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Private Investments in Norway and the User Cost of Capital

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Abstract:

This paper has three main points. First, we loose information about the capital accumulation process if too heterogeneous types of real capital are included it the aggregate 'real capital'. Second, we get a better model by estimating both real capital and gross investments in the same system. Third, temporal fluctuations in the user cost of capital may have permanent effects on capital accumulations.

Keywords: Real capital, investments, user cost, cointegrated VAR.

JEL classification: C32, E22

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Section 1: Introduction and overview

There are two important reasons for being interested in modelling investments. First, since fluctuations in investments are larger than fluctuations in other components of demand, we must understand investments in order to understand business cycles. Second, investments increase the stock of real capital, and therefore play an important part in determining a country's production capacity and its possibilities for economic growth.

In a majority of empirical studies all investments in fixed capital is modelled together, although there is a big difference between different types of real capital. It may take longer time to adjust the stock of buildings than the stock of machinery. It is therefore preferable, to divide the stock of capital goods into more homogenous groups, than to model the heterogeneous group of all real capital together. This is done here, where we have divided the stock of real capital into two groups. On the one hand we are modelling buildings and structures, and on the other hand machinery. By modelling these groups separately, we get more precise estimates on the adjustment process than we would have obtained by not taking into account that real capital is a very heterogeneous group.

Another contribution in this paper is to examine if we get a more precise model for investment accumulation by including both real capital and gross investments in the estimated system. Normally only real capital or gross investment is used. By including both we get more information about the accumulation process, which can give us a better model for predicting the further process.

There are some previous studies on the relationship between the user cost of capital and investments in Norway; see Biørn (1979), Dûfenberg et al. (1994). The data for real capital have since been altered dramatically due to the change from linear to geometric depreciation in the Norwegian national accounts. Therefore there is a good reason for a new examination on the relationship between the user cost of capital and investment.

Many approaches have been taken to model investments, both at the firm level and at an aggregate level. For recent surveys see for example Chirinko (1993) and Caballero (1997). We will use a version of the neo-classical model pioneered by Jorgenson (1963,1971). The theory behind the user cost of capital is presented in section 2.

There are many approaches for calculating the user cost of capital. We assume that investors are domestic residents, and thus their required return on equity should depend on how the return of alternative financial saving is taxed. In the model derived in section 2 therefore, we take taxes for both firms and investors into account when calculating the user cost of capital. Before the Norwegian tax reform of 1992, the tax system lead to different user cost of capital depending upon how the investment was financed. Since 1992, however, the tax system has been neutral to a large extent.

In section 3 we give a summary of the size of the different taxes since 1978 and calculate the user cost of capital. We calculate the user cost of capital for both buildings and machinery. These user costs differ for three reasons. First, their price indices differ. Second, the tax deprecation rates differ among different types of real capital. Finally, machinery depreciates more rapidly than buildings. Since the user cost of capital depends upon all these three factors (among others), they all contribute to different costs of capital between the two.

In section 4 we postulate two equations that we estimate. In the first equation we express real capital as a function of production and the user cost of capital. Based on the long run relationship between gross investments and real capital we derive the second equation, where gross investment is expressed as a function of production and the user cost of capital.

The empirical analysis is presented in section 5. We test the two equations from section 4 for two types of real capital: (i) buildings and structures and (ii) other real capital than buildings and structures (hereafter called machinery, although this group also includes transport material and boats). The results from the empirical tests are also discussed here. Section 6 concludes.

Section 2: The user cost of capital

In 1992 new tax rules were introduced in Norway. The tax reform led to significant changes in the tax system. In the next subsection we calculate the user cost of capital before 1992, and in the last subsection in this section we will show how to calculate the user cost of capital thereafter. The model we use is closely related to Berg (1986).

The user cost of capital before 1992

The cash flow to the stockholders (Y) depends on the dividend (D) and new stock emissions $(\dot{S})$, and how dividends and price gains are taxed. Before 1992 stockholders did not pay taxes on price gains if they had owned the stock for at least three years.[1] In the following we will assume that the investor keeps his stocks for at least three years, and thus we do not take this tax into account. The only tax in equation (2-1) is therefore the tax on dividends, τ_d.

(2-1) $$Y = (1-\tau_d)D - \dot{S}$$

In this section we will assume that the investor is risk neutral, which implies that investors will require the same return whether they invest the money market (the left hand side in equation (2-2)) or in the stock market (the right hand side).[2] Here V is the value of the stocks, r is the money market interest rate before tax on interest, i is the same interest rate after tax on interest, where τ_r is the tax rate on interest.[3]

(2-2) $$iV = Y + \dot{V}, \qquad i = r(1-\tau_r)$$

The solution to the differential equation system (2-1) and (2-2) is given by equation (2-3), where we have assumed away so-called 'rational bubbles'.[4] The stockholder's value is the present value of the stockholders cash flow, where the interest rate after tax is used as discount rate.

(2-3) $$V_0 = \int_0^\infty \left[(1-\tau_d)D - \dot{S}\right] e^{-it}\, dt$$

The company's budget constraint is given in equation (2-4). On the left hand side we have placed the factors that (normally) lead to cash inflows. The revenue of the corporation, $p{\cdot}f(K,L)$, depends upon the price of the output, p, and the production, $f(K,L)$, where K is the stock of real capital and L is the labour force. $\dot{B}$ is the increase in the company's debt, and $\dot{S}$ is new stock emissions. The factors leading to cash outflows are placed on the right hand side of equation (2-5). q is the price on real capital and J is gross investment in real capital, w is the wage, B is the firm's debt and T is the corporate tax.

(2-4) $$pf(K,L) + \dot{B} + \dot{S} = qJ + wL + rB + T + D$$

Before 1992 companies paid taxes both to the state and to the local authorities. The tax bases for the two taxes were different, however. The basis for the tax to the local authorities was the revenue minus

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[1] More precisely; before 1980 this period was 5 years, from 1980 to May 1986 the period was 2 years, and from June 1986 and till 1992 the investor had to owe the stocks for 3 years for the price gain to be tax-free.

[2] In section 3 we will include a risk premium. This risk premium is not included here to make the calculation simpler.

[3] Henceforth a dot above a variable denotes its derivative with respect to time.

[4] Assuming away 'rational bubbles' is here the same as to assume that the transversality condition holds. See for example Obstfeld and Rogoff (1996) pp. 121-124 for an argument of why 'rational bubbles' are not so rational after all.

labour costs, cost on loans and tax depreciation allowances (*A*). In the basis for tax to the state, the dividend was also subtracted.

In equation (2-5) total corporate taxes *T* is divided into taxes to the state T_S and taxes to the local authorities T_K. Similarly, τ_S and τ_K are tax rates to the state and the local authorities respectively.

$$
\begin{aligned}
(2\text{-}5)\qquad T &= T_S + T_K \\
&= \tau_S\left[pf(K,L) - wL - rB - A - D\right] + \tau_K\left[pf(K,L) - wL - rB - A\right] \\
&= \tau\left[pf(K,L) - wL - rB - A - dD\right]
\end{aligned}
$$

where $\tau = \tau_S + \tau_K$ is the total tax rate and $d = \tau_S/\tau$ can be interpreted as the tax credit on dividend. By inserting (2-5) into (2-4) and solving for the dividend we get (2-6).

$$
(2\text{-}6)\qquad D = \frac{1}{1-d\tau}\left[(1-\tau)(pf(K,L) - wL) - qJ + \tau A - (1-\tau)rB + \dot{B} + \dot{S}\right]
$$

In the following we will write depreciation allowances as in equation (2-7) where *z* is the present value of depreciation allowances for real capital and A_0 is the present value of depreciation allowances for investments already made.

$$
(2\text{-}7)\qquad \int_0^\infty e^{-it} A\,dt = \int_0^\infty e^{-it} zqJ\,dt + A_0
$$

By inserting (2-6) and (2-7) into (2-3) we get the expression for the stockholders present value:

$$
\begin{aligned}
(2\text{-}8)\qquad V_0 &= \int_0^\infty e^{-it}\left[\frac{1-\tau_d}{1-d\tau}\left\{(1-\tau)\left[pf(K,L) - wL\right] - (1-z\tau)qJ - (1-\tau)rB + \dot{B} + \dot{S}\right\} - \dot{S}\right]dt \\
&\quad + \frac{1-\tau_d}{1-d\tau}A_0
\end{aligned}
$$

In this model we have to make assumption on how the company finances its investments. These assumptions are given in equation (2-9), where we assume that both debt and equity capital increase with the value of real capital. Other assumptions could have been made, but the assumptions in (2-9) make it easy to show how the user cost of capital depends upon how the investment is financed.

