CPB Memorandum

CPB Netherlands Bureau for Economic Policy Analysis

Department	:	Modeling, labor and Income
Unit	:	Macro modeling
Author(s)	:	Nick Draper and Free Huizinga
Date	:	July 10, 2001

The effect of corporate taxes on investment and the capital stock

This paper analyses the effect of the corporate tax rate on the cost of capital and investment through two different channels. The first one concerns the fairly standard change in the user cost of capital, which determines a firm's optimal capital stock given that the firm is located in the Netherlands. The paper demonstrates that a reduction in the corporate tax rate reduces the user cost of capital because cost of capital is not fully deductible. The second channel deals with the direct effect of corporate taxation on profits. If capital is sufficiently mobile, the after tax profit margin cannot be affected by the corporate tax rate in equilibrium. Therefore, a rise in the corporate tax rate must be compensated by a compensating rise in the markup. We have assumed that only 35% of necessary markup rise will actually be established. To get a feel for the quantitative effects of these two channels, they have been incorporated into the JADE model, the econometric macro model of CPB. The results suggest that only considering the user cost of capital approach ignores an important aspect of the impact of a change in corporate taxation

1 Introduction

This paper analyses the effect of the corporate tax rate on the cost of capital and investment. The paper derives a formula for the cost of capital in which taxes and different sources of finance are explicitly taken into account. The main result is that a decrease in the corporate tax rate has a positive, neutral or negative effect on the marginal incentive to invest if capital costs are less than fully, fully or more than fully deductible from corporate taxable income. Calibration for the Dutch case indicates that a decrease in the corporate tax rate has a positive effect on the marginal incentive to invest. Since capital costs in the Netherlands are less than fully deductible from corporate taxation, a reduction in the corporate tax rate has a positive effect on marginal investment.

The intuition for the result that corporate taxes are marginally neutral if capital costs are fully deductible is that in that case the marginal benefit and marginal cost of capital both fall proportionally with the corporate tax rate, so that the marginal cost and marginal benefit of investment remain equal at the current capital stock. The corporate tax rate then acts as a pure profits tax. An increase in the corporate tax rate may still hurt overall investment because new firms may decide not to invest at all or to invest elsewhere. So, a proper analysis of the corporate tax rate should also take the location decision into account, not just the marginal investment decision. The paper suggests a simple way of doing that. A simulation with the macro model JADE provides an indication of the magnitude of both effects.

2 The setup

For given paths of investment and employment over time, the value of a firm may be determined by a budget restriction indicating how much the firm can pay out in dividends each period and an arbitrage equation which values this stream of dividends in the capital market.

The budget restriction can be written in several ways, two of which are of particular interest. The first focusses on the financing of new investment:

$$\begin{aligned} p_{i,t} i_t &= p_{y,t} y_t - w_t l_t - \rho_{b,t} B_{t-1} - T_t - D_t + N_t + \Delta B_t \\ &= RE_t + N_t + \Delta B_t \ . \end{aligned} \tag{1}$$

Here p_i denotes the price of investment goods, i investment, p_y the price of value added, y value added, w the wage rate, l employment, ρ_b the nominal interest rate on corporate bonds, B the nominal corporate debt, T the net corporate tax liability (net of any deductions and subsidies), D

the dividend payment, N the issue of new shares and RE retained earnings. Δ is the first difference operator so that $\Delta B_t = B_t - B_{t-1}$ is the net issue of new debt. In general, capital letters denote nominal variables and lowercase letters real variables. The subscript $t+j$ refers to period $t+j$. Revenue minus wage bill, interest payments, net corporate taxes and dividend payments equals retained earnings. So, new investment can be financed by retained earnings (that is, by reducing dividend payments), by issuing new shares and by issuing new bonds. The second way of writing the budget constraint focusses on the payment of dividends:

$$D_t = p_{y,t} y_t - w_t l_t - \rho_{b,t} B_{t-1} - T_t - p_{i,t} i_t + N_t + \Delta B_t . \tag{2}$$

It is just a rewriting of the previous equation.

The arbitrage equation indicates how this dividend stream is valued by the capital market:

$$\rho_{a,t+1} V_t = (1 - \tau_g)(\Delta V_{t+1} - N_{t+1}) + (1 - \tau_p) D_{t+1} . \tag{3}$$

Here $\rho_{a,t}$ is the nominal after tax return on alternative assets (adjusted for risk), τ_g is the personal tax rate on capital gains and τ_p the personal income tax rate. V_t is the value of the firm at the end of period t. The firm is valued such that the return $\rho_{a,t+1} V_t$ from having invested V_t in alternative assets equals the return on owning the firm which consists of a capital gain of $\Delta V_{t+1} - N_{t+1}$ taxed at the rate τ_g and a dividend D_{t+1} taxed at the rate τ_p.[1]

To get an explicit expression for the value of the firm, we solve the above equation forward. We assume $\rho_{a,t}$ to be an exogenous constant and find

$$V_t = \sum_{j=1}^{\infty} \left(\frac{1-\tau_p}{1-\tau_g} D_{t+j} - N_{t+j} \right) \left(\frac{1}{1+\frac{\rho_a}{1-\tau_g}} \right)^j . \tag{4}$$

[1] The intuition behind this equation is as follows. Suppose you have V_t to invest this period. If you invest in the alternative asset you will have $(1+\rho_{a,t+1}) V_t$ next period. If you buy the firm, you will own $V_{t+1} - N_{t+1}$ in stocks next period, receive $(1-\tau_p) D_{t+1}$ in after tax dividends and have to pay $\tau_g(V_{t+1} - N_{t+1} - V_t)$ in capital gains taxes. You are neutral between these options if $(1+\rho_{a,t+1})V_t = V_{t+1} - N_{t+1} + (1-\tau_p) D_{t+1} - \tau_g(V_{t+1} - N_{t+1} - V_t)$, which is the arbitrage equation above.

This equation indicates that reducing dividends D and new share issues N by the same amount in any period raises the value of the firm if the capital gains tax is lower than the personal income tax. The budget constraint indicates that such an operation is also feasible. In the Netherlands the capital gains tax is zero. So the firm should not issue new shares and pay dividends at the same time. In fact, stockholders would prefer the firm not to pay dividends at all, but pay out their profits by buying back shares (which would make N negative). Since in practice firms do pay dividends, there must be additional restrictions on the firm other than the simple budget constraint modelled above. For instance, there are legal restrictions on firms' buying back their own stock. Rather than modelling these, however, we will assume an exogenous dividend and new share issue policy and consider the effects of this policy on the financing cost of the firm and on the impact of taxation on firm behaviour. A similar issue will arise with the firm's debt policy, and there we will use the same approach.[2]

Tax reform: the tax plan 2001

Starting in 2001 the Dutch tax code will be changed.[3] The important changes for this paper are that actual returns on wealth are no longer taxed by the personal income tax. Instead, there will be a 30% tax on a presumed rate of return of 4% on personal wealth, regardless of how it is invested and what its actual return is. De facto, this amounts to a 1.2 % wealth tax with no tax on dividends and capital gains. The arbitrage condition (3) then becomes

$$(\rho_{a,t+1} - \tau_f)V_t = (\Delta V_{t+1} - N_{t+1}) + D_{t+1} - \tau_f V_t \ . \qquad (5)$$

The capital gains tax rate τ_g and the personal tax rate on dividends τ_p are zero, and there is a fixed tax rate τ_f equal to 1.2% on wealth both when investing in the alternative asset and when investing in the firm.[4] The fixed tax $\tau_f V_t$ drops out of this equation, and therefore, as of 2001, equations (3) and (4) hold with both τ_g and τ_p equal to zero. In the remainder of the paper we set τ_g equal to zero since that is the case both before and after the tax reform. We keep the personal

[2] The general setup in this paper is not novel, but builds on papers such as Auerbach (1983), Brock and Turnovsky (1981), and Hasselman (1994). What we add is tractability for macroeconomic modelling purposes by means of specific assumptions about financing ratios, a discussion about inframarginal effects and an impression of the size of macroeconomic effects using the CPB macro model JADE.

