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Micro Data On Capital Inputs: Attempts to Reconcile Stock and Flow Information

Abstract:
We evaluate consequences of some important assumptions ofthe perpetual inventory method of capital stock calculation under geometric depreciation. The data are plant-level panel data from the Norwegian manufacturing statistics, containing independent measures of capital stocks and gross investment flows for two capital types and three industries. First, we look at consequences of choosing different depreciation rates a priori, when we use as benchmark for the level of the capital stocks deflated fire insurance values in a specific year. The choice of depreciation rate is of substantial importance, some values resulting in decreasing, other in increasing capital stocks over time. Second, we attempt to estimate depreciation rates by combining time series on gross investment and fire insurance values for the same period. In our regression models, both systematic and random measurement errors in the fire insurance values and various forms of heterogeneity in the coefficient structure are represented. We conclude that the estimated depreciation rates vary significantly with the specification of the measurement error process and that heterogeneity in this process across plants is important.

Keywords: Depreciation. Capital stock calculation. Panel data. Perpetual inventory method

JEL classification: C23, C81, D24, D92

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1 Introduction

In the literature, there is a vast body of articles that analyse the process whereby output is produced from combinations of inputs. While inputs of labour measured in man hours, energy, and materials in many cases are observed directly, capital stock series need in general to be calculated by using imputational methods and approximations. A common challenge in empirical analyses of the production process,[1] that do not put rigid *a priori* restrictions on the capital stock effects, is therefore how to measure the capital input and, if necessary, the user cost of this input.[2]

In analyses based on observations from *micro units*, various approaches to calculate capital stocks have been applied, depending on the information available. We may distinguish between two main traditions: one that primarily uses information about the level of capital stocks, and one that primarily uses information about gross investment flows, usually combined with level information to some extent. Recent examples within the first tradition are Bughin (1993) and Wolfson (1993), both using companies' book values from annual financial reports to obtain capital stock series, and Lindquist (1995, 2000), Ohanian (1994), Førsund and Hjalmarsson (1988), and Reynolds (1986), all using output capacities measured in tonnes as proxies for capital stocks. Companies' stock exchange values and fire insurance values have also been used as proxies in such studies. For an example of the latter, see Biørn, Golombek, and Raknerud (1998).

The dominant approach in the empirical literature, though, is the *perpetual inventory method*, which belongs to the second tradition. In essence, this method means calculating capital stock series by cumulating past and present gross investment series in quantity terms, while assuming a specific weighting system, often derived from assuming an *a priori* fixed technical depreciation rate. Recent examples are Klette and Griliches (1996) who analyse Norwegian manufacturing industries, Hsiao and Tahmiscioglu (1997) who analyse U.S. manufacturing industries, and Galeotti *et al.* (1997) who analyse Italian manufacturing industries. If the data on gross investments do not go backwards a sufficient number of periods in relation to the assumed maximal life time of the capital, at least one benchmark value for the level of the capital stock is needed. Klette and Griliches use plant data on fire insurance values to obtain a benchmark, Hsiao and Tahmiscioglu use the companies' net property value as a starting value while Galeotti *et al.* use companies' book value for a given year as a benchmark. In microeconometric analy-

[1] Capital stock variables are needed also in other branches of economics, for example in studies of economic growth and investment behaviour, national accounting, and studies of corporate tax systems.

[2] See Biørn (1989) for a discussion of the user cost of capital and the associated capital stock concepts within the neo-classical framework.

ses applying the perpetual inventory method, it is common to use aggregate or sectoral investment goods deflators from the national accounts to deflate the (benchmark) capital stocks in value terms.

Within this second tradition, there are also studies that, rather than calculating capital stock series, estimate these stocks as an integral part of a more comprehensive model. The capital accumulation relationship, defining capital stocks, may for instance be inserted in an optimizing behavioural model, such as a factor demand system, or included in a production function. The unknown parameters of the whole model, including the rate of depreciation, are estimated simultaneously, and capital stock series can then be calculated using the specified capital accumulation relationship. Recent examples are Doms (1996) and Prucha and Nadiri (1996). One major shortcoming of this approach is that the inference about the capital accumulation process is likely to be influenced by specification errors or incorrect assumptions in the behavioural model.

Little has been done to evaluate the effect of important *a priori* assumptions when calculating capital stock series, although there are a few important exceptions. Miller (1983, 1990) and Barnhart and Miller (1990) discuss several problems in applying the perpetual inventory method. In Usher (1980), many of the problems that arise in measuring capital stocks are addressed. In this paper, we take one step in the direction of evaluating the consequences of some important assumptions in the perpetual inventory approach. We confine attention to the capital accumulation process on its own, and do not restrict its parameters to satisfy some *a priori* specified optimising behaviour. We present two kinds of investigations.

Within the perpetual inventory tradition it is common to decide upon depreciation rates *a priori*.[3] *First*, we evaluate this procedure by calculating capital stock series from different depreciation rates picked within the range usually reported in the literature (Section 4). The capital stock series we obtain in this way show considerable sensitivity to the choice of depreciation rate, both in terms of level and growth pattern and both at the micro and the industry level.

Second, we attempt to *estimate depreciation rates* by combining time series of capital stocks and flows. This is our main objective of the paper. We have access to *plant specific* time series for overlapping years – recorded by independent measurements – on fire insurance values and gross investment for the same period. Previous attempts in the literature to make such stock-flow confrontations at the micro level have, very often, applied accounting data at the *firm* (company) level, not at the level of the technical

[3] Hulten and Wykoff (1981), Hulten *et al.* (1989), and Biørn (1998) attempt to estimate depreciation structures econometrically from prices of capital goods traded in second-hand markets; Jorgenson (1996) gives a recent survey of empirical studies of depreciation.

production unit, the plant (establishment). Having data at the plant level is an obvious advantage when the structure of capital depreciation varies across plants belonging to the same company. Furthermore, using accounting data as proxies for levels of capital stocks in a technical sense, most likely involves a *measurement error problem.* Such data are, in the main, related to the capital's wealth dimension, and are measured on a historical cost basis, see, *e.g.*, Wadhwani and Wall (1986). Measurement errors are probably present also when other proxies for the level of the capital stock are applied.

