Capital Spending in the Swedish Forest Industry Sector — Four Classical Investment Models

Tommy Lundgren*

Abstract

The determinants of capital spending in the Swedish forest industry are analyzed with classical investment models. During the period 1962–1994, ouput and cash-flow are significant determinants of investment, while user cost of capital is not. Thus, fiscal policies targeted at stimulating demand and profits will have an impact on investments according to the models estimated. Monetary policy apparently have lesser or no impact at all, should it affect capital cost.

Keywords: Accelerator, cash-flow, investment, neoclassical.

~

Introduction

The Swedish forest sector is characterized by a high level of capital intensity and investment constitutes a substantial part of total annual expenditures. The capital stock is 1.5 million SEK per employee in the pulp and paper industry, or more than 2.5 times the capital-labor ratio in the Swedish manufacturing industry. This paper sheds light on the determinants of investment in the Swedish forest industry sector, using classical investment models.

Numerous theoretical and empirical studies have been focused on explaining investment behavior on both national and industry level.[1] Clark put forward his famous accelerator principle as early as 1917 where he argued that changes in output effects the level of investment. This principle was elaborated by Chenery (1952) and Koyck (1954) into the flexible accelerator, where the time structure of fixed capital spending was accentuated. Meyer & Kuh (1957) incorporated financial considerations into their investment model, arguing that profits are an important source of investment

* Tommy Lundgren, Department of Forest Economics, SLU, S-901 83 Umeå, Sweden. E-mail: Tommy.Lundgren@sekon.slu.se.

The author would like to thank Bengt Kriström and two anonymous referees for helpful comments and suggestions. Financial support from Tore Browalds Research Foundation, Handelsbanken, is greatfully acknowledged.

[1] For detailed surveys of investment literature see for example Eisner & Strotz (1963), Jorgenson (1971) or Chirinko (1993).

funding due to imperfect capital markets. Jorgenson and his collaborators initiated the development of a neoclassical theory of investment in a series of influential papers.[2] Tobin (1969) suggested that the incentive to invest depends on the marginal value of the ratio of the market value of a firm, measured as the ratio of stock price to the cost of acquiring new capital. Tobin's *q* model explicitly incorporates market expectations of future profits (through stock prices). However, the *q* model is hard to implement empirically since marginal *q* is difficult to approximate. Hayashi (1982) shows that if investment adjustment costs are incorporated into the standard neoclassical model it becomes identical to Tobin's *q* model.

Econometric studies based on classical investment theory show that four factors play a key role in determining fixed capital expenditures: (*i*) output, (*ii*) cash-flow, (*iii*) the user cost of capital and (*iv*) marginal *q*. The relationship between the first three factors (*i–iii*) and investment spending in the Swedish forest industry is the focus of attention in this paper.

The paper is organized as follows: In section two we outline the relationship between the capital stock and investment expenditures. Section three contains a brief description of the data and the lag profile of the empirical equations. In section four we derive four empirical models of investment which we apply to Swedish forest industry data (1962–1994). Conclusions are offered in section five.

CAPITAL STOCK AND INVESTMENT

A firms current capital stock at time t is defined as accumulated investments minus capital deterioration. Let us define a time period of length $t - i$. During this period the firm spends I_{t-i} on buildings and machines. I_{t-i} is a measure of total or gross investment. These investments provides services over several periods. If we denote the capital stock as K_t we can write:

$$K_{t,t-i} = s_{t,i} I_{t-i}. \tag{1}$$

[2] This series of papers started with Jorgenson (1963).

This is the amount of investment in period $t - i$ surviving to time t where $s_{t,i}$ is the survival rate for investment of age i to time t. Aggregating over vintages surviving up to period t will give us capital stock at time t.

$$K_t = \sum_{i=0}^{n} K_{t,t-i} = \sum_{i=0}^{n} s_{t,i} I_{t-i}, \tag{2}$$

where n is the life span of the investment.

To represent the life pattern, or mortality distribution, of $s_{t,i}$, the most common approach is to assume that capital deteriorate at a constant rate, say δ% per time period. This would imply an exponential time path of physical deterioration. The 'one hoss shay' method is based on the assumption that once a machine or building is put into place, it provides services at a constant rate during subsequent time periods until it suddenly fades away. This method introduces some analytical problems and is not easy to implement in empirical applications. The exponential decay method is by far the most popular mortality distribution model in empirical investment models.[3]

If the survival pattern is time invariant, $s_{t,i} = s_i$, then, with constant exponential deterioration, the survival rate s_i for an asset of age i is $s_i = (1 - \delta)^i$. Substitute this into (2) and rewrite the end of time period t net capital stock, recognizing that net investment, I_t^n, equals $K_t - K_{t-1}$:

$$K_t = I_t + (1 - \delta) K_{t-1}. \tag{3}$$

Capital stock equals total or gross investment plus previous period capital stock less capital depreciation. Calculating capital stock in this way is known as the perpetual inventory method. By rearranging we can divide gross investments (I_t) into net investments and replacement investment

$$I_t = \Delta K_t + \delta K_{t-1}. \tag{4}$$

[3] See Coen (1975) for a discussion and testing of different types of mortality distributions.

Most theories of investment behavior relate the demand for new buildings or machinery to the gap between the desired capital stock, K^*, and the actual capital stock, K. Let K_{t-1} be net capital stock at the end of the previous time period and K_t^*, the desired capital stock at end of current time period. If we define λ as speed of adjustment between K_{t-1} and K_t^*, we can write net investment in current period as equation

$$K_t - K_{t-1} = \lambda\left(K_t^* - K_{t-1}\right). \tag{5}$$

Under the assumption of an exponential mortality distribution for capital, replacement investment is δK_{t-1} and gross investment can be written as

$$I_t = \lambda\left(K_t^* - K_{t-1}\right) + \delta K_{t-1} = \lambda K_t^* + (\delta - \lambda) K_{t-1}. \tag{6}$$

This enables us to formulate an econometric model and estimate various models of investment.