(2-9) $$B = bqK \quad \Rightarrow \quad \dot{B} = b(\dot{q}K + q\dot{K})$$
$$\dot{S} = s(\dot{q}K + q\dot{K})$$

We must also have in mind that the net investment equals gross investment minus depreciation of real capital. For simplicity the depreciation of real capital is assumed to be geometric;

(2-10) $$\dot{K} = J - \delta K .$$

Since we in the empirical analysis will allow for scale advantages, we here assume that the corporation faces a downsloping demand function. We let, however, the corporation to be price taker in the input/factor market. The company maximizes stockholders' present value (equation (2-8)), subject to how they finance their investments (equation (2-9)), the depreciation of real capital (equation (2-10)) and the downsloping demand function where $\varepsilon = -\frac{dx}{dp}\frac{p}{x}$ is the demand elasticity. The first order equations of the Hamilton function are derived in (2-11a) - (2-11c).

(2-11a) $$\frac{d\Lambda}{dL_t} = 0 \Rightarrow p\frac{\varepsilon - 1}{\varepsilon} f'_L = w$$

(2-11b) $$\frac{d\Lambda}{dJ_t} = e^{-it}\left\{\frac{1-\tau_d}{1-d\tau}\left[-(1-z\tau)q + (b+s)q\right] - sq\right\} + \lambda = 0$$
$$\Rightarrow \lambda = e^{-it}\left\{\frac{1-\tau_d}{1-d\tau}\left[(1-z\tau) - (b+s)\right] + s\right\}q$$
$$\Rightarrow \dot{\lambda} = -(i - \frac{\dot{q}}{q})e^{-it}\left\{\frac{1-\tau_d}{1-d\tau}\left[(1-z\tau) - (b+s)\right] + s\right\}q$$

(2-11c) $$\frac{d\Lambda}{dK_t} = e^{-it}\left\{\frac{1-\tau_d}{1-d\tau}\left[(1-\tau)p\frac{\varepsilon-1}{\varepsilon}f'_K - (1-\tau)rbq + (b+s)(\dot{q} - \delta q)\right] - s(\dot{q} - \delta q)\right\}$$
$$+ \dot{\lambda} - \delta\lambda = 0$$
$$\Rightarrow \dot{\lambda} - \delta\lambda = -e^{-it}\left\{\frac{1-\tau_d}{1-d\tau}\left[(1-\tau)P\frac{\varepsilon-1}{\varepsilon}f'_K - (1-\tau)rbq + (b+s)(\dot{q} - \delta q)\right] - s(\dot{q} - \delta q)\right\}$$

By inserting λ from (2-11b) into (2-11c) we get equation (2-12).

(2-12) $$c = p\frac{\varepsilon-1}{\varepsilon}f'_K = q\frac{1}{1-\tau}\left[(1-z\tau)\left(i - \frac{\dot{q}}{q} + \delta\right) + rb(1-\tau) + \left(\frac{1-d\tau}{1-\tau_d}s - (b+s)\right)i\right]$$

where $i = r(1-\tau_r)$. Equation (2-12) expresses the user cost of capital for different values of *b* and *s*. We will now solve for the user cost of capital for three special situations. First we solve for the user cost of capital if the investment is financed by withholding internal profits. This involves setting *b*=*s*=0 and is done in equation (2-13).

(2-13) $$c = p\frac{\varepsilon-1}{\varepsilon}f'_K = q\frac{1}{1-\tau}\left[(1-z\tau)\left(i-\frac{\dot{q}}{q}+\delta\right)\right] = q\frac{1-z\tau}{1-\tau}\left(r(1-\tau_r)-\frac{\dot{q}}{q}+\delta\right)$$
if $b = s = 0$.

The second special case is if the investment is financed by debt. This involves setting *b*=1 and *s*=0 and the result is given in equation (2-14). The user cost of capital in equations (2-13) and (2-14) are equal if and only if the tax on interest rate equals the corporate tax, that is $\tau_r = \tau$.

(2-14) $$c = p\frac{\varepsilon-1}{\varepsilon}f'_K = q\frac{1}{1-\tau}\left[(1-z\tau)\left(i-\frac{\dot{q}}{q}+\delta\right)+r(\tau_r-\tau)\right] \text{ if } b=1, s=0.$$

The third special case is when the investment is financed by new equity. Then *b*=0 and *s*=1, and the expression is given in equation (2-15). From (2-15) we see that the user cost of capital is normally not equal to the user cost of capital when the investment is financed by neither internal earnings nor debt. Financing investments by new equity is more expensive than financing by internal earnings if the state tax (τ_S=dτ) (which involves a tax reduction on dividend) is less than the tax on dividends (τ_d).

(2-15) $$c = p\frac{\varepsilon-1}{\varepsilon}f'_K = q\frac{1}{1-\tau}\left[(1-z\tau)\left(i-\frac{\dot{q}}{q}+\delta\right)+\left(\frac{\tau_d-\tau_S}{1-\tau_d}\right)r(1-\tau_r)\right] \text{ if } b=0, s=1.$$

Financing by new equity is more expensive than debt financing if, and only if,

(2-16) $$\left(\frac{\tau_d-\tau_S}{1-\tau_d}\right)(1-\tau_r)-(\tau_r-\tau)$$

is positive.

The user cost of capital since 1992

The tax reform of 1992 made the calculation of the user cost of capital much simpler. One complicated rule is the tax for price gains on stocks. Only the price gain not caused by withholding of dividends is to be taxed. As a simplification we will assume that there is no tax on price gain.

The simplifications we can make in the calculation are given in equation (2-17). Since 1992 the dividend is not taxed, and in the taxation of the firm there is no tax reduction when the firm pays out dividend. The tax rate on interest and the corporate tax rate are equal (28 per cent).

(2-17) $$\begin{aligned} \tau_d &= d = 0 \\ \tau_r &= \tau = 0.28 \end{aligned}$$

With these simplifications the user cost of capital is independent of how the investment is financed, and is given in equation (2-18).

(2-18) $$c = p\frac{\varepsilon - 1}{\varepsilon} f'_K = q\frac{1 - z\tau}{1 - \tau}\left(i - \frac{\dot{q}}{q} + \delta\right)$$

Section 3: The calculation of the user cost of capital

Many problems arise when calculating the user cost of capital. First, we must decide how to handle uncertainty. Second, we must calculate the effective corporate tax. The third and fourth problems are to calculate the present value of tax depreciation and to decide which depreciation rate to use. The final problem is to choose the source of finance.

Uncertainty

In the model in section 2 we simplified by assuming that investors were risk neutral. Of course, this is not the case in practice. Investors will (normally) require an expected return greater than the after tax interest rate as a compensation for uncertainty. To control for uncertainty we include a risk premium in the expression for the user cost of capital. It is important to note that the corporate risk premium is independent of the corporation's debt to equity ratio. Equation (3-1) will help illustrating this.

(3-1) $$i + \theta = i\frac{B}{V + B} + k_S\frac{V}{V + B}$$

The total value of the firm is $V+B$, where the stockholder's value is V and the creditor's value is B. If the probability of bankruptcy is zero, the debt holder will claim a revenue equal to the money market interest rate. The cost of debt for the corporation is the after tax interest rate, since debt is subtracted from the tax bases; k_s is the required return for stockholders, and θ is the risk premium for the corporation. The left hand side in equation (3-1) is often called the WACC (weighted average cost of (finance-) capital).[5] Solving for k_s gives us

(3-2) $$k_s = i + \theta_S \text{ where } \theta_S = \left[1 + \frac{B}{V}\right]\theta .$$

The required return for stockholders depends on the debt to equity ratio, since the stockholders required excess return (θ_S) depends on the debt to equity ratio. If this ratio is low, the total uncertainty is spread over many stocks and the uncertainty per stock is relatively small. Therefore, the required return on equity is close to the WACC. θ=0 represent the case where investors are risk neutral. The required return for stockholders is then equal to the after tax interest rate.