Although it is well understood that both measurement errors and heterogeneity in parameter structure are likely to be important when estimating depreciation rates from micro data, no previous analyses have, to our knowledge, examined these issues simultaneously within the perpetual inventory framework. Our analysis (Section 5) focuses on the specification of the measurement error and plant heterogeneity. Both systematic and random errors in the fire insurance values are allowed for, and various forms of heterogeneity in the coefficient structure are represented. We find that introducing such heterogeneity influences the estimated depreciation rates substantially, and generally, the estimates tend to be higher. We also find strong indications that our level proxies, the deflated fire insurance values, systematically differ from the capital stocks implied by the gross investment series in both levels and trend patterns.

Our primary data source is plant-level panel data from the annual manufacturing statistics database of Statistics Norway, and all calculations are done separately for three industries and two kinds of capital for each industry. Hence, the capital categories we consider throughout this paper are more homogeneous than in most other studies, which use capital as one aggregate.

2 The capital accumulation process

There is a close relationship between the capital stock accumulation and the flow of investment. We assume discrete time, and let subscript t denote period t. By definition,

$$K_t = K_{t-1} - D_t + J_t, \tag{1}$$

where K_t is the capital stock at the end of period t, D_t is the technical depreciation, or retirement, of capital in period t and J_t is the gross investment in period t, all in quantity terms. A distinction between gross and net capital is often made, see, *e.g.*, Biørn (1989, chapter 3). The former represents the productive capacity of the capital stock and measures the instantaneous flow of capital services, while the latter represents the capital's wealth dimension and measures the prospective flow of capital services. In general, gross and net capital will not be numerically equal.[4] In analyzing production technologies, we are primarily interested in the productive capacity of the capital stock and will therefore concentrate on gross capital.[5] Eq. (1) says that the change in gross capital from one period to the next, net investment, depends on gross investment and the technical depreciation, *i.e.*, the loss of efficiency and physical disappearance of old capital goods.

The level of aggregation of capital is important. The total capital stock of a plant or firm is, in general, not an aggregate of homogeneous units, but consists of buildings, structures, machinery, and transport equipment of various kinds. The level of aggregation will in practice reflect the data available and the purpose of the study. If the various capital types enter the production process differently, there will be a trade-off between simplicity and representing the data generating process in a realistic way. However, even when an aggregate capital measure is chosen, the calculation of the capital stock series should be done at the most disaggregate level whenever possible. With a disaggregated approach, one can take into account that the depreciation pattern varies across capital types. For example, it is generally assumed that buildings have longer service lives than machineries and hence the form of their survival pattern differ.

Because data on depreciation in general are not available, the survival profile of the capital must be specified. This is usually done parametrically. The survival function defines the proportion of an investment made a certain number of periods ago that still exists as productive capital. Let B_s denote the share of the capacity of a capital stock invested which survives at age s, $s = 0, 1, 2, \ldots$. The (gross) *capital stock* in period t can then be written as the following weighted sum of past gross investment:

$$K_t = \sum_{s=0}^{\infty} B_s J_{t-s}. \tag{2}$$

We assume that B_s is non-increasing in s, with $B_0 = 1$ and $B_\infty = 0$. This is the mathematical description of the perpetual inventory method. Technical depreciation in period t can then be written as

$$D_t = J_t - (K_t - K_{t-1}) = \sum_{s=1}^{\infty} b_s J_{t-s}, \tag{3}$$

where

$$b_s = B_{s-1} - B_s, \qquad s = 1, 2, \ldots . \tag{4}$$

[4] They are, however, equal in the special case where the technical depreciation structure follows an exponential (with continuous time) or geometric (with discrete time) pattern. Then technical and economic depreciation will also coincide numerically.

[5] Some authors use the term gross capital to denote cumulated gross investment, while net capital denotes gross capital minus cumulated depreciation.

If B_s is geometrically declining, often denoted as *geometric decay*, with factor $1-\delta$ ($0 \leq \delta < 1$), we have $B_s = (1-\delta)^s$, $s = 0, 1, \ldots$, and, from (4), $b_s = \delta(1-\delta)^{s-1}$, $s = 1, 2, \ldots$, so that (2) and (3) take the form

$$K_t = \sum_{s=0}^{\infty}(1-\delta)^s J_{t-s}, \tag{5}$$

$$D_t = \delta \sum_{s=1}^{\infty}(1-\delta)^{s-1} J_{t-s} = \delta K_{t-1}. \tag{6}$$

We can then interpret δ as the (technical) depreciation rate, *i.e.*, the part of the capital stock at the end of period $t-1$ which vanishes during period t. Geometric decay is the only survival function for which D_t/K_{t-1} is constant over time for any gross investment path.[6]

Combining (1) and (6), we get

$$K_t = (1-\delta)K_{t-1} + J_t, \tag{7}$$

or equivalently,

$$K_t = (1-\delta)^{-1}[K_{t+1} - J_{t+1}]. \tag{8}$$

From (7) we find, by inserting recursively for $K_{t-1}, K_{t-2}, \ldots$, that

$$K_t = (1-\delta)^{t-\theta} K_\theta + \sum_{s=0}^{t-\theta-1}(1-\delta)^s J_{t-s}, \tag{9}$$

which expresses K_t by means of a benchmark value of the capital in period θ ($\theta < t$), and the investment flow during the intervening period, *i.e.*, $J_{\theta+1}, J_{\theta+2}, \ldots, J_t$. From (8) we find, by inserting recursively for $K_{t+1}, K_{t+2}, \ldots$, that

$$K_t = (1-\delta)^{t-\theta} K_\theta - \sum_{s=1}^{\theta-t}(1-\delta)^{-s} J_{t+s}, \tag{10}$$

which expresses K_t by means of a benchmark value of the capital in period θ ($\theta > t$) and the investment flow during the intervening period, *i.e.*, $J_{t+1}, J_{t+2}, \ldots, J_\theta$. The first term on the right hand side of (9) and (10) shows that the effect on the capital stock in period t of changes in its benchmark value in period θ depends on the depreciation rate and the distance between the two periods. Hence, if (9) or (10) are used for calculation of capital stock series for a given gross investment series, the sensitivity of the capital stocks to measurement errors in the benchmark capital value depends on δ and $t-\theta$.

