line basis and were eligible for the concession (BIE 1993). After 1987 buildings are depreciated over the usual 40 years and are no longer eligible

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[1] An exception noted by BIE (1993) is that costs associated with routine testing and data collection are eligible for the R&D tax concession but not included in the Frascati definition. Also, costs related to patenting included in the Frascati definition are not eligible for the tax concession.

[2] However, as of the 2007-08 financial year (which is outside of the period of this study) a new 'international premium scheme' for cross border contracting is available (see ATO 2007 for details)

for the enhanced deduction. Another 1987 amendment allowed syndicates of firms to access the scheme (Lattimore 1997). The intention was to encourage pooling of resources but the syndication was effectively used by firms to trade tax losses (Banks 2000). Another change in 1987 was to include a limited amount of R&D undertaken by Australian companies abroad as eligible expenditure (IT 244 1987).[3] In 1994, the minimum expenditure threshold was reduced from $50 to $20 thousand (Lattimore 1997).

The scheme underwent major reform in 1996. The rate of deduction was cut from 150% to 125% of eligible expenditure and the scope of eligible expenditure revised. Interest on debt and non-consumed feed stock in pilot plants is no longer eligible. Also, prior to the 1996 reforms expenditure on pilot plants could be written off over three years and subsequently over their useful lives (Lattimore 1997). Core technology expenditure includes expenditure to acquire, or to acquire the right to use, technology for the purpose of continuing the development of that technology (ATO 2002). Prior to the amendments in 1996, core technology purchases could be deducted in the year of expenditure. After the 1996 reforms, deductions for ‘core technology’ expenditure are limited to a maximum of one-third of total R&D expenditure related to the core technology, though remaining amounts can be carried forward.

An incremental scheme, known as the 175% premium deduction, was introduced in 2001. Under the incremental scheme firms can claim an additional 50% deduction on the portion of expenditure exceeding average nominal expenditure over the prior three years. This is in addition to the 125% deduction available on all R&D expenditure, meaning ‘incremental’ expenditure attracts a 175% deduction in total. The rationale behind the bonus concession is to provide additional incentive while limiting deductions on infra-marginal R&D investment – that is, investment that would have occurred in the absence of the concession.

A small businesses tax offset scheme was introduced in 2002. Under the tax offset scheme, firms with a turnover of less than $5m can claim the concession as a tax offset (rebate) of 30c for each dollar of eligible R&D expenditure, provided expenditure is between the floor ($20 thousand) and a maximum (cap) of $1 million. This reform allowed small technology start-ups not currently earning taxable income to benefit from the scheme. Also from 1 July 2002 eligible R&D activities must be supported by an R&D plan (CIE 2003).

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[3] This was further codified in 2004 (see IR&D Board 2004)

Other tax policy changes affected the value of the R&D tax concession, most importantly, variation in the rate of corporate income tax rate (CIT). As the concession is provided in the form of enhanced deduction, its effective value increases with CIT. Between 1985 and 2005, the CIT was adjusted 6 times and ranged from 49% to 30%.

The tax treatment of dividends also influences the effective value of the tax concession. For example, the dividend imputation system can lead to "clawback of the R&D subsidy to companies through the taxation of their shareholders" (BIE 1993 p.220). The dividend imputation system was introduced in 1989 and 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 (also known as imputation credits) commensurate with the CIT they pay. Franking credits are allocated to shareholders with dividend payments and effectively reduce personal income tax (PIT) liabilities by the amount already paid by the company as CIT. Franked dividends paid to foreign shareholders are also exempt from withholding tax (ATO 2006). [4]

The portion of company profits that is exempt from CIT on account of the concession is not eligible for franking credits. For example, if the marginal dollar spent on R&D is eligible for the 125% deduction a consequence is that $0.25 of company profit is now exempt from CIT. The benefit of this tax exemption to shareholders depends on what the firm does with this 'concessionary income' (see also BIE 1993). The firm can retain and reinvest it; it can be paid out as unfranked dividends; or, if the firm has excess franking credits,[5] it can be paid out as franked dividends. If concessionary income is paid out as unfranked dividends the marginal dollar is taxed at the shareholder's marginal rate. If the shareholder pays a marginal rate of taxation equal to or greater than the prevailing CIT rate (currently 30%) the shareholder pays as PIT all of the tax that the company avoided through the R&D tax concession. When this happens, the benefit of the concession is said to be 'washed out.' If the shareholders marginal rate of taxation is less than 30% a fraction of the benefit is washed out. In practice, almost all of the benefit of the concession paid out as unfranked dividends to individual Australian taxpayers will be washed out. Very little will be washed out when paid to superannuation

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[4] From 2000 franking credits in excess of shareholders total PIT liabilities can be returned in individual investors as an offset (rebate). However, foreign investors cannot received a rebate for excess franking credits.

[5] For example franking credits may be carried over from ordinary profit that has previously not been returned to shareholders.

funds.[6] Half the benefit will be washed out if the concessionary income is paid to foreign shareholders as unfranked dividends.[7]

The interaction between the imputation system and the R&D tax concession will not be considered in the empirical analysis in this paper. However it is important that the imputation system acts to dilute the impact of the tax concession. There is evidence that firms respond less to R&D tax incentives when they operate in a country that also has in place a dividend imputation system (Thomas et al. 2003).

The many changes in the R&D tax concession policy underlie substantial time series variation in the value of the scheme. This can be viewed as a set of natural experiments that provide an opportunity to assess the scheme. However, this ongoing policy variation may have reduced the effectiveness of the scheme. In particular, it is argued that R&D investment requires commitment over a long period and investors will be deterred by continual variation in policy. Several authors have proposed that policy uncertainty will dilute the effectiveness of an incentive scheme (for example, Hall 1992a; Guellec and Pottelsberghe 2003). Based on analysis of cross-country data, Guellec and van Pottelsberghe (2003) find that the more volatile the policy, the less effective it is.

Table 1 Summary of Major Phases of the R&D Tax Concession

Year	Policy Event
1985	Concession introduced at a rate of 150% of eligible R&D expenditure
1987	Syndicates of firms eligible to apply
	R&D buildings excluded from the scheme and depreciation is changed from 3 to 40 years.
1994	The minimum expenditure was reduced from $20,000 to $50,000
1996	Rate of deduction reduced to 125%
	Interest on debt and unconsumed feedstock no longer eligible
	Depreciation of pilot plants changed from 3 years to the assets useful life
	Claims relating to ‘core technology’ capped at one third total related claimable expenditure
2001	Incremental tax concession (175% premium deduction) introduced.
2002	Extended access (tax offset) scheme for small business introduced

Source: (BIE 1993; SFPAC 1999; ATO 2002; CIE 2003; AusIndustry 2006; 2008b)

[6] Super funds pay 15% on unfranked dividends, but excess franking credits arising out of regular income can be used to reduce tax liabilities.
[7] Shareholders in most countries are subject to a 15% withholding tax on unfranked dividend payments, franked dividend payments are exempt from withholding tax.

3. Literature Review

A central challenge in estimating the effectiveness of tax policy on R&D is finding a suitable quantitative measure of policy that is exogenous and that exhibits sufficient variation to identify the effect of policy. A number of approaches have been employed in the existing literature including: surveying firms and R&D managers, cross-country econometric analysis; estimating firm level R&D investment demand equations with a policy shift dummy or a using a constructed user cost of R&D.