The following example illustrates why the risk premium for the corporation is independent of the debt to equity ratio. Imagine a corporation where one investor owns all the stocks and supplies all loans. Then the cash flow from the corporation to the investor is independent of the debt to equity ratio of the corporation. Therefore the required total return from the firm should be independent of how it is financed. This will indeed be the case if the corporate risk premium is independent of the debt to equity ratio.

The same example shows why it is wrong to control for uncertainty by assuming that the stockholders risk premium is independent of the debt to equity ratio. The WACC would then decrease with the debt to equity ratio, implying that the investor should require a lower total cash flow from the corporation, which cannot be rational. This example clarifies why the correct approach to control for uncertainty, is to let the corporate risk premium to be independent of the debt to equity ratio, and not to let the stockholders risk premium be independent of the debt to equity ratio.

Unfortunately, it is impossible to observe the risk premium. However, we can get a rather good idea on the size of the risk premium by observing the excess return in the stock market. According to Johnsen (1996), the average excess return on stocks at the Norwegian Stock Exchanges was approximately 5 per cent in the period 1970 - 1994. When Johnsen (op cit.) controls for the fact that

[5] Strictly speaking, the WACC will not be independent of the debt to equity ratio when different financial sources are taxed differently. The calculation will, however, be valid for our purpose, since all the different effects of alternative financial

the average debt to equity ratio for companies registered on the Norwegian Stock Exchange is 3:2, and that debt and equity are taxed differently, he concludes that the corporate risk premium seems to be approximately 4.5 per cent before tax. Johnsen (op cit.) suggest this risk premium to be used for public investments, and this view is supported in the Norwegian public report NOU 1997:27. Since we will use the risk premium in a period where the tax rate is changing, it is better to operate with a risk premium after tax, since it is the after tax premium that is interesting for the investors. The after tax risk premium we will use is 3.25 per cent, which is equal the risk premium Johnson (op cit.) suggested minus the tax rate after 1992.[6] If θ=3.25 and the debt to equity ratio is 1:1, the stockholders risk premium is 6.5 per cent.

The effective corporate tax

Before the tax reform in 1992 there were many funds in which the corporation could invest some of their surplus to postpone, avoid or reduce the corporate tax. The most important of these funds was the consolidation fund. In the period 1982 to 1991 firms could place between 16 and 23 per cent of their surplus in this fund, and money placed in the fund was totally tax free. In the calculation of the effective corporate tax we have only taken this fund into account. In table 3-1 we summarize the corporate taxes from 1978 to 1997 ('Tax rate' in the table), the maximum share of the surplus that could be put into the consolidation fund ('ratio'), and calculate the effective corporate tax rate ('effective tax rate').[7] We use the effective corporate tax rate in the calculation of the user cost of capital.

Table 3-1: The effective corporate tax, 1978-97

Period	Tax rate	ratio	effective tax rate
1978-81	0.508	0.000	0.508
1982	0.508	0.160	0.427
1983	0.508	0.200	0.406
1984	0.508	0.220	0.396
1985-91	0.508	0.230	0.391
1992-97	0.280	0.000	0.280

Sources: Larsen (1992,1993), and Holmøy, Larsen and Vennemo (1993).

sources are taken into account in the last part of equations (2-14) and (2-15).

[6] The risk premium is calculated as $4.5 \cdot (1-.28) \approx 3.25$, where 0.28 is the tax rate after the tax reform.

[7] The effective tax rate (τ) is calculated as $\tau = T \cdot (1-\nu)^{-1}$, where T is the "Tax rate" and ν is the "ratio".

The present value of tax depreciation

From 1978 to 1981 the tax depreciation allowances in Norway were based on linear depreciation. For buildings and structures the corporation could maximize the present value of tax deprecations allowances by writing down the value by 3.75 per cent the first 5 years, by 2.5 per cent the next 32 years, and by the last 1.25 per cent 38 years after the investment took place. For machinery the rates were 15 per cent the first 3 years, 10 per cent the next 4 years, and the last 5 per cent 9 years after the investment took place. The value of the tax depreciation allowances for this period is given by equation (3-3). We assume that corporations claim all their allowable tax depreciation allowances.[8]

$$z = \frac{a_1}{R}\left[1-(1+R)^{-t1}\right] + \frac{a_2}{R}\left[(1+R)^{-t1}-(1+R)^{-t2}\right] + \frac{a_3}{R}\left[(1+R)^{-t2}-(1+R)^{-t3}\right], \quad (3\text{-}3)$$

where $R=i+\theta$, a_1 is the tax depreciation rate the first $t1$ years, a_2 is the tax depreciation rate from year $t1$ to $t2$, and a_3 is the tax depreciation rate from year $t2$ to $t3$.

Since 1982 the tax depreciation has been geometrical, and in the first 10 year of this period it was possible to write off some of the investment immediately. Table 3-2 summarizes the tax depreciation rules for both buildings and structures and machinery.

Table 3-2: Maximal tax depreciation rates since 1982

	buildings&structures		machinery	
	Year 0	Annually	Year 0	Annually
1982-83	0.10	0.08	0.00	0.30
1984-85	0.09	0.09	0.00	0.35
1986	0.08	0.08	0.00	0.35
1987-91	0.07	0.07	0.00	0.30
1992-97	0.00	0.05	0.00	0.30

Sources: Larsen (1992,1993), and Holmøy, Larsen and Vennemo (1993).

For this period we have calculated the present value of tax depreciation by equation (3-4).

$$z = s_1 + (1-s_1)s/(s+R), \quad (3\text{-}4)$$

[8] Aarbu and MacKie-Mason (1998) reports that approximately 40 percent of Norwegian firms did not use maximum tax depreciation allowances in 1988 and 1991. After the tax reform in 1992 the share was reduced to 20 percent in 1993.

where s_1 is the immediate depreciation allowance and s is the annual depreciation rate.

The depreciation rate

Statistics Norway uses geometrical depreciation rates in the National Account; see Todsen (1997a,b). The depreciation rates we use here are 0.035 for buildings and structures and 0.125 for machinery. These depreciation rates imply an average lifetime of approximately 57 years for buildings and structures and 16 years for machinery. For formal estimation and calculation of the depreciation rates, see appendix B.

The source of finance

In table 3-3 we present the different taxes in the years 1978-91 we are using in this analysis. The tax on interest ('*Tr*' in the table) was in this period progressive, and depended upon the income of the taxpayer. As Holmøy et al. (1993) we use the highest marginal tax rate, since we assume that the representative stockholder pays the highest tax rate.

The effective corporate tax (*T*) is the effective tax rate the firm is facing if it fully utilized the possibility of placing some of their profits in the consolidation fund, cf. table 3-1. The tax to the state (*Ts*) was a fixed rate in the whole period (27.8 per cent). Tax on dividend (*Td*) was only paid to the state. This tax rate was also progressive, and we use the highest marginal tax rate.

In right hand side of table 3-2 we have also calculated the tax wedges between the different sources of financing. Form the table we see that the highest marginal tax on interest rates is higher than the effective corporate tax rate in every year, that is $Tr\text{-}T>0$. This implies that financing investments by debt were (on the margin) more expensive than financing investments by internal funds. Until 1988 internal financing were cheaper than financing by internal issuing new stocks, since $Ts\text{-}Td<0$ in this period. Finally, stock emissions were cheaper than financing investments by debt.

However, our results depend crucially on the restriction that that the investors are paying the highest marginal tax rates, and that firms fully utilized the possibility of placing profit in the consolidation fund. Berg (1986) has calculated tax rates for the representative stock holder that are lower than the highest marginal tax rates, and he also assumes away the possibility for firms to place some of their profits in a consolidation fund. He then finds that the tax on interest is approximately equal to the corporation tax, and that tax rate the corporation is paying to the state approximates the investors' tax on dividends. This leads to the conclusion that the user cost of capital is independent of how the investment is financed.