[6] An alternative survival profile is the simultaneous retirement or 'sudden death', in which all capital units retain their full efficiency during their whole life-time and then disappear completely. Then net and gross capital will not be equal, and depreciation rates will depend on the time path of gross investment.

We choose (5) as our basic hypothesis on the depreciation structure. It is simple – since it contains only one unknown parameter – but restrictive – since the implied hazard rate of depreciation (in a corresponding stochastic interpretation of the depreciation process) is age invariant and equal to $b_s/B_{s-1} = \delta$. Several other parametrisations have been proposed in the literature though, most containing more than one unknown parameter, and with hazard rates depending on the age of the capital.[7] A distinct advantage with the geometric decay specification from a practical point of view is that it leads to (9) and (10), in which information about the age distribution of the benchmark capital stock [K_θ in (9) and (10)] is not needed for computing capital stocks in other periods.

Depreciation rates are in general unobservable, and the next challenge is therefore how to measure these parameters. It is common, even in micro-economic studies, to use depreciation rates applied by statistics producing agencies in calculating national accounts data as proxies for the true rates.[8] However, this practice has its weaknesses because few statistics producing agencies have investigated thoroughly (at least in recent years) the survival profiles of capital goods. Central statistical offices often "pick" service lives or depreciation rates from other countries, and hence there is a tendency to a circle effect where one or a few empirical investigations largely determine the survival profiles of capital goods in many national accounts.[9]

[7] We could, for instance, replace (5) by a finite order MA, AR, or ARMA process (possibly with some parameter restrictions). This could, however, increase the number of parameters to be estimated substantially.

[8] Cf. the UN meetings in the Canberra Group on Capital Stock Statistics.

[9] Furthermore, there may be a gap between the observed investment outlays and the growth in the productive capital stock. Jorgenson (1963) and Jorgenson and Stephenson (1967) argue that time is required for the completion of new investment projects. Kydland and Prescott (1982) define this as the 'time-to-build'. We may therefore wish to replace (1) by $K_t = K_{t-1} - D_t + S_t$, where S_t represents the capital finished and put into use during period t and added to the productive capital stock at the end of this period. Gross investment in period t, J_t, as usually reported by the plants as the sum of the 'values put in place' of current investment projects, may then exhibit a lead in relation to the capital put into use in period t. Then the relationship between S_t and J_t may be represented by a distributed lag mechanism, and equality between these two variables will hold only 'in the long run'. As 'time-to-build' processes are not easily observable, the formulation of the capital accumulation process for empirical purposes must be given either in terms of the gross investment series J_t available, or be based on specific assumptions about the lag distribution or estimates taken from other studies or own 'guesstimates'. A reasonable assumption is that 'time-to-build' is important for large investment projects in buildings and structures, but less so for smaller investment in machinery and transport equipment. Also, the data frequency may be of relevance; with annual data, 'time-to-build' is probably less important than with, for example, quarterly data. If there is virtually no lag between capital put in place and capital put into use, $S_t = J_t$ holds as a good approximation for all t.

3 Data sources

The Norwegian Manufacturing Statistics database contains annual plant-level panel data. All large plants, *i.e.*, with 5 or more employees until the year 1992 and with 10 or more employees thereafter, are included. We use data from the following industries: Pulp and paper (341), Chemicals (351), and Basic metals (37). The industry numbers given in parenthesis follow the Standard of Industrial Classification (SIC) System. Our sample includes data from the years 1972 – 1993.

Available variables that are relevant in the calculation of the capital stock series are (i) fire insurance values for the two categories Machinery and transport equipment (Machinery, for short) and Buildings and structures (Buildings, for short); (ii) gross investment (including net sales of capital) in Machinery, Transport equipment, and Buildings and structures; (iii) rent value of real capital, both income and expenditure, on the two capital types defined in (i); (iv) repair and maintenance costs split according to whether the work is done by own employees or by others.

Using deflated fire insurance values as direct measures of the capital stock of different categories may seem an appealing approach. A major problem is that the quality of the reported fire insurance values is thought to be relatively poor due to a lack of quality control. We therefore decided not to use these data as our only source of capital information.

In order to be able to compute capital stock series by means of the perpetual inventory formula (2), one needs time series for gross investment at least a number of periods backwards equal to the maximal life-time of the capital, *i.e.*, the largest i for which B_i is positive. In the geometric decay case, which is characterized by a infinite survival function [cf. (5)], the function must be truncated in some way. We do not have a sufficient number of *early* observations on gross investment in our sample, and therefore need to combine the data on investments with some level information to obtain a benchmark value for the capital stock. We use deflated fire insurance values to construct benchmark values, and (9) and (10) can then be used to calculate capital stock series.

A further question is how to define gross investment. We can either use the data reported by the plants directly, or we can add the data on *maintenance work and repair* to the gross investment figures reported. One argument for the latter approach is that these components in general are very large in comparison with the gross investment recorded. This may reflect, for example, that some plants define replacement investment, *i.e.*, investment to compensate for depreciation, as maintenance work and repair. Measured relative to the value of gross investment, the value of maintenance work and repair is as much as 75 per cent on average.[10]

4 Constructing capital stock series from pre-selected depreciation rates

In this section, we evaluate some consequences for calculated capital stock series of choosing *a priori* depreciation rates within the range usually reported in the literature. We distinguish between two capital types, Machinery (including transport equipment) and Buildings (including structures). The deflated fire insurance values are used to obtain level information in a given reference year, which is selected as a benchmark according to some rules that we describe below. Under geometric depreciation with pre-selected depreciation rates, capital stock in the remaining years can be constructed by utilising data on gross investment and recursions based on (9) and (10).

It is not clear how one should select the benchmark year. One possibility is to use the first year in which the plant occur in the sample; the drawback is that no fire insurance data for the years 1972 – 1973 are available. Missing observations also occur for some plants in certain other years. To select the benchmark year we sort (in ascending order) the time series for the deflated fire insurance values for the individual plant. The deflating is based on the corresponding aggregate investment price index according to the national accounts. Instead of using, for instance, the calendar year corresponding to the highest or smallest value of the sorted time series, we choose the 75 percentile since this is believed to be less influenced by measurement errors. Table 1 shows how the reference year is chosen depending on the number of observations of the individual plant. In general, for each plant, the reference year will depend on the capital type. From each reference year, we use (9) and (10) to calculate time series for the capital stock of Machinery and Buildings separately. For an example, see Appendix 1.