A handful of recent studies have considered the effect of tax policy on private sector R&D using cross-country data (Guellec and Pottelsberghe 2000; Bloom et al. 2002; Falk 2006). These studies have found an elasticity ranging from 15% in the short run to about unity in the long run. Cross-country analysis exploits variation in policy between jurisdiction, and as such aims to disentangle contemporaneous macroeconomic events (Bloom et al. 2002). However, if countries are inclined to introduce R&D tax incentives in response to poor innovative performance, the approach may suffer simultaneity bias. Additionally, results based on cross country data are sensitive to estimation approach and to the inclusion of outliers (Falk 2006; Thomson 2008), which is not altogether surprising given they are based on only a few hundred noisy aggregate level observations. It should also be remembered that the coefficients of cross-sectional regression are simply averages for the countries covered. More detailed country level studies are considered a useful contribution to the policy debate

An approach based on firm level data, is to survey R&D managers and firms claiming the tax incentive. Survey results reported by Mansfield (1986) suggest the policy had only a minimal effect. Two recent survey evaluations of the Australian R&D tax concession (DITR 2005; DITR 2007a) found that that while the majority of beneficiaries of the policy describe it favourably approximately 30% of respondents concede that their R&D endeavours would be neither smaller nor have been completed at a slower rate in the absence of the programme. The limitations of basing conclusions on subjective survey results are well known. In particular, respondents' "interests presumably would not [lie] in understating the benefits." (Banks 2000 p.4).

A quantitative approach to evaluating the effect of fiscal incentives using firm level data is to estimate an investment demand equation with policy shift dummies (Eisner 1984; Bernstein 1986; BIE 1993; Thomas et al. 2003). For example, using a binary dummy to capture the effect of the introduction of the concession, Eisner et al (1984) failed to observe a significant effect of the tax credit in the USA. In contrast, Thomas et al (2003) find tax incentives to have a significant effect in most countries but also that the dividend imputation system in Canada and in France reduces the effect of the R&D incentive. They find that the joint effect of the two tax policies in France is “practically zero” (ibid p. 50). A principal disadvantage of this approach is that a binary policy dummy, is not a great deal of information from which to observe a firm level response, and in particular, it is difficult to separate the effect of policy from other macroeconomic events.

A comprehensive assessment of the Australian R&D tax concession, undertaken by the Bureau of Industry Economics (BIE 1993), reports both survey data as well as analysis of firm financial data. Data used for the statistical analysis includes 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.[8] As such the ‘policy dummy’ varies between periods, with the introduction of the scheme, and between the registered and unregistered firms. Statistical analysis failed to find a robust relationship between the tax incentive and R&D investment. The data suggest a modest effect over the year the policy was introduced, but not over longer periods and the report cautions that there is a “strong likelihood” that increases in R&D over the period the policy was introduced reflects reclassification of existing expenditure. The oft-cited inference of the report is 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 (p.155).

The fourth approach, pioneered by Hall (1992a), is to calculate a firm specific user cost of R&D and include this in an R&D investment demand equation (see also Dagenais et al. 1997; Mulkay and Mairesse 2003). The results from this type of study have varied, with estimates of the short run elasticity of between -0.07 to -0.85 and a long run elasticity ranging from about unity and -2.7 (Hall 1992a; Dagenais et al. 1997). However, Dagenais et al (1997) report the result is sensitive to controlling for firm heterogeneity (ibid p.17).

The general approach of these studies is to calculate a firm specific cost of R&D, which is typically based on a firm’s actual ability to benefit from the scheme. For example, firms’ ability to benefit from tax incentives vary because of profit status, expenditure relative to caps and floors in the scheme. Further, in the case of incremental incentives[9] both the level and growth of R&D expenditure determine a firm’s ability to benefit from the scheme. However, a drawback of using the effective subsidy rate is that many of these factors are chosen simultaneously with R&D investment, leading to possible problems of endogeneity. For

[8] Registration is open to non-registered firms, which leads one to suspect selection bias, in that companies anticipating increased R&D expenditure may be more likely to register for the credit than those which intend to cease conducting R&D.

[9] Where incentives in place are designed such that expenditure above some defined base is eligible.

example, this will occur where credits are given on incremental expenditure, or if firms chose R&D in relation to caps and floors to maximise the effective subsidy.

Researchers have employed a range of methods to account for this endogeneity issue. For instance, the tax price variable included in Hall’s (1992a) regression is a forecast based on information available to the firm at time t-1. The instruments used include “past tax status of the firm, and its sales and R&D growth rates” (ibid p.20). However, it is not clear that these instruments are strictly exogenous. The design of the scheme (the credit applies to expenditure above the average of the previous 3 years) implies that the effective tax price in period t depends on spending in periods t-1 to t-3. An optimising firm can therefore choose these simultaneously to maximise the benefit from the concession. Therefore investment in period t-1 is not independent of investment in period t, but rather optimised with respect to anticipated investment in period t (see for example, Richardson and Wilkie (1995) who analyse a firm’s optimal response to such a policy). It is argued here that where the measure of tax price is dependent directly on the firms R&D activity it will be very difficult to comprehensively address this source of endogeneity. The analysis presented in this study aims to avoid this problem by employing a measure of user cost of R&D that reflects national tax policy combined with a firm specific required rate of return that reflects industry characteristics and firm level financial leveraging.

4. Model and Empirical Approach

The focus of this investigation is to estimate the elasticity of R&D investment with respect to the user cost of R&D. The analysis is based on a neoclassical framework, augmented with controls for other determinants of R&D. Failure to properly account for the range of important firm level determinants of R&D can introduce omitted variable bias. Important firm characteristics include potentially observable factors such as liquidity constraints, firm size and cost factors as well as a range of other factors more difficult or impossible to measure.

The principal variable of interest is the user cost of R&D which incorporates both the financial cost of capital as well as the effect of taxation. The financial cost of capital, also known as the investment hurdle rate, or required rate of return (ROR), will differ among firms and potentially among projects. The most important determinant of the required ROR is the premium required by investors to hold risk (Cochrane 2005). The required rate of return (ROR) on a given project is a function of the distribution of expected returns over time. More specifically, the required ROR is conjectured to be a function of the covariance of the asset payoffs with marginal utility (Cochrane 2005).

In practice, the financial cost of capital generally varies between the sources of funds. There are two general modes of finance available to firms, debt financing and equity financing. Equity includes capital raised through share issues and retained earnings. Different assets are more suited to one source of finance or the other. For example, assets that have a high salvage value offer greater collateral and are therefore thought to be more suited to debt finance. Further debt requires a stable cash flow to service interest repayments (Hall 2005). It is widely conjectured that equity finance is more suitable for R&D projects (ibid). In practice, investment is financed via a mix of debt and equity chosen to minimise financial costs. A standard measure of the cost of capital is the weighted average cost of capital (WACC). The WACC is the average of the cost of debt (i.e., interest repayments) and the cost of equity, weighted by their relative shares of a firm's total capital.

