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Russell Thomson

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Russell Thomson
Melbourne Institute of Applied Economic and Social Research
The University of Melbourne

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Melbourne Institute of Applied Economic and Social Research
The University of Melbourne
Victoria 3010 Australia
***Telephone* (03) 8344 2100**
***Fax* (03) 8344 2111**
***Email* melb-inst@unimelb.edu.au**
***WWW Address* http://www.melbourneinstitute.com**

Abstract

This paper presents new estimates of the efficacy of R&D tax incentives using cross-country cross-industry data and a novel measure of tax policy that incorporates differences in the average capital–labour ratio in R&D investment across industries and variation in the tax treatment of different expenditure types across countries and over time. The results suggest that, in the short run, industry increases R&D investment by 0.24 dollars for every dollar of tax revenue forgone. The results appear to be more robust than estimates based on cross-country or firm-level data.

JEL classification: E22, O31, O57

Keywords: Innovation policy, R&D tax credits, determinants of R&D investment

1. Introduction

Do tax credits induce investment in research and development (R&D)? This paper contributes evidence using newly published data on R&D activity by type of expenditure at the industry level across 23 OECD countries. A novel country–industry specific measure of the tax policy is developed that incorporates differences in the average capital–labour ratio in R&D investment across industries, and variation in the tax treatment of different expenditure types across country and over time.

Existing evidence on the influence of tax policy on R&D investment is mixed. The fundamental problem of research design relates to finding an exogenous measure of tax policy that exhibits sufficient variation for robust identification. To date research has taken one of two approaches: cross-country or firm-level. The novel cross-industry cross-country approach pursued in this paper addresses many of the drawbacks reflected in these traditional approaches.

The firm-level approach involves modelling R&D investment on firms' effective benefit from the prevailing tax policy. Variation in firms' ability to benefit from tax credits typically depends on their profit status as well as their current and historic R&D expenditure. Unfortunately, from a statistical perspective, both of these are endogenous to current R&D investment; that is, R&D investment and its after-tax cost are jointly determined (Hall 1995). Over and above endogeneity issues, statistical identification in firm-level studies is complicated by the fact that R&D expenditure depends largely on idiosyncratic unobservable firm-level attributes (Griffiths and Webster 2010). For example, some researchers find that the estimated effect of tax credits is fragile to controlling for fixed effects (e.g., Mairesse and Mulkey 2004). Reflecting these difficulties, estimates of the elasticity of R&D with respect to tax price have varied considerably—ranging from zero (Eisner *et al.* 1984; Thomson 2010) to –2.7 (Hall 1992).

Cross-country analysis is the principal alternative to firm-level studies. Cross-country analysis exploits ostensibly exogenous policy variation between countries to estimate the effect of tax policy on aggregate R&D investment. Studies which have considered the issue using cross-country data have made important inroads. These studies have estimated that the short-run tax price elasticity with respect to demand for R&D is somewhere between 15 and 30 per cent in the short run and up to around unity in the long run (Guellec and Pottelsberghe 2000; Bloom *et al.* 2002; Falk 2006). Wilson *et al.* (2009) modestly expand the available sample by considering US state-level tax incentives and investment in a manner analogous to the cross-country approach. These studies all rely on only a few hundred noisy, highly persistent observations and as such can also be prone to fragility (e.g., see Falk 2006). Moreover, since major revisions to tax policy are rare, identification can rest on a handful of observations. It will be demonstrated below that the cross-country approach appears to exhibit serious fragility to the inclusion of outliers.

2. Approach and Methodology

This paper uses recently released OECD cross-country industry-level data to identify the elasticity of R&D investment with respect to tax price. The data cover a panel of 31 industries in 23 OECD counties covering the years 1988 to 2005. The dependent variable is R&D financed by the business enterprise sector measured in constant 2005 international dollars (OECD 2011a). The novel approach to identification involves exploiting variation in tax treatment of R&D expenditure types (e.g., labour and capital) in each country and variation in the expenditure mix across industries. The tax treatment of different types of expenditure varies because credits do not generally apply to all types of expenditure. For example, over much of the period considered in this study Netherlands provided a tax credit on labour expenses only (see Thomson 2012 for details). Different expenditure types are also subject to different rates of allowable depreciation.

The estimating equation follows the parsimonious structure proposed by Bloom *et al.* (2002). The specification allows for a partial adjustment by including a lagged dependent variable which includes industry value-added, as well as year effects to account for shared macroeconomic shocks and the general trend toward more generous tax policy. The estimating equation is given by:

$$\text{R\&D}_{ijt} = \beta_1 + \beta_2 \text{R\&D}_{ijt-1} + \beta_3 \text{tax\_price}_{ijt} + \beta_4 \text{IVA}_{ijt} + \alpha_{ij} + \varepsilon_{ijt} \quad (1)$$

where $\text{R\&D}_{ijt}$ is the aggregate R&D investment of industry *i* in country *j* in year *t*. **IVA** is industry value added (OECD 2011b) and **tax_price** is a measure of tax policy. The error structure is assumed to reflect both industry–country fixed effects (denoted by α_{ij}) and an idiosyncratic component (denoted by ε_{ijt}).