In order to evaluate the constructed time series of capital stocks when applying different depreciation rates, it is useful to consider some of their implications at the industry level. For a given calendar year, one can aggregate the stocks over the plants in each industry. The sensitivity of the calculated capital stock series to the choice of depreciation rate is illustrated in Tables 2a – 2c, which relate to Pulp and paper, Chemicals, and Basic metals, respectively. The tables contain the aggregate results for both capital types; the separate results for Machinery and Buildings are given in Appendix 2. The

[10] With our data, we have the possibility to take into account that plants can *rent and lease capital.* We choose to ignore this, however, mainly because we face a major challenge of how to deflate these data. Measured relative to the value of gross investment, the value of net lease of capital is only 4 per cent on average.

last column in each table gives, for comparison, the corresponding figures from the national accounts.[11] In the national accounts, which use gross investment recorded in the manufacturing statistics and assume geometric depreciation, the fire insurance values are not utilised as benchmarks, however. When long time series for gross investment are available this may give an adequate approximation because the initial capital stocks can be set to zero.[12]

Table 1. Rule for selecting the reference year

Number of years the plant is observed	Observation number in the sorted data vector used as benchmark
19 – 22	5
15 – 18	4
11 – 14	3
7 – 10	2
1 – 6	1

We find that the choice of depreciation rates is very important for both the level of the capital series and their growth profile, some values resulting in decreasing, other in increasing capital stocks, given the benchmark values. We also find significant discrepancies between our constructed capital figures and the corresponding national accounts figures, also when similar depreciation rates are used. Some differences in the levels were expected, however, for reasons pointed out earlier. The difference is most pronounced for Machinery. Errors in the level of the capital stock series will, of course, affect other variables derived from it. For instance, an error in a capital series by a factor k will affect the estimated rate of return by a factor of $1/k$.

In general, the true rates of depreciation are unknown parameters, and we believe that the lesson which can be learnt from this exercise, *i.e.*, that calculated capital stock series depend significantly on pre-selected depreciation rates, carries over to other micro data. A framework for estimating depreciation rates, rather than picking their values *a priori*, is therefore desirable, when possible. In the next section we present a framework in which depreciation rates are estimated, combining stock and flow information on capital.

[11] The Norwegian national accounts office has recently carried through a main revision of the national accounts data, starting in 1978. For the preceding years growth rates from old national accounts data have been utilised to construct national accounts data for the years 1972 – 1977.

[12] Furthermore, the results will differ because the national accounts series are adjusted due to the presence of small plants, which are not covered by the primary statistics. And, while we include repair expenses in the gross investment figures, this is not the case in the national accounts data.

5 Estimating depreciation rates from plant-level data

Our data set has the great advantage from the point of view of estimating depreciation rates econometrically that it contains time series, for overlapping years, of both capital stock variables and corresponding flow variables, gross investment, observed by independent measurements. We use our framework with geometric decay depreciation, not in its basic form, but with parametric specifications allowing for both systematic and random errors in the fire insurance value as a measure of the capital variable in a technical sense. Our starting point is (5), which for plant i, with a plant specific depreciation rate δ_i, is represented as (we suppress, for simplicity, the subscripts for industry and capital type)

$$K_{it} = \sum_{s=0}^{\infty}(1-\delta_i)^s J_{i,t-s} + u^*_{it}, \tag{11}$$

i.e., the capital stock, for plant i in year t, K_{it}, (which is unobserved) is written as a weighted sum of past investments, J_{it}, with plant specific, geometrically declining weights. The error term, u^*_{it}, takes account of deviations from this rule.

Several reasons can be given why we should not expect (deflated) fire insurance values and (unobserved) productive capital stocks to coincide. We mention a few: First, the plants' propensity to insure their capital stock may be changing over time, exhibiting, for example, a smooth time trend, that may be common or plant specific. Second, the capital variable which the plants insure may include not only tangible objects, but also immaterial capital like research and development, good-will, know-how, etc. Third, insurance value is a value related concept. Not infrequently full replacement values rather than replacement values after deduction of cumulated depreciation up to the current service age seem to be reported. Productive capital stocks are technical, capacity related concepts. Fourth, improper price indices may be used in deflating the reported insurance values. Other reasons why (11) may be too simplistic when applied to plant-level panel data are (i) changing depreciation rates over time within the assumed geometric structure, (ii) investment in the aggregated capital types, Buildings and Machinery, may change in composition with respect to service life during the observation period, and (iii) even for the most disaggregate capital types, the depreciation profile may be non-geometric.

Based on these considerations, we have chosen the following formalization of the relationship between the fire insurance value of plant i in period t and the unobserved capital stock

$$H_{it} = c^*_i + \tau^*_i(t-1971) + A_i K_{it} + \epsilon_{it}, \tag{12}$$

where A_i is a scaling factor for plant i, representing the systematic component of the measurement error in the fire insurance value, τ^*_i is a trend coefficient, representing possible trend effects in the insurance behaviour of the plants, c_i^* is an intercept term – all of which may be plant specific, as indicated by subscript i – and ϵ_{it} is an error term, including the random part of the measurement error. The error terms in (11) and (12) are assumed to be independently distributed. White noise properties for u_{it}^* and ϵ_{it} are assumed (although arguments could be given for applying MA or AR processes). We refer to A_i as the *scale parameter*, δ_i as the *depreciation parameter*, and τ_i^* as the *trend parameter*. In the empirical applications, we consider not only the case where these parameters are plant specific, but also cases in which some of them are assumed plant invariant for each industry.