Acknowledging that there are a number of possible methods for estimating the firm level financial cost of capital, two alternative measures are considered in this study. Each of the measures is incorporated in the user cost of R&D that takes into account the effect of R&D tax policy. Details of the construction of the user cost of R&D used in this study are discussed in section 5.

Related to the cost of external capital is the issue of firm liquidity. When a firm's investment in R&D is limited by the availability of internal sources of funds a firm is said to be liquidity constrained. A liquidity constraint arises when an inventor, or a firm with an identified R&D investment opportunity, has a lower required ROR than potential project financiers. A range of attributes of R&D conspire to inhibit a firm's ability to raise external capital for the purpose of funding R&D projects. The difficulties in securing debt finance, such as low project salvage value, were acknowledged above. Asymmetric information can mean investors are unable to accurately assess the likelihood of project success. This will occur where information costs are high or markets for information are imperfect. Arrow (1962) identified that the market for information will be incomplete if inventors are reluctant to disclose information about their R&D investment opportunities because of the threat of imitation.

To test the importance of liquidity, several past authors have incorporated cash-flow into empirical models. Many, but not all, have found this to be significant (Cohen 1995; Hall 2005). For example, a study by Hall et al (1998) finds that cash flow is an important determinant of investment in R&D for US firms in the high technology sectors but may be less important for firms in French and Japanese firms. The authors suggest that this is a reflection of institutional differences between countries relating to corporate governance that affect the willingness of investors to support risky long term investments.

A complication in identifying the effect of liquidity is that cash flow can alternatively be interpreted as a signal of future profitability (Cohen 1995). The analysis in this paper incorporates the ‘current ratio,’ also known as working capital ratio, to measure liquidity and the availability of internal funds. A firm’s current ratio is given by the ratio of current assets to current liabilities. Current assets are defined as those that can be converted into cash in a short period of time, usually one year or less. If a firm’s current ratio is greater than one, the firm has free internal funds available for investment, while if it is less than one the firm does not have enough liquidity at hand to meet its immediate obligations.

Widely attributed to Schumpeter (1943), firm size and market power are another important group of firm attributes that have been conjectured to determine innovative performance. There are a number of possible mechanisms through which size and market power are thought to influence innovative performance. One argument proposes a firm’s ability to overcome issues of liquidity, based on the argument that large firms have advantages in raising capital, and have greater access to internal sources of finance. Large firms can also spread fixed costs across greater total sales. Therefore, a firm’s incentive to innovate is thought to be an increasing function of the scale of their complimentary assets relating to distribution and marketing (Teece 1986). Large firms are also thought to be able to internalise dynamic knowledge spillovers and to spread risk by diversifying across multiple research activities (Symeonidis 1996). On the other hand, some recent authors have suggested small firms have an advantage in R&D relating to more direct managerial control, superior ‘creativity’ and institutional ‘flexibility’ (Cohen 1995; Barlow 2006). The relationship between firm size and innovation has been widely studied and has failed to establish a robust positive relationship between R&D intensity and firm size (Cohen 1995).

Associated with the proposed relationship between firm size and innovation performance are diversification advantages. Diversified firms, such as large conglomerates that operate in multiple industrial sectors, are thought to have a greater ability to exploit new technology. That is, diversified firms are better placed to capture positive spillovers arising from R&D (Weder and Grubel 1993) and in particular the output of basic research (Nelson 1959).

In this paper, total employees will be included to control for firm size. A practical empirical measure of diversification is not available. However, by controlling for firm fixed effects and firm size overall it is expected to capture the principal variation in firm diversification. As opposed to financial measures of firm size, the number of employees allows better identification of the effects of scale separately from financial factors which are of independent interest.

Schumpeter proposed that monopoly power is a fundamental driver of innovation. This insight is reflected in a range of endogenous growth models (Romer 1990; Grossman and Helpman 1991; Aghion and Howitt 1992). Conversely, common wisdom has long held that greater competition can spur productivity enhancing innovation (Aghion and Griffith 2005). This apparent conflict has been the subject of a substantial empirical research effort. Early efforts used market concentration ratios as a measure of market power to assess the relationship between competition and innovation. Several authors have commented that increased concentration does not necessarily correlate with reduced competition and further will be subject to reverse causality (Symeonidis 1996; Aghion and Griffith 2005). Supernormal profit, or firm level rent, has been used as an alternative measure of market power (Nickell 1996).

Acknowledging the difficulty in measuring market power the current study considers that in the short term, a firm’s competitive environment can largely be considered an industry specific effect. This is further justified by the observation of Cohen (1995) who notes that “empirical findings leave little support for the view that industrial concentration is [an] independent determinant of innovative behaviour … once one controls for firm size” (ibid p.196).

Many authors have highlighted the importance of ‘demand-pull’ in driving innovation (Schmookler 1966; Scherer 1982). This theory proposes that potential innovators will react to profit opportunities perceived in the market. An analogous mechanism was proposed by Hick’s (1932) theory of induced innovation, whereby changes in factor prices spur innovation. Indicators of demand prospects applied in empirical analysis have included growth in sales at the firm level, or growth in value added at the industry level (Love and Roper 1999; Griffiths and Webster 2004) and fixed capital investment (Schmookler 1966; Scherer 1982). The specification adopted in this paper is based on a modified neoclassical model and includes growth in sales.

The policy implications of induced innovation are important. In broad terms, innovation policy can be categorised as acting either via push factors or via pull factors. Policies relating to ‘push’ factors include subsidies and grants to firms as well as funding for basic research undertaken in the higher education sector or government institutes. Among the most important policy levers available to governments that influence ‘demand pull’ factors are intellectual property rights. These aim to ensure potential innovators are able to appropriate profit from their endeavours. Other policies that implicitly aim to ‘induce innovation’ include environmental Pigouvian taxes. For example, a goal of a carbon tax or emissions trading scheme is, at least in part, that price signals induce innovation in efficient low emission technology. That is, the elasticity of output with respect to emissions is expected to change over time.

Many important factors, such as market structure, technological opportunity and appropriability conditions will be common to each industrial sector. As a result, the average R&D intensity of firms in different industries differ considerably Rather than control for industry directly the analysis in this paper will account for all time invariant firm fixed effects. This acknowledges that a great range of unobservable firm characteristics will be important in determining innovative performance. These include a firm’s unique human capital assets, technological capabilities and managerial strategy. For example, recent evidence has found managerial and HR strategy are indeed important determinants of R&D investment (Griffiths and Webster 2004). Other firm characteristics that are unobservable in practical terms relate to the geographic distribution of firms’ activities including their proximity to customers, suppliers as well as to institutes of higher education. While a researcher cannot hope to include all relevant factors, these can largely be controlled through an estimation procedure that accounts for unobserved time invariant firm attributes.

Economic Model

The primary aim of this paper is to estimate the short run elasticity of R&D with respect to its user cost. The analytical framework draws upon the neoclassical model of investment (Jorgenson 1963). The following canonical model illustrates Jorgensen’s approach and the user cost of capital.