[3] For an extensive discussion of the effects of the tax reform on investment incentives, see A.L. Bovenberg and H. ter Rele (1998).

[4] The nominal after tax return on the alternative asset ρ_a may also change due to the tax reform. This is a general equilibrium issue and beyond the scope of this paper. Such a change would not affect the theoretical derivations in this paper, but would affect the numerical calculation of the capital cost.

tax rate on dividends τ_p as part of the derivation so that we can describe both the situation before and after the tax reform.

3 The maximization problem

To formulate the maximization problem of the firm we need to flesh out the budget constraint. We assume that y_t equals output net of adjustment cost, written as $y_t = F(k_{t-1}, l_t) - c(i_t, k_{t-1})$, where F is a standard production function and c the adjustment cost function. Net taxes T_t consist of the corporate tax rate τ_c times taxable revenue minus subsidies: $T_t = \tau_c(p_{y,t}y_t - w_t l_t - \rho_{b,t}B_{t-1} - A_t) - sp_{i,t}i_t$, where A_t is the fiscal depreciation allowance and s the investment subsidy rate. Fiscal depreciation is based on the historical cost price of investment and is geometric with a fiscal depreciation rate v.[5] That means that, in period t, the firm is allowed to deduct $v(1-v)^{\tau-1}p_{i,t-\tau}i_{t-\tau}$ for the investment purchased in period $t-\tau$, for all $\tau \geq 1$. We assume that in each period a fraction b_0 of the principal of the debt is repaid, and a fraction b_1 of new investment is financed with new debt. Debt payment, therefore, equals $(\rho_{b,t} + b_0)B_{t-1}$, and total debt evolves as $B_t = (1 - b_0)B_{t-1} + b_1 p_{it} i_t$. We assume that a fraction n of new investment is financed with new equity: $N_t = np_{it}i_t$. Substituting, we may rewrite the expression for dividends as

$$D_t = (1-\tau_c)\big[p_{y,t}\big(F(k_{t-1}, l_t) - c(i_t, k_{t-1})\big) - w_t l_t\big] - (1 - b_1 - n - s)\,p_{i,t}i_t \\ - \big((1-\tau_c)\rho_{b,t} + b_0\big)B_{t-1} + \tau_c A_t\ . \tag{6}$$

The firm's maximization problem can be written as

$$\max\ L_t = \sum_{j=1}^{\infty} \Big((1-\tau_p)D_{t+j} - N_{t+j} - q_{t+j}[k_{t+j} - (1-\delta)k_{t+j-1} - i_{t+j}] \\ + \lambda_{t+j}[B_{t+j} - (1-b_0)B_{t+j-1} - b_1 p_{i,t+j}i_{t+j}] \\ + \mu_{t+j}[N_{t+j} - np_{i,t+j}i_{t+j}] \Big)\left(\frac{1}{1+\rho_a}\right)^j . \tag{7}$$

The Lagrangian incorporates the fact that in the Netherlands the capital gains tax equals zero, so τ_g equals zero. The first constraint indicates the accumulation of capital, with δ denoting the

[5] Fiscal depreciation may be linear or degressive. Fiscal depreciation equal to a fixed percentage of the book value is allowed if the original investment becomes less productive with age. Since we assume that physical depreciation is exponential, a degressive fiscal depreciation scheme indeed seems most appropriate.

physical rate of depreciation. The Lagrangian has been formulated so that the signs of the Lagrange mulitpliers q_t, λ_t and μ_t are all positive. q_t is the shadow value (marginal benefit) of installed capital, and λ_t and μ_t the shadow cost (marginal cost) of debt and new equity. Since debt and new equity policy are exogenous, the marginal payout of profits to the shareholders takes place through dividends.

To keep the model simple, we assume that the firm is a price taker in the product and financial markets. That is, we assume that the prices $p_{y,t}$ and $p_{i,t}$ of value added and investment and the nominal interest rates ρ_a and ρ_b are given to the firm. Moreover, we assume that the prices grow at a constant inflation rate π and that the nominal interest rates are constant.

The Lagrangian contains the present value of the depreciation allowance as one of its determinants. To differentiate that with respect to i_t, it is helpful to use the following result derived in the appendix:

$$\sum_{j=1}^{\infty} A_{t+j} \left(\frac{1}{1+\rho_a} \right)^j AF_t + \sum_{j=1}^{\infty} \frac{\nu}{\rho_a + \nu} \, i_{t+j} p_{i,t+j} \left(\frac{1}{1+\rho_a} \right)^j . \tag{8}$$

where AF_t equals the depreciation allowance for investment purchased up to period t. This component of the depreciation allowance is fixed. For future investment i_{t+j}, $j \geq 1$, the present value at time $t+j$ of the depreciation allowance per guilder invested is $\nu / (\nu + \rho_a)$. To get the present value at time t, this value is discounted for another j periods.

The first order conditions are:

$$F_{l,t} = \frac{w_t}{p_{y,t}} , \tag{9}$$

$$q_t = \frac{(1-\tau_p)(1-\tau_c) p_{y,t+1} \left(F_{k,t+1} - c_{k,t+1} \right) + q_{t+1}(1-\delta)}{1+\rho_a} , \tag{10}$$

$$q_t = \left[(1-\tau_p)(1-b_1-n-s-\tau_c\frac{\nu}{\rho_a+\nu}) + b_1\lambda_t + n\mu_t\right]p_{i,t} + (1-\tau_p)(1-\tau_c)p_{y,t}c_{i,t} \;, \tag{11}$$

$$\lambda_t = \frac{(1-\tau_p)[(1-\tau_c)\rho_b + b_0] + \lambda_{t+1}(1-b_0)}{1+\rho_a} \;, \tag{12}$$

$$\mu_t = 1 \;. \tag{13}$$

Here the subscripts *l*, *i* and *k* refer to partial derivatives with respect to employment, investment and capital. The first first-order equation says that the marginal product of labour equal the real product wage in each period, irrespective of personal or corporate taxation. The reason that taxes drop out of this equation is that labour costs are fully deductible in each period, so that both the after tax marginal product of labour and the after tax wage cost fall by the same amount. Because there is no adjustment cost for employment, the standard first order condition holds in each period.

Equation (10) states that the shadow price of capital, q_t, has two components, both of which occur in the next period and are discounted by $1+\rho_a$. The first benefit of investment is increased production, including the effect on installation costs. The second benefit is that a fraction $1-\delta$ is still available for use in the next period, which has a shadow price of q_{t+1}.

Equation (11) says that investment takes place until the shadow price of capital equals its marginal cost, which consists of two components: the marginal cost of purchasing the investment good and the marginal cost of installing it. The marginal cost of purchasing investment depends on the way it is financed, as indicated by the term in between square brackets. The marginal financing cost per guilder invested has five components: a fraction $1-b_1-n-s-\tau_c\nu/(\rho_a+\nu)$ is financed with retained earnings at an after tax cost of $1-\tau_p$ per guilder invested, a fraction b_1 is financed with debt at an after tax cost of λ_t, a fraction n by new equity at an after tax cost of μ_t, a fraction s is paid for with investment subsidies, and a fraction $\tau_c\nu/(\rho_a+\nu)$ is paid for by the depreciation allowance. Since retained earnings is the residual source of finance, subsidies and the depreciation allowance reduce financing by retained earnings one for one.