Table 3-3: Corporate and personal taxes and the ranking of the user cost of capital, 1978-91

Year	*Tr*	*T*	*Ts*	*Td*	*Tr-T*	*Ts-Td*	Eq. (2-16)	Definitions
1978	0.754	0.508	0.278	0.529	0.246	-0.251	-0.115	
1979	0.754	0.508	0.278	0.529	0.246	-0.251	-0.115	*Tr*: tax on
1980	0.754	0.508	0.278	0.529	0.246	-0.251	-0.115	interest
1981	0.654	0.508	0.278	0.424	0.146	-0.146	-0.058	
1982	0.704	0.427	0.278	0.474	0.277	-0.196	-0.167	*T*: effective
1983	0.684	0.406	0.278	0.454	0.278	-0.176	-0.176	corporate
1984	0.679	0.396	0.278	0.449	0.283	-0.171	-0.183	tax
1985	0.669	0.391	0.278	0.444	0.278	-0.166	-0.179	
1986	0.664	0.391	0.278	0.444	0.273	-0.166	-0.173	*Ts*: tax to the
1987	0.560	0.391	0.278	0.340	0.169	-0.062	-0.128	state
1988	0.480	0.391	0.278	0.315	0.089	-0.037	-0.061	
1989	0.456	0.391	0.278	0.246	0.065	0.032	-0.088	*Td*: tax on
1990	0.430	0.391	0.278	0.222	0.039	0.056	-0.080	dividends
1991	0.405	0.391	0.278	0.195	0.014	0.083	-0.075	

Sources: Larsen (1992,1993), and Holmøy, Larsen and Vennemo (1993).

Offerdal (1990b) finds that financing investments by debt were cheapest in the years 1962-1987, and use of internal funds the most expensive. He, however, uses average marginal tax rates documented in Offerdal (1990a). Sinn (1987) characterizes the Norwegian tax system as a 'fully imputation system', which involves that both debt and emission will dominate financing by internal funds. On the other hand, Holmøy et al. (1993), find the same ranking of different sources of financing investment caused by tax wedges as we do.

In the calculation of the user cost of capital we have only considered tax wedges between different sources of finance. Asymmetric information is another reason for why the cost different types of financial sources differ. Myers and Majluf (1984) show that corporations might have to sell new stocks at a lower price than their actual value. The discount is often called a 'lemon premium'; see Akerlof (1970). The assumptions behind this 'lemon premium' are that the market does not know so much about the corporation as the managers of the corporation do, and that the managers act in the interest of 'old' stockholders. For the firm it will be profitable to issue new stocks if the stocks are 'overvalued' in the market. The market knows this, and will therefore interpret an emission as a signal that the corporation is 'overvalued'. At the same time the corporation makes the emission public their stocks will drop.[9] This will increase the cost of financing investments by emission, and in the case of no tax wedges and no probability of bankruptcy, financing by emission will always be dominated by debt financing, cf. Myers and Majluf (op cit.) and Noe (1988). Since corporations did use debt financing before the tax reform of 1992, we will interpret this as that the 'lemon premium' in the stock market is as high as the tax difference between financing by equity and financing by debt. We will therefore use the user cost we found under the assumption that the investment was financed by debt as a proxy of the actual user cost of capital.

We use equation (3-5) to calculate the user cost of capital. In the equation we use the annual interest rate, annual increase in the price of real capital, and the annual depreciation rate.

$$c = q\frac{1}{1-\tau}\left[(1-z\tau)\left(r(1-\tau_r)+\theta-\frac{q-q_{-4}}{q}+\delta\right)+r(\tau_r-\tau)\right] \quad (3\text{-}5)$$

In figure 3-1 we have plotted the user cost of capital for buildings and structures for the three different types of financing. From the figure we see that although they differ before 1992, they do not differ that much.[10] From figure 3-2 we see that the same is the case for the three different sources of financing machinery investments. The correlations between user costs with different financial sources are reported in table 3-4 (for buildings and structures) and 3-5 (for machinery). We only report the correlation before 1992, since the different user costs were equal from 1992.

Table 3-4: Correlation between different user costs for buildings and structures, 1978-91

	Internal financing	Debt financing
Debt financing	0.966815	
Emission financing	0.99412	0.986331

Table 3-5: Correlation between different user costs for machinery, 1978-91

	Internal financing	Debt financing
Debt financing	0.990133	
Emission financing	0.996765	0.997858

[9] Empirical tests support this, see for example the list of empirical papers supporting the view that stock decreases on announcement of equity issue in Harris and Raviv (1991), table V p. 339 or VII p. 345. According to the same theory, stock prices increases on announcement of debt-for-equity exchanges or stock repurchases, and decreases on announcement of equity-for-debt exchanges. This is also supported by number of empirical tests, see Harris and Raviv (op cit.). However, the theoretical view that stock prices increases on announcement of debt issues is not supported in all empirical tests. On the other hand, non of the papers not supporting this view find the opposite relationship.

[10] From the figure we see that the user cost of capital for buildings and structures is negative in the beginning of the 1980's if the investment is financed by internal profit or stock emission, but positive if the investment is financed by debt. Since we in the empirical testing use the log of the user cost of capital, this is additional argument for using the 'debt financed' user cost.

Figure 3-1: The user cost of capital for buildings and structures

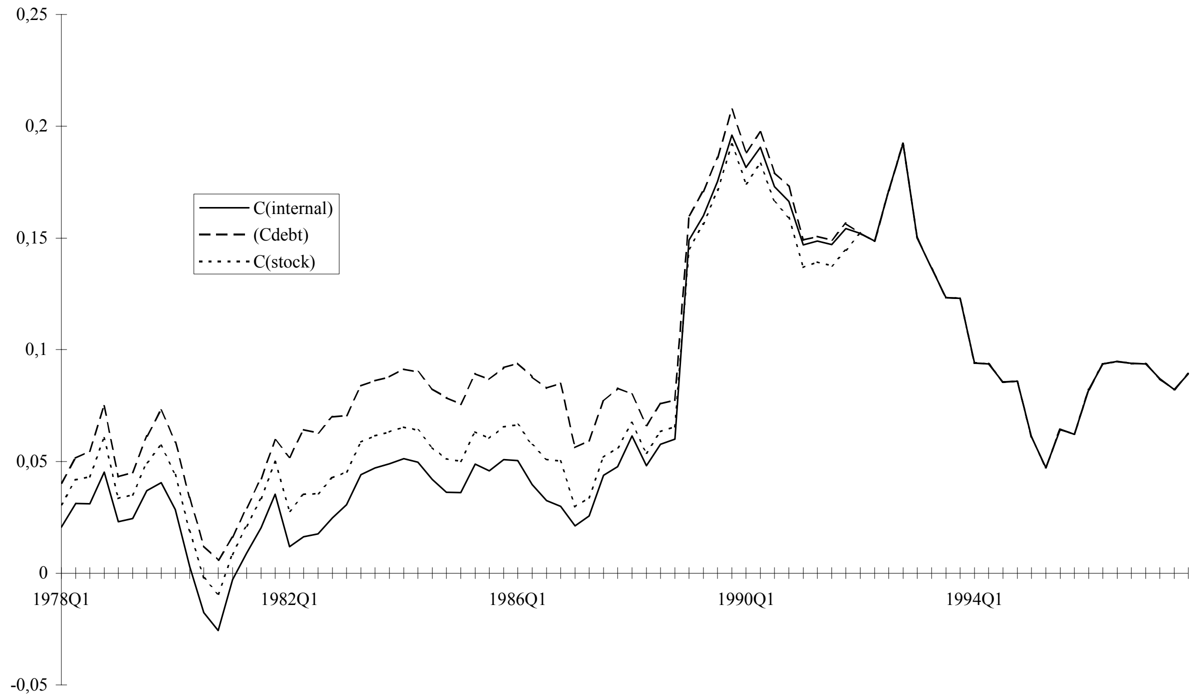
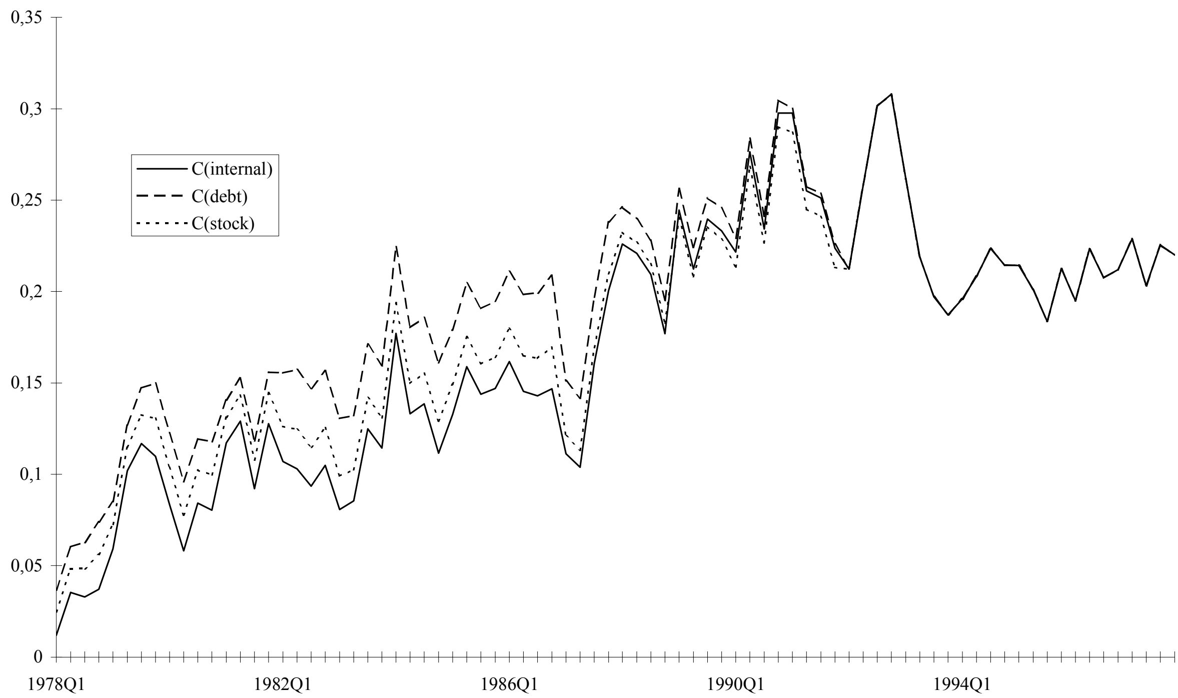