The unobserved capital variable K_{it} is eliminated by inserting (11) into (12), giving

$$H_{it} = c_i^* + \tau_i^*(t-1971) + \frac{A_i}{1-(1-\delta_i)L} J_{it} + u_{it}, \tag{13}$$

where $u_{it} = A_i u_{it}^* + \epsilon_{it}$ and L denotes the lag-operator. Multiplying through (13) by the lag-polynomial $1-(1-\delta_i)L$, we get

$$H_{it} = c_i + \tau_i(t-1971) + (1-\delta_i)H_{i,t-1} + A_i J_{it} + v_{it}, \tag{14}$$

where $c_i = \delta_i c_i^* + (1-\delta_i)\tau_i^*$, $\tau_i = \delta_i \tau_i^*$, and $v_{it} = u_{it} - (1-\delta_i)u_{i,t-1}$, and hence $\tau_i^* = \tau_i/\delta_i$ and $c_i^* = (1/\delta_i)[c_i - ((1/\delta_i) - 1)\ \tau_i]$.

We estimate (14) and use the relationships defined above to obtain estimates of c_i^* and τ_i^*. To calculate standard error of the estimated parameters, a first order Taylor expansion of the non-linear relationships is used [cf. Kmenta (1986, p. 486)]. The lagged endogenous variable in (14) is correlated with the error term v_{it} since the latter follows an MA(1)-process if u_{it} is white noise. Hence, OLS yields inconsistent estimates, and we therefore estimate (14) with instrumental variables for H_{it}.

Altogether, we specify ten models for the two capital types and three industries, characterized by the following parameter restrictions:

Model A: $c_i^* = c^*,\ \tau_i^* = \tau^*,\ \delta_i = \delta,\ A_i = A,\ \forall i.$
Model B: $c_i^* = c^*,\ \tau_i^* = 0,\ \delta_i = \delta,\ A_i = A,\ \forall i.$
Model C: $c_i^* = c^*,\ \tau_i^* = \tau^*,\ \delta_i = \delta,\ A_i = 1,\ \forall i.$
Model D: $c_i^* = c^*,\ \tau_i^* = 0,\ \delta_i = \delta,\ A_i = 1,\ \forall i.$
Model E: $\tau_i^* = \tau^*,\ \delta_i = \delta,\ A_i = A,\ \forall i.$
Model F: $\tau_i^* = \tau^*,\ \delta_i = \delta,\ \forall i.$
Model G: $\delta_i = \delta,\ A_i = A,\ \forall i.$
Model H: $\tau_i^* = 0,\ \delta_i = \delta,\ A_i = A,\ \forall i.$
Model I: $\tau_i^* = 0,\ \delta_i = \delta,\ \forall i.$
Model J: All intercepts and slope coefficients are plant specific.

When estimating the models some observations have been disregarded. For the left hand side variables only observations dated later than 1974 are included, since fire insurance values for 1972 and 1973 are missing and the lagged endogenous variable occurs on the right hand side. Furthermore, we only include observations where the deflated fire insurance values exceed 1 million 1991-NOK. The models are estimated by the TSP 4.3 software, see Hall (1996).

The depreciation parameter should be positive, and within the same industry, we expect its value to be smaller for Buildings than for Machinery, because Buildings, on average, are expected to have a longer life time. Furthermore, the scale parameter should have a positive sign, since an increase in the latent capital variable should be followed by an increase in the deflated fire insurance value [cf. (12)].

Consider first the results for the models with no systematic heterogeneity across plants, *i.e.*, *Models A – D* in Tables 3 and 4. The OLS estimates of the most general model within this model class, Model A, are reported in Table 3 for reasons of comparability with other results, although, as mentioned above, it yields inconsistent estimates. We therefore concentrate on the IV-estimation results. The estimated trend parameter τ^* is clearly not significant,[13] indicating that there is no trend in the plants' tendency to insure their capital stock over time. A zero restriction on the trend parameter leaves both the depreciation and the scale parameter virtually unaffected; compare Models B and D with Models A and C, respectively. Furthermore, although we find that the intercept term c^* is significantly different from zero in only a few cases, the scale parameter A is in general significantly different from unity. The latter implies that the measurement error involved when using the fire insurance value as a proxy for the level of the capital stock is not purely random but also has a systematic component.

While Model B is most consistent with $\tau^* = 0$ and $A \neq 1$, it produces negative estimates of the depreciation parameter in two cases. If we restrict the scale parameter to unity, however, as in Model C and D, all depreciation parameters come out with the correct sign. It should be noted that introducing the unity restriction on the scale parameter increases the estimated depreciation parameter.

Consider next the models with plant specific coefficients, *i.e.*, *Models E – J* in Tables 5 and 6. The most general model, Model J, leads to estimating (14) on data for each plant separately. However, since the estimated depreciation parameters and scale coefficients in this model to a large extent turned out to be incongruous with *a priori* assumptions and quite unstable, they are not reported. This may reflect overparametrisation and it seemed necessary to impose some restrictions on the coefficient structure across plants. In Models E – I, the depreciation parameter is equal across all plants classified in the same industry, while the intercept term is plant specific.

[13] Throughout, the significance level is set to 5 per cent.

Models E and F imply that there is a significant trend in the insurance behaviour in three and four cases, respectively. This gives some support to the hypothesis that there has been a systematic trend in plants' tendency to insure their capital stock, which suggests a systematic measurement error in the fire insurance values as a proxy for the capital stock. It is, of course, crucial to take this into account if the aim is to calculate capital stock variables, K_{it}, from (12). It is interesting to notice that the estimated depreciation parameters are relatively robust with respect to imposition of the zero restriction on the trend parameter; compare Model E with Model H, and Model F with Model I. If we allow the trend parameter to be heterogeneous across plants, as in Model G, we get implausible depreciation parameters; the estimates are either negative or very large. We therefore did not go further on this route. The estimated scale parameters in Models E and H are in general significantly less than unity. Hence, when heterogeneity is introduced in the relationship between the latent capital variable and the fire insurance value, we find clear evidence of a systematic measurement error. Negative scale parameters (cf. Tables 5 and 6) are, of course, inconsistent with *a priori* assumptions.

Consider next the effect of introducing plant specific scale parameters on the depreciation parameters. Comparing Model E with F, and Model H with I, we find that the depreciation parameter in some cases is substantially affected. Hence, our data support the conclusion that the estimated depreciation parameter is more sensitive to plant invariance in the scale parameter than to zero restrictions on the trend effect.