The measure of tax policy is based on the standard adaptation of Jorgenson's (1963) 'user cost of capital'. The measure is commonly referred to as the 'tax price' of R&D and was first proposed by Warda and McFetridge (1982) and subsequently used by Bloom *et al.* (2002), Guellec and van Pottelsberghe (2003), Wilson (2009) and others. However in this analysis, unlike all previous studies, the tax component of the user cost of R&D is calculated separately for each type of expenditure (e.g., capital and labour) in each country in each year. Except for calculating separate measures of tax price of each expenditure type, the calculations used here follow the standard assumptions adopted by past authors. The measure reflects the reductions to corporate tax liabilities associated with each dollar invested in R&D for a representative large firm. The calculations assume that firms have sufficient taxable income to claim the full amount of R&D tax incentives in the current year and ignore personal income tax and tax treatment of dividends and capital gains.

The formula for the tax price of R&D is given by:

$$\text{tax\_price} = \frac{\text{ATC}}{1 - \text{CIT}} \tag{2}$$

where ATC is the after-tax cost of R&D allowing for reductions in corporate income tax liabilities that result from the expenditure; and CIT is the corporate income tax rate. The after-tax cost of R&D investment can be expressed in general terms as:

$$\text{ATC} = 1 - (\text{CIT}) \times \overbrace{(\text{NPV of allowable claims}) \times (\text{proportion deductable})}^{\text{Total value of allowable deductions}} - (\text{credit}) \tag{3}$$

This states that a firm's after-tax cost is reduced by allowable deductions multiplied by the corporate income tax rate (CIT) as well as any explicit tax credits. The value of deductions is determined by two factors: (1) the net present value (NPV) of the stream of allowable claims; and (2) the proportion of the NPV that can be deducted. In some countries eligible expenditure can be deducted at a rate greater than 100 per cent, which will be referred to as augmented deduction. Note that the tax system provides an implicit subsidy if the allowable rate of depreciation is more rapid than the economic depreciation of the technology produced through the R&D investment.

For this analysis, the after-tax cost of four categories of R&D expenditure was calculated: 'current expenditure', 'labour costs', 'machinery and equipment', and 'buildings and structures'. The calculations include representative allowable deduction as well as eligibility to special credits or augmented deductions for each category (for details see Thomson 2012). In all cases in the sample, labour expenses can be deducted at 100 per cent in the year they are incurred (or more where augmented deduction is allowable). The net present value (NPV) of deductions for tangible capital was based on allowable depreciation schedules that are defined in the national tax code.

A common type of policy, known as an incremental scheme, is where only R&D expenditure over and above a defined base level is eligible for credits or augmented deductions. The base is most commonly defined as the average expenditure in the previous three years. This type of incremental scheme presents a complexity to modelling the effective incentive power of tax policy. Only firms which increase their year-on-year R&D expenditure receive any benefit. For a firm that increases nominal spending, the marginal R&D dollar is eligible for the tax credit, but also reduces the share of future expenditure which will be eligible. Following past authors, we model incremental schemes, where the base is defined as a trailing *k*-period moving average, the credit or deduction rate is multiplied by $1-\frac{1}{k}\sum_{i=1}^{k}(1+r)^{-i}$ which reflects the marginal value of an incremental incentive for a firm with increasing R&D expenditure or equivalently the average share of eligible expenditure for a firm maintaining constant real R&D expenditure (see Richardson and Wilkie 1995). Consistent with past studies, a fixed 10 per cent discount rate is applied.

To arrive at a measure of the industry-specific tax price in each country, the four separate measures (for each expenditure class) are combined as a weighted average. A measure of industry tax price that is based on weighting the tax prices of each expenditure class by the prevailing expenditure mix will be endogenous if industries in each country optimise their expenditure mix to maximise their tax benefit. To avoid this potential problem, industry-specific tax price is measured by weighting the national tax prices of each expenditure class by the *global* expenditure share mix for each industry.

Data included in the regression estimates are summarised in Table 1.

