



Fiscal Incentives for Research and Development

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Abstract

It is often argued that since the social return to R&D exceeds the private return, the government should provide incentives for R&D expenditure. This paper considers the issue of the impact of such incentives on the fiscal position of the government, using a simple comparative static model. In particular, it is argued that it is possible that the social return from R&D might be sufficient to allow R&D incentives to more than pay for themselves. The model is calibrated to examine what values of the key parameters are required in order for this conclusion to hold.

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1. Introduction

It is often argued that the social return to R&D spending exceeds the private return,¹ and that for this reason the government should provide incentives to the private sector to undertake R&D, since otherwise there would be an inefficiently low level of R&D. However, a government considering whether to provide such incentives must consider the impact that this would have on its fiscal position. The purpose of this paper is to provide a policymaker with some rough approximations of the fiscal implications of providing R&D incentives.

This policy question is particularly pressing for countries that are going through the transition from developing to developed country status. The transition is generally held to be associated with a reduced reliance on factor, particularly capital, accumulation, and increased reliance on growth of total factor productivity. Since the latter is, at the very least, substantially associated with technological change, a relevant question for countries faced with the transition to greater reliance on technological progress is whether policy intervention can ease the transition. This paper investigates a limited dimension of this broader question - viz. the impact of fiscal incentives for R&D on tax revenues and output.

The model presented here is a simple comparative static model - quite a simplification to make in the context of issues which are in many respects dynamic. However, we believe that the trade-off is worthwhile in that, providing that the model is not too far off as an approximation of the economy,

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¹The classic exposition is Arrow (1962). For a more recent discussion, see Hall (1996).

its simplicity allows most of the parameters to be matched to economic variables for which we have empirical estimates, or at least some idea of what would constitute reasonable estimates.

The model involves perfectly competitive firms, and the difference between the private and social returns to R&D is captured through a spillover effect, whereby an increase in R&D spending by one firm raises the productivity of other firms (perhaps through the acquisition of knowledge which is not fully excludable). We do not explicitly model the international transfer of knowledge, although the return to R&D in our model could be interpreted as arising in part from an increased ability to absorb foreign technologies.² Again, for simplicity, we treat all expenditure on R&D and physical capital as current expenditure - i.e. it is not the stock of capital and R&D that is productive, but rather its flow.

The structure of the paper is as follows. In section 2., the model is formulated. In section 3., the impact of fiscal incentives on tax revenue is considered, and then in section 4. their impact on output is discussed. Finally, in section 5. the model is applied empirically to investigate what sort of parameter values would lead to a positive or negative impact on tax revenue. Section 6. concludes.

2. Formulating the model

Assume that an economy comprises identical, price-taking firms which produce a single good by means of the following production technology:

$$Y = Y(R_T, R, L, K); Y_i > 0; Y_{ii} < 0; Y_{ij} = 0 \text{ for } i \neq j; i, j = R_T, R, L, K \quad (1)$$

where Y is the output of the firm, R is the R&D undertaken by the firm, L is the firm's labour input, K is the firm's capital input, and R_T is the total level of R&D in the economy, which the firm takes as given. Assume the marginal product of all inputs to be positive but diminishing, and the cross partial derivatives to be zero.

The government sets the tax rate, as well as the level of tax incentives, at the beginning of the period. Given these values, firms then try to maximise after-tax profits. The problem facing an individual firm is thus:

$$\max_{R, L, K} \pi = (1 - \tau) [Y(R_T, R, L, K) - wL - rK] - hR(1 - \lambda) [1 - \tau(1 + \delta)] \quad (2)$$

where π is after-tax profit, w is the wage rate,³ r is the cost of capital, h is the cost of R&D, τ is the corporate tax rate, δ is the additional rate at which R&D can be deducted from before-tax profits,

²For a paper which explicitly addresses the international transfer of knowledge in a tax incentive model, see Griffith et al (2001).

³Input prices are measured in units of the output good. (*Is this footnote necessary?*)

and λ is the proportion of R&D that is funded by government grants.⁴

Relevant first order conditions are then:

$$\begin{aligned} Y_L(R_T, R^*, L^*, K^*) &= w \\ Y_K(R_T, R^*, L^*, K^*) &= r \\ Y_R(R_T, R^*, L^*, K^*) &= \frac{h(1-\lambda)[1-\tau(1+\delta)]}{1-\tau} \end{aligned} \quad (3)$$

where $*$ denotes the profit-maximising level of the input. The assumptions on the production function imply that the profit function is concave, hence the first order conditions identify a maximum.

Since firms are assumed to be identical, the total level of R&D expenditure in the economy will be given by $R_T = nR^*$, where n denotes the number of firms in the economy. Since the firms are perfectly competitive, n is arbitrary, thus we will normalise n on 1 for convenience.

Tax revenue, T , from the representative firm is given by:

$$T = \tau [Y - wL^* - rK^* - hR^*(1-\lambda)(1+\delta)] - \lambda hR^* \quad (4)$$

which represents the tax revenue on net output, less any R&D subsidy paid from the fiscus to the firm.