Figure 3-2: The user cost of capital for machinery



From the tables we see that the correlations between different user costs depending upon how the investment is financed, were very high. For buildings and structures the correlation between the 'debt financed' user cost and the 'internal financed' user cost is 96.7 percent, and the correlation between the 'debt financed' user cost and the 'emission financed' user cost is 98.6 percent. For machinery the correlation between the 'debt financed' user cost and the user cost when the investment is financed by internal profit or emission is between 99 and 100 per cent. With these high correlations, we believe that our empirical results do not depend crucially upon the fact that we only use the 'debt finance' user cost as the user cost of capital in the empirical tests.

Section 4: Two equilibrium correction specifications

In this section we derive two equilibrium correction models that we test empirically in section 5. We found the first order condition for real capital in section 2. If we assume a CES (Constant Elasticity of Substitution) production function as

(4-1) $$X = f(K,L) = \left[\alpha K^{\frac{\sigma-1}{\sigma}} + \beta L^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}\nu}$$

where σ and ν are respectively the elasticises of substitution and scale, we obtain[11]

(4-2) $$\log K = \eta + \kappa \log X - \sigma \log C, \text{ where } \kappa = \left(\sigma + \frac{1-\sigma}{\nu}\right), \; C = c/p$$

and η is a constant. Note that the ratio between real capital and production is constant (that is κ=1) if there is a constant return to scale (ν=1) or if the elasticity of substitution is unity (σ=1). The latter corresponds to the Cobb-Douglas product function, and was used by Jorgenson (1963).

In the long run equilibrium, with no growth in real capital, gross investments equal real capital depreciation, i.e. $J = \delta K$. Taking the log on both sides yields[12]

(4-3) $$\log J = \log \delta + \log K \, .$$

[11] From (3-5) we have $c/p = f'_K(\varepsilon-1)/\varepsilon$. By finding the derivate of productions with respect to capital from (4-1) and solving for real capital yields (4-2). The calculation is of (4-2) is still valid if we divide real capital into buildings and machinery, provided that the elasticity of substitution between all production factors, i.e. $X = \left[\alpha_b K_b^{\frac{\sigma-1}{\sigma}} + \alpha_m K_m^{\frac{\sigma-1}{\sigma}} + \beta L^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}\nu}$.

[12] This is also a valid transformation if the real capital grows in the long run equilibrium. Let the depreciation of real capital depend upon the stock of real capital in the previous period, and g be the growth rate for real capital (that is $K=(1+g)K_{-1}$). Then $J=(\delta+g)/(1+g)K$ in the long run equilibrium. Taking the log yields an equation like (4-3) apart from a constant.

Combining (4-2) and (4-3) yields

$$\text{(4-4)} \qquad \log J = (\eta + \log\delta) + \kappa\log X - \sigma\log C .$$

We only assume (4-2) - (4-4) to hold in the long run equilibrium. There are several reasons why the relationships do not hold in the short run.

Some authors assume quadratic implementation costs. They therefore use either an Euler equation approach or a partial adjustment model to estimate the investment equation, see for example Chirinko (1993) for an overview. Caballero (1997), on the other hand, argues that there are fixed implementation costs at the micro level. He shows that under some assumptions, a partial adjustment model can be used to model investments at the macro level.

Another reason why (4-2) - (4-4) will not hold all the time might be that the management of the firm need time to decide what sort of investment they will make. Investment might also be irreversible, and then it can be profitable to wait and see if a rise in sales is permanent before the investment eventually is made; see Dixit and Pindyck (1994). To take dynamics into account, we will estimate a cointegrated VAR (vector autoregressive) model. Let $y_t = (k_t, j_t, x_t, c_t)'$, where small case letters indicates that the variable is measured in logs (i.e. $k_t = \log K_t$ etc)[13] and the subscript t indicates time. Furthermore, let Π and Γ be 4x4 matrixes of coefficients; D_t a k-dimensional vector of deterministic variables (i.e. constant, seasonal dummies and other dummies) and λ an 4xk matrix of corresponding coefficients. Finally, Δ is the difference operator and the vector ε_t is assumed to be white noise Gaussian (ε_t~$N(0,\Omega)$).

$$\text{(4-5)} \qquad \Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1}\Gamma_i \Delta y_{t-i} + \lambda D_t + \varepsilon_t$$

The rank of Π corresponds to the number of cointegrating relationships. We write $\Pi=\alpha\beta'$, where the adjustment matrix α and the matrix of cointegrating vectors β are both 4xr matrixes (r is the number of linear independent cointegrating vectors). We expect (4-2) - (4-4) to be cointegrating vectors. However, since (4-2) - (4-4) are linear dependent (i.e. either one of them can be constructed by a linear relationship of the other two), they will correspond to two linearly independent cointegrating vectors.

[13] Therefore, c denotes henceforth the log of the real user cost, whereas it in previous sections denoted nominal user cost.

If the real user cost of capital is stationary, the real user cost of capital will also be a cointegrated vector alone. Therefore we will expect there to be three cointegrating vectors in our system.

Section 5: Empirical results

We estimate two different versions of (4-5): one where *k* and *j* corresponds to real capital and investments in buildings, and another where they corresponds to real capital and investments in machinery.

Investments in buildings and structures

When estimating the cointegrated VAR model for buildings we have included three dummies in addition to a constant and seasonal dummies: *d*90 is a dummy that equals unity in every quarter of 1990 and zero otherwise; *d*93 equals unity in every quarter of 1993 and zero otherwise; *dc* equals unity in the second and third quarter of 1980, 2nd in the 3rd quarter of 1980 and zero otherwise. The two first dummies are included to adjust for reclassification of some real capital (see appendix B), and the latter dummy controlles for significant changes in the user cost in 1980.

The estimation period is from the first quarter of 1980 to the last quarter of 1997. We need 4 lags for the diagnostic tests to be acceptable (i.e. p=4). However, with four lags many coefficients must be estimated and the number of degree of freedom is therefore low. We have therefore replicated all the estimates in the case of 2 lags.

From table 5-1 we see that we have some problems with normality in the system with four lags. This is mostly due to some normality problems in the equation for the user cost (p-value of 0.046).[14] However, normality is not a crucial assumption for valid estimates.

The cointegrating rank test tests the number of cointegrating vectors. The hypothesis of three cointegrating vectors is not rejected, whereas hypotheses of less than three vectors are rejected.

The stationary tests test if a variable constitute a cointegrating vector alone (leaving the other two unrestricted). The test confirms our expectation that the user cost is stationary, whereas the other variables are not.