The result that financing investment with retained earnings carries an after tax financing cost of $1 - \tau_p$ per guilder invested may seem odd. The reason is that all costs are valued in terms of after tax income streams to the stockholder. Retained earnings finance implies that dividends are reduced to pay for the investment. So, if the firm invests one more guilder, dividends are reduced by the same amount and the after tax income to the stockholder is reduced by $1 - \tau_p$ guilders. Therefore, the cost of retained earnings finance equals $1 - \tau_p$ per guilder invested.

The marginal cost of debt, λ_t, consists of the interest and principal payment that occurr next period plus the marginal cost of the remaining debt next period, valued at λ_{t+1}. Since the firm considers all elements in the dynamic equation for λ_t as exogenous constants, it will also consider λ_t as constant. Solving (12) for constant λ gives

$$\lambda = (1 - \tau_p) \frac{(1 - \tau_c)\rho_b + b_0}{\rho_a + b_0} \ . \tag{14}$$

The cost of debt depends, among other things, on the fraction of debt that is repaid each period, b_0. If $(1 - \tau_c)\rho_b < \rho_a$, λ rises with b_0, and so the cost of debt finance falls if it is paid back more slowly. We can also see this in another way. If $(1 - \tau_c)\rho_b < \rho_a$, then $\lambda < 1 - \tau_p$, that is the cost of debt finance is less than the cost of retained earnings finance, and it is optimal to maintain a maximum debt-equity ratio. One way to achieve that is to reduce debt repayment.

Equation (13) indicates that the cost of new share issue, μ_t, equals 1. This confirms the earlier result that new share finance is more expensive than retained earnings finance, which costs $(1 - \tau_p)$ per guilder invested. Moreover, if $(1 - \tau_c)\rho_b < \rho_a$, debt finance is cheaper than retained earning finance. So then debt finance is cheapest and new share issue is the most expensive. However, as indicated above, we assume that there are reasons not included in this model that prevent the firm from using only debt to finance investment and thus from having a debt-equity ratio of 100%.

4 The steady state

We will first analyse the steady state.[6] In the steady state the capital stock is constant, so that $i_t = \delta k_{t-1}$. We assume that when investment equals depreciation, (marginal) adjustment cost is zero, so that $c = c_i = c_k = 0$. Also, all prices rise with the inflation rate π, including the shadow price of capital q_t, so that $q_{t+1} = q_t(1+\pi)$. Equation (10) for the shadow price of capital then becomes

$$q = (1 - \tau_p)(1 - \tau_c)\frac{p_y F_k}{r_a + \delta} . \tag{15}$$

where r_a is defined as the real after tax rate of return on alternative assets, that is $1+r_a = (1+\rho_a)/(1+\pi)$. The marginal value of capital equals the present discounted value of a steady stream of after tax marginal products and depreciation allowances, discounted by the real interest rate plus the depreciation rate.

Because marginal adjustment costs are zero in the steady state, the equation equating the marginal value of capital to its marginal cost, (11), becomes

$$q = \left[(1 - \tau_p)(1 - b_1 - n - s - \tau_c\frac{\nu}{\rho_a + \nu}) + b_1\lambda + n\right]p_i . \tag{16}$$

where we substituted $\mu = 1$. The marginal cost of capital is a weighted average of the marginal costs of the different ways of financing investment.

We assume that in the steady state the debt is a constant fraction of the value of the capital stock, valued at the current price p_i, that is, $B_t / p_{i,t}k_t$ is constant in the steady state and equal to b_1. This implies that the debt repayment rate b_0 equals the nominal depreciation rate, that is, the rate at which the nominal value of the capital stock depreciates over time due to the combined effects of physical depreciation and inflation. A unit of capital worth $p_{i,t}$ this period will depreciate to $1-\delta$

[6] For convenience, we look at the steady state with constant levels of capital, labour and output. The analysis for a steady state growth path with constant growth rates for capital, labour and output has the same qualitative results. This will be implicitly shown in the next section, where we will show that the qualitative results for the static steady state also hold on an arbitrary optimal transition path.

units of capital worth $(1-\delta)p_{i,t+1}$ next period. The nominal depreciation rate is, therefore, $[p_{i,t} - (1-\delta)p_{i,t+1}] / p_{i,t}$ which in the steady state equals $\delta(1+\pi) - \pi$. Setting b_0 equal to this and combining (14), (15) and (16) gives

$$(1-\tau_c)p_y F_k = \left[\left(1-b_1+\frac{\tau_p}{1-\tau_p}n-s\right)(r_a+\delta) + b_1(r_b+\delta) - \tau_c\left(\nu\frac{r_a+\delta}{\rho_a+\nu}+\frac{b_1\rho_b}{1+\pi}\right)\right]p_i \,. \qquad (17)$$

where, r_b is the real interest rate on corporate debt, that is, $1+r_b = (1+\rho_b)/(1+\pi)$. This equation equates the after tax nominal marginal product to the after tax user cost of capital. The user cost of capital involves equity finance (both retained earnings and new shares), bond finance and tax breaks. Finance through new share issue carries a cost premium over finance through retained earnings. The equation may be solved for the optimal capital stock by inverting F_k.

The corporate tax rate enters the expression in three ways: by reducing the after tax nominal marginal revenue product, through the deductibility of depreciation allowance and through the deductibility of the nominal interest on bonds. The net effect of these three effects is in general ambiguous. To get some intuition for the net effects, consider the following argument. If there is no corporate tax, the optimal capital stock equates the marginal product of capital with its marginal cost. The corporate tax reduces the marginal revenue product by a fraction τ_c. The corporate tax is, therefore, neutral with respect to the optimal capital stock if is also reduces the marginal cost of capital by the same fraction τ_c , for in that case marginal revenue and marginal cost of capital remain equal at the original level of the capital stock. In terms of equation (17), this means that we have to be able to write its right hand side as $(1-\tau_c)$ times a remainder term that does not involve τ_c. This, in turn implies that

$$\left(1-b_1+\frac{\tau_p}{1-\tau_p}n-s\right)(r_a+\delta) + b_1(r_b+\delta) = \left(\nu\frac{r_a+\delta}{\rho_a+\nu}+\frac{b_1\rho_b}{1+\pi}\right) \,. \qquad (18)$$

The left hand side of this equation is the cost of capital not counting the tax deduction. The right hand side equals the allowed deduction. So the corporate tax is neutral with respect to the optimal capital stock if the tax deduction equals the full before tax cost of capital, that is, if the cost of capital is fully deductible. The tax system encourages investment if the right hand side is larger than the left hand side, that is, if the cost of capital is more than fully deductible, and vice versa.[7] Note that here we consider the condition for neutrality of the corporate tax rate by itself, or conditional on the subsidy rate. We can also consider neutrality of the combined tax and subsidy rates. The combined system is neutral if the right hand side of (17) divided by $(1-\tau_c)$ does not depend on s and τ_c.