3. Impact of fiscal incentives on tax revenue

3.1. Changes in the rate of tax allowance

The change in tax revenue when the rate of the tax allowance is increased is given by:

$$\frac{\partial T}{\partial \delta} = \tau \left[\begin{array}{l} Y_{R_T} \frac{\partial R^*}{\partial \delta} + Y_R \frac{\partial R^*}{\partial \delta} + Y_L \frac{\partial L^*}{\partial \delta} + Y_K \frac{\partial K^*}{\partial \delta} - w \frac{\partial L^*}{\partial \delta} \\ -r \frac{\partial K^*}{\partial \delta} - h(1-\lambda)(1+\delta) \frac{\partial R^*}{\partial \delta} - (1-\lambda)hR^* \end{array} \right] - \lambda h \frac{\partial R^*}{\partial \delta}$$

⁴All types of expenditure can be fully deducted once for purposes of calculating taxable profits. Accordingly, a value of $\delta = 0.5$ must be interpreted as meaning that a firm can claim one and a half times the amount of its R&D expenditure as a tax deduction. Thus the form of the tax incentive that we are considering is one in which the government allows a deduction against the firm's taxable income, although in practice there are many different ways in which governments have structured tax incentives. Note also that we assume that R&D funded by government grant cannot also be claimed by the firm as a tax deduction.

Substituting in for the first order conditions $Y_L = w$ and $Y_K = r$ from equation (3) yields:⁵

$$\begin{aligned}
 \frac{\partial T}{\partial \delta} = & \underbrace{\tau Y_{R_T} \frac{\partial R^*}{\partial \delta}}_{\substack{1) \text{ marginal tax} \\ \text{revenue} \\ \text{due to} \\ \text{spillover} \\ \text{from R\&D}}} + \underbrace{\tau Y_R \frac{\partial R^*}{\partial \delta}}_{\substack{2) \text{ marginal tax} \\ \text{revenue} \\ \text{due to private} \\ \text{marginal product} \\ \text{of R\&D}}} & (5) \\
 & \underbrace{-\tau h(1-\lambda)(1+\delta) \frac{\partial R^*}{\partial \delta}}_{\substack{3) \text{ marginal tax} \\ \text{loss} \\ \text{due to} \\ \text{increased} \\ \text{R\&D}}} - \underbrace{\tau h(1-\lambda) R^*}_{\substack{4) \text{ marginal tax} \\ \text{loss} \\ \text{on existing} \\ \text{R\&D}}} - \underbrace{\lambda h \frac{\partial R^*}{\partial \delta}}_{\substack{5) \text{ increased} \\ \text{grant} \\ \text{cost due to} \\ \text{increased} \\ \text{R\&D}}} \\
 & \underbrace{\hspace{10em}}_{\text{cost of increased tax allowance}}
 \end{aligned}$$

We now substitute for the remaining first order condition from equation (3), that for Y_R , to get:

$$\frac{\partial T}{\partial \delta} = \tau \left[Y_{R_T} \frac{\partial R^*}{\partial \delta} - \frac{h\delta(1-\lambda)}{1-\tau} \frac{\partial R^*}{\partial \delta} - h(1-\lambda) R^* \right] - \lambda h \frac{\partial R^*}{\partial \delta} \quad (6)$$

Notice that the combined effect of the extra tax revenue due to the private marginal product of R&D [effect (2) in equation 5] and the extra tax deduction claimed by the firm due to the increase in R&D [effect (3) in equation 5] is given by the second term in brackets in equation (6), and that it is negative. Thus unless there is some spillover effect from R&D, increasing the rate of the tax allowance will reduce tax revenue. This is of course as expected: the presence of tax incentives causes the firm to choose a level of R&D at which the private marginal product of R&D is less than its price, leading to a reduction in before-tax profits and thus lower tax revenue unless the social marginal product of R&D is greater than its private marginal product.

We define the following variables:

$$Y_{R_T} \frac{R^*}{Y} \equiv \phi, \quad \frac{\partial R^*}{\partial \delta} \frac{1}{R^*} \equiv \eta, \quad \alpha \equiv \frac{hR^*}{Y}$$

⁵Note that this causes the terms containing the effect of labour and capital to disappear from the tax equation. This is because at the profit-maximising level, the marginal products of these factors of production are set equal to their prices. Thus, when there is any marginal change in the employment of these factors, the effect on tax revenue due to the resulting change in output is exactly offset by the change in the amount of expenditure that can be deducted from taxable profits.

which is to say that the elasticity of output with respect to the spillover effect of R&D is ϕ , that the semi-elasticity of R&D with respect to the tax allowance is η , and that the ratio of Gross Expenditure on R&D (GERD) to output, reflecting the initial research intensity of the economy, is α . Dividing equation (6) through by Y and rearranging yields:

$$\begin{aligned} \frac{\partial T}{\partial \delta} \frac{1}{Y} &= \tau \left[Y_{R_T} \frac{R^*}{Y} \frac{\partial R^*}{\partial \delta} \frac{1}{R^*} - \frac{\delta(1-\lambda)}{1-\tau} \frac{\partial R^*}{\partial \delta} \frac{1}{R^*} \frac{hR^*}{Y} - (1-\lambda) \frac{hR^*}{Y} \right] - \lambda \frac{\partial R^*}{\partial \delta} \frac{1}{R^*} \frac{hR^*}{Y} \\ &= \tau \phi \eta - \tau \frac{\delta(1-\lambda)}{1-\tau} \alpha \eta - \tau(1-\lambda) \alpha - \lambda \alpha \eta \end{aligned} \quad (7)$$

which gives the change in tax revenue, as a proportion of output, when there is a change in the rate of tax allowance for R&D expenditure.