THE INVESTMENT DATA AND LAG PROFILE

Data

The Swedish forest sector data[4] is divided into two subindustries: the sawmill industry and the pulp & paper industry. Gross investment data for these two industries, and on integrated level, are separated into buildings, B_i, and machinery, M_i, where $i = S$ (sawmill industry), P (pulp & paper industry) and *Int* (integrated industry).

Mean values for gross investments, I_t, capital stocks, K_t, and investment ratios, I_t/K_{t-1}, are presented in Table 1. The capital stocks are calculated using equation (3).[5] The investment ratio is higher for machinery on both disaggregated and integrated level. This is not surprising, when the rate of capital decay is usually higher for machines. To simplify comparison, the investment ratios are used as dependent variables in all empirical models.

[4] More detailed information about the data can be found in Appendix 1.

[5] The depreciation rates (δ) for buildings and machinery are 2.9% and 8.7% respectively. See Appendix 1.

TABLE 1. MEAN VALUES (1990 PRICES). ANNUAL DATA 1962–1994.

	B_{Int}	M_{Int}	B_S	M_S	B_P	M_P
I_t, billion SEK	1.32	4.63	0.39	0.78	0.93	3.84
K_t, billion SEK	34	50	9	7	27	43
I_t/K_{t-1}	0.04	0.09	0.04	0.12	0.04	0.09

B_{Int}:Buildings, integrated industry M_{Int}: Machinery, integrated industry
B_S :Buildings, sawmill industry M_S :Machinery, sawmill industry
B_P:Buildings, paper pulp industry M_P: Machinery, pulp paper industry

Lag Profile

The investment equations in this paper are specified so that the expected change in an explanatory variable, Δx_t^E, is approximated by an Almon (1968) lag polynomial formulated as:

$$P(L)\Delta x_t = \sum_{i=0}^{q} \beta_i \Delta x_{t-i},$$

where

$$\beta_i = \alpha_0 + \alpha_1 i + \alpha_2 i^2 + \ldots + \alpha_p i^p,\ i = 0,\ldots,q > p.$$

We also assume a Koyck (1954) type of adjustment process for capital as in (5).[6] When imposing the Almon lag structure to the explanatory variables, the full effects of the determinants appear only gradually. This is accentuated by the Koyck type of capital adjustment process. The initial part of the lag distribution is dominated by a polynomial lag distribution, and the tail by a geometric distribution. This method was suggested by Hall & Sutch (1968) and has been applied in econometric investment studies by Catinat *et al* (1987) and Kaskarelis (1993).

THEORETICAL AND EMPIRICAL MODELS OF INVESTMENT: THEORY, SPECIFICATION AND TESTING

In this section we explore three possible determinants of capital spending in the forest industry sector. To simplify the notation in the econometric equations we set $I\,K_t = I_t/K_{t-1}$.

[6] For literature on distributive lag models, see for example Griliches (1967) or Rowley & Trivedi (1975).

The Flexible Accelerator Model

The accelerator principle is based on the assumption that desired capital is determined by a constant capital/output ratio

$$K_t^* = aY_t. \tag{7}$$

The flexible accelerator model[7] specifies an investment equation where adjustment of the capital stock is not instant. Desired capital stock may, for example, deviate from the level actually observed due to adjustment costs or the time it takes to install machinery or build new plants.[8] The increase of the capital stock during a period of time is a fixed proportion of the difference between desired and actual stock. Substituting (7) into (5) and changing the determinant of capital stock to expected rather than actual output yields

$$\Delta K_t = \lambda a Y_t^E - \lambda K_{t-1}, \tag{8}$$

or

$$K_t = \lambda a Y_t^E + (1-\lambda) K_{t-1}.$$

If adjustment is instantaneous, $\lambda = 1$, and expectations are static, $Y_t^E = Y_t$, the flexible accelerator collapses to the rigid accelerator $K_t = aY_t$.

Econometric Specification of a Flexible Accelerator Model

Assume that the firm tries to maintain an optimal relationship between desired capital stock and output specified as in (8) and that capital stock adjusts according to (5). Add replacement investment[9] to both sides of (8) to obtain an equation describing gross investment:

$$I_t = \lambda a Y_t + (\delta - \lambda) K_{t-1}. \tag{9}$$

Some manipulation gives[10],

---

[7] Chenery (1952) and Koyck (1954).

[8] See Gould (1968) for a discussion of adjustment costs in investment or Bergman (1996) for an empirical study estimating adjustment costs in investment (the Swedish forest sector). All lags due to the firm adopting to new circumstances in its environment are usually referred to as gestation lags.

[9] The replacement investment model assumed is simply δK_{t-1}. This is the geometric mortality distribution model discussed earlier.

[10] We form a new equation by lagging (9) by one time period and multiplying this equation on both sides by $(1- \delta)$. Subtract this product from (9), rewrite, combine, collect terms and divide through by previous period capital stock.

$$\frac{I_t}{K_{t-1}} = \lambda a \left(\frac{Y_t - (1-\delta) Y_{t-1}}{K_{t-1}} \right) + (1-\lambda) \frac{I_{t-1}}{K_{t-1}}. \tag{10}$$

By changing the determinant of desired capital stock to expected rather than actual change in output, and assuming adaptive expectations, we can approximate $[Y_t - (1 - \delta)Y_{t-1}]^E / K_{t-1}$ with $P(L)[Y_t - (1 - \delta)Y_{t-1}]/K_{t-1}$, where $P(L)$ is an Almon lag polynomial.