To get a further feel for equation (17), consider some special cases. First, suppose that personal and corporate taxes and investment subsidies are zero, that is τ_p, τ_c and s are zero. Then (17) simplifies to the standard first order condition for capital:

$$p_y F_k = [(1-b_1)r_a + b_1 r_b + \delta)p_i \, . \tag{19}$$

Now, allow for taxes and subsidies, but assume that investment is financed only by retained earnings. Furthermore assume that the depreciation allowance is zero. Then b_1, n and v are zero, and (17) becomes

$$(1-\tau_c)\,p_y F_k = (1-s)\,(r_a+\delta)\,p_i \, . \tag{20}$$

So, the combined effect of tax and subsidy is neutral with respect to the steady state capital stock if the subsidy rate equals the corporate tax rate. Note that a subsidy equal to the corporate tax rate is equivalent to a system in which investment can be fully expensed, that is, immediately deducted from taxation. So, if investment can be fully expensed, the tax system is also neutral with respect to the capital stock. The reason for the neutrality result is simple and basically the same as used above: both marginal benefit and marginal cost of capital are reduced in the same proportion, so the optimal capital stock remains unchanged. Clearly, if the subsidy rate exceeds the tax rate, there is a marginal subsidy to investment and the capital stock rises, and vice versa.

Now assume that at the margin all investment is bond financed and there are depreciation allowances, but no subsidies ($b_1 = 1$, s and n are zero). Then the general condition for neutrality (18) reduces to the condition that the depreciation allowance v equals $\delta(1+\pi) - \pi$, that is v has to equal the economic nominal depreciation rate. Note that if investment is partly financed by retained earnings ($b_1 < 1$), the tax system is no longer neutral, because the cost of capital is no longer fully deductible. The (implicit) interest cost of equity is not deductible.

[7] For a formal derivation, see the appendix.

So, for the tax system to be neutral, the full cost of capital has to be deductible. This can be achieved in several ways, such as through a subsidy rate equal to the corporate tax rate, an immediate deduction of the full purchase price of the new investment or through a deduction scheme in which the interest and depreciation costs are fully deductible, including the implicit interest cost of equity. Note that the cost of labour is always fully deductible, so that the corporate tax rate has no direct effect on employment in any case.[8]

So, if the cost of capital and labour are fully deductible, corporate taxes become a pure profits tax. Under constant returns to scale and perfect competition, total revenue equals total costs, profits are zero and there is no tax collection at all. Under imperfect competition, there are profits, so corporate taxes may raise revenue without affecting the capital stock.

Capital taxation may even raise revenue and stimulate investment at the same time. For instance, if new investment is purely bond financed and the fiscal depreciation rate exceeds the economic one, the corporate tax provides a marginal subsidy to capital. Total tax collections may still be positive, if profits are positive. If monopolistic competition with restricted entry leads to a capital stock that is too low (as indicated by the fact that price equals a markup over marginal cost), the corporate tax system may be designed so as to counteract this distortion and achieve a first best outcome.

With free entry, however, we cannot just look at the marginal conditions for investment, but also have to consider the inframarginal effects. Firms' entry decisions are based on overall profitability. If the net effect of a change in taxation is to raise tax revenue, new firms will be deterred from entering, regardless of the marginal conditions. For an open economy like the Netherlands, the inframarginal effects are likely to be large. We return to this point later on in the paper.

5 Dynamics

Now we consider the full dynamic system, which allows for an evaluation of the impact of the corporate tax on investment outside of the steady state. We maintain the assumptions that ρ_b, ρ_a and π are constant. Dynamics occurs because after a shock capital does not immediately jump to the new steady state, but follows a transition path. During the transition period F_k is not constant and c_k and c_i are not zero. Looking at the first order conditions, this affects the second and third equations (the q equations). The equation for λ does not contain dynamics even

[8] There may be an indirect effect on labour if corporate taxes change the capital stock.

though it is a difference equation, because all variables in it are considered to be exogenous constants by the firm. Hence λ immediately jumps to its new steady state value, given by (14). We maintain the assumption that on the transition path the debt-capital stock ratio remains constant, so that b_0 remains equal to the nominal depreciation rate $\delta(1+\pi) - \pi$.

Solving (10) forward yields

$$q_t = (1-\tau_p)(1-\tau_c)\left[\sum_{j=0}^{\infty} \frac{p_{y,t}\left(F_{k,t+j+1} - c_{k,t+j+1}\right)}{1+r_a}\left(\frac{1-\delta}{1+r_a}\right)^j\right]. \tag{21}$$

The shadow price of capital equals the present value of the future marginal products (net of marginal adjustment cost). This stream depreciates at the physical depreciation rate δ. Note that in the steady state the marginal product is constant and the marginal adjustment cost is zero, so that the above expression simplifies to its steady state version.[9]

To find the expression for the optimal transition path for capital, we combine (11), (13), (14) and (21) which yields

$$(1-\tau_c)\sum_{j=0}^{\infty}\left[\frac{p_{y,t}\left(F_{k,t+j+1} - c_{k,t+j+1}\right)}{1+r_a}\left(\frac{1-\delta}{1+r_a}\right)^j\right] =$$

$$\left[\left(1 - b_1 + \frac{\tau_p n}{1-\tau_p} - s\right)(r_a+\delta) + b_1(r_b+\delta) - \tau_c\left(\nu\frac{r_a+\delta}{\rho_a+\nu} + \frac{b_1\rho_b}{1+\pi}\right)\right]\frac{p_{i,t}}{r_a+\delta} + (1-\tau_c)p_{y,t}c_{i,t}\ . \tag{22}$$

This expression sets the present value of the additional production associated with one unit of additional investment equal to the present value of the cost of one unit of additional investment. This additional cost consists of the cost of purchasing the investment and the cost of installing it. The cost of purchasing the investment is the same as in the steady state, except that it is here written in terms of the present value of the cost instead of the one period cost. That is, the term between square brackets in (22) equals the terms in square brackets in (17), but here it is multiplied by $p_{i,t}$ divided by $r_a+\delta$ instead of by $p_{i,t}$.

[9] On a steady state growth path, adjustment costs are not zero, so we need to use the general expressions in this paragraph.

In the previous section we derived that the tax and subidy system is neutral with respect to the marginal condition for the capital stock if the full cost of investment is tax deductible. In terms of (17) this means that the term in square brackets in that equation can be written as the product of $1-\tau_c$ and something that does not involve the tax or subsidy rates. In that case the factor $1-\tau_c$ drops out of the equation and the tax and subsidy rates no longer enter the marginal condition for capital.

Inspection of (22) reveals that the conditions for marginal neutrality of the tax and subsidy system on the transition path are the same as in the steady state. The tax and subsidy variables drop out of (22) if the term in square brackets can be written as the product of $1-\tau_c$ and something that does not involve the tax or subsidy rates. Since the terms in square brackets in (17) and (22) are the same, the conditions for neutrality are the same as well.

Moreover, the direction of the effects of taxation are the same on the transition path and in the steady state. If taxation reduces the term in square brackets by less than a factor $1-\tau_c$, the optimal capital stock falls both in and out of the steady state. In that case an increase in the corporate tax rate reduces investment immediately and the capital stock will move gradually to a lower new steady state value.