The firm’s objective function represents the discounted stream of profit. Final goods and technology capital are produced via the same production function $f(G,L)$. The inputs to production are technology stock (denoted as G), as well as a variable input (denoted as L). Profit is taxed at rate τ and tax incentives are incorporated by allowing the NPV of deductions of R&D expenditure to differ from τ. Each dollar invested in R&D reduces tax liabilities by A dollars. Technology stock is subject to the accumulation restriction given by:

$$G_t = (1-\delta)G_{t-1} + R_t \quad (1)$$

where R represents R&D expenditure (i.e., investment in technology stock) and δ is the rate of depreciation/obsolescence. The firm’s objective function is given by:

$$\sum_{s=t}^{\infty}(1+r)^{t-s}\left((1-\tau)\left(f(G_{s-1},L_s)-w_sL_s\right)-(1-A)R_s\right). \quad (2)$$

Directly substituting the capital accumulation restriction (1) into (2) gives the first order condition:

$$f_G\left(G^*,.\right)=\frac{1-A}{1-\tau}(r+\delta):=c \quad (3)$$

Equation (3) says that the optimising firm will invest to equate the marginal revenue product (MRP) of technology stock with the opportunity cost of holding or 'renting' it for one period. The right hand side of (3) is called the user cost of R&D (denoted here as c) and is equal to the after tax purchase price multiplied by the net required rate of return, which is the market required ROR, plus depreciation less capital gains.

Assuming CES production technology, it follows that $\Delta G_t=\Delta(Y_tc_t^{-\sigma})$, where σ is the elasticity of substitution. Substituting this into the capital accumulation restriction (eqn 1) gives the following simple R&D demand equation.

$$R_t=\delta G_{t-1}+\Delta G^*=\delta G_{t-1}+\Delta(Y_tc_t^{-\sigma}) \quad (4)$$

The estimation equations are formulated from the modified version of Equation (4) with other determinants of R&D investment identified in the preceding section added. Controlling for scale, liquidity constraints and growth in demand the equation becomes:

$$R_{it}=\alpha_1G_{it-1}+\alpha_2\Delta c_{it-1}+\alpha_3CR_{it-1}+\alpha_4EMP_{t-1}+\alpha_6\Delta SALES_{it} \quad (5)$$

In addition, a simple dynamic model is also estimated that bypasses the difficult issue of estimating R&D stock. This specification entails replacing lagged R&D stock with lagged R&D expenditure and is consistent with several past papers (Griffiths and Webster 2004).

$$R_{it}=\alpha_1R_{it-1}+\alpha_2\Delta c_{it-1}+\alpha_3CR_{it-1}+\alpha_4EMP_{t-1}+\alpha_6\Delta SALES_{it} \quad (6)$$

Models are estimated using natural logarithm of all variables, except those representing growth rates. This was done in order that every variable have a similar (small) variance, and further because the log specification achieved a better fit. Specifications based on simple dynamic model in logs has also been employed successfully by previous authors (e.g., Hall 1992a; BIE 1993; Griffiths and Webster 2004).

Table 2 Variable Definitions and Economic Concepts They Represent

Economic Concept	Variable	Measure
R&D stock	G_{it}	Imputed firm R&D stock, based on PIM
Availability of internal funds	CR	Current Ratio, an indicator of access to internal sources of finance. The current ratio is the ratio of current assets to current liabilities. Recall current assets are assets that can be converted into cash in a short period of time, usually one year or less
User Cost of R&D	c_{it}	is the user cost of R&D. ΔC_{it} is the annual growth rate in user cost of capital.
Firm Size	EMP_{it}	Total number of employees
Growth in Demand, or alternatively, the accelerator effect	$\Delta SALES_{it}$	is the growth in real sales
Business Cycle	ΔGDP_{it}	GDP growth controlling for macro economic conditions and the business cycle effects.

Estimation Strategy

As indicated previously, unobserved firm heterogeneity reflecting differences in managerial strategy, attitude to risk, internal firm capabilities are important determinants of R&D investment. While some of these will evolve over long time horizons it is proposed that over the short time frame considered here they can be considered largely time invariant. Controlling for time invariant heterogeneity also accounts for a number of observable factors, such as industry, foreign ownership[10] and ownership type (public / private etc).

Estimating the model using fixed effects (FE) may result in dynamic panel or Nickell bias (Nickell 1981) which arises because under the FE transformation the transformed lagged dependent variable is correlated to the (transformed) error term (i.e., $Cov\left(R_{it-1} - \overline{R}, \varepsilon_{it} - \bar{\varepsilon}_i\right) \neq 0$). To redress this problem the dynamic model is estimated using differenced GMM (Arellano and Bond 1991). In summary, the differenced GMM estimator is chosen observing that the panel can be characterised as wide and short (around 500 firms with an average length of five years) and further that while the dependent variable is persistent the autoregressive coefficient is not close to one. Rather than first differencing, the forward orthogonal deviations transformation is applied to maximise the data available for the estimation, as suggested by Roodman (2006). The forward orthogonal transformation

[10] In the IBISWorld dataset foreign ownership is constant over time for all firms. Given the average observations per firm is less than 5 years, this may be a true reflection of reality. While there is existing concern that this may reflect measurement error in a few cases, there is little that can be done given the data available.

involves purging the fixed effects by subtracting the average of all available future observations. FE estimates are also reported for completeness. As the main variation in the policy variable we aim to exploit is over time, the estimates include a common time trend rather than year dummies. Year dummies are considered in robustness checking.

5. Data

Firm-level financial data are taken from the IBISWorld database. IBISWorld is a private market research and analysis firm. The criteria for including firms in the IBISWorld dataset include total market capitalisation, market share and subjectively perceived importance in the Australian and New Zealand market. The sample represents a large proportion of expenditure by large Australian firms and a significant sample of total R&D expenditure. Company financial figures are deflated using CPI (WB 2007).The panel is unbalanced and includes data for the period 1989 to 2006, with the bulk of the observations relate to the years from 1992 to 2005. R&D expenditure data are not collected for all firms in the database. Only firms reporting non-zero R&D expenditure are considered because the nature of the data is such that it is not possible to distinguish between missing data and true zero expenditure.

Measuring the Cost of R&D Investment

The traditional instrument for analysing the effect of taxation on capital accumulation is Jorgenson's (1963) user cost of R&D (UCRD), which is defined in equation (3). The UCRD reflects the combined effect of a number of economy-wide and firm-specific variables. Of particular interest here is the policy component (incorporating both A_{it} and τ_t), and the financial cost of capital to the firm (r_{it}). These are discussed in the following sections.

Financial Cost of Capital

The actual R&D *project* hurdle rate is unobservable. The measures considered here reflect estimates of the general cost of capital to the firm; i.e., it is not specific to the type of investment within the firm. In addition to being the only feasible option for empirical analysis, this is justified on the basis that providers of capital generally invest in firms rather than individual projects. The current study considers two simple measures of the financial cost of capital. Each of these has strengths and weaknesses. One is based on a return on assets and the second is derived from the capital asset pricing model (CAPM).