The estimated econometric equation is written

$$I K_t = A_0 + (1-\lambda) I K_{t-1} + A_1 \, \Delta Y \, K_t + \varepsilon_t, \tag{11}$$

where A_0 is a constant, $A_1 = \lambda\Sigma_i a_i$ and $\Delta YK_t = [Y_t - (1-\delta)Y_{t-1}]/K_{t-1}$. The investment ratio depends on the ratio of the expected change in output to previous period capital stock spread out over several periods. A_0, $(1 - \lambda)$ and A_1 are coefficients to be estimated. The depreciation rate could also be estimated, but here it is treated as a given constant parameter.

Estimation and Testing: The Accelerator Model

The model specification generating the most significant sum of lag coefficients, A_1, measured as the lag sum coefficient t-value, are reported. Coefficient estimates and statistical diagnostics are presented in Table 2. The data and all diagnostic tests are described in Appendix 1 and Appendix 2.

TABLE 2. THE FLEXIBLE ACCELERATOR MODEL.

Coefficients	B_{Int}	M_{Int}	B_S	M_S	B_P	M_P
A_0	0.007	0.038*	0.008	0.007	0.008	0.029
1–λ	0.719**	0.409**	0.691**	0.782**	0.637**	0.447**
A_1	0.118**	0.446**	0.154*	0.181**	0.148**	0.567**
Diagnostics						
R^2	0.77	0.55	0.62	0.60	0.62	0.52
DH	0.89	1.29	0.63	2.28*	1.38	–1.01
HET	7.38	8.54	10.31	19.33*	15.31	9.01
NORM	2.72	1.00	0.59	3.95	0.31	0.74
ARCH(1)	0.71	0.12	0.02	0.53	0.22	0.05
CHOW	1.84	1.21	1.29	0.89	3.89*	2.35

* p-value < 0.05 , ** p-value < 0.01

Only a few tests are rejected at the 5% significance level. All coefficients have the desired sign. Lag sum coefficients for the output variable, $\Delta Y K_t$, are positive and statistically significant in all estimated models. The long run coefficients for the demand variable, calculated by dividing through with the estimated sluggishness coefficient λ, are: 0.42 (B_{Int}), 0.75 (M_{Int}), 0.50 (B_S), 0.83 (M_S), 0.41 (B_p) and 1.02 (M_p). This suggests a positive relationship between investment and changes in output. In general, changes in the demand variable seem to have a larger effect on investment in machinery than investment in buildings.

In a study of Swedish total manufacturing data (1955–1980) by Johansson & Johansson (1984), the estimated coefficients are lower but the general pattern is the same. Johansson & Johansson apply a flexible accelerator model with an Almon lag structure to the demand variable and their estimates of the sum of lag coefficients for the output variable are 0.57 for investments in machinery and 0.10 for investments in buildings. However, the estimated lag sum for buildings is not statistically significant.

In Kriström (1990) a flexible accelerator model is estimated with quarterly data (1968:1–1982:4) for the Swedish sawmill industry, paper industry and pulp industry (paper and pulp industries not integrated). His results are not as statistically convincing as the results presented in Table 2. Kriström's lag sums are considerably lower and statistical significance of the output coefficient is achieved only for investment in machinery in the sawmill and pulp industry.

Kopcke (1993) report results for an investment accelerator model for all U.S. private businesses. The lag sums for buildings and machines are 0.17 and 0.19 respectively.

In summary, the flexible accelerator model produce satisfying empirical results when applied to data on annual investment spending for the Swedish forest industry, and in comparison to the studies cited above, our results suggests that investment in the Swedish forest sector is relatively sensitive to changes in demand.

The Cash-flow Model

Financial considerations are absent in the flexible accelerator model. This has led many researchers to postulate that the availability of funds has a significant impact on investment decisions. Advocates of cash-flow models argue that internal flow of funds is the preeminent source of financing investment and more important than availability of external debt or equity financing. Most cash-flow models specify investment expenditures as a variable proportion of internal cash-flow (an accelerator type of model). The level of internal funds are, of course, affected by the current level of profits and the optimal/desired capital stock can be made to depend on variables capturing the level of actual or expected profits.

Meyer & Kuh (1957) argue that there are imperfections in capital markets. They base their argument on the observation that the lending rate does not equal the borrowing rate in most money markets. If the level of risk increase when financing investment with external funds, firms will prefer internal funds financing and investment expenditure can be made to depend on a cash-flow variable.

Clark (1979) suggested that a combination of the accelerator model and a cash–flow model is desirable since profits alone does not seem to explain much of investment volatility. However, this kind of econometric specification will most probably generate bad estimates due to multicollinearity problems. Kuh (1963) points out that: ''...the expectational hypothesis for profits cannot, and perhaps should not, be distinguished from the sales level or capacity accelerator hypothesis. The main candidate variable for the expectational hypothesis is simply net income after tax, a secondary candidate being gross operating profit. Both variables will have strong correlations with the level of sales (output).'' According to this argumentation a combined accelerator-cash-flow model will most likely yield biased estimates. Johansson & Johansson (1984) and Kriström (1990) apply an accelerator-cash-flow model with moderate success on Swedish manufacturing data and forest sector data.

Econometric Specification of a Cash-flow Model

We adopt the Meyer and Kuh argument in specifying the econometric model. The cash-flow model estimated is simply the flexible accelerator model where we replace the output variable, Y, with a cash-flow variable, F. The estimated econometric equation is written

TABLE 3. THE CASH-FLOW MODEL.