Table 1 Data summary

Variable	Mean	Std dev.
Corporate tax rate (CIT)	0.346	0.094
tax_price	0.937	0.122
Industry value added ($ millions)	18,000	49,700
R&D ($ million)	537	1,773

3. Estimation and Results

Before presenting the industry-level results, Table 2 illustrates the potential fragility of cross-country analysis and thereby a measure of the advantage of the approach developed in this study. The first column in Table 2 depicts estimates of a model analogous to that of Guellec and van Pottelsberghe (2003) which is estimated using the (larger) sample of aggregate country-level observations compiled for this study. The estimated short-run elasticity is 0.18, which is reasonably similar to the 0.27 estimated by Guellec and van Pottelsberghe. The second column presents the same model estimated on a sample that omits very large policy shifts; specifically, the three observations where the tax price changed by more than 30 per cent year-on-year. With these large shifts omitted the estimated elasticity of tax price is found to be statistically indistinguishable from zero. The third and fourth columns present a similar exercise using the estimating equation preferred by Bloom *et al.* (2002). The results presented in Table 2 are based on data that have been compiled independently using similar methods to previous authors; it is not the actual data that these authors compiled. However, Guellec and van Pottelsberghe did provide the actual data they used in their study and it was confirmed that the same fragility is observable using their data: omitting observations where the tax price changes by more than 30 per cent results in an estimated elasticity that is indistinguishable from zero.

Table 2 Cross-country estimates and robustness to outliers

Dependent variable:	**Δ R&D**			**R&D**	
	(1)	(2)		(3)	(4)
Δ R&D$_{t-1}$	0.157***	0.148***	**R&D$_{t-1}$**	0.865***	0.853***
	(0.0484)	(0.0479)		(0.0302)	(0.0309)
Δ tax_price$_{t-1}$	–0.179*	–0.0312	tax_price$_{t-1}$	–0.176**	–0.124
	(0.105)	(0.147)		(0.0836)	(0.0855)
Δ GDP$_{t-1}$	0.608***	0.663***	**GDP$_{t-1}$**	0.00905	0.0486
	(0.234)	(0.232)		(0.110)	(0.110)
Δ RDFGOV$_{t-1}$	–0.0132	–0.0130			
	(0.0128)	(0.0126)			
Δ HERD$_{t-1}$	0.0163	0.0225			
	(0.0582)	(0.0577)			
Δ GOVRD$_{t-1}$	0.157***	0.165***			
	(0.0594)	(0.0586)			
Country fixed effects	N	N		Y	Y
Year dummies	Y	Y		Y	Y
Observations	379	376		409	405
R-squared	0.183	0.168		0.997	0.997

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

Estimates using the preferred cross-country cross-industry approach are presented in Table 3. Each model includes country–industry fixed effects and year dummies. The coefficients depicted in column (1) are estimated on the full sample. In column (2), instances where the tax price changed by more than 30 per cent are omitted from the estimating sample. In column (3) the sample is restricted to industries in manufacturing sectors only. The main result is that the short-run tax price elasticity of private sector R&D investment is 0.25–0.30. The result is also robust to estimating in differences and the inclusion of additional control variables analogous to those included by Guellec and van Pottelsberghe (2003). The long-run effect is effectively determined by the estimate of the adjustment coefficient, which confronts its own estimation issues that this paper does not aim to contribute to.

Table 3 Regression results

Variables	Full sample (1)	No 'outliers' (2)	Manufacturing only (3)
$R\&D_{t-1}$	0.725***	0.722***	0.678***
	(0.00870)	(0.00933)	(0.0104)
IVA_{t-1}	0.173***	0.177***	0.159***
	(0.0235)	(0.0249)	(0.0248)
Tax-price_{t-1}	–0.262***	–0.234***	–0.305***
	(0.0778)	(0.0885)	(0.0853)
Country–industry fixed effects	Y	Y	Y
Year effects	Y	Y	Y
Observations	6,658	6,164	5,282

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

4. Conclusion

Notwithstanding worldwide enthusiasm for tax incentives for R&D, existing evidence on their effectiveness remains mixed. A fundamental issue of research design is finding an exogenous measure of tax policy that exhibits sufficient variation to robustly identify their impact. The analysis presented in this paper exploits the fact that different tax treatment of different expenditure classes implies that tax policies vary in their relative generosity across industries.

The results suggest that, in the short run, industry increases R&D by 0.24 dollars for every dollar of tax revenue forgone. Most importantly the estimates appear to be considerably more robust than those derived using the traditional cross-country or firm-level approaches. The findings are robust to reasonable variation in estimation approach and whether or not the largest policy revisions are included in the estimating sample.

The identification approach, based on exploiting inter-industry differences in the composition of expenditure and differences in tax treatment of these, may also prove useful in estimating the efficacy of other tax-based investment incentives (e.g., fixed capital investment incentives). The approach could also be used to investigate whether particular classes of expenditure are more amenable to influence by tax incentives.

Before concluding it is important to acknowledge the remaining caveats that have not been addressed by this study. First, it is possible that some of the observed effect of tax credits represents a reclassification of existing expenditure. Second, it is possible that, if inputs to R&D are inelastic, subsidising R&D investment will lead to inflated factor input prices rather than increased real expenditure (Goolsbee 1998). Though in this regard, recent evidence indicates that input price inflation is not a significant concern in aggregate (Thomson and Jensen 2012).

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