3.2. Changes in the level of the grant

The change in tax revenue when the rate of the tax grant is increased is given by:

$$\frac{\partial T}{\partial \lambda} = \tau \left[\begin{array}{l} Y_{R_T} \frac{\partial R^*}{\partial \lambda} + Y_{R_i} \frac{\partial R^*}{\partial \lambda} + Y_L \frac{\partial L^*}{\partial \lambda} + Y_K \frac{\partial K^*}{\partial \lambda} - w \frac{\partial L^*}{\partial \lambda} \\ -r \frac{\partial K^*}{\partial \lambda} - h(1-\lambda)(1+\delta) \frac{\partial R^*}{\partial \lambda} + (1+\delta) hR^* \end{array} \right] - \lambda h \frac{\partial R^*}{\partial \lambda} - hR^*$$

Substituting for $Y_L = w$ and $Y_K = r$ once again causes the terms involving labour and capital to vanish, yielding:

$$\begin{aligned} \frac{\partial T}{\partial \lambda} &= \underbrace{\tau Y_{R_T} \frac{\partial R^*}{\partial \lambda}}_{\substack{1) \text{ marginal tax} \\ \text{revenue} \\ \text{due to} \\ \text{spillover} \\ \text{from R\&D}}} + \underbrace{\tau Y_{R_i} \frac{\partial R^*}{\partial \lambda}}_{\substack{2) \text{ marginal tax} \\ \text{revenue} \\ \text{due to private} \\ \text{marginal product} \\ \text{of R\&D}}} + \underbrace{\tau(1+\delta) hR^*}_{\substack{3) \text{ decreased} \\ \text{tax deductions} \\ \text{due to higher} \\ \text{grant funding}}} \\ &\quad \underbrace{\hspace{15em}}_{\text{benefit from increased grant}} \\ &= \underbrace{-\tau h(1-\lambda)(1+\delta) \frac{\partial R^*}{\partial \lambda}}_{\substack{4) \text{ marginal tax} \\ \text{loss} \\ \text{due to} \\ \text{increased} \\ \text{R\&D}}} - \underbrace{\lambda h \frac{\partial R^*}{\partial \lambda}}_{\substack{5) \text{ increased grant} \\ \text{cost} \\ \text{on existing} \\ \text{R\&D}}} - \underbrace{hR^*}_{\substack{6) \text{ increased grant} \\ \text{cost} \\ \text{due to} \\ \text{increased R\&D}}} \\ &\quad \underbrace{\hspace{15em}}_{\text{cost from increased grant}} \end{aligned}$$

From equation (3), we can again substitute in for Y_R :

$$\frac{\partial T}{\partial \lambda} = \tau \left[Y_R \frac{\partial R^*}{\partial \lambda} - \frac{h\delta(1-\lambda)}{1-\tau} \frac{\partial R^*}{\partial \lambda} + (1+\delta)hR^* \right] - \lambda h \frac{\partial R^*}{\partial \lambda} - hR^* \quad (8)$$

Notice that, for the same reasons as discussed above in the case of the tax allowance, the combined effect of the extra tax revenue due to the private marginal product of R&D [effect (2)] and the extra tax deduction claimed by the firm due to the increase in R&D [effect (4)] is negative.

We can differentiate through equation (3) to obtain the following two expressions:⁶

$$\begin{aligned} \frac{\partial R^*}{\partial \delta} &= \frac{-h(1-\lambda)\tau}{(1-\tau)Y_{RR}} \\ \frac{\partial R^*}{\partial \lambda} &= \frac{-h[1-\tau(1+\delta)]}{(1-\tau)Y_{RR}}. \end{aligned}$$

Since we have assumed that the private return from R&D exhibits diminishing marginal productivity ($Y_{RR} < 0$), $\frac{\partial R^*}{\partial \delta} > 0$ provided $\lambda < 1$ and $\frac{\partial R^*}{\partial \lambda} > 0$ provided $\tau < \frac{1}{1+\delta}$. These are plausible assumptions, since if $\lambda > 1$, the grant more than pays for the R&D costs, so the firm will undertake R&D purely in order to receive the grant. The $\tau < \frac{1}{1+\delta}$ assumption is also reasonable since, if we assume that $\delta < 1$ (i.e. the government does not allow more than double deduction of R&D expenditure), then $\frac{\partial R^*}{\partial \lambda} > 0$ unless $\tau > 0.5$, a relatively high tax rate on firms. For the rest of paper, we will adopt the parameter restrictions $\lambda < 1$, $\delta < 1$ and $\tau < \frac{1}{1+\delta}$.

Given our assumptions, we can use the above expressions to establish the following relationship:

$$\frac{\partial R^*}{\partial \lambda} = \frac{[1-\tau(1+\delta)]}{(1-\lambda)\tau} \frac{\partial R^*}{\partial \delta}. \quad (9)$$

Substituting for equation (9) into equation (8), dividing through by Y and rearranging yields:

$$\begin{aligned} \frac{\partial T}{\partial \lambda} \frac{1}{Y} &= \frac{[1-\tau(1+\delta)]}{(1-\lambda)\tau} \left(\phi\tau\eta - \frac{1-\lambda}{1-\tau}\tau\alpha\delta\eta - \alpha\lambda\eta - \tau(1-\lambda)\alpha \right) \\ &= \frac{[1-\tau(1+\delta)]}{(1-\lambda)\tau} \left(\frac{\partial T}{\partial \delta} \frac{1}{Y} \right) \end{aligned} \quad (10)$$

which gives the change in tax revenue, as a proportion of output, when there is a change in the level of the grant for R&D expenditure. Given the assumptions that we are making, $\frac{[1-\tau(1+\delta)]}{(1-\lambda)\tau} > 0$, and thus $\frac{\partial T}{\partial \lambda} \frac{1}{Y}$ is a positive function of $\frac{\partial T}{\partial \delta} \frac{1}{Y}$.