Coefficients	B_{Int}	M_{Int}	B_S	M_S	B_P	M_P
b_0	0.004	0.035**	0.009	0.037*	0.008	0.055**
$1-\lambda$	0.862**	0.631**	0.774**	0.650**	0.758**	0.412**
b_1	0.110**	0.364**	0.089**	0.339**	0.113**	0.569**
Diagnostics						
R^2	0.73	0.65	0.64	0.76	0.59	0.58
DH	1.18	−0.29	−0.55	0.34	1.74	−0.20
HET	3.81	8.91	12.58	15.98	8.15	9.31
NORM	1.53	0.28	3.09	8.06*	0.17	1.17
ARCH(1)	0.27	0.03	0.50	0.03	0.10	0.03
CHOW	1.24	1.51	0.75	3.73*	1.54	1.03

* p-value < 0.05 , ** p-value < 0.01

$$IK_t = B_0 + (1-\lambda) IK_{t-1} + B_1 \Delta FK_t + \varepsilon_t. \tag{12}$$

where B_0 is a constant, $B_1 = \lambda\Sigma_i b_i$ and $\Delta FK_t = [F_t-(1-\delta)F_{t-1}]/K_{t-1}$, where F is net operating profits. Similar equations have been analyzed by Kopcke (1982; 1985; 1993) for private business U.S. data.

Estimation and Testing: Cash-flow Model

The model specification generating the most significant sum of lag coefficients, B_1, measured as the lag sum coefficient t-value, are reported. Coefficient estimates and statistical diagnostics are presented in Table 3. The dependent variable is the same as in the flexible accelerator model (IK_t).

The cash-flow model results are very similar to the flexible accelerator model results. Again, only a few tests are rejected at the 5% significance level and all coefficients have the desired sign. The long run coefficients for the cash-flow variable, calculated by dividing through with the estimated sluggishness coefficient λ, are: 0.80 (B_{Int}), 0.99 (M_{Int}), 0.39 (B_S), 0.97 (M_S), 0.47 (B_P) and 0.97 (M_P).

In summary, the cash-flow model estimation results show that changes in cash-flow, here represented by net operating surplus, are positively related to investment spending in the Swedish forest industry sector. Again, as in the flexible accelerator, investment in machinery seems to be more sensitive to changes in the explanatory variable.

Neoclassical Models

The neoclassical models accentuates the role of user cost of capital as a determinant of investment.

Let us start by making a few assumptions: (*i*) The firm maximizes the discounted flow of profits over an infinite time horizon. (*ii*) All firms operates in a world of static expectations and perfect capital markets. (*iii*) Delivery lags, adjustment costs and vintage effects are absent in the theoretical model. (*iv*) Capital depreciates at a geometric rate.[11]

Consider then the following dynamic maximization problem:

$$\underset{\{I,K,L\}}{\text{Max}} \int_{t_0}^{\infty} \left\{ \left[pY(t) - qI(t) - wL(t) \right] \exp(-rt) \right\} dt, \tag{13}$$

subject to

$$\begin{aligned} Y(t) &= f(K,L), \\ dK(t)/dt &= I(t) - \delta K(t), \\ K(t_0) &= K_0, \\ \lim_{t\to\infty} K(t) &= K_\infty, \end{aligned}$$

where

$$\begin{aligned} Y(t) &= f(K,L) = \text{two-factor production function}, \\ I(t) &= \text{gross investment}, \\ K(t) &= \text{capital stock}, \\ L(t) &= \text{labor input in production}, \\ dK(t)/dt &= \text{change in capital stock with respect to time}, \\ K(t_0) &= \text{initial capital stock}, \\ \lim_{t\to\infty} K(t) &= \text{non-negative value}, \\ p &= \text{price of output}, \\ q &= \text{price of new capital}, \\ w &= \text{wage rate}, \\ r &= \text{real financial cost of capital}. \end{aligned}$$

[11] This presentation owes much to Nickell (1978) and Kriström (1990).

This problem can be analyzed using standard optimal control methods. The Hamiltonian is

$$H(t) = \left[pY(t) - qI(t) - wL(t)\right]\exp(-rt) + \theta(t)\left[I(t) - \delta K(t)\right], \quad (14)$$

where $\theta(t)$ can be interpreted as the shadow price of investment. The optimal control conditions are (ignoring time index):

$$\frac{dH}{dI} = -q\exp(-rt) + \theta = 0,$$

$$\frac{dH}{dL} = pY_L\exp(-rt) - w\exp(-rt) = 0,$$

$$\frac{d\theta}{dt} = -\frac{dH}{dK} = -pY_K\exp(-rt) + \delta\theta,$$

$$\lim_{t\to\infty}\theta(t)K(t) = 0.$$

Solving yields the necessary conditions well known from elementary microeconomics:

$$\frac{q}{p}(r+\delta) = Y_K, \quad (15)$$

$$\frac{w}{p} = Y_L. \quad (16)$$

The user cost of capital[12] equals the marginal product of capital in production (Y_K), and the real wage must equal marginal product of labor (Y_L). A non-constant price of investment, $q(t)$, would introduce a capital gains term in (15).[13] Given an explicit production function we can insert an expression for Y_K and, solve for K. This will give us the optimal time path for capital stock. The solution to the problem formulated in (13) also yields the optimum demand for labor. From an econometric viewpoint the demand for capi-

[12] The definition of user cost of capital varies. Usually $(r + \delta)$ is referred to as the gross cost of capital and $q\ (r + \delta)$ or $q/p\ (r + \delta)$ as user cost of capital.

[13] The capital gain on investment goods, or how much the price q has risen after we bought the machine, should be included when there exist a second hand market for investment goods. The expression for capital cost would then read $R = q/p\ (r + \delta - (dq/dt\ q^{-1}))$. That is, a rise in q would lessen capital costs. However, in practice a well working second hand market does not exist for industrial machinery and buildings, and dq/dt is usually taken to be zero.

tal and for labor should be estimated simultaneously. However, in this paper we will focus on capital demand and estimate (15) independently.