The simpler of the two measures considered is the return on assets (ROA). This is essentially equivalent to the book value of WACC.[11] The logic behind this measure is that, averaged over the business cycle, the return actually generated by the company's assets should be correlated to the return required by investors. The return on assets is given by:

$$ROA_{it} = \frac{profit_{it} + interest_{it}}{assets_{it}}$$

where profit is measured before tax and extraordinary items, and the denominator is the book value of total assets. A methodological issue arises because R&D investment is not capitalised in firm financial statements. This means the denominator will be underestimated for firms who invest heavily in R&D, implying overestimated returns. For this reason, the formula is modified by adding an imputed R&D stock to the denominator and adding back annual R&D expenditure to the numerator. This modification does not change the measure a great deal because R&D stock is generally a small share of total assets. However, it is acknowledged that this is not a trivial assumption; the difficulties in accurately measuring the value of technology stock are an important challenge in the study of R&D investment. For the purpose of the regression analysis, the cost of capital employed the simple average of the risk free rate and a four year moving average (trailing) book value of ROA.

An obvious advantage of ROA is its relative simplicity and the fact that values are derived directly from firms' financial data. In this way all firms are treated identically regardless of whether they are listed, unlisted, foreign or domestic. A disadvantage of the return on assets measure is that past profitability may reflect firm technological advantages or demand prospects. Note though that the model will control for growth in sales and past R&D performance, which will minimise this concern.

The preferred measure of required ROR is calculated using the capital asset pricing model (CAPM). As noted previously, asset pricing theory generally finds the required ROR is a function of the covariance of the asset payoffs with the investors marginal utility (Cochrane 2005). The seminal CAPM predicts that the required ROR is an increasing function of the contribution an asset will make to the variance of an investor's overall portfolio. The required return is therefore an increasing function of the covariance of asset returns and returns on the investor's portfolio. The intuition is that, with a concave utility function, a downward movement in asset returns has a greater impact on utility when it occurs concurrently with a

[11] The return on assets, is equivalent to the WACC with the cost of equity calculated as the ex post return on book value of equity and excluding consideration of liabilities other than debt (e.g., trade credit and provisions).

downward movement in the investor's entire portfolio return. The CAPM gives the cost of equity as:

$$R_{it} = R_f + \beta_i \left(E\left(R_m \right) - R_f \right)$$

were R_{it} is the required rate of return on asset i, R_f is the risk free rate of return, β_i is the covariance between the asset returns and the market returns; and, $\left(E(R_m) - R_f \right)$ is the risk premium, or the difference between the expected return on the market and the risk free rate.

Based on this formula, required ROR for firms in the current sample was estimated incorporating industry volatility and firms' financial leveraging. The risk free rate used here is based on the implied annual return on 5 year treasury bonds. Long run estimates of the risk premium on listed Australian equity have varied between 6% (Brailsford et al. 2006) and 7.9% (Officer 1989). Reflecting this, analysis in this paper applies a risk premium of 7%.

To estimate firm-level required ROR, firm betas were obtained from Bloomberg[12] for a sample of 374 listed firms that are included in the IBISWorld set. Using this sample, the average industry level beta was then calculated at the 2 digit ANZSIC level. These industry average beta's are then "un-levered" using Hamada's (1972) equation to remove the effect on risk of financial leveraging. Industry average un-levered betas are given by:

$$\beta_{Iu} = \frac{\overline{\beta}_I}{1 + (1 - \tau)\overline{de_I}}$$

where $\overline{de_I}$ is the industry average long run debt to equity ratio and τ is the headline CIT. $\overline{\beta}_I$ is the average beta of all firms in the industry in the matched sample. The debt to asset ratio considered is non-current liabilities divided by the book value of equity. Firm specific betas are then calculated by re-leveraging based on firm specific debt to equity ratio. A two year moving average is used to smooth measurement error. Firms with book value of debt to equity above 5 were dropped from the sample.[13]

The cost of capital estimated using the CAPM reflects a more traditional finance approach to estimating the cost of equity. It has the advantage of being underpinned by a more complete theory of investor behaviour. However, it too is subject to some limitations. In particular about 30% of all observations are not publicly listed companies, investors in these firms will not necessarily hold efficient, diversified portfolio's that are assumed by the

[12] Downloaded from the website of Prof. Aswath Damodaran, Stern School of Business. Documentation notes that these are estimated by regressing weekly returns on stock against the local index, for the period 2002-2003.
[13] This affected 127 observations for which R&D data was also available.

CAPM. It is argued that this estimated required ROR reflects meaningful information about risk associated with the industry and financial leveraging that is available to investors ex ante. Furthermore, survey evidence suggests the CAPM is widely used in practice to price equity for investment decisions (Brailsford et al. 2004).

Policy Component

R&D tax policy is though to influence R&D behaviour through its effect on the cost of finance. R&D tax policy in Australia has undergone a number of changes over the period under consideration. In principle, the policy is available to all firms. However, the ability to benefit from the R&D Tax Concession varies among firms, depending on profit status and, after 2001, the level of R&D expenditure relative to the average over the previous three years.

In principle, if a company does not earn a taxable income it cannot benefit from the tax concession in that year, unused deductions can be carried forward to reduce taxable income in future years. Some past authors have incorporated this firm specific time cost into their calculation of the UCRD. However, there are further complications some of which are specific to Australia. In particular, prior to 1996 loss making firms had the potential to benefit from the tax concession through the syndicate scheme. As described in section 2, the scheme allows members of a research syndicate to claim their proportion of R&D at the concessionary rate and therefore the scheme “effectively allows [firms] to trade their tax losses … for R&D.” (Lattimore 1997 p.129). While no new syndicates could be registered after 1996 several remained in place for some time (SFPAC 1999). More generally, actual profit status provides only a noisy signal of *expected* profit status which is the variable of underlying interest. This is because many exogenous, random factors, including changes to input costs, sales or overall business conditions, can affect a firm’s profit. On balance, it is considered that to incorporate the time value of carrying forward concession benefits will add little information while it introduces measurement error and possible endogeneity, as such it will not be pursued.

The bonus 175% deduction, introduced in 2001, applies to nominal expenditure above the average of the preceding 3 years. The bonus deduction is only available on incremental expenditure, therefore firms effectively choose their R&D investment and average subsidy rate simultaneously. Everything else being equal, the more firms spend on R&D the lower the average tax price they will face. As observed previously, with a three year moving average base, the price of current R&D depends on R&D expenditure in the past three periods and as such these are all parts of the firm’s optimal dynamic programme. That is, R&D in each of these periods can be chosen simultaneously to maximise tax benefit. It is considered here that this source of endogeneity will be very difficult to avoid if the measure of tax price is calculated to include this source of variation.

In line with the foregoing discussion, variation tax policy is incorporated in the user cost of capital via a simple macroeconomic level indicator known as the b-index, thereby ensuring the measure is exogenous. The b-index reflects the tax component of user cost of R&D for a representative firm i.e., $b_t = \frac{1-A_t}{1-\tau_t}$.

Following the standard assumptions first proposed by McFetridge and Warda (1983) the representative firm is assumed to make a constant real R&D investment assuming a discount rate of 10%.[14] The measure also reflects changes to the treatment of depreciation requirements for capital equipment purchases. The representative R&D investment is assumed to comprise 90% current expenditure, two thirds of which represents the wages of researchers (60% total expenditure), with the remaining 10 percent comprising equally machinery and equipment and buildings and structures. This is reflective of the approximate composition of expenditure reported in industrial surveys (McFetridge and Warda 1983; ABS 1990-2006; Bloom et al. 2002).