⁶Note that in deriving these expressions, we have used the assumption made in equation (1) that the cross partial derivatives $Y_{R_i L_i}$ and $Y_{R_i K_i}$ are zero.

3.3. Determinants of the impact of tax incentives on tax revenue

Proposition 1 *An increase in tax incentives⁷, whether in the form of a tax allowance or a grant, will increase the tax revenue iff:*

$$\phi > \frac{\alpha\delta(1-\lambda)}{1-\tau} + \frac{\alpha(1-\lambda)}{\eta} + \frac{\alpha\lambda}{\tau} = \phi_{\min} \quad (11)$$

Proof. In equation (7) set $\frac{\partial T}{\partial \delta} \frac{1}{Y} > 0$. ■

Remark 2 *Since ϕ and η are the parameters which would be the most difficult to estimate empirically, it is useful to interpret equation (11) such that it states, for a particular estimate of η , what level the estimate of ϕ must exceed if an increase in the level of the tax incentive is to have a positive effect on tax revenue.*

Remark 3 *In the case where currently there are no incentives for R&D in the economy, i.e. $\delta = \lambda = 0$, equation (11) reduces to:*

$$\phi > \frac{\alpha}{\eta}$$

Proposition 4 *A larger spillover effect of R&D improves the tax impact of an increase in tax incentives.*

Proof. Immediately from:

$$\frac{\partial \left(\frac{\partial T}{\partial \delta} \frac{1}{Y} \right)}{\partial \phi} = \tau\eta > 0$$

■

Remark 5 *The only impact of a higher spillover effect is to increase tax revenue due to a greater expansion of output.*

Proposition 6 *The fiscal impact of a higher responsiveness of R&D to the increase in the tax allowance is ambiguous - if ϕ is below a certain threshold level, the effect is negative, and if ϕ is above the threshold level, the effect is positive.*

Proof. From:

$$\frac{\partial \left(\frac{\partial T}{\partial \delta} \frac{1}{Y} \right)}{\partial \eta} = \tau\phi - \tau \frac{\delta(1-\lambda)}{1-\tau} \alpha - \lambda\alpha$$

⁷Since we have shown in equation (10) that $\frac{\partial T}{\partial \lambda} \frac{1}{Y}$ is a positive function of $\frac{\partial T}{\partial \delta} \frac{1}{Y}$, we will limit our proofs below to the case of changes in the tax allowance, since the identical conditions will apply to changes in the level of the grant.

whether the effect is positive or negative depends on whether:

$$\phi \geq \frac{\alpha\delta(1-\lambda)}{1-\tau} + \frac{\alpha\lambda}{\tau} \quad (12)$$

■

Remark 7 Note that equation (12) is the same as equation (11) except that it excludes the term $\frac{\alpha(1-\lambda)}{\eta}$. This is because equation (11) can be broken down into two effects. First, the spillover effect must be sufficient to ensure that the increase in tax revenue covers the increase in fiscal costs caused by the higher tax incentive at the initial level of R&D. Second, the spillover effect must also be sufficient to cover the increased fiscal costs caused by the additional R&D induced by the higher tax incentive. This second requirement is given by the first and last terms on the right hand side of equation (11). Equation (12) corresponds to this same requirement. Thus, if ϕ exceeds this level, then the benefit from an increase in R&D is sufficient to compensate for the costs associated with this increase in R&D. Note that even if $\phi < \phi_{\min}$ (so that a higher tax allowance leads to a reduction in tax revenue because the fiscal benefits of the higher level of R&D do not outweigh the increase in fiscal costs on the current level of R&D), provided equation (12) is satisfied, then a higher responsiveness of R&D to the level of the tax allowance will be associated with an improved fiscal outcome (in this case the tax loss caused by an increase in the tax allowance is reduced).

Remark 8 In the case where currently there are no incentives for R&D in the economy, i.e. $\delta = \lambda = 0$, a higher estimate of η unambiguously improves the fiscal outcome of an increase in either of the tax incentives.

Remark 9 In the case where there are existing fiscal incentives for R&D, it is crucial to estimate the ϕ parameter with some degree of accuracy. If ϕ is estimated to exceed the level specified in equation (12), but in fact it does not, then not only will the fiscal effect turn out to be worse than expected due to the lower estimate of ϕ , but also due to the fact that the η effect is actually negative for the fiscal outcome, and not positive as anticipated.

Proposition 10 Whether a given increase in the tax allowance rate or the grant rate will yield a better outcome depends on the values of τ , δ and λ .