Assuming a CES technology:

$$Y = \psi\left[\tau K^{-\rho} + (1-\tau)L^{-\rho}\right]^{-\frac{\nu}{\rho}}, \tag{17}$$

where ψ is an efficiency parameter, τ is a distribution parameter, ρ is the substitution parameter and ν is the scale parameter. Totally differentiating (17) with respect to K, substituting for Y_K (15) and rearranging gives us an expression for capital demand:[14]

$$K^{*} = \phi Y^{e} R^{-\sigma}, \tag{18}$$

where ϕ is a constant in the parameters of the CES production function and $R = q(r + \delta)/p$. The elasticities are $e = 1/\nu$ and $\sigma = 1/(1 + \rho)$, where σ is the elasticity of substitution between capital and labor[15] in the CES production function. Note that if $\sigma = 0$ and $e = 1$, (18) reduces to the accelerator model discussed earlier.

By restricting e and σ to unity ($\rho = \nu = 1$), implying a standard Cobb–Douglas technology, the demand function for capital is modified to

$$K^{*} = \alpha Y R^{-1}, \tag{19}$$

where α is the elasticity of output with respect to capital[16] derived from a standard Cobb–Douglas technology.

---

[14] See any elementary microeconomic literature for derivation of marginal product of capital in the case of CES technology. With our technology specification marginal product of capital is :

$$Y_K = \frac{1}{\psi\tau\nu}\left(\frac{Y^{\frac{1}{\nu}}}{K}\right)^{1+\rho}.$$

Note that the capital demand equation derived from a cost minimization problem would include the wage rate as a determinant of desired capital stock (K^*).

[15] $\sigma = \dfrac{\partial \log(K/L)}{\partial \log(Y_L/Y_K)} = \dfrac{1}{1+\rho}$. σ is also the elasticity of K with respect to user cost of capital, R.

[16] $\alpha = \dfrac{dY}{dK}\dfrac{K}{Y}$.

Econometric Specification of Two Neoclassical Models

Neoclassical I: Insert (19) in (5) and manipulate the this equation in the same way as the accelerator and cash- flow models.[17] The equation estimated is

$$IK_t = C_0 + (1-\lambda) IK_{t-1} + C_1 \Delta YRK_t + \varepsilon_t, \tag{20}$$

where

$$\begin{aligned} C_0 &= \text{a constant}, \\ C_1 &= \lambda \textstyle\sum_i \alpha_i, \\ \Delta YRK_t &= \left[Y_t R_t^{-1} - (1-\delta) Y_{t-1} R_{t-1}^{-1}\right] \big/ K_{t-1}, \\ R &= q(r+\delta)/p. \end{aligned}$$

The calculation of the real financial cost of capital r are based on Swedish aggregate manufacturing. This might not be such a bad approximation since more or less the same tax laws holds for the forest sector as for manufacturing in general. Even if the approximation is wrong for the forest sector at levels, the changes may be good approximations.

The investment ratio, IK_t, is presumed to be positively related to changes in output and negatively related to the user cost of capital. Before presenting the estimation results we discuss an alternative empirical equation.

Neoclassical II. Eisner & Nadiri (1968) modified Jorgenson's model by relaxing the unity restrictions on the elasticities e and σ. We derive an alternative neoclassical specification similar to Eisner & Nadiri (1968).[18] Desired capital stock is derived using a CES–technology as in (17). To simplify, we

[17] As the careful reader may already have noted, this contradicts the theoretical model outlined above. The desired capital stock was derived, in theory, under the assumption that delivery of capital goods is immediate (assumption iii), but the estimated empirical equation is based on a geometric adjustment process for capital and a distributed lag (the Almon polynomial) for the explanatory variable(s). In other words, there is an important difference between the empirical and the theoretical model. This is one of the major criticisms of neoclassical models. The interpretation of the distributed lag coefficients is that it takes time for the firm to adjust to changes in the economic environment. This is often referred to as the 'gestation lag' problem.

[18] See also Bergström & Södersten (1984).

assume a slightly modified capital adjustment process given by:

$$\log K_t - \log K_{t-1} = \lambda\left(\log K_t^* - \log K_{t-1}\right). \qquad (21)$$

Inserting equation (18), which represent the desired capital stock for a CES-technology firm, we can write

$$\log K_t - \log K_{t-1} = \lambda\left(\log\phi + e\log Y_t - \sigma\log R_t - \log K_{t-1}\right).$$

Add δ to both sides of this equation to obtain a relationship describing the investment ratio:[19]

$$I\,K_t = \lambda\left(\log\phi + e\log Y_t - \sigma\log R_t - \log K_{t-1}\right) + \delta. \qquad (22)$$

We form a new equation by lagging (22) by one time period and adding the term $\lambda\delta$. Subtract this new equation from both sides of (22). After rewriting, combining and collecting terms we have

$$I\,K_t = \lambda\,\delta + (1-\lambda)I\,K_{t-1} + \lambda\,e\Delta\log Y_t - \lambda\,\phi\,\Delta\log R_t. \qquad (23)$$

The estimated equation is obtained by changing the explanatory variables from actual to expected values using an Almon polynomial lag:

$$I\,K_t = D_0 + (1-\lambda)I\,K_{t-1} + D_1\,\Delta\log Y_t - D_2\,\Delta\log R_t + \varepsilon_t, \qquad (24)$$

$D_0 = \lambda\delta$, $D_1 = \lambda\,\Sigma_t\,e_i$ and $D_2 = \lambda\,\Sigma_j\,\sigma_j$. Estimating this equation will give us the estimates on the two elasticities, e and σ, restricted to unity in the Neoclassical I model.