6 Infra marginal effects: a suggestion

In the steady state, we may define the pre-tax user cost of capital, p_k as

$$p_k = \frac{1}{(1-\tau_c)}\left[\left(1-b_1+\frac{\tau_p}{1-\tau_p}n-s\right)(r_a+\delta) + b_1(r_b+\delta) - \tau_c\left(\nu\frac{r_a+\delta}{\rho_a+\nu}+\frac{b_1\rho_b}{1+\pi}\right)\right]p_i\ . \qquad (23)$$

This is the steady state pre-tax user cost of capital in the sense that it equals the pre-tax product of capital in the steady state, see equation (17). With p_k defined in this way, we can write the firm's maximization problem as

$$\max_{l,k}\ \Pi = (1-\tau_c)\left(p_y F(k,l) - wl - p_k k\right)\ . \qquad (24)$$

where Π denotes per period profits. This maximization problem leads to the same steady state first order condition as before. We also define $y = F(k,l)$ and $c_y = (wl + p_k k) / y$, so that y equals output and c_y unit cost. After tax profits are $(1-\tau_c)(p_y y - c_y y)$. The after tax markup or profit margin, m, is defined as after tax profits divided by total costs

$$m = \frac{(1-\tau_c)\ (p_y y - c_y y)}{c_y y} \ . \tag{25}$$

Now assume that entry takes place until m has a certain value m^* determined by the international capital markets.[10] This implies that

$$p_y = c_y \left(1 + \frac{m^*}{1-\tau_c}\right) \ . \tag{26}$$

$m^*/(1-\tau_c)$ can be thought of as a pre-tax or gross markup. So, if the corporate tax rate rises, the gross markup has to rise in order for net profitability defined in term of the after tax profit margin to stay in line with international requirements.

The analysis is this section represents the extreme case in which an increase in the corporate tax rate is fully passed on into prices so that net profitability does not change. If the firm's profitability is solely product based, for instance because of brand loyalty or patent rights, this extreme case may be realistic for the long run. If profits are, however, also location specific, so that moving to another country will reduce profitability, the firm may not move in response to an inframarginal tax. In that case, the firm's net profit margin will be reduced if the corporate tax rises. This case will be particularly relevant for the short run.

7 Simulation

To get a feel for the effects of a change of the corporate tax rate on investment and the overall economy, we have to embed the equations derived in this paper into a macro model. For that purpose we use the JADE model, the operational macro model of CPB. We ran two simulations. In the first we focused on the effects of a change in the corporate tax rate without considering the inframarginal or entry/exit issue. For that purpose we used equation (23), the equation for the pre-tax user cost of capital in the steady state as the cost of capital equation in the term

[10] This begs the question why m* is positive, or more generally, why there are profits in the steady state. The reason may be that profits serve to offset initial setup costs.

$p_y F_k - p_k$, the error correction term in the capital stock equation. This term represents the error in equation (17), which is the first order condition for capital in the steady state.

Table 7.1 presents the calibrated[11] user cost of capital and its determinants for the exposed and sheltered sectors for 1990. There are no investment subsidies, so s=0. The tax rate on dividends is set equal to the overall income tax rate, including contributions to the social security system, and equals 0.36. 45% of investments are financed with new debt (b_1=0.45) and 3% with new equity (n=0.03). Debt and equity finance both carry a risk premium. The risk premium on debt is set at 2%. This risk premium is determined in such a way that the development of the cost price roughly equals the price development. The physical depreciation rates are derived from the capital statistics, in Dutch the "kapitaalgoederenstatistiek" collected by Statistics Netherlands. The fiscal depreciation rates are higher than the physical ones, so that in terms of depreciation allowance there is a positive incentive to invest. However, the implicit interest rate on equity finance, including the risk premium, is not deductible, which reduces the incentive to invest. The latter effect dominates so that a reduction in the corporate tax rate on balance reduces the marginal incentive to invest.

Table 7.1 User costs of capital and its determinants in 1990[a)]

	user cost of capital[b]								equipment			buildings		
	equipment	buildings	τ_c	τ_p	r_a	r_b	n	b_1	ν	δ	$\hat{p}_i$	ν	δ	$\hat{p}_i$
exposed	0.11	0.07	0.34	0.36	$(1-t_c)r$+0.05	r+0.02	0.03	0.45	0.100	0.04	0.038	0.055	0.02	0.056
sheltered	0.18	0.08	0.34	0.36	$(1-t_c)r$+0.05	r+0.02	0.03	0.45	0.153	0.10	0.038	0.055	0.03	0.056

a) s=0, r is the long-term interest rate (8,9% in 1990)

b) as a fraction of the price of investment goods p_i

Table 7.2 presents the results of a reduction in the corporate taxes by 1% GDP (the corporate tax rate falls about 8.5 percentage point). Because for the Dutch case the cost of capital is not fully deductible, a decline in corporate tax rate reduces the user costs of capital and improves investment. In the paper this happens because marginal profitability improves, and possibly, through a substitution effect. In the macro model there is an additional effect through increased aggregate demand, partly though the multiplier effect and partly because the cost reduction is ultimately passed on into lower prices, improved competitiveness and increased net exports. The

[11] The overall effect of a change in the corporate tax rate equals roughly the effect of a comparable change in the income tax rate. This is required, because the incidence of both taxes is borne by the immobile factor of production, labor.

increase in production also raises employment. The reduced cost of capital lowers equilibrium unemployment and raises the equilibrium labour income share.[12]

Table 7.2 Cumulated effects of a reduction in corporate taxes by 1% GDP, user cost of capital channel

		1999	2000	2002	2006
p r i c e s					
wage rate enterprises	%	-0.13	-0.09	0.02	0.10
gross value added private sector	%	-0.09	-0.07	-0.03	-0.13
q u a n t i t i e s					
private consumption	%	0.04	0.15	0.48	0.92
private investment excl. dwellings	%	0.34	0.55	0.64	1.35
exports of goods excl. energy	%	0.05	0.07	0.04	0.09
imports of goods	%	0.10	0.18	0.32	0.65
net national income	%	0.01	0.09	0.24	0.44
gross value added exposed	%	0.07	0.11	0.17	0.37
gross value added sheltered	%	0.07	0.17	0.35	0.70
employment enterprises (fte)	%	0.08	0.12	0.23	0.51
empl.enterprises(fte) low skilled	%	0.11	0.16	0.30	0.66
empl.enterprises(fte) high skilled	%	0.06	0.10	0.20	0.42
unemployed persons	D	-3.6	-5.3	-9.2	-19.0
q u o t e s					
capacity utilization rate exposed	D	0.04	0.05	0.07	0.11
capacity utilization rate sheltered	D	-0.10	0.00	0.03	0.02
current account (% NNI)	D	-0.06	-0.08	-0.17	-0.36
labour income share enterprises	D	-0.02	-0.03	0.00	0.15

In the second simulation we consider the effects of a change in the corporate tax rate through the entry/exit decisions of firms. For that purpose we included equation (26) as the error correction term in the price equations. For m^* we chose the value 0.13 based on estimation results in Broer, Draper and Huizinga (2000).[13] Again we consider a reduction in the corporate taxes by 1 % GDP. We have assumed that the gross markup will fall by 35% of the amount predicted by equation (26), so that the gross markup falls, but the net markup rises. Table 7.3 presents the results. Prices fall because the gross markup falls. This stimulates exports,

[12] For an analysis of the relationship between the cost of capital and equilibrium unemployment and the equilibrium labour income share, see D.A.G. Draper and F.H. Huizinga (2000).

[13] The estimated long run gross markup is .2. With τ_c equal to .35, this implies that $m^* = 0.13$.

production and employment. Equilibrium unemployment falls because the gross markup falls, which allows firms to pay a higher labour income share. The infra-marginal effects on investment are in between the elasticities that can be calculated from the economic literature. The results of Devereux-Griffith (1998), Hines (1999) and Gorter Parikh (2000) point to a corporate tax rate semi-elasticity on investment in between 0.1 and 0.4.[14]

The results of the two simulations are qualitatively similar. The results suggests that it is improper to ignore the infra-marginal effects of a change in the corporate tax rate.