From the discussion of Models E – I above, we can conclude that the relationship between the latent capital variable K_{it} and the observed fire insurance value H_{it} seems to vary across industries and capital categories. When both the scale parameter and the intercept term are plant specific, *i.e.*, in Model F, the estimated depreciation rate for Buildings are *higher* than for Machinery in all the three industries considered. This, rather surprising result, may to some extent be ascribed to the fact that the insurance behaviour vis-à-vis Buildings is different from that of Machinery in a way not captured by our model. It may for example be more difficult to assess the "true" value of Machinery than of Buildings, since Buildings are more frequently traded in second hand markets.

By comparing the models without heterogeneity with those with heterogeneity we find a clear evidence that introducing heterogeneity in the scale parameter or intercept term influences the estimates of the depreciation parameters substantially. Generally, the estimates seem to be higher when allowance is made for parameter heterogeneity than when full homogeneity is assumed.

In Table 7 the residual coefficient of variation (RCV) of Models A – I is given along with the number of observations and the mean of the left hand side variable.[14] The RCV in general is large, and we will not put too much emphasis on this measure as a tool for discriminating between the models. It is interesting to notice that the RCV tends to be smaller in models with heterogeneity in the coefficients than in models without such heterogeneity.

Our overall conclusion then is that the measurement error involved when using fire insurance values as proxies for capital stocks includes systematic as well as random components. We recommend that a relatively general relationship between the latent capital variable and the proxy variable should be specified and tested. In our data we found that the trend effect is of minor importance, while a non-unitary scale parameter in general is important. All the regressions include an intercept term, however, which also represents a systematic measurement error component.

6 Concluding remarks

There is no obvious, uniquely "right" way to construct capital stock series. The chosen method will very much depend on the data available and the purpose of the investigation. The most common approach in the micro-econometric literature is the perpetual inventory method supplemented by the assumption of a geometrically declining survival pattern of the capital stock. The value of depreciation rates are typically decided upon *a priori*. In econometric production and cost function analyses, the calculation of capital stocks is seldom considered a research task on its own, and little is done to evaluate the consequences of important assumptions about the capital input.

The purpose of this paper has been two-fold, first to check the robustness of choosing different 'reasonable' depreciation rates *a priori*, and second to investigate whether stock information (deflated fire insurance series) and flow information (gross investment series) can be reconciled, and in this process analyse the importance of measurement errors and heterogeneity.

We have used plant-level panel data from the Norwegian manufacturing statistics, and have calculated capital stock series for two capital types and three industries: Pulp and paper, Chemicals, and Basic metals. Two kinds of investigations have been performed. First, we have examined the robustness of the results, *i.e.*, the implication on the calculated capital stock series, when choosing different depreciation rates *a priori*. The depreciation rates chosen are within the range usually reported in the literature. As

[14] The number of observations, and hence also the mean of the left hand side variable, vary across the alternative models for the same industry and capital category because of our choice of instruments and the pre-exclusion of plants with less than 10 observations in some regressions.

a benchmark for the level of the capital stocks, we have used deflated fire insurance values in a specific year picked by an *a priori* defined procedure. The conclusion is that the choice of depreciation rates is of substantial importance both for the level of the capital series and their growth profile, some values resulting in decreasing, other in increasing capital stocks over time.

Second, we have tried to estimate the depreciation rates by combining time series data on gross investments and fire insurance values, again assuming geometric depreciation. The model allows for both systematic and random measurement errors in the fire insurance values as a measure of the capital stock in a technical sense. Depreciation rates have been estimated under different assumptions about the systematic and random measurement errors.

We conclude that the measurement error involved when using deflated fire insurance values as proxies for the latent capital stock variable includes systematic as well as random components. The relationship between the fire insurance values and the true capital stock variable varies across capital type and industry, however. From this we recommend that a rather general relationship should be specified and tested when attempting to reconcile stock information based on a proxy variable and flow information from micro units. While we have found only modest support for the hypothesis that plants' insurance behaviour has changed systematically over time, since the trend effect is of minor importance, more support is found for a non-unitary a scale parameter. Hence, there is a systematic discrepancy between the latent capital stock and deflated fire insurance values.

We have found a clear evidence that introducing heterogeneity in the scale parameter or intercept term influences the estimates of the depreciation rates substantially. Generally, the estimates seem to be higher when allowance is made for parameter heterogeneity than when the model is homogeneous across the plants. When both the scale parameter and the intercept term are plant specific, the estimated depreciation rate for Buildings are higher than for Machinery in all the three industries considered. This, rather surprising, result may to some extent be ascribed to the differences in the insurance behaviour vis-à-vis the two capital categories.

It is clear that further research is needed in this field, with focus on the measurement error and importance of heterogeneity when attempting to estimate capital stock variables and/or depreciation rates. We expect this issue to be of general importance, and it would be of interest to analyse the relationship between the true capital stock variables and its proxy variables within other information sets. It might also be worthwhile to incorporate more elaborate time series methods and/or more flexible parametrisations of the depreciation process.

Table 2a. Aggregate capital stock in Pulp and paper. Implications of different depreciation rates. Mill. 1991-NOK

Year	Alternative depreciation rates			NNA[a]
	M: 8%, B: 4%	M: 6%, B: 3%	M: 4%, B: 2%	M: 8%, B: 4%
1972	73097	50184	34946	10792
1973	68802	48598	34874	10793
1974	65211	47473	35174	11074
1975	62173	46670	35703	11842
1976	59066	45618	35925	12081
1977	55690	44086	35564	12612
1978	52416	42390	34886	13410
1979	49572	40999	34454	14151
1980	54087	45651	39117	16178
1981	52462	45407	39846	17625
1982	48665	42895	38280	17150
1983	45441	40834	37106	16522
1984	42638	39046	36109	16146
1985	40907	38287	36153	15807
1986	39592	37838	36444	15915
1987	38586	37575	36827	16301
1988	37450	37137	37023	16233
1989	36316	36669	37192	15781
1990	35655	36594	37700	15863
1991	35239	36748	38446	16065
1992	35325	37211	39306	18008
1993	33375	35658	38200	17771

[a] National Accounts.