Depreciation for tax purposes is calculated on a straight line basis according to the following standard rules: Machinery and Equipment: (1980-1996) 3 years, (1996-) 5 years. Buildings and Structures (1980-1986) 3 years (Lattimore 1997 p.94), (1987-) 40 years. Values of CIT (τ_t) applied are given by: 46% (1980-86), 49% (1987-88), 39% (1989-1993), 33% (1994-95), 36% (1996-1999), 34% (2000), 30% (2001-2006).

Summary User Cost of Capital

The analysis will consider two alternative measures of the user cost of R&D. Each is based on Jorgenson's cost of capital, which is given by: $c_{it} = (r_{it} + \delta) \times b_t$ where b is the b-index, which represents the tax component of user cost of R&D of marginal expenditure for a representative firm that increases nominal expenditure in each period. The rate of depreciation (δ) is assumed to be 15% (following Hall 1990; Shanks and Zheng 2006).[15] The two alternative measures of required ROR (r) are used, resulting in two measures of user cost of

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[14] In the case of an incremental incentive with the base defined as a moving average, the effective average incentive, assuming constant real expenditure on R&D, is equivalent to the marginal incentive under the weaker assumption that the firm increases expenditure above the base each period.

[15] Acknowledging this is somewhat arbitrary, alternative values were considered and these did not change the fundamental result.

R&D. The first, denoted by UCRD1, uses the measure based on average ROA. The second uses the required ROR derived by using the CAPM and is denoted by UCRD2.

Other Data

The risk free rate is the return on 5 year government bonds obtained from the Reserve Bank of Australia website. The real risk free rate is the nominal return on bonds less the rate of inflation estimated using CPI. Firms' R&D stock is imputed using the perpetual inventory model. A discount rate of 15% is assumed following Hall (1990) and Shanks and Zheng (2006). The initial level of R&D stock is assumed to be in equilibrium; i.e., $RS_i = \frac{R_i}{\delta}$. Prior to calculating the R&D stock a few missing values are linearly interpolated. This for 116 firms in the final sample, for 111 of which four or fewer missing points are filled in this way. The interpolated figures are only used for the calculation of the R&D stock, the dependent variable (R&D) is not interpolated in this way.

Table 3 Summary Statistics

Variable		*Obs*	*Mean*	*Std. Dev.*	*Min*	**Max**
RD_{it}	R&D Expenditure ($ '000)	2025	9,488	21,916	1.92	283,588
G_{it-1}	R&D Stock ($ '000)	2025	58,263	129,337	4.42	1,259,955
CR_{it-1}	Current Ratio (Liquidity)	2025	1.68	1.06	0.17	13.92
EMP_{it-1}	Employees	2025	3,116	8,146	4	88,995
$\Delta SALES_{it}$	Growth rate of Sales	2025	0.05	0.26	-2.67	2.89
$UCRD1_{it}$	User cost of R&D base on lagged average return on assets	1756	0.19	0.03	0.13	0.38
$UCRD2_{it}$	User cost of R&D base on CAPM	2025	0.21	0.02	0.16	0.30
b_t	R&D tax policy measure, the b-index	2025	0.85	0.06	0.72	0.90

6. Results

In order to set the stage for the estimates based on firm level data, it is useful to first reflect on the trends in aggregate national BERD against tax policy. Figure 1 depicts b_t against the BERD intensity of the Australian economy between 1980 and 2005. Some commentators have pointed to the downturn in aggregate BERD that occurred after 1996, at the same time as the tax concession rate was reduced from 150% to 125% (see for example 2000). However, note that contemporaneous correlation of the policy shift and the reduction in BERD in 1996 is atypical in a broader historical context. There have been several changes to tax policy, reflected by variation in the b-index over the period. However, these earlier policy shifts do not appear to be associated with commensurate variations in BERD intensity. Further evidence against attributing the downturn in R&D purely to the tax policy change in 1996 is provided by Banks (2000), who notes that the aggregate R&D of firms registered with the IR&D board actually increased between the financial years 1995-96 and 1998-99.

Figure 1 BERD Intensity and R&D Tax Policy 1980-2005

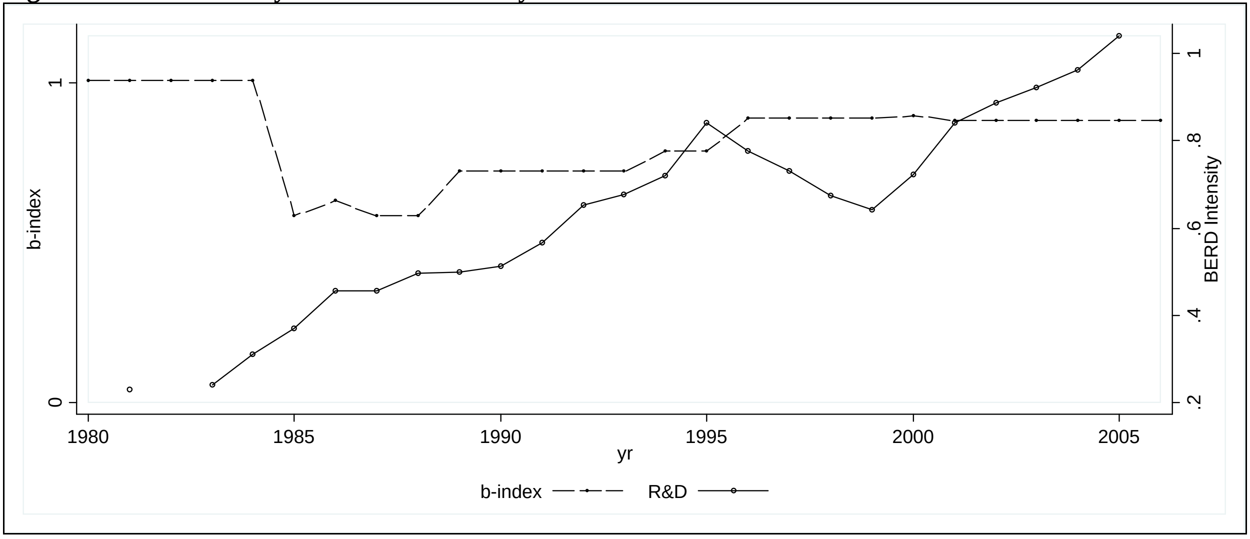

Table 4 depicts estimates of a firm R&D investment demand with the b-index (b_t) included independently of the risk free interest rate. In addition to being a useful starting point, the b-index has the advantage of being strictly exogenous. The standard neoclassical model including the imputed R&D stock is presented in column (I) and the dynamic model, estimated using the differenced GMM, is presented in column (II). The policy variable is not found to be significant in either estimate, though it does exhibit the expected sign. These results suggest that, holding other factors constant, R&D investment is not observed to increase following an increase in the generosity of the tax policy (reduction in after tax price).

It is difficult to disentangle other macroeconomic events from changes in tax policy using the b-index because it only exhibits inter-temporal variation. With such a short panel temporal variation alone does not provide a very strong basis on which to retrieve the policy effect. The constructed measures of user cost of R&D, incorporating firm specific cost of capital, essentially represent the same economic concept, the investment hurdle rate. However, the constructed measures exhibit both cross sectional and time series variation and hence it is hoped will enable the firm response to cost to be observed.