The test for weak exogenity implies testing if a variable do not adjust to any of the cointegrating relationships (i.e. the row in α corresponding to the variable consists of zeros only). This implies that the variables do not adjust to any of the long run relationships. From the tests we see that this is rejected for all the variables except production. However, in the case with two lags only, the hypothesis that production is weakly exogenous is rejected at the 5 percent level.

In the next test we test whether the cointegrating vectors are as we expected, i.e. we test if

(5-1) $$\beta' = \begin{pmatrix} 1 & 0 & -\kappa & 0 \\ 0 & 1 & -\kappa & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}.$$

The first row in β' corresponds to (4-2), the second to (4-4) and the third to the hypothesis that the user cost is stationary. These restrictions on the cointegrating space are not rejected. The estimated cointegrating space together with their adjustment parameters is (for p=4)

(5-2) $$\alpha\beta' y = \begin{pmatrix} \underset{(0.006)}{-0.0348} & \underset{(0.001)}{0.0094} & \underset{(0.001)}{-0.0007} \\ \underset{(0.391)}{-1.6293} & \underset{(0.092)}{-0.2664} & \underset{(0.033)}{-0.0477} \\ \underset{(0.240)}{0.5067} & \underset{(0.056)}{-0.0400} & \underset{(0.020)}{-0.0083} \\ \underset{(0.788)}{2.5798} & \underset{(0.185)}{0.5409} & \underset{(0.066)}{-0.4071} \end{pmatrix} \begin{pmatrix} 1 & 0 & \underset{(0.037)}{-1.0387} & 0 \\ 0 & 1 & \underset{(0.037)}{-1.0387} & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} k \\ j \\ x \\ c \end{pmatrix}.$$

The estimated value of κ is 1.039 (1.076 with two lags), with a standard error of 0.037 (0.068 with two lags). We can therefore not reject that κ=1, which can imply constant return to scale or that the elasticity of substitution (between buildings and other input factors) is unity.

From the loading matrix in (5-2) we see that the stock of buildings adjusts to both of the first two cointegrating vectors (as can be seen from the first two coefficients in the first row of α.) This implies that disequilibria in both the capital to production ratio and the investments to production ratio lead to adjustments in real capital.[15] Similarly, gross investments in buildings adjust to the same ratios. Therefore, gross investments help predicting real capital, and vice versa.

The last test reported in table 5-1 implies testing if it is only the user cost that adjusts to the last cointegrating vector. If this is the case, it implies that a temporary change in the user cost will have no effect on the level of any of the other variables in the long run.[16] This hypothesis is not rejected.

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[14] The diagnostic tests for the individual equations are not reported here.

[15] We refer to the first cointegrating relationship as the capital to production ratio and the second as the investments to production ratio since κ is not significantly different form unity.

[16] This test corresponds her of testing if the last row in the 'moving-average impact matrix' consists of zeros only.

Table 5-1: Estimation results, buildings and structures

	4 lags	2 lags	Test (d.f.)
Diagnostic tests			
AR 1-5	1.209 [0.18]	1.431 [0.03] *	F-test
Normality	16.584 [0.03] *	42.286 [0.00] **	Chi^2 (8)
Hetero	0.272 [1.00]	0.838 [0.89]	F-test
Cointegrating rank			
rank(Π)=0	310.18 [0.00] **	293.47 [0.00] **	
rank(Π)=1	86.87 [0.00] **	74.26 [0.00] **	
rank(Π)=2	34.80 [0.00] **	23.01 [0.00] **	
rank(Π)=3	0.30 [0.59]	0.95 [0.33]	
Stationary tests			
k	32.904 [0.00] **	20.999 [0.00] **	Chi^2 (1)
j	32.993 [0.00] **	20.940 [0.00] **	Chi^2 (1)
x	29.259 [0.00] **	17.489 [0.00] **	Chi^2 (1)
c	0.536 [0.46]	1.710 [0.19]	Chi^2 (1)
Weak exogenity			
k	81.129 [0.00] **	57.371 [0.00] **	Chi^2 (3)
j	40.271 [0.00] **	18.941 [0.00] **	Chi^2 (3)
x	7.765 [0.05]	9.755 [0.02] *	Chi^2 (3)
c	49.867 [0.00] **	48.314 [0.00] **	Chi^2 (3)
Combined tests			
$k-\kappa x$, $j-\kappa x$, c as cointegrating vectors	0.569 [0.75]	1.771 [0.21]	Chi^2 (2)
$k-\kappa x$, $j-\kappa x$, c as cointegrating vectors with *k, j* and *x* weakly exogenous wrt. *c*	3.527 [0.62]	1.771 [0.41]	Chi^2 (5)

The table reports test value and p-value for each test, the latter in brackets. One asterisk indicates significance at the 5 percent level, and two at 1 percent level. In the last column the test distribution and degrees of freedom is reported. For the two F-tests the degrees of freedom depends on the number of lags in the system and is therefore not reported.

Investments in machinery

In the system for machinery we have included one dummy in addition to a constant and seasonal dummies. This is a step dummy taking the value zero until the last quarter of 1991 and the value one thereafter. This dummy (*sd*92) is included in order to pick up the shift in the real machinery capital to production ratio in the 1990's; see figure A-2 in appendix A. This dummy is restricted to lie in the cointegrating space, which implies that it is not allowing for shifts in the trends.

We have some problems with autocorrelation in the errors in this system. However, we have no problem with autocorrelation in any of the individual equations in the system in the case with 4 lags. (With 2 lags we have significant problems with autocorrelation in the equation for the user price.)

The cointegrating rank test indicates two or three cointegrating vectors in the system with four lags, depending on whether we choose a critical level of 5 percent or 1 percent. With two lags in the system the test indicates three or four cointegrating vectors (the latter corresponding to a situation where all the variables are stationary with a possible deterministic shift in 1992). Based on these results and what we expected with respect to the number of cointegrating vectors, we continue the analysis with three cointegrating vectors.

The stationary tests confirm our expectation that the user cost is stationary, and the other variables are not. The test on weak exogenity yields mixed results, depending on whether we look at the system with 4 or 2 lags.

In the test of whether the cointegrating vectors are as we expected, i.e. if the cointegrating space is as in (5-1), we cannot reject these cointegrating vectors. The estimated cointegrating space together with their adjustment parameters is (for p=4)

(5-3) $$\alpha\beta' y^* = \begin{pmatrix} \underset{(0.025)}{-0.0220} & \underset{(0.021)}{-0.0162} & \underset{(0.140)}{-0.0009} \\ \underset{(0.674)}{0.2482} & \underset{(0.567)}{-1.5761} & \underset{(0.140)}{-0.1464} \\ \underset{(0.358)}{0.7952} & \underset{(0.301)}{-0.2233} & \underset{(0.074)}{-0.0799} \\ \underset{(0.946)}{1.8532} & \underset{(0.796)}{-0.2856} & \underset{(0.196)}{-1.1057} \end{pmatrix} \begin{pmatrix} 1 & 0 & \underset{(0.057)}{-1.0706} & 0 & \underset{(0.0164)}{0.1116} \\ 0 & 1 & \underset{(0.057)}{-1.0706} & 0 & \underset{(0.012)}{0.0812} \\ 0 & 0 & 0 & 1 & \underset{(0.041)}{0.2421} \end{pmatrix} \begin{pmatrix} k \\ j \\ x \\ c \\ sd92 \end{pmatrix}.$$

The estimated value of κ is 1.071 in the system with four lags, with a standard deviation of 0.057 (and 1.085 and 0.076 respectively in the system with 2 lags). Since the estimated values of κ differ from unity with less 1.5 times their standard deviations these results are consistent with either constant return to scale or an elasticity of substitution equal to unity.