To get an impression of the combined effects of the marginal and infra-marginal effects the results in tables 7.2 and 7.3 need to be added. They can be compared with the effects of a reduction in income taxes by 1% GDP, which are presented in appendix B.

[14] Devereux-Griffith (1998) estimate that a reduction in the effective tax rate by 1% increases the probability that a firm chooses to invest in that country by between 0.4 and 1.7 %. The effective tax rate in the Netherlands is about 30% (source: Worldscope database) and the statutory rate 35%. Assuming proportionality, a 1% point decrease in the statutory tax rate leads to a (30/35)% = .85% point, or 2.8% reduction in the effective tax rate and an increase in the probability to invest in the Netherlands of between 1.1 and 4.8%. We assume that this leads to the same increase in foreign capital invested in the Netherlands. About 30% of foreign capital inflow is direct investment (as opposed to portfolio investment), and foreign capital makes up about 30% of total capital invested in the Netherlands. So, a rough estimate indicates that a 1% increase in foreign capital inflow corresponds to a 0.3 x 0.3 = 9% increase in total direct investment in the Netherlands. So, a 1% point reduction in the corporate capital stock increases investment through the entry / exit channel by between .09 x 1.1 and .09 x 4.8 %, that is, between 0.1 and 0.44%.

An alternative approach is to look at direct estimates of the corporate tax rate on FDI. This leads to semi-elasticities of the effective tax rate with respect to FDI inflow of between -1.5 (consensus estimate of Hines, 1999) and -4.3 (Gorter-Parish, 2000),. In the Netherlands, FDI is about 50% of total capital investment. However, most of that is purely financial transactions. Probably only 20% of total FDI represents new direct investment. Assuming again that a 1% point decrease in the statutory tax rate leads to a 0.85% point decrease in the effective tax rate, we estimate that a decrease in the corporate tax rate leads to an increase in investment of between 0.85 x 0.5 x 0.2 x 1.5 and 0.85 x 0.5 x 0.2 x 4.3 %, that is between 0.13 and 0.36%, about the same effect as calculated using the results of Devereux-Griffith.

Table 7.3	Cumulated effects of a reduction in corporate taxes by 1% GDP, entry / exit channel				
		1999	2000	2002	2006
p r i c e s					
wage rate enterprises	%	-0.38	-0.59	-0.74	-0.67
gross value added private sector	%	-0.43	-0.72	-1.08	-1.35
q u a n t i t i e s					
private consumption	%	-0.10	-0.14	-0.03	0.33
private investment excl. dwellings	%	0.07	0.23	0.89	1.68
exports of goods excl. energy	%	0.29	0.63	1.18	1.58
imports of goods	%	0.17	0.37	0.88	1.40
net national income	%	-0.16	-0.20	-0.09	0.16
gross value added exposed	%	0.17	0.33	0.66	0.99
gross value added sheltered	%	0.01	0.09	0.37	0.82
employment enterprises (fte)	%	0.02	0.07	0.27	0.71
empl.enterprises(fte) low skilled	%	0.02	0.08	0.35	0.96
empl.enterprises(fte) high skilled	%	0.02	0.07	0.22	0.56
unemployed persons	D	-1.0	-3.8	-13.0	-29.1
q u o t e s					
capacity utilization rate exposed	D	0.13	0.24	0.39	0.38
capacity utilization rate sheltered	D	0.03	0.09	0.24	0.26
current account (% NNI)	D	-0.09	-0.10	-0.14	-0.25
labour income share enterprises	D	0.03	0.08	0.20	0.56

8 Conclusions

This paper considers two channels for the impact of a change in the corporate tax rate. The first one concerns the change in the user cost of capital, which determines a firm's optimal capital stock given that the firm is located in the Netherlands. A reduction in the corporate tax rate reduces the user cost of capital because cost of capital is not fully deductible. The second channel deals with the direct effect of corporate taxation on profits. If capital is sufficiently mobile, the after tax profit margin cannot be affected by the corporate tax rate in equilibrium. Therefore, a rise in the corporate tax rate must be compensated by a compensating rise in the gross markup. To get a feel for the quantitative effects of these two channels, they have been incorporated into the JADE model, the econometric macro model of CPB. Simulations indicate that both channels are of the same order of magnitude. This suggests that only considering the user cost of capital approach ignores an important aspect of the impact of a change in corporate taxation.

References

A.J. Auerbach (1983), 'Taxation, Corporate Financial Policy and the Cost of Capital', *Journal of Economic Literature*, vol. 93.

W.A. Brock and S.J. Turnovsky (1981), 'The Analysis of Macroeconomic Policies in Perfect Foresight Equilibrium', *International Economic Review*, vol. 22.

A.L. Bovenberg and H. ter Rele (1998), 'Reforming Dutch capital taxation: An analysis of incentives to save and invest', CPB research memorandum No. 142.

D.P. Broer, D.A.G. Draper and F.H. Huizinga (2000), 'The equilibrium rate of unemployment in the Netherlands,' *De Economist*, 148, pp.345-371.

M.P. Devereux and R. Griffith (1998), 'Taxes and the location of production:evidence from a panel of US multinationals,' *Journal of Public Economics* 68, pp. 335-367

D.A.G. Draper and F.H. Huizinga (2000), "ELIS: Equilibrium Labour Income Share,' *De Economist*, 148, pp. 671-684.

J. Gorter and A. Parikh (2000), 'How mobile is capital within th EU?,' *CPB Reserch Memorandum no 172, The Hague.*

B.H. Hasselman (1994), 'Investment, Q and Financing', CPB research memorandum No. 77.

J.R. Hines (1999), Lessons from behavioural responses to international taxation,' *National Tax Journal, pp. 305-323.*

Appendix A: derivations

Depreciation: equation (8)

The discounted value of the fiscal depreciations can be split up into depreciations on the existing capital stock at time *t*, AF_t, and the discounted value of depreciations on new investments:

$$\sum_{j=1}^{\infty}\left(\frac{1}{1+\rho_a}\right)^j A_{t+j} = \sum_{j=1}^{\infty}\sum_{\tau=1}^{\infty} \nu(1-\nu)^{\tau-1} i_{t+j-\tau} p_{i,t+j-\tau}\left(\frac{1}{1+\rho_a}\right)^j . \tag{a.1}$$