Proof.

$$\begin{aligned} \frac{\partial T}{\partial \delta} \frac{1}{Y} - \frac{\partial T}{\partial \lambda} \frac{1}{Y} &= \frac{\partial T}{\partial \delta} \frac{1}{Y} - \frac{[1 - \tau(1 + \delta)]}{(1 - \lambda)\tau} \left(\frac{\partial T}{\partial \lambda} \frac{1}{Y} \right) \\ \frac{\partial T}{\partial \delta} \frac{1}{Y} &\geq \frac{\partial T}{\partial \lambda} \frac{1}{Y} \text{ iff } \tau \geq \frac{1}{2 + \delta - \lambda} \end{aligned} \quad (13)$$

■

Remark 11 *Alternatively, this result can be interpreted as saying that if $\tau > 1/(2 + \delta - \lambda)$, then achieving a particular increase in tax revenue would require a larger increase in the grant rate than in the tax allowance rate.*

Remark 12 *In the case where currently there are no incentives for R&D in the economy, i.e. $\delta = \lambda = 0$, equation (13) reduces to:*

$$\frac{\partial T}{\partial \delta} \frac{1}{Y} \geq \frac{\partial T}{\partial \lambda} \frac{1}{Y} \text{ iff } \tau \geq \frac{1}{2}$$

4. Impact of fiscal incentives on output

If we now assume that the government's primary interest is in increasing output rather than tax revenue, we need to examine the impact of tax incentives on a measure of output that the government would be interested in maximising. Assuming that the prices of factor inputs reflect true social costs of these resources, the government will seek to maximise:

$$S = Y(R_T, R^*, L^*, K^*) - hR^* - wL^* - rK^*$$

where S represents a measure of net output that reflects social welfare.

The relevant first order condition for the case of change in the tax allowance rate is:

$$\frac{\partial S}{\partial \delta} = (Y_{R_T} + Y_R - h) \frac{\partial R^*}{\partial \delta} + (Y_K - r) \frac{\partial K^*}{\partial \delta} + (Y_L - w) \frac{\partial L^*}{\partial \delta}$$

Recalling from above that $\frac{\partial K^*}{\partial \delta} = \frac{\partial L^*}{\partial \delta} = 0$, the first order condition simplifies to:

$$\frac{\partial S}{\partial \delta} = (Y_{R_T} + Y_R - h) \frac{\partial R^*}{\partial \delta} \quad (14)$$

Now substitute in from equation (3) for firm's profit-maximising value of Y_R to obtain:

$$\begin{aligned}\frac{\partial S}{\partial \delta} &= \left(Y_{R_T} + \frac{h(1-\lambda)[1-\tau(1+\delta)]}{1-\tau} - h \right) \frac{\partial R^*}{\partial \delta} \\ &= \left(Y_{R_T} - h\lambda - h\delta\tau \frac{1-\lambda}{1-\tau} \right) \frac{\partial R^*}{\partial \delta}\end{aligned}$$

Note that in the presence of tax incentives, the private marginal product of output is always less than the social cost of R&D (since the private cost of R&D is less than the social cost due to the tax incentives).

Dividing through by Y and rearranging so as to substitute in for α , η and ϕ yields:

$$\frac{\partial S}{\partial \delta} \frac{1}{Y} = \phi\eta - \lambda\eta\alpha - \delta\tau \frac{1-\lambda}{1-\tau} \eta\alpha \quad (15)$$

If instead the government seeks to increase output through changes in the level of the grant, the relevant derivative is:

$$\frac{\partial S}{\partial \lambda} = (Y_{R_T} + Y_R - h) \frac{\partial R^*}{\partial \lambda}$$

Substituting for equation (9) and equation (14), dividing through by Y and rearranging yields:

$$\frac{\partial S}{\partial \lambda} \frac{1}{Y} = \frac{[1-\tau(1+\delta)]}{(1-\lambda)\tau} \frac{\partial S}{\partial \delta} \frac{1}{Y} \quad (16)$$

Thus, as was the case above, for the parameter values we have assumed, $\frac{\partial S}{\partial \lambda} \frac{1}{Y}$ is a positive function of $\frac{\partial S}{\partial \delta} \frac{1}{Y}$.

4.1. Determinants of the impact of tax incentives on net output

Proposition 13 *An increase in tax incentives,⁸ whether in the form of a tax allowance or a grant, will increase net output iff:*

$$\phi > \lambda\alpha + \delta\tau \frac{1-\lambda}{1-\tau} \alpha = \phi_{\min}^S \quad (17)$$

Proof. In equation (15) set $\frac{\partial S}{\partial \delta} \frac{1}{Y} > 0$ and note that $\eta > 0$ since $\frac{\partial R^*}{\partial \delta} > 0$. ■

Remark 14 *Note that at the point where a change in the tax allowance has no effect on net output, the condition that:*

$$\phi = \lambda\alpha + \delta\tau \frac{1-\lambda}{1-\tau} \alpha$$

⁸ Again, since $\frac{\partial S}{\partial \lambda} \frac{1}{Y}$ is a positive function of $\frac{\partial S}{\partial \delta} \frac{1}{Y}$, in the proofs we will only consider changes in the rate of tax allowance.

is equivalent to:

$$Y_{R_T} + Y_R = h$$

In other words, the social marginal product of R&D - its private marginal product plus the spillover effect - is equal to its social cost.

Remark 15 In the case where currently there are no tax incentives in the economy, then equation (17) simplifies to:

$$\phi > 0$$

i.e. provided there is some spillover effect, an increase in tax incentives will increase net output. Note that there is the potential for a conflict of goals for the policymaker. If there is a spillover effect, but it is smaller than ϕ_{\min} , then the government must decide whether or not it is prepared to take actions to increase net output, even if that leads to a deterioration in the fiscal position.