Table 5-2: Estimation results, machinery

	4 lags	2 lags	Test (d.f.)
Diagnostic tests			
AR 1-5	1.529 [0.02] *	1.905 [0.00] **	F-test
Normality	13.230 [0.10]	13.230 [0.10]	Chi^2 (8)
Hetero	0.385 [1.00]	0.918 [0.73]	F-test
Cointegrating rank			
rank(Π)=0	117.19 [0.00] **	108.96 [0.00] **	
rank(Π)=1	65.86 [0.00] **	62.16 [0.00] **	
rank(Π)=2	17.90 [0.02] *	25.49 [0.00] **	
rank(Π)=3	2.98 [0.08]	4.32 [0.04] *	
Stationary tests			
k	11.934 [0.00] **	16.820 [0.00] **	Chi^2 (1)
j	11.613 [0.00] **	16.634 [0.00] **	Chi^2 (1)
x	11.372 [0.00] **	16.487 [0.00] **	Chi^2 (1)
c	1.290 [0.26]	0.710 [0.40]	Chi^2 (1)
Weak exogenity			
k	8.351 [0.04] *	5.137 [0.16]	Chi^2 (3)
j	17.507 [0.00] **	9.102 [0.03] *	Chi^2 (3)
x	6.852 [0.08]	20.393 [0.00] **	Chi^2 (3)
c	42.119 [0.00] **	20.627 [0.00] **	Chi^2 (3)
Combined tests			
$k-\kappa x$, $j-\kappa x$, c as cointegrating vectors	1.707 [0.43]	3.940 [0.14]	Chi^2 (2)
$k-\kappa x$, $j-\kappa x$, c as cointegrating vectors with *k, j* and *x* weakly exogenous wrt. *c*	12.039 [0.03] *	10.531 [0.06]	Chi^2 (5)

The table reports test value and p-value for each test, the latter in brackets. One asterisk indicates significance at the 5 percent level, and two at 1 percent level. In the last column the test distribution and degrees of freedom is reported. For the two F-tests the degrees of freedom depends on the number of lags in the system and is therefore not reported.

According to the loading matrix in (5-3) real capital adjusts to the capital to production ratio (i.e. the first cointegrating vector) and the investments adjusts to the investments to production ratio (i.e. the second cointegrating vector). However, real capital may not adjust to the investments to production ratio and investments may not adjust to the capital to production ratio (since both the adjustments coefficients are insignificant according to their t-values).

The hypothesis that a temporary change in the user cost will have permanent effect on the other variables is rejected in the system with four lags. In the system with two lags this hypothesis is not rejected, but is close to be so (a p-value of 0.06). We therefore reject this hypothesis.[17] Estimation results (not reported in the table) indicates that an increase in the user price of 1 percent will lead to a decline in real capital, investments and production of 0.01 or 0.05 percent in the long run, depending on whether we include four or two lags respectively.

Section 6: Conclusions

This paper has three main conclusions:

- It is normal to include all types of real capital in the aggregate 'real capital' in macroeconometric analysis. However, this aggregate then includes very heterogeneous types of real capital. Some of these types of real capital can be adjusted quickly, others not. Here, therefore, we divide this aggregate into to types of real capital; buildings and machinery. Our estimates of the loading matrixes (α) support the view that different types of real capital adjust differently. The estimated α for buildings differs clearly from the α for machinery.[18]

- Including both real capital and gross investments in the same analysis may lead to a better model. This view is supported in the case with buildings, but not in the case with machinery.

- The real user cost of capital is stationary. However, temporary changes in the user cost may have permanent effects on capital accumulation. The hypothesis that temporary user cost changes has no permanent effects was not rejected for buildings. For machinery, however, the hypothesis seems to be rejected. Therefore, temporary user cost changes seems to have permanent effects on real capital, gross investments and production.

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[17] If we only test the additional hypothesis that k, j and c are weakly exogenous with respect to the last cointegrating vector, this hypothesis is clearly rejected. For p=4 the critical value is 12.039-1.707=10.322, and with 5-2=3 degrees of freedom the probability value is 0.02. However, for p=2; 6.591 [0.09].

[18] The speed of adjustment will not only depend on the loading matrixes, but also on the short run dynamics. Therefore, based on the reported estimates we cannot determine whether buildings or machinery adjusts fastest, but only say that they adjust differently (i.e. following different paths in their adjustment processes). However, a further examination would probably lead to the conclusion that machinery adjusts faster than buildings.

Finally, our results indicate that the elasticity of scale is close to constant or the elasticity of substitution is close to unity (or both).

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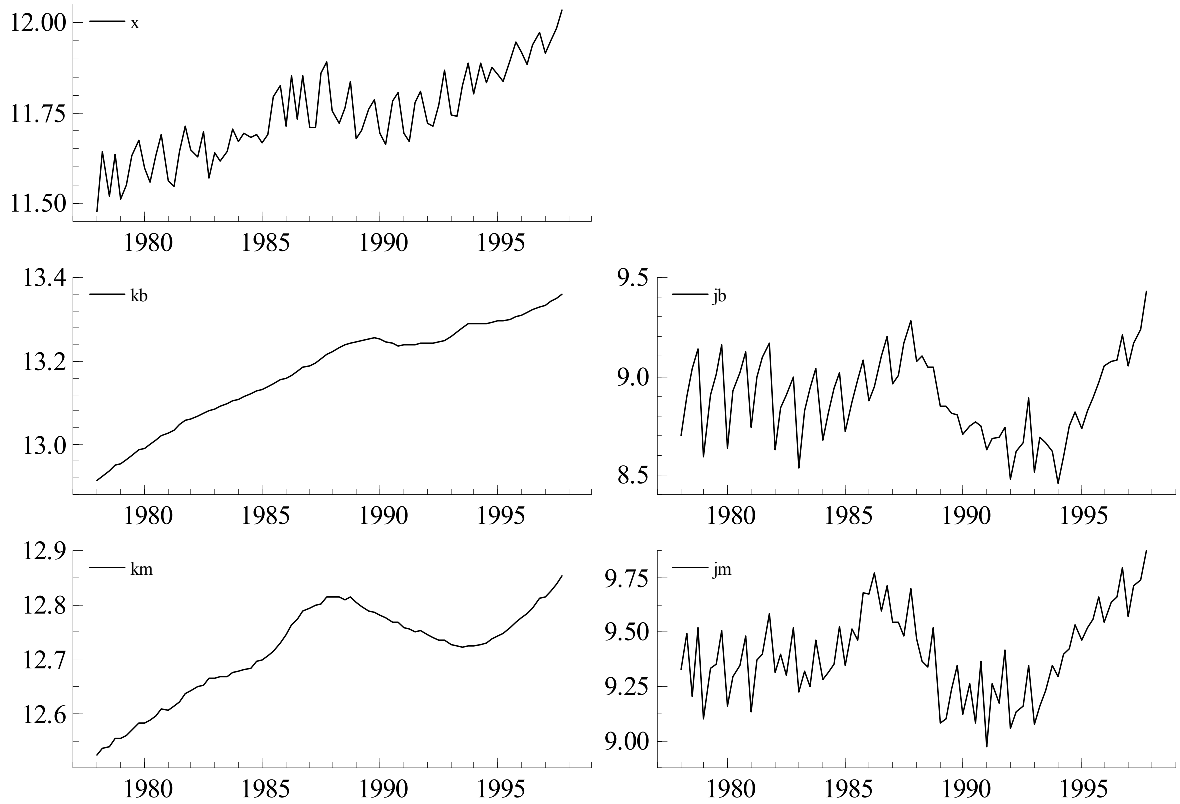
Appendix A

Data presentation

By production we here mean value added. By using value added we can limit ourselves to use only to types of production factors; real capital and labour. The time series for value added in Mainland Norway (excluded public sector) is shown in figure 5-1 (the first graphs). Time series for the stock of and gross investments in buildings and structures are plotted in the second row of the figure. In the last row the same time series are plotted for machinery.