We split this expression into two components, AA an AB, with AA equal to

$$\begin{aligned} AA &= \sum_{j=1}^{\infty}\sum_{\tau=1}^{j} \nu(1-\nu)^{\tau-1} i_{t+j-\tau} p_{i,t+j-\tau}\left(\frac{1}{1+\rho_a}\right)^j \\ &= \sum_{\tau=1}^{\infty}\sum_{j=\tau}^{\infty} \nu(1-\nu)^{\tau-1} i_{t+j-\tau} p_{i,t+j-\tau}\left(\frac{1}{1+\rho_a}\right)^j \\ &= \sum_{\tau=1}^{\infty}\sum_{u=0}^{\infty} \nu(1-\nu)^{\tau-1} i_{t+u} p_{i,t+u}\left(\frac{1}{1+\rho_a}\right)^{u+\tau} \\ &= \sum_{u=0}^{\infty}\sum_{\tau=1}^{\infty} \nu(1-\nu)^{\tau-1} i_{t+u} p_{i,t+u}\left(\frac{1}{1+\rho_a}\right)^{u+\tau} \\ &= \sum_{u=0}^{\infty} \frac{\nu}{\rho_a+\nu} i_{t+u} p_{i,t+u}\left(\frac{1}{1+\rho_a}\right)^{u} . \end{aligned} \tag{a.2}$$

and AB equal to

$$\begin{aligned} AB &= \sum_{j=1}^{\infty}\sum_{\tau=j+1}^{\infty} \nu(1-\nu)^{\tau-1} i_{t+j-\tau} p_{i,t+j-\tau}\left(\frac{1}{1+\rho_a}\right)^j \\ &= \sum_{\tau=1}^{\infty}\sum_{u=1}^{\infty} \nu(1-\nu)^{u+j-1} i_{t-u} p_{i,t-u}\left(\frac{1}{1+\rho_a}\right)^j \\ &= \sum_{u=1}^{\infty}\sum_{\tau=1}^{\infty} \nu(1-\nu)^{u+j-1} i_{t-u} p_{i,t-u}\left(\frac{1}{1+\rho_a}\right)^j \\ &= \sum_{u=1}^{\infty} (1-\nu)^u \frac{\nu}{\nu+\rho_a} i_{t-u} p_{i,t-u} . \end{aligned} \tag{a.3}$$

Therefore,

$$\sum_{j=1}^{\infty}\left(\frac{1}{1+\rho_a}\right)^j A_{t+j} = \sum_{j=1}^{\infty}(1-\nu)^j \frac{\nu}{\nu+\rho_a} i_{t-j}p_{i,t-j} + \sum_{j=0}^{\infty}\frac{\nu}{\rho_a+\nu} i_{t+j}p_{i,t+j}\left(\frac{1}{1+\rho_a}\right)^j$$

$$= \sum_{j=0}^{\infty}(1-\nu)^j \frac{\nu}{\nu+\rho_a} i_{t-j}p_{i,t-j} + \sum_{j=1}^{\infty}\frac{\nu}{\rho_a+\nu} i_{t+j}p_{i,t+j}\left(\frac{1}{1+\rho_a}\right)^j \qquad \text{(a.4)}$$

$$= AF_t + \sum_{j=1}^{\infty}\frac{\nu}{\rho_a+\nu} i_{t+j}p_{i,t+j}\left(\frac{1}{1+\rho_a}\right)^j ,$$

where AF_t equals the depreciation allowance on investments installed up to time t:

$$AF_t = \sum_{j=0}^{\infty}(1-\nu)^j \frac{\nu}{\nu+\rho_a} i_{t-j}p_{i,t-j} . \qquad \text{(a.5)}$$

The value of AF_t is given and therefore does not affect the optimization problem.

The Lagrangian

Define DA_t as the dividends before the depreciation allowance, that is

$$DA_t = (1-\tau_c)\left[p_{y,t}\left(F(k_{t-1}, l_t) - c(i_t, k_{t-1})\right) - w_t l_t\right] - (1-b_1-n-s)\,p_{i,t}i_t$$
$$- \left((1-\tau_c)\,\rho_{b,t} + b_0\right)B_{t-1} . \qquad \text{(a.6)}$$

Then the Lagrangian can be written as

$$\max\ L_t = \sum_{j=1}^{\infty}\Big((1-\tau_p)\,DA_{t+j} + \tau_c\frac{\nu}{\rho_a+\nu}p_{i,t+j}i_{t+j} - N_{t+j}$$
$$- q_{t+j}[k_{t+j} - (1-\delta)\,k_{t+j-1} - i_{t+j}]$$
$$+ \lambda_{t+j}[B_{t+j} - (1-b_0)\,B_{t+j-1} - b_1 p_{i,t+j}i_{t+j}] \qquad \text{(a.7)}$$
$$+ \mu_{t+j}[N_{t+j} - n p_{i,t+j}i_{t+j}]\Big)\left(\frac{1}{1+\rho_a}\right)^j$$
$$+ \tau_c AF_t .$$

This Lagrangian leads directly to the first order conditions (9) through (13).

The steady state

In the steady state c = $c_i = c_k = 0$. Also, all prices rise with the inflation rate π, including the shadow price of capital q_t, so that $q_{t+1} = q_t(1+\pi)$. Equation (10) reads in the steady state as

$$q = \frac{\left((1-\tau_p)\left[(1-\tau_c)p_y F_k\right] + q(1-\delta)\right)(1+\pi)}{1+\rho_a} \quad . \tag{a.8}$$

Define $1+r_a = (1+\rho_a)/(1+\pi)$. Substituting this gives

$$q = (1-\tau_p)(1-\tau_c)\frac{p_y F_k}{r_a+\delta} \quad , \tag{a.9}$$

which is equation (15). Rewriting this equation in terms of the after tax marginal product of capital gives

$$(1-\tau_c)p_y F_k = \frac{r_a+\delta}{1-\tau_p} q \quad . \tag{a.10}$$

Substituting equation (16) gives

$$\begin{aligned}(1-\tau_c)p_y F_k &= \frac{r_a+\delta}{1-\tau_p}\left[(1-\tau_p)(1-b_1-n-s-\tau_c\frac{\nu}{\rho_a+\nu}) + b_1\lambda + n\right]p_i \\ &= (r_a+\delta)\left[1-b_1-n-s-\tau_c\frac{\nu}{\rho_a+\nu} + b_1\frac{\lambda}{1-\tau_p} + \frac{n}{1-\tau_p}\right]p_i \\ &= (r_a+\delta)\left[1-b_1+\frac{\tau_p}{1-\tau_p}n-s-\tau_c\frac{\nu}{\rho_a+\nu} + b_1\frac{\lambda}{1-\tau_p}\right]p_i \quad .\end{aligned} \tag{a.11}$$

Substituting (14) gives

$$(1-\tau_c)p_y F_k = (r_a+\delta)\left[1-b_1+\frac{\tau_p}{1-\tau_p}n-s-\tau_c\frac{\nu}{\rho_a+\nu} + b_1\frac{(1-\tau_c)\rho_b+b_0}{\rho_a+b_0}\right]p_i \quad . \tag{a.12}$$

Substituting $b_0 = \delta(1+\pi) - \pi$ gives

$$\begin{aligned}(1-\tau_c)p_y F_k &= (r_a+\delta)\left[1-b_1+\frac{\tau_p}{1-\tau_p}n-s-\tau_c\frac{\nu}{\rho_a+\nu} + b_1\frac{(1-\tau_c)\rho_b+\delta(1+\pi)-\pi}{\rho_a+\delta(1+\pi)-\pi}\right]p_i \\ &= (r_a+\delta)\left[1-b_1+\frac{\tau_p}{1-\tau_p}n-s-\tau_c\frac{\nu}{\rho_a+\nu} + b_1\frac{\rho_b-\pi+\delta(1+\pi)-\tau_c\rho_b}{\rho_a-\pi+\delta(1+\pi)}\right]p_i \quad .\end{aligned} \tag{a.13}$$

Define $r_b = (1+\rho_b)/(1+\pi)-1= (\rho_b-\pi)/(1+\pi)$. Also, $r_a = (\rho_a-\pi)/(1+\pi)$. Substituting these relations gives

$$(1-\tau_c)\,p_y F_k = (r_a+\delta)\left[1-b_1+\frac{\tau_p}{1-\tau_p}n-s-\tau_c\frac{\nu}{\rho_a+\nu} + b_1\frac{r_b+\delta-\tau_c\rho_b/(1+\pi)}{r_a+\delta}\right]p_i$$

$$= \left[\left(1-b_1+\frac{\tau_p}{1-\tau_p}n-s\right)(r_a+\delta) + b_1(r_b+\delta)-\tau_c\left(\nu\frac{r_a+\delta}{\rho_a+\nu}+\frac{b_1\rho_b}{1+\pi}\right)\right]p_i\,, \tag{a.14}$$

which is equation (17).