Estimation and Testing: Neoclassical Models

The dependent variable is $IK_t = I_t / K_{t-1}$, which is the same as in the flexible accelerator and cash-flow models. The new explanatory variables are the Jorgenson mixed demand-capital cost-variable, $\Delta Y_t R_t^{-1} / K_{t-1}$, the percentage change in output, Δ log Y_t, and percentage change in user cost of

[19] Recognizing that d log $K/dK=1/K$ we can write Dlog K_t+d » D$K_t/K_{t-1}+d$ = I_t/K_{t-1}.

capital, $\Delta \log R_t$. In the Neoclassical I model ΔY and ΔR are combined into a composite variable. In the Neoclassical II model the output variable, $\Delta \log Y_t$, and the capital cost variable, $\Delta \log R_t$, enter the regressions separately. This enables us to separate the effects of changes in output and user cost of capital.

The specification generating the most significant sum of lag coefficients for C_1, D_1 and D_2, measured as absolute t-value of the lag sum coefficient, are reported in Table 4 and Table 5.

Diagnostic tests indicate that the Neoclassical I model is well specified. The lag sum coefficients for investments in buildings are low when they represent elasticity of output with respect to capital. The long run coefficients, calculated by dividing through with the estimated sluggishness coefficient λ, are: 0.021 (B_{Int}), 0.125 (M_{Int}), 0.013 (B_S), 0.109 (M_S), 0.012 (B_P) and 0.115 (M_P).

In Johansson & Johansson (1984) the estimated sum of lag coefficients for Swedish aggregate manufacturing are 70 for investment in machinery and 25 for investment in buildings. Kriström (1990) present estimates for a Jorgenson model for the Swedish sawmill industry, pulp industry and paper industry that are extremely low, implying an elasticity of output with respect to capital very close to zero. For example, Kriströms estimate of sum of lag coefficients for the pulp industry is 0.00008, but still highly significant. It should be noted that the magnitude of the absolute value of the estimated elasticity C_1 is highly affected by the scaling of the variables entering the regression.[20] Since we do not know how the variables are scaled in Johansson & Johansson (1984) and Kriström (1990), we cannot properly compare their results to ours.

The standard Jorgenson model often generates far lower estimates of the elasticity α than those associated with the Cobb-Douglas technology.[21] Our elasticity estimates from the Swedish forest sector are reasonably realistic for the

[20] The sum of lag coefficients can only be interpreted as the elasticity of output with respect to capital if the investment and output variable are scaled correctly.

[21] For example, for total U.S. manufacturing, Jorgenson & Stephenson report an estimate of 0.05813. See Eisner & Nadiri (1968) p 371.

TABLE 4. NEOCLASSICAL I MODEL.

Coefficients	B_{Int}	M_{Int}	B_S	M_S	B_P	M_P
C_0	0.006	0.039^{**}	0.015^{*}	0.038^{**}	0.008	0.039^{**}
$1-\lambda$	0.806^{**}	0.466^{**}	0.606^{**}	0.524^{**}	0.749^{**}	0.487^{**}
C_1	0.004^{**}	0.067^{**}	0.005^{**}	0.052^{**}	0.003^{**}	0.059^{**}
Diagnostics						
R^2	0.71	0.60	0.69	0.85	0.57	0.58
DH	1.31	1.28	–0.77	1.03	1.50	0.14
HET	4.19	10.36	7.99	8.49	8.50	13.71
NORM	0.88	0.37	3.62	0.86	1.15	1.94
ARCH(1)	1.14	1.88	0.55	0.07	0.80	0.99
CHOW	1.13	0.17	2.74	3.99^{*}	2.49	0.59

* p-value < 0.05 , ** p-value < 0.01

models describing investment in machinery, and without further investigation we conclude that the Neoclassical I model seems to work well. The user cost of capital seems to have a negative effect on the investment ratio in this model specification. We now turn to the Neoclassical II model.

TABLE 5. NEOCLASSICAL II MODEL.

Coefficients	B_{Int}	M_{Int}	B_S	M_S	B_P	M_P
C_0	0.010	0.038^{**}	0.010	0.021	0.014^{*}	0.037^{*}
$1-\lambda$	0.728^{**}	0.625^{**}	0.682^{**}	0.837^{**}	0.542^{**}	0.589^{**}
C_1	0.077^{**}	0.198^{**}	0.156^{**}	0.316^{**}	0.114^{**}	0.186^{*}
C_2	0.010	0.067	–0.018	0.125^{*}	–0.002	–0.023
Diagnostics						
R^2	0.76	0.55	0.69	0.66	0.57	0.38
DH	1.66	–0.55	1.00	1.10	2.18^{*}	–1.34
HET	21.89	15.74	24.29	25.46	11.52	28.89^{*}
NORM	2.55	0.25	3.70	1.74	1.29	1.09
ARCH(1)	1.38	0.02	0.39	0.05	0.09	0.25
CHOW	1.04	0.78	0.68	0.66	2.38	1.40

* p-value < 0.05 , ** p-value < 0.01

The estimation results for the Neoclassical II model in Table 5 show that restricting the scale elasticity, e, and elasticity of substitution, σ, to unity, as implied in the Neoclassical I model, are not supported by the data. None of the elasticity estimates are close to unity. The estimated value of $\Sigma_j \sigma_j$ is not significantly different from zero except in the M_S model. This implies that the Neoclassical II model breaks down to an accelerator type model in five of the six estimated equations. The long run coefficients for the demand variable $\Delta \log Y_t$, calculated by dividing through with the estimated sluggishness coefficient λ, are: 0.283 (B_{Int}), 0.528 (M_{Int}), 0.491 (B_S), 1.939 (M_S), 0.249 (B_P) and 0.453 (M_P). The long run coefficients for the user cost of capital variable, $\Delta \log R_t$, are: 0.037 (B_{Int}), 0.179 (M_{Int}), –0.057 (B_S), 0.767 (M_S), –0.004 (B_P) and –0.056 (M_P).