Table 2b. Aggregate capital stock in Chemicals. Implications of different depreciation rates. Mill. 1991-NOK

Year	Alternative depreciation rates			NNA[a]
	M: 13.5%, B: 4%	M: 10.13%, B: 3%	M: 6.75%, B: 2%	M: 13.5%, B: 4%
1972	125631	63654	32587	13322
1973	111003	58851	31606	13066
1974	97484	54093	30477	12955
1975	86166	50202	29811	14114
1976	76470	46791	29266	16046
1977	74760	49626	33986	18242
1978	88684	61336	43735	19192
1979	79607	57502	42752	18188
1980	71489	53901	41739	17324
1981	64806	51018	41155	16855
1982	58760	48174	40360	16272
1983	52790	44820	38745	15685
1984	48575	42742	38197	15482
1985	44770	40828	37713	15256
1986	41619	39251	37400	15269
1987	39285	38188	37422	15400
1988	37159	37184	37442	15430
1989	35353	36314	37486	15312
1990	33417	35111	37055	15158
1991	32801	35147	37823	15388
1992	31349	34235	37561	14973
1993	30080	33419	37331	14440

[a] National Accounts.

Table 2c. Aggregate capital stock in Basic metals. Implications of different depreciation rates.
Mill. 1991-NOK

	Alternative depreciation rates			NNA[a]
Year	M: 8%, B: 4%	M: 6%, B: 3%	M: 4%, B: 2%	M: 8%, B: 4%
1972	86942	54950	34152	17018
1973	82194	53689	34700	17112
1974	79437	53713	36171	17703
1975	76390	53475	37543	18423
1976	73287	53104	38749	18902
1977	70691	52949	40047	19410
1978	67655	52219	40754	19621
1979	64741	51407	41295	19602
1980	63080	51668	42843	20097
1981	62723	53091	45507	21635
1982	61183	53195	46806	22425
1983	59055	52513	47208	22243
1984	56881	51729	47510	22196
1985	58346	54416	51188	23264
1986	57468	54717	52476	25046
1987	57117	55364	53994	25399
1988	55754	55077	54696	24967
1989	54796	54903	55261	24665
1990	52413	53321	54455	24473
1991	51095	52807	54752	24106
1992	49331	51804	54555	23493
1993	47798	50972	54497	22524

[a] National Accounts.

Table 3. Model A. Standard errors in parentheses[a,b]

Industry	Capital category	OLS-estimates[c]				IV-estimates[d]			
		c*	τ*	δ	A	c*	τ*	δ	A
Pulp and paper	M	-3531517 (16638688)	-19562 (74831)	-0.005 (0.006)	0.650 (0.085)	-1831163 (4405556)	-22845 (41279)	-0.010 (0.007)	0.578 (0.089)
	B	-133751 (121690)	6934 (3370)	0.043 (0.008)	0.212 (0.014)	-9340064 (64159191)	24795 (93581)	0.003 (0.008)	0.194 (0.014)
Chemicals	M	236710 (735614)	-938 (24515)	0.056 (0.015)	1.146 (0.248)	1933648 (16709751)	-10586 (148051)	0.011 (0.017)	0.384 (0.284)
	B	-330801 (477191)	10637 (15931)	0.057 (0.014)	1.905 (0.210)	-254375 (635962)	7353 (19766)	0.051 (0.017)	1.866 (0.228)
Basic metals	M	-202208 (97046)	22535 (5933)	0.275 (0.019)	3.113 (0.250)	3647223 (16510293)	65508 (163924)	-0.014 (0.031)	0.550 (0.349)
	B	166267 (149767)	-1798 (6379)	0.090 (0.012)	0.851 (0.109)	72784 (172403)	1916 (7074)	0.085 (0.012)	0.787 (0.111)

[a] All coefficients are plant invariant.
[b] A first order Taylor-expansion is used to calculate the standard error of c* and τ* , cf. Kmenta (1986, p. 486).
[c] The OLS estimates are biased.
[d] Investment lagged one period and deflated fire insurance value lagged two periods are identifying instrumental variables.

Table 4. Models B, C and D. IV-estimates. Standard errors in parentheses [a,b]

Industry	Capital category	Model B: τ* =0			Model C: A=1			Model D: τ*=0, A=1	
		c*	δ	A	c*	δ	τ*	c*	δ
Pulp and paper	M	107270 (181558)	-0.011 (0.007)	0.575 (0.089)	-3791584 (4621141)	0.011 (0.005)	34276 (36218)	-171328 (274665)	0.010 (0.005)
	B	1048902 (4218556)	0.002 (0.008)	0.194 (0.014)	44802 (38070)	0.138 (0.014)	-21 (1990)	44431 (10339)	0.138 (0.013)
Chemicals	M	804792 (1374129)	0.011 (0.017)	0.383 (0.284)	106904 (1381085)	0.041 (0.010)	2088 (37346)	183015 (196786)	0.041 (0.010)
	B	-22376 (113960)	0.050 (0.017)	1.867 (0.228)	-2091675 (11484300)	0.010 (0.013)	21297 (99306)	273133 (537286)	0.010 (0.013)
Basic metals	M	-247124 (1498272)	-0.010 (0.029)	0.584 (0.337)	1015858 (8247372)	0.018 (0.018)	-12388 (116202)	161678 (583369)	0.018 (0.018)
	B	118495 (38112)	0.084 (0.012)	0.783 (0.110)	33959 (136484)	0.099 (0.010)	2960 (6040)	98929 (31555)	0.098 (0.010)

[a] All coefficients are plant invariant. Investment lagged one period and deflated fire insurance value lagged two periods are identifying instrumental variables.
[b] A first order Taylor-expansion is used to calculate the standard error of c* and τ* , cf. Kmenta (1986, p. 486).