Table 4 Preliminary Regression Results

	(I) FE	(II) GMM
G_{it-1}	0.762***	
	(0.090)	
RD_{it-1}		0.631***
		(0.066)
Δb_{it-1}	-0.147	-0.319
	(0.50)	(0.43)
r_t	0.0598	0.0438
	(0.060)	(0.052)
CR_{it-1}	0.0957	0.0362
	(0.070)	(0.057)
EMP_{it-1}	0.181***	0.124**
	(0.058)	(0.052)
$\Delta SALES_{it}$	0.300***	0.379***
	(0.092)	(0.097)
ΔGDP_t	-0. 0227	-0. 399
	(2.6)	(2.5)
Observation	2031	1490
# Firms	493	329
Rho	0.6	.
m1, m2; H		0.0; 0.82; 0.22

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
m1 m2 H refer to first (second) order autocorrelation and Hansen test

The main regression results, including the two constructed measures of UCRD, are reported in Table 5. The results based on UCRD1 (required ROR based on historical ROA) are presented in columns (I)-(III). Columns (IV)-(VI) report the estimates including UCRD2 (required ROR derived from CAPM). Columns (I) and (IV) present the model that most directly reflects the modified neoclassical specification. In both cases, the residuals[16] exhibit strong serial correlation implying dynamic misspecification and that the estimated errors will be incorrect. FE estimates of the simple dynamic model are reported in columns (II) and (V). The residuals of these models do not result in serial correlation. Further, the dynamic model avoids estimating firms' R&D stock. Taking these factors into account, the simple dynamic model is preferred. The FE estimates (presented in columns II and V) may suffer from dynamic panel bias because of the correlation between the LDV and the transformed error term. Differenced GMM estimates are reported in columns (III) and (VI).

[16] Retrieved from the equivalent least squares dummy variable estimates (LSDV).

Table 5 Regression Results

	(I) FE	(II) FE	(III) GMM	(IV) FE	(V) FE	(VI) GMM
$RDStock_{it-1}$	0.773***			0.714***		
	(0.095)			(0.086)		
RD_{it-1}		0.504***	0.517***		0.472***	0.533***
		(0.049)	(0.071)		(0.045)	(0.060)
$\Delta UCRD1_{it-1}$	0.306	-0.00441	-0.174			
	(0.24)	(0.22)	(0.22)			
$\Delta UCRD2_{it-1}$				0.117	-0.0425	-0.0708
				(0.27)	(0.24)	(0.23)
CR_{it-1}	0.0595	0.0343	0.0492	0.108	0.0692	0.0571
	(0.073)	(0.065)	(0.062)	(0.069)	(0.063)	(0.058)
EMP_{it-1}	0.170***	0.149***	0.134**	0.220***	0.193***	0.160***
	(0.061)	(0.055)	(0.060)	(0.055)	(0.052)	(0.053)
$\Delta SALES_{it}$	0.317***	0.333***	0.346***	0.302***	0.331***	0.359***
	(0.10)	(0.096)	(0.10)	(0.091)	(0.088)	(0.095)
ΔGDP_{t}	-0.675	-0.245	0.822	0.105	-0.379	0.178
	(2.62)	(2.61)	(2.56)	(2.59)	(2.54)	(2.39)
Obs	1756	1756	1327	2025	2025	1487
# Firms	397	397	289	491	491	328
Rho	0.62	0.71	.	0.62	0.72	.
m1, m2; H			0.0; 0.72; 0.34			0.0; 0.76; 0.44

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
m1 m2 S refer to first (second) order autocorrelation and Hansen test

The principal result is that neither of the constructed measures of required rate of return are significant at conventional levels. As a corollary there is no evidence that tax incentives are an effective policy tool. Several other authors have found only a fragile result, including BIE (1993) which did not find a robust effect for the policy over all periods, and Dagenais (1997) who noted that no significant effect could be observed when controlling for firm specific effects. Of course, this result is not consistent with some past studies, most notably Hall (1992a). Three general reasons are conjectured as to why the results differ from some previous studies. These are methodological differences; unique characteristics of the Australian circumstance; and the general statistical difficulties in observing the effect of tax policy on R&D.

The first possible reason relates to differences in methodology between this study and previous studies that have found an effect. The principal methodological difference between this and previous studies is that UCRD applied in this study reflects a combination of macroeconomic policy and firm level financial cost of capital, whereas previous authors have generally utilised a measure incorporating the realised effective value of tax incentives. Measures based on a firm's effective tax subsidy can be subject to endogeneity because the tax price and level of R&D expenditure are simultaneously chosen (Hall and Van Reenen 2000). To account for this, past studies have employed an instrumental variable technique, for example, employing inter alia lagged tax price as instruments. These may not be suitable exogenous instruments because, as was discussed in section 3, with an incremental scheme and a three year moving average base, R&D investment in period t and period t+4 can be simultaneously chosen to maximise the benefit of the tax concession.

An alternative possible reason that the measure of user cost of R&D applied here is not found to be significant is that it may be that firms actually do not react strongly to financial factors which provides the principal source of variation in the UCRD employed. Several authors have found that a user cost of R&D based on financial, or economic, factors is not significant, while a user cost incorporating effective tax subsidy is significant (Bloom et al. 2002; Mulkay and Mairesse 2003). R&D tax incentives are thought to affect R&D by altering the cost of capital and this assumption underpins the framework of analysis for this and other studies. If financial factors in the cost of capital are not important determinants of R&D investment this raises the question as to what the actual mechanism, through which tax policy affects R&D, might be. It is also noteworthy that results reported in Table 4 did not find the policy variable to be significant.

A second reason for the failure to observe an effect of the user cost of capital is that Australia represents a specific, indeed unique, case. There are two important features of the Australian policy environment: the dividend imputation system and the fact that the incentive has been subject to substantial variation over time. For example, Guellec and van Pottelsberghe (2003) report evidence that the more volatile R&D tax policy is, the less effective it is. Similarly, as was described in section 2 the dividend imputation system in Australia acts to weaken the R&D tax concession policy. Thomas et al (2003) provide evidence that R&D tax incentives are less effective in countries that provide imputation credits.

The third important reason that no effect can be observed is that it reflects the general statistical and measurement difficulties faced by all evaluations of this kind. In particular, measurement issues and the difficulty of isolating the possibly small effect of policy among the many other factors driving firm R&D investment. Firm R&D investment schedules are very volatile in time series and, further, R&D investment choices are generally found to be largely explained by unobserved time invariant heterogeneity (Cohen 1995; Griffiths and

Webster 2004). In the current results, the dominance of the unobserved time invariant heterogeneity can be seen from the very high rho values, which represent the proportion of overall variation, accounted for by firm specific effects. The dominance of these firm specific factors further hinders isolating the, possibly small, effect of policy. For example, Dagenais et al (1997) found no effect of tax policy when controlling for firm heterogeneity.