Proposition 16 A larger spillover effect of R&D improves the output effect of an increase in tax incentives.

Proof.

$$\frac{\partial \left(\frac{\partial S}{\partial \delta} \frac{1}{Y} \right)}{\partial \phi} = \eta > 0$$

■

Remark 17 The only impact of a higher spillover effect is to increase output.

Proposition 18 The fiscal impact of a higher responsiveness of R&D to the increase in the tax allowance is ambiguous - if ϕ is below ϕ_{\min}^S , the effect is negative, and if ϕ is above ϕ_{\min}^S , the effect is positive.

Proof.

$$\frac{\partial \left(\frac{\partial S}{\partial \delta} \frac{1}{Y} \right)}{\partial \eta} = \phi - \lambda\alpha - \delta\tau \frac{1-\lambda}{1-\tau} \alpha$$

Whether the effect is positive or negative depends on whether:

$$\phi > \lambda\alpha + \delta\tau \frac{1-\lambda}{1-\tau} \alpha = \phi_{\min}^S$$

■

Remark 19 *This implies that a higher η magnifies the impact of an increase in tax allowances on net output: if it is positive, it makes it more positive, and if it is negative, it makes it more negative. Thus, as remarked above, it is important to estimate ϕ as accurately as possible.*

Proposition 20 *Whether a given increase in the tax allowance rate or the grant rate will yield a better outcome again depends on the values of τ , δ and λ :*

$$\frac{\partial S}{\partial \delta} \frac{1}{Y} \geq \frac{\partial S}{\partial \lambda} \frac{1}{Y} \text{ iff } \tau \geq \frac{1}{2 + \delta - \lambda}$$

Proof. Analogous to proposition (10). ■

5. Applying the model

How might we apply the model empirically? Most of the parameters of the model - α , δ , λ and τ - are likely to be known with a great deal of certainty, but a significant amount of uncertainty might attach to the remaining two parameters - ϕ and η . The model enables a policymaker to assess for which range of estimates of ϕ and η an increase in tax incentives will have the desired effect, at least at the margin.

As an example, consider a country which does not have any existing tax incentives for R&D. The first implication of the model is that if the government believes that there are any spillover effects from R&D, then at least some level of tax incentives is appropriate if its goal is to increase social welfare. However, if the government is constrained in its budget position, then the spillover effect must not only be present, but also be sufficiently high, i.e. $\phi > \frac{\alpha}{\eta}$. If not, then the government has to decide whether it is prepared to sustain a fiscal loss in order to promote greater net output. In Table 1, which is illustrated in Figure 1, we provide a tabulation of ϕ_{\min} for various values of α and η . The range of values for α is chosen on the basis that the business R&D - GDP ratio is typically 1% - 2% (Hall et al (2000), referencing OECD (1984)). Note that at low levels of η , ϕ_{\min} is relatively high, while as η increases, ϕ_{\min} falls rapidly. Thus provided the government is confident that there is at least some degree of responsiveness on the part of firms to tax incentives, then the spillover effect is not required to be especially large in order for the tax consequences of the allowance to be positive.

INSERT TABLE 1 ABOUT HERE.

INSERT FIGURE 1 ABOUT HERE.

Let us use South Africa, for which α is estimated to be around 0.7%, as an example. If the estimate of η is low, such as 1% (i.e. R&D increases by 1% for every 1 unit - or 100 percentage point - increase in the tax allowance rate), then ϕ must exceed 0.7 (i.e. a 1% increase in R&D must lead to a 0.7% increase in output due to the spillover effect). If the estimate of η is instead 10%, then ϕ_{\min} is 0.07 and if η is estimated to be 20%, ϕ is only required to exceed 0.04.

INSERT TABLE 2 ABOUT HERE.

INSERT FIGURE 2 ABOUT HERE.

Another way to look at the implication of the parameter values is to calculate the impact on tax revenue of increasing the tax incentive rate (at the margin) for different estimates of ϕ and η . Again, for concreteness, consider the case of South Africa, for which α is 0.7% and τ is 37.5%, and examine the impact of a change in the tax allowance rate, δ . Table 2, which is illustrated in Figure 2, tabulates a range of estimates for ϕ and η , and for each combination of ϕ and η , the number inside the table represents the instantaneous semi-elasticity of tax revenue with respect to a marginal change in the tax allowance rate ($\frac{\partial T}{\partial \delta} \frac{1}{Y}$). For example, if ϕ is estimated to be 0.1 and η is estimated to be 10%, then the instantaneous semi-elasticity of tax revenue is 0.11% of output, which implies that tax revenue increases by an amount equivalent to 0.11% of output per unit (100 percentage point) increase in the tax allowance rate. Again, the implication is that for not-implausible estimate of ϕ and η , it is possible for the fiscus to provide incentives for R&D and actually enjoy an increase in tax revenues.

6. Concluding remarks

From the above, it is apparent that, although in some cases the policymaker might be faced with a dilemma, in that while social efficiency calls for R&D incentives, they might impose a cost on the fiscus which would conflict with other goals such as deficit reduction, this need not necessarily be the case. In fact, for quite plausible parameter values, the R&D incentives might even more than pay for themselves.