According to the Neoclassical II model, user cost of capital, R, does not play a crucial role in determining investment spending in the Swedish forest sector. The lag sum $\Sigma_j \sigma_j$ have the desired sign and is statistically significant only in the case of investment in machinery in the sawmill industry. The Neoclassical II model estimation results contradicts the results generated from the Neoclassical I model. In the Neoclassical I model the lag sum coefficients of the composite 'output-user cost of capital'-variable are all statistically significant. This is probably a result of how the variables Y and R enter the regressions. A possible explanation is that the correlation between I K and R is too weak and therefore the composite variable ΔYRK_t is dominated by the output term Y.

Conclusion

Demand and cash-flow variables are important when the forest industry firm decides on the level of investment according to the flexible accelerator and cash-flow models. The two estimated neoclassical models produce somewhat ambiguous results. The Neoclassical I model generates statistically significant coefficients of the composite 'output-user cost of capital'-variable, while the Neoclassical II model shows that user cost of capital alone has no impact on investment, except for machinery investment in the sawmill industry. From these results we can conclude that user cost of capital has no significant effect on the investment decision. Furthermore, there is no evidence that the determinants of investment differ within the forest industry sector. Investment in the sawmill industry and in the pulp & paper industry seem to be based on essentially the same decision parameters.

The models that produce the best fit are the cash-flow model and Neoclassical I model. The adjusted R^2 for these models are slightly higher than the flexible accelerator and Neoclassical II models.[22] It should be pointed out that the differences between the models are fairly small. One possibility to separate the models would be to perform a 'horse race' where these four conventional model specifications are compared by evaluating the forecasting ability in an out-of-sample period.

The accelerator and cash-flow models are attractive because of their simplicity, and they seem to explain investment variations in the forest sector reasonably well. The standard criticism of these models is that they lack sufficient theoretical underpinnings. The neoclassical models are derived from a rigid microeconomic theory. To an economist this is certainly an appealing approach, and as a consequence the neoclassical theory of investment has often been referred to as one of the best 'marriages' between economic theory and empirical work.

The results presented in this paper, if correct, are important when considering different policies to stimulate investments in the Swedish forest sector. Our results show that demand variables are important, which is in line with many other studies. They are also quite stable across the two sub-industries. Thus, demand variables seem important for investment in the sawmill and pulp & paper industry, while capital costs are less important. According to the models estimated, fiscal policies targeted at stimulating demand, and indirectly cash-flow, will have a positive impact on investments. Monetary policy apparently have lesser or no impact at all, should it affect capital cost.

REFERENCES

Almon, S., 1968. Lags between Investment Decisions and Their Causes. *The Review of Economics and Statistics*, 50(2), pp. 193–207.

[22] Looking at mean values of adjusted R^2 across estimated models.

Bergman, M., 1996. *Estimating Investment Adjustment Costs and Capital Depreciation Rates from the Production Function*. Department of Economics, Umeå University,Umeå Economic Studies no 406.

Bergström, W. & Södersten, J., 1984. Do Tax Allowances Stimulate Investment? *Scandinavian Journal of Economics*.

Berndt, E. R., 1991. *The Practice of Econometrics — Classic and Contemporary* (Addison: Wesley Publishing Company Inc, U.S.A).

Catinat, M., Cawley, R., Hzkovitz, F., Italianer, A. & Mors, M., 1987. The Determinants of Investment, *The European Economy* 31, pp. 11–60.

Chenery, H. B., 1952. Overcapacity and the Acceleration Principle. *Econometrica* 20(1), pp. 1–28.

Chirinko, R. S., 1993. Business Fixed Investment Spending: Modeling Strategies, Empirical Results, and Policy Implications, *Journal of Economic Literature* 31, pp. 1875–1911.

Clark, M., 1917. Business Acceleration and the Law of Demand: A Technical Factor in Economic Cycles, *Journal of Political Economy* 25(1), pp. 217–235.

Clark, P. K., 1979, Investments in 1970:s — Theory, Performance and Prediction, *Brookings Papers on Economic Activity* 1, pp. 73–124.

Coen, R. M., 1975. Investment Behavior, the Measurement of Depreciation, and Tax Policy, *American Economic Review* 65(1), pp. 59–74.

Durbin, J., 1970. Testing for Serial Correlation in Least Squares Regression When Some of the Regressors Are Lagged Dependent Variables. *Econometrica* 38(3), pp. 410–421.

Eisner, R. & Nadiri, M. I., 1968. Investment Behavior and Neo–Classical Theory, *The Review of Economics and Statistics* 50(3), pp. 369–382.

Eisner, R. & Strotz, R. H., 1963. Determinants of Business Investment, in *Impacts of Monetary Policy, Research Studies Prepared for the Commision on Money and Credit* (Englewood Cliffs, N.J.: Prentice–Hall.) pp. 59–236.

Gould, J. P., 1968. Adjustment Costs in the Theory of Investment of the Firm, *Review of Economic Studies* 35(1), pp. 47–55.

Griliches, Z., 1967. Distributed Lags: A Survey, *Econometrica* 35(1), pp. 16–49.

Hall, R. E. & Sutch, R. C., 1968. A Flexible Infinite Distributed Lag, paper presented at 1967 Econometric Society Meetings, abstracted in *Econometrica* 1968, pp. 91–92.