Neutrality

The above equation can be written as:

$$p_y F_k = \frac{A-\tau_c B}{1-\tau_c}p_i \equiv p_k\,, \tag{a.15}$$

with

$$A = \left(1-b_1+\frac{\tau_p}{1-\tau_p}n-s\right)(r_a+\delta) + b_1(r_b+\delta) \quad \text{and} \quad B = \frac{\nu(r_a+\delta)}{\rho_a+\nu}+\frac{b_1\rho_b}{1+\pi}\,. \tag{a.16}$$

Differentiating the user cost of capital p_k with respect to τ_c gives:

$$\frac{\partial p_k}{\partial \tau_c} = \frac{A-B}{(1-\tau_c)^2}\,, \tag{a.17}$$

so that the user cost of capital rises with, falls with or is independent of a change in the corporate tax rate if A is larger than, smaller than or equal to B. If at the margin all investment is bond financed and there are no subsidies (b_1=1, s and n zero), equality of A and B implies

$$r_b+\delta = \frac{\nu(r_a+\delta)}{\rho_a+\nu}+\frac{\rho_b}{1+\pi}\,. \tag{a.18}$$

Substituting $r_b = (\rho_b-\pi)/(1+\pi)$ and $r_a = (\rho_a-\pi)/(1+\pi)$ gives

$$\nu = \delta(1+\pi)-\pi\,. \tag{a.19}$$

Dynamics

Solving equation (10) forward gives

$$
\begin{aligned}
q_t &= \sum_{j=0}^{\infty}\left[\frac{(1-\tau_p)(1-\tau_c)\,p_{y,t+j+1}\left(F_{k,t+j+1}-c_{k,t+j+1}\right)}{1+\rho_a}\left(\frac{1-\delta}{1+\rho_a}\right)^{j}\right] \\
&= (1-\tau_p)(1-\tau_c)\sum_{j=0}^{\infty}\left[\frac{p_{y,t}\left(F_{k,t+j+1}-c_{k,t+j+1}\right)}{1+r_a}\left(\frac{1-\delta}{1+r_a}\right)^{j}\right].
\end{aligned}
\tag{a.20}
$$

Substituting (11) and dividing by $1-\tau_p$ gives

$$
\begin{aligned}
&(1-\tau_c)\sum_{j=0}^{\infty}\left[\frac{p_{y,t}\left(F_{k,t+j+1}-c_{k,t+j+1}\right)}{1+r_a}\left(\frac{1-\delta}{1+r_a}\right)^{j}\right] = \\
&\left[1-b_1-n-s-\frac{\tau_c\nu}{\rho_a+\nu}+\frac{b_1\lambda_t+n\mu_t}{1-\tau_p}\right]p_{i,t} + (1-\tau_c)\,p_{y,t}c_{i,t}\,.
\end{aligned}
\tag{a.21}
$$

Substituting (13) and 14) gives

$$
\begin{aligned}
&(1-\tau_c)\sum_{j=0}^{\infty}\left[\frac{p_{y,t}\left(F_{k,t+j+1}-c_{k,t+j+1}\right)}{1+r_a}\left(\frac{1-\delta}{1+r_a}\right)^{j}\right] = \\
&\left[1-b_1+\frac{\tau_p n}{1-\tau_p}-s-\frac{\tau_c\nu}{\rho_a+\nu}+b_1\frac{(1-\tau_c)\rho_b+b_0}{\rho_a+b_0}\right]p_{i,t} + (1-\tau_c)\,p_{y,t}c_{i,t}\,.
\end{aligned}
\tag{a.22}
$$

Substituting $b_o = \delta(1+\pi) - \pi$, gives

$$
\begin{aligned}
&(1-\tau_c)\sum_{j=0}^{\infty}\left[\frac{p_{y,t}\left(F_{k,t+j+1}-c_{k,t+j+1}\right)}{1+r_a}\left(\frac{1-\delta}{1+r_a}\right)^{j}\right] = \\
&\left[1-b_1+\frac{\tau_p n}{1-\tau_p}-s-\frac{\tau_c\nu}{\rho_a+\nu}+b_1\frac{\rho_b-\pi+\delta(1+\pi)-\tau_c\rho_b}{\rho_a-\pi+\delta(1+\pi)}\right]p_{i,t} + (1-\tau_c)\,p_{y,t}c_{i,t}\,.
\end{aligned}
\tag{a.23}
$$

Substituting $r_b = (\rho_b - \pi)/(1+\pi)$ and $r_a = (\rho_a - \pi)/(1+\pi)$ gives

$$(1-\tau_c)\sum_{j=0}^{\infty}\left[\frac{p_{y,t}\left(F_{k,t+j+1}-c_{k,t+j+1}\right)}{1+r_a}\left(\frac{1-\delta}{1+r_a}\right)^j\right]=$$

$$\left[1-b_1+\frac{\tau_p n}{1-\tau_p}-s-\frac{\tau_c \nu}{\rho_a+\nu}+b_1\frac{r_b+\delta-\frac{\tau_c\rho_b}{1+\pi}}{r_a+\delta}\right]p_{i,t}+(1-\tau_c)p_{y,t}c_{i,t}= \tag{a.24}$$

$$\left[\left(1-b_1+\frac{\tau_p n}{1-\tau_p}-s\right)(r_a+\delta)+b_1(r_b+\delta)-\tau_c\left(\frac{\nu(r_a+\delta)}{\rho_a+\nu}+\frac{b_1\rho_b}{1+\pi}\right)\right]\frac{p_{i,t}}{r_a+\delta}$$

$$+(1-\tau_c)p_{y,t}c_{i,t}\ .$$

which is equation (22) in the main text.

Appendix B: Simulation reduction in income taxes

Table 8.1 Cumulated effects of a reduction in income taxes by 1% GDP

		1999	2000	2002	2006
p r i c e s					
wage rate enterprises	%	-0.89	-1.22	-1.07	-0.82
gross value added private sector	%	-0.23	-0.45	-0.62	-0.64
q u a n t i t i e s					
private consumption	%	0.95	1.24	1.55	1.91
private investment excl. dwellings	%	1.01	1.83	1.83	1.87
exports of goods excl. energy	%	-0.08	0.02	0.32	0.56
imports of goods	%	0.62	0.80	1.18	1.49
net national income	%	0.41	0.54	0.71	0.93
gross value added exposed	%	0.36	0.51	0.77	0.98
gross value added sheltered	%	0.57	0.87	1.23	1.62
employment enterprises (fte)	%	0.45	0.80	1.14	1.46
empl.enterprises(fte) low skilled	%	0.59	1.03	1.42	1.85
empl.enterprises(fte) high skilled	%	0.37	0.67	0.97	1.23
unemployed persons	D	-18.9	-30.2	-37.9	-47.8
q u o t e s					
capacity utilization rate exposed	D	0.20	0.19	0.21	0.14
capacity utilization rate sheltered	D	0.15	0.06	0.04	0.06
current account (% NNI)	D	-0.39	-0.51	-0.65	-0.75
labour income share enterprises	D	-0.56	-0.54	-0.25	-0.03