However, note that we have not considered additional costs that might have to be incurred, such as the costs of administering R&D incentives. These can potentially be significant. For example, if R&D expenditure qualifies for special tax treatment, then firms have an incentive to reclassify other types of expenditure as R&D. Given that it is difficult to give an unambiguous definition of what constitutes R&D expenditure, problems of this nature might require considerable effort on the

part of the tax authorities to ensure that the incentives are not being abused. For example, almost 80% of returns claiming R&D credits are audited in the US, resulting an average net downward adjustment of about 20% of the credits claimed (Hall et al (2000), citing U.S. General Accounting Office (1989)). To the extent that such costs arise, our rather optimistic conclusion that it might be possible for the authorities to have their cake and eat it, in the sense of stimulating R&D while increasing tax revenues, would have to be qualified.

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Figure 1:
Phi min for country with no existing tax incentives

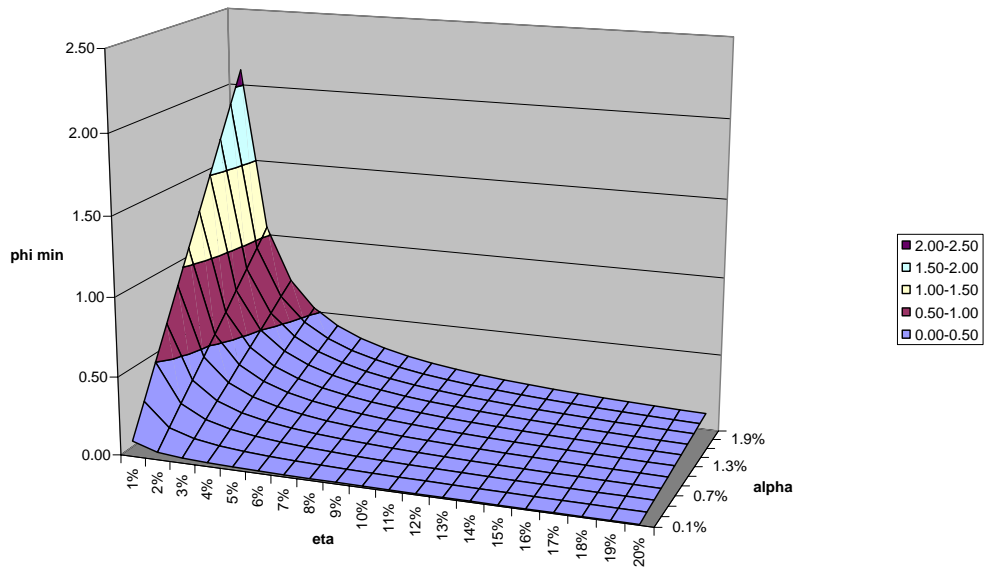


Figure 2:
Impact on tax revenue of a change in the tax allowance rate, calibrated to South Africa