Hayashi, F., 1982. Tobin's Marginal q and Average q: A Neoclassical Interpretation, *Econometrica* 50(1), pp. 213–224.

Jorgenson, D. W., 1963. Capital Theory and Investment Behavior, *American Economic Review* 53(2), pp. 247–259.

Jorgenson, D. W., 1971. Econometric Studies of Investment Behavior: A Survey, *Journal of Economic Literature* 9(4), pp. 1111–1147.

Johansson, M. & Johansson, P. O., 1984. *Byggnads- och maskininvesteringar. En översikt över investeringsfonderna 1938–1983*, Rapport R9 Byggforskingsrådet. Liber.

Kaskarelis, I. A., 1993. The Determinants of Investment in Greek Manufacturing, *Applied Economics* 25, pp. 1125–1135.

Kopcke, R. W., 1982. Forecasting Investment Spending: The Performance of Statistical Models, *New England Economic Review* November/December (Boston, Mass: Federal Reserve Bank of Boston) pp. 13–32.

Kopcke, R. W., 1985. The Determinants of Investment Spending, *New England Economic Review* July/August (Boston, Mass: Federal Reserve Bank of Boston) pp. 19–35.

Kopcke, R. W., 1993. The Determinants of Business Investment: Has Capital Spending Been Surprisingly Low?, *New England Economic Review* January/February (Boston, Mass: Federal Reserve Bank of Boston) pp. 3–30.

Koyck, L. M., 1954. *Distributed Lags and Investment Analysis* (Amsterdam: North–Holland).

Kriström, B., 1990. *The Classical Theories of Investment and the Forest Sector; Some Results*, Department of Forest Economy, SLU, Working paper 111.

Kuh, E. E., 1963. *Capital Stock Growth: A Micro — Economic Approach* (Amsterdam: North–Holland).

Meyer, J. A. & Kuh, E. E., 1957. *The Investment Decision: An Empirical Study* (Cambridge, Mass.: Harvard University Press).

Nickell, S. J., 1978. *The Investment Decisions of Firms* (Oxford: Cambridge University Press).

Rowley, J. C. R. & Trivedi, P. K., 1975. *Econometrics of Investment* (John Whiley & Sons).

Tobin, J., 1969. A General Equilibrium Approach to Monetary Theory, *Journal of Money Credit and Banking* 1(1), pp. 15–29.

APPENDIX 1

Investment

I is gross fixed capital expenditure in 1990 prices (current price series from SCB F 1962–1995; sni33111, sni34111 and sni34112). Deflator for investments in buildings is Building Price Index taken from Byggindex, SCB. Deflator for investment in machinery is Investment Good Index taken from SCB, series P. Data on Investment Good Index was only available 1972–1994 and the period 1962–1972 was interpolated assuming that Investment Good Index is closely correlated with the overall producer price index.

Capital Stock

K is generated from the series *I*, according to the perpetual inventory method where $K_t = (1-\delta)K_{t-1} + I_{t-1}$. The depreciation rates for buildings and machinery were set to $\delta_b = 0.029$ and $\delta_m = 0.087$. These depreciation rates where calculated for the Swedish forest industry during the period 1980–1990 by SCB. See Bergman (1996) p. 9 for more details on how these rates were derived. Initial capital stock values, K_0, was obtained by using fire insurance values sawmill and paper & pulp industry from 1964 published by SCB (industridata).

Output

Y is value added in 1990 prices (current price series from SCB series F 1962–1994; sni33111, sni34111, sni34112). Deflators are taken from SCB, series P; Producer Price Index for the sawmill (sni33111) and pulp & paper industry (sni34111 + sni34112).

Cash-flow

F is net operating surplus in 1990 prices (current price series from SCB, series N, sni 33111, sni34111 and sni 34112). Deflators are Building Price Index taken from Byggindex, SCB. Deflator for investment in machinery is the Investment Good Index, SCB, series P.

Cost of capital

R is user cost of capital defined as $q(r+\delta)/\text{p}$, where $r+\delta$ is real financial cost of capital plus economic depreciation. The time series on *r* were supplied by Jan Södersten, Department of Economics, Uppsala University. The calculation of the real financial cost of capital *r* are based on Swedish aggregate manufacturing. This might not be such a bad approximation since more or less the same tax laws holds for the forest sector as for manufacturing in general. Even if the approximation is wrong for the forest sector at levels, the changes may be good approximations. More information about the r used in this paper can be found in Bergström & Södersten (1984). We use the *r* that corresponds to the 'new view' in Bergström & Södersten (1984).

APPENDIX 2

(*k* = number of estimated coefficients. *Nob* = number of observations).

$\overline{R}^2$ is the adjusted coefficient of determination.

DH is the Durbin's *h* statistic for single lagged dependent variable. The test statistic is normally distributed and critical values can be obtained from Durbin (1970).

HET is the White test for heteroscedasticity based on a regression of the squared residuals on cross-products of the exogenous variables. The test statistic is chi-squared distributed with degrees of freedom equal to $((k+1)k)/2)-1$.

NORM is the JB Lagrange Multiplier test of the residuals' skewness and kurtosis. The test statistic is chi squared distributed with 2 degrees of freedom.

ARCH(1) is the autoregressive conditional heteroscedasticity test based on the regression of the squared residuals on lagged squared residuals. That is, a test to see if the variance of the residuals depend on the size of the preceding residuals. The test statistic is chi-squared distributed with degrees of freedom equal to number of exogenous variables.

CHOW is a F-type test for stability of coefficients. Sample is split into equal halves and the first subsample is tested against the second. Degrees of freedom is equal to $(k, Nob - 2k)$.