It is also worth highlighting the difficulties in measuring the firm specific cost of R&D. For example, current accounting practices do not capitalise R&D expenditure and similarly technological assets are not well recorded or measured in a standard way. This has important implications for the measurement of total firm assets and shareholder equity. In this paper, the R&D stock was imputed using standard, yet unavoidably somewhat arbitrary, assumptions regarding starting stock and depreciation. As accounting practices are improved and standardised, better measures can be used in a range of cost of capital methodologies that will likely improve the accuracy of the result.[17]

Results for other determinants are similar regardless of which measure of user cost is used. The other determinants of firms' R&D considered in the model generally conform to our priors. Business conditions measured by GDP growth are not found to be significant. Fragility in the estimated coefficient is not wholly unexpected given the short length of the panel and that the only source of variation in this variable is across time. It is important to control for GDP growth because of its possible relationship with real interest rate. However these results suggest that controlling for growth in firm's own sales, the general business conditions are insignificant.

Firm current ratio is a measure of the availability of internal sources of finance. This is not found to be significant in either model, implying no evidence in support of the contention that internal funds are preferred in financing R&D or that firms investing in R&D are capital constrained. Some previous authors have included cash-flow as a proportion of capital stock which is then interpreted as an indicator of the availability of internal funds. Several authors have found that cash flow is an important determinant of R&D and interpreted this as evidence that liquidity is an important determinant of R&D investment (see Cohen 1995 and; Hall 2005 for reviews). As discussed in section 4, cash flow can also be interpreted as an indicator of profitability and future demand. In contrast the measure employed here captures the availability of internal sources of funds after all current liabilities have been paid. It may be that these measures are then capturing somewhat different economic phenomenon.

[17] See Hunter et al (2005) for a discussion on contemporary issues relating to accounting practices for intangibles in the context of Australia.

Alternatively, the absence of a strong result in these estimates may simply reflect the sample. In particular the sample considered in this analysis consists generally of large firms which in turn are generally considered to have advantages in raising capital. Finally it may be a feature of Australian equity markets such as the high share of foreign ownership. Recall that previous research has found the effect of liquidity to differ between nations (Hall et al. 1998).

Several researchers have observed firm R&D expenditure by Australian firms exhibits substantially volatility (Bosworth and Rogers 1998; DITR 2007b; Thomson 2008), implying that firms are frequently adjusting R&D expenditure. Not withstanding this, it appears that lagged R&D expenditure is a strong determinant of current R&D, even controlling for firm specific time invariant heterogeneity. The lagged dependent variable is a strong determinant of R&D investment. This reflects both the common element of replacement investment and may also reflect more complex dynamic issues relating to adjustment or time varying firm specific technological opportunity.

Firm size is found to be a significant determinant of R&D investment. A lagged R&D performance is included in the model this can be interpreted that the growth rate of R&D is higher among larger firms. This is broadly consistent with the Schumpeterian hypothesis that large firms have advantages in R&D due to their ability to appropriate the returns and capture dynamic spillovers from innovation.

The results show a strong accelerator effect in that a dominant variable in explaining R&D investment appears to be growth in total sales, with an elasticity around 40%. This result is consistent with recent firm level empirical literature (Mulkay and Mairesse 2003; Griffiths and Webster 2004). The growth rate in total sales revenue is interpreted as an indicator of output demand prospects. It may also reflect firm R&D investment opportunities. This is consistent with the suggested importance of ‘demand pull’ in directing innovation (Scherer 1982) and with the notion of induced innovation attributable to Hicks (1932).

Robustness Checking

As a robustness checking exercise a dynamic model was estimated including the level of the user cost of R&D rather than the year on year change (i.e., a partial adjustment model). This specification is prevalent in the existing literature based on a belief that that adjusting R&D expenditure is a costly and slow process which firms generally avoid. Results are presented in Table 6 and are entirely consistent with those discussed in the preceding section. In particular no role for the cost of capital in determining R&D investment can be identified.

Table 6 Robustness Testing, Partial Adjustment Specification

	(I) GMM	(II) GMM
RD_{it-1}	0.512***	0.517***
	(0.072)	(0.062)
$UCRD1_{it}$	-0.00719	
	(0.30)	
$UCRD2_{it}$		-0.240
		(0.23)
CR_{it-1}	0.0565	0.0632
	(0.062)	(0.060)
EMP_{it-1}	0.151**	0.180***
	(0.060)	(0.054)
$\Delta SALES_{it}$	0.338***	0.346***
	(0.10)	(0.094)
ΔGDP_{t}	0.441	0.778
	(2.51)	(2.34)
Obs.	1326	1486
# Firms	287	326
m1, m2; H	0.0; 0.81; 0.33	0.0; 0.81; 0.25

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
m1 m2 S refer to first (second) order autocorrelation and Hansen test
Regressions also control for trends

7. Discussion and Conclusion

This paper considered the determinants of R&D investment by a large sample of Australian firms. The principal interest has been to evaluate the importance of the cost of capital, and in particular the explanatory power of the R&D tax concession in Australia. It has been proposed that Australia represents a good case study because of the frequent revisions of both the tax concession arrangements and of the headline tax rate which affects the effective generosity of the scheme.

The framework for the analysis is a simple neoclassical model focusing on the short run elasticity of R&D with respect to the user cost of R&D. A range of possible methods for estimating the financial cost of capital exist. For this reason, two alternative measures of the financial cost of capital were considered. Each applies the same general indicator of tax generosity (the b-index), combined with a measure of required ROR based on the CAPM and the return on book value of assets, respectively.

The results do not provide statistical support for the view that the user cost of R&D is a significant determinant of firm level investment in R&D. Consequently, there is no evidence that tax policy can influence firms' investment in R&D via its effect on the user cost of R&D.

The result differ from some important previous studies and most notably Hall (1992a). Several possible reasons for this have been conjectured, principally stemming from the different measure of user cost of R&D applied in this study. In particular, past studies may have failed to appropriately deal with possible endogeneity in the cost of capital variable. Alternatively it may be that firms do not react to the financial cost of capital.

The results presented in this paper also attest that research into the role of price in R&D investment decisions has not yet arrived at consensus. This is not altogether surprising in light of the complex statistical and methodological issues confronted by this endeavour. In particular, the statistical difficulties inherent in finding possibly small effects of policy in the context of noisy R&D schedules dominated by idiosyncratic firm specific factors.

As regards the explanatory power of other proposed determinants of firm level R&D, the results are largely consistent with those of previous studies. Working capital ratio, or current ratio, is not found to be a significant determinant of R&D expenditure. That is, there is no evidence that liquidity plays a major role in determining R&D investment. Finally, and consistent with previous studies, a strong firm level accelerator effect can be observed. Growth in sales, interpreted as a signal of future profitability and output demand is found to be a dominant determinant of firm level investment in R&D. From a policy perspective, this finding suggests governments may do well emphasising pull factors rather than push factors in order to influence technological development. For example, it may be more effective to ensure firms face appropriate price signals than to directly subsidise R&D in advance of commercial need. To illustrate, consider the emerging policy objective of greater energy efficiency and reducing industry CO_2 emissions. To this end, governments have the choice between subsidising investment in R&D, or alternatively, stimulating technological change by through market signals. The results in this paper suggest the latter choice will be more effective whether or not coupled with the former.

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