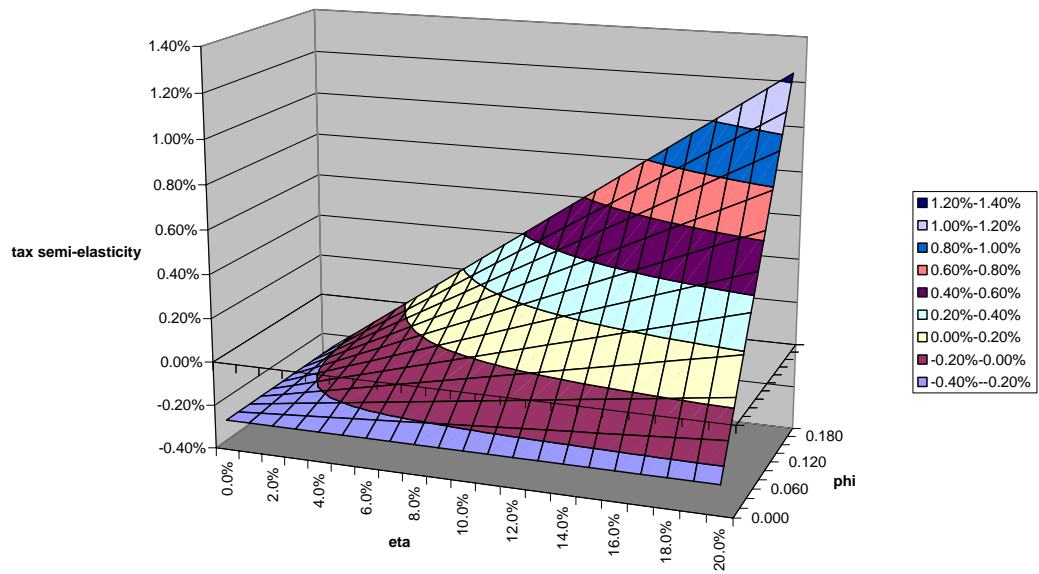


Table 1: Phi min for a country with no existing tax incentives

		α										
		0.1%	0.3%	0.5%	0.7%	0.9%	1.1%	1.3%	1.5%	1.7%	1.9%	2.1%
η	1%	0.10	0.30	0.50	0.70	0.90	1.10	1.30	1.50	1.70	1.90	2.10
	2%	0.05	0.15	0.25	0.35	0.45	0.55	0.65	0.75	0.85	0.95	1.05
	3%	0.03	0.10	0.17	0.23	0.30	0.37	0.43	0.50	0.57	0.63	0.70
	4%	0.03	0.08	0.13	0.18	0.23	0.28	0.33	0.38	0.43	0.48	0.53
	5%	0.02	0.06	0.10	0.14	0.18	0.22	0.26	0.30	0.34	0.38	0.42
	6%	0.02	0.05	0.08	0.12	0.15	0.18	0.22	0.25	0.28	0.32	0.35
	7%	0.01	0.04	0.07	0.10	0.13	0.16	0.19	0.21	0.24	0.27	0.30
	8%	0.01	0.04	0.06	0.09	0.11	0.14	0.16	0.19	0.21	0.24	0.26
	9%	0.01	0.03	0.06	0.08	0.10	0.12	0.14	0.17	0.19	0.21	0.23
	10%	0.01	0.03	0.05	0.07	0.09	0.11	0.13	0.15	0.17	0.19	0.21
	11%	0.01	0.03	0.05	0.06	0.08	0.10	0.12	0.14	0.15	0.17	0.19
	12%	0.01	0.03	0.04	0.06	0.08	0.09	0.11	0.13	0.14	0.16	0.18
	13%	0.01	0.02	0.04	0.05	0.07	0.08	0.10	0.12	0.13	0.15	0.16
	14%	0.01	0.02	0.04	0.05	0.06	0.08	0.09	0.11	0.12	0.14	0.15
	15%	0.01	0.02	0.03	0.05	0.06	0.07	0.09	0.10	0.11	0.13	0.14
	16%	0.01	0.02	0.03	0.04	0.06	0.07	0.08	0.09	0.11	0.12	0.13
	17%	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.10	0.11	0.12
	18%	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.11	0.12
	19%	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11
	20%	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11

Table 2: Impact on tax revenue of a change in the tax allowance rate, calibrated to South Africa

		ϕ										
		0.000	0.020	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200
η	0.0%	-0.26%	-0.26%	-0.26%	-0.26%	-0.26%	-0.26%	-0.26%	-0.26%	-0.26%	-0.26%	-0.26%
	1.0%	-0.26%	-0.26%	-0.25%	-0.24%	-0.23%	-0.23%	-0.22%	-0.21%	-0.20%	-0.20%	-0.19%
	2.0%	-0.26%	-0.25%	-0.23%	-0.22%	-0.20%	-0.19%	-0.17%	-0.16%	-0.14%	-0.13%	-0.11%
	3.0%	-0.26%	-0.24%	-0.22%	-0.20%	-0.17%	-0.15%	-0.13%	-0.11%	-0.08%	-0.06%	-0.04%
	4.0%	-0.26%	-0.23%	-0.20%	-0.17%	-0.14%	-0.11%	-0.08%	-0.05%	-0.02%	0.01%	0.04%
	5.0%	-0.26%	-0.23%	-0.19%	-0.15%	-0.11%	-0.08%	-0.04%	0.00%	0.04%	0.08%	0.11%
	6.0%	-0.26%	-0.22%	-0.17%	-0.13%	-0.08%	-0.04%	0.01%	0.05%	0.10%	0.14%	0.19%
	7.0%	-0.26%	-0.21%	-0.16%	-0.11%	-0.05%	0.00%	0.05%	0.11%	0.16%	0.21%	0.26%
	8.0%	-0.26%	-0.20%	-0.14%	-0.08%	-0.02%	0.04%	0.10%	0.16%	0.22%	0.28%	0.34%
	9.0%	-0.26%	-0.20%	-0.13%	-0.06%	0.01%	0.08%	0.14%	0.21%	0.28%	0.35%	0.41%
	10.0%	-0.26%	-0.19%	-0.11%	-0.04%	0.04%	0.11%	0.19%	0.26%	0.34%	0.41%	0.49%
	11.0%	-0.26%	-0.18%	-0.10%	-0.02%	0.07%	0.15%	0.23%	0.32%	0.40%	0.48%	0.56%
	12.0%	-0.26%	-0.17%	-0.08%	0.01%	0.10%	0.19%	0.28%	0.37%	0.46%	0.55%	0.64%
	13.0%	-0.26%	-0.17%	-0.07%	0.03%	0.13%	0.23%	0.32%	0.42%	0.52%	0.62%	0.71%
	14.0%	-0.26%	-0.16%	-0.05%	0.05%	0.16%	0.26%	0.37%	0.47%	0.58%	0.68%	0.79%
	15.0%	-0.26%	-0.15%	-0.04%	0.08%	0.19%	0.30%	0.41%	0.53%	0.64%	0.75%	0.86%
	16.0%	-0.26%	-0.14%	-0.02%	0.10%	0.22%	0.34%	0.46%	0.58%	0.70%	0.82%	0.94%
	17.0%	-0.26%	-0.14%	-0.01%	0.12%	0.25%	0.38%	0.50%	0.63%	0.76%	0.89%	1.01%
	18.0%	-0.26%	-0.13%	0.01%	0.14%	0.28%	0.41%	0.55%	0.68%	0.82%	0.95%	1.09%
	19.0%	-0.26%	-0.12%	0.02%	0.17%	0.31%	0.45%	0.59%	0.74%	0.88%	1.02%	1.16%
20.0%	-0.26%	-0.11%	0.04%	0.19%	0.34%	0.49%	0.64%	0.79%	0.94%	1.09%	1.24%	