Figure A-1: The data

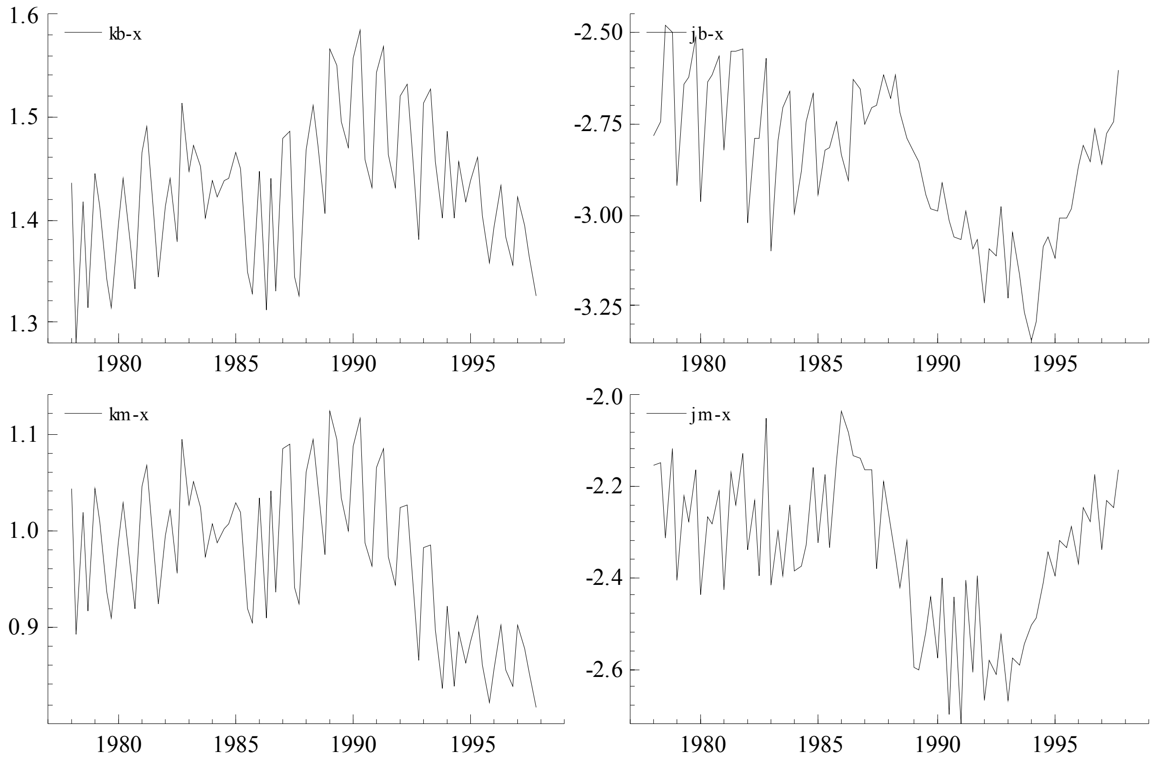


Form the figure we see that production declined in the years 1988-91. Investments both in buildings and machinery declined in the same period, but since buildings depreciates slowly the decline in investments in buildings did not reduce the stock of buildings. (The decrease in the stock of buildings in 1990 was caused by a reclassification of real capital; see below.) The stock of machinery, however, did decrease around 1990.

There has been done some reclassification of real capital in buildings and structures. The most important ones are that railroads were reclassified form private to public real capital in 1990, and that 'Luftfartsverket' and 'Statsbygg' were reclassified from public to private real capital in 1993. The decrease in the stock of buildings and structures in 1990 is caused by the reclassification of real capital.[19]

In the figure below we have plotted the real capital to production ratio and the investments to production ratio (both in logs) for both buildings and structures and other real capital.

Figure A-2: Ratios



[19] In appendix B, where we calculate the depreciation rate, figure B-1 illustrates how important these reclassifications are.

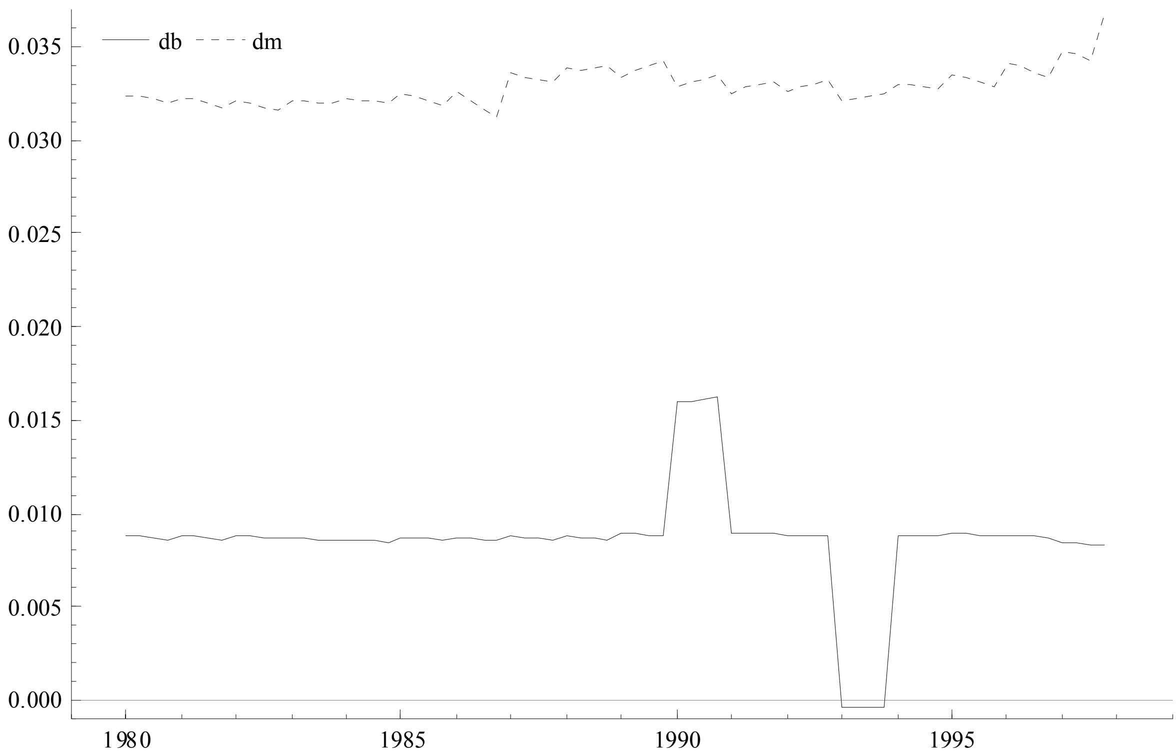
Appendix B

Depreciation rates

In this appendix we will estimate the depreciation rates for buildings and machinery. In the figure below we have calculated the quarterly depreciation rate for the two types of real capital. By assuming geometric depreciation, the depreciation rate for every time period can be calculated by

(B-1) $$\delta_t = (J_t - \Delta K_t) / K_{t-1}.$$

Figure B-1: Depreciation rates



From the figure we can see that the quarterly depreciation rate for buildings and structures is about 0.009, and the depreciation rate for other real capital is about 0.033. From the figure we see that there are two temporary shifts in the depreciation rate, one in 1990 and another in 1993. These two shifts are caused by reclassification of some real capital. Until 1990 railroads ('NSB Jernbaneverket') was a part of private mainland Norway, but from 1990 this type of real capital was classified as public real capital. In 1993 both 'Luftfartsverket' and 'Statsbygg' were reclassified from public real capital to private real capital.

We can estimate the quarterly depreciation rates by estimating an autoregressive distributed lag function. We use 4 lags, and the long run solution is reported in equation (B-2) for buildings and structures, and in equation (B-3) for other real capital. In equation (B-2) we have included dummies in 1990 and 1993 to control for the temporary shifts in the depreciation rate. The estimation period is 19080Q1-1997Q4. For buildings and structures we obtain

$$\text{(B-2)} \qquad Jb_t - \Delta Kb_t = \underset{(0.000)}{0.008884} Kb_{t-1} + \underset{(49.9)}{4038} d90_t - \underset{(47.0)}{5202} d93_t$$

where 0.008884 is the quarterly depreciation rate, and standard deviation is reported in the parentheses. Similarly, for machinery

$$\text{(B-3)} \qquad Jm_t - \Delta Km_t = \underset{(0.000)}{0.03293} Km_{t-1}$$

where the depreciation rate is 0.03292. The estimated quarterly depreciation rates can be calculated to yearly depreciation rates. This is done with the formula in (B-4).

$$\text{(B-4)} \qquad (1-\delta_A) = (1-\delta_Q)^4 \Leftrightarrow \delta_A = 1-(1-\delta_Q)^4$$

By using equation (B-4) we find that the yearly depreciation rate is approximately 0.035 for buildings and structures, and 0.125 for other real capital.[20] This corresponds to a lifetime for buildings and structures for approximately 57 years, and a lifetime for other real capital for 16 years. The lifetime L is calculated with the formula (B-5), which is called the "double-declining balance" profile.

$$\text{(B-5)} \qquad \delta = 2 / L$$

We use these depreciation rates in the calculation of the user cost of capital.

[20] Estimating on annual data (i.e. 4th quarter data for real capital and the sum of quarterly data for investments) yields approximately the same annual depreciation rates.

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