Table 5. Models E, F and G. IV-estimates. Standard errors in parentheses [a,b]

Industry	Capital category	Model E: c* is plant-specific[c]			Model F: c* and A are plant-specific[d]		Model G: c* and τ* are plant-specific[c]	
		τ*	δ	A	τ*	δ	δ	A
Pulp and paper	M	14208 (5908)	0.073 (0.017)	0.401 (0.101)	17639 (7146)	0.069 (0.019)	0.574 (0.062)	0.345 (0.104)
	B	4309 (5895)	0.033 (0.032)	0.189 (0.015)	4176 (1097)	0.185 (0.034)	-0.117 (0.060)	0.146 (0.018)
Chemicals	M	14259 (7353)	0.220 (0.044)	-0.935 (0.336)	12759 (130744)	0.015 (0.062)	1.517 (0.299)	-1.523 (0.483)
	B	11760 (8595)	0.133 (0.027)	1.703 (0.345)	23783 (18789)	0.068 (0.029)	0.429 (0.045)	2.331 (0.347)
Basic metals	M	17677 (16454)	0.146 (0.108)	0.300 (0.341)	24734 (12278)	0.204 (0.127)	-0.499 (0.440)	0.227 (0.521)
	B	5761 (1685)	0.412 (0.034)	0.573 (0.119)	7326 (1958)	0.384 (0.036)	0.796 (0.059)	0.723 (0.129)

[a] The estimates of the plant specific coefficients are not reported. Only plants observed 10 years or more are included.
[b] A first order Taylor-expansion is used to calculate the standard error of c* and τ* , cf. Kmenta (1986, p. 486).
[c] Investment lagged one period and deflated fire insurance value lagged two periods are identifying instrumental variables.
[d] Deflated fire insurance value lagged two periods is instrumental variable.

Table 6. Models H and I. IV-estimates. Standard errors in parentheses[a]

Industry	Capital category	Model H: τ*=0; c* is plant-specific[b]		Model I: τ*=0; c* and A are plant-specific[b]
		δ	A	δ
Pulp and paper	M	0.060 (0.015)	0.399 (0.101)	0.053 (0.017)
	B	0.033 (0.028)	0.190 (0.015)	0.146 (0.029)
Chemicals	M	0.195 (0.042)	-0.867 (0.335)	0.013 (0.056
	B	0.124 (0.026)	1.763 (0.341)	0.060 (0.027)
Basic metals	M	0.123 (0.799)	0.283 (0.342)	0.142 (0.093)
	B	0.381 (0.032)	0.547 (0.118)	0.347 (0.033)

[a] The estimates of the plant specific coefficients are not reported. Only plants observed 10 years or more are included.
[b] Investment lagged one period and deflated fire insurance value lagged two periods are identifying instrumental variables.

Table 7. Regression diagnostics

Model	Number of observations		Mean of left hand side variable		Residual coefficient of variation (RCV)[a]	
	M	B	M	B	M	B
	Pulp and paper					
A_{OLS}	2049	1806	201001	72962	0.4095	0.4494
A_{IV}	1894	1683	208548	75123	0.3951	0.4419
B	1894	1683	208548	75123	0.3950	0.4418
C	1894	1683	208548	75123	0.3972	0.7522
D	1894	1683	208548	75123	0.3972	0.7520
E	1722	1548	224489	79629	0.3750	0.4368
F	1721	1536	224618	80198	0.3829	0.4223
G	1721	1536	224618	80198	0.3705	0.4679
H	1722	1548	224489	79629	0.3754	0.4367
I	1721	1536	224618	80198	0.3836	0.4266
	Chemicals					
A_{OLS}	884	840	400623	183482	0.5450	0.7599
A_{IV}	836	799	413897	189245	0.5389	0.7539
B	836	799	413897	189245	0.5386	0.7535
C	836	799	413897	189245	0.5372	0.7621
D	836	799	413897	189245	0.5369	0.7617
E	786	761	437849	197963	0.4928	0.7444
F	786	760	437849	198221	0.5269	0.7522
G	786	760	437849	198221	0.6577	0.6821
H	786	761	437849	197963	0.4949	0.7445
I	786	760	437849	198221	0.5269	0.7535
	Basic metals					
A_{OLS}	1458	1387	346239	168248	0.9768	0.6643
A_{IV}	1376	1313	358036	171556	1.0410	0.6366
B	1376	1313	358036	171556	1.0389	0.6363
C	1376	1313	358036	171556	1.0262	0.6370
D	1376	1313	358036	171556	1.0257	0.6368
E	1252	1196	377910	182312	0.9856	0.6036
F	1244	1187	380328	183672	0.9842	0.6056
G	1244	1187	380328	183672	1.3813	0.6275
H	1252	1196	377910	182312	0.9963	0.6043
I	1244	1187	380328	183672	1.0129	0.6084

[a] Defined as the standard error of regression (SER) divided by the empirical mean of the left hand side variable.

Table A1a. Construction of capital stock data for a specific plant. Machinery. The depreciation rate is 4%. Mill. 1991-NOK

Year	Gross investment	Deflated fire insurance value[a]	Calculated capital stock
1972	23.43	NA	337.43
1973	6.78	NA	330.71
1974	5.91	111.42	323.39
1975	5.83	96.21	316.29
1976	8.06	95.65	311.70
1977	19.37	90.54	318.60
1978	17.64	95.78	323.50
1979	29.36	121.48	339.92
1980	19.35	158.92	345.67
1981	10.15	154.10	342.00
1982	9.83	186.72	338.14
1983	9.11	188.58	333.73
1984	20.88	242.75	341.26
1985	11.61	316.66	339.22
1986[b]	12.96	338.62	338.62
1987	3.54	339.23	328.61
1988	4.85	340.28	320.32
1989	10.56	371.01	318.07
1990	10.09	393.92	315.44
1991	4.93	102.57	307.75
1992	6.04	102.64	301.48
1993	10.01	281.58	299.43

[a] NA signifies no data.
[b] The benchmark year is 1986.

Table A1b. Construction of capital stock data for a specific plant. Buildings. The depreciation. rate is 4%. Mill. 1991-NOK

Year	Gross investment	Deflated insurance value[a]	Calculated capital stock
1972	0.70	NA	53.39
1973	0.75	NA	52.01
1974	1.71	NA	51.64
1975	1.60	NA	51.18
1976	1.62	NA	50.75
1977	18.67	43.87	67.39
1978	3.01	50.23	67.70
1979	8.00	57.74	72.99
1980	3.80	65.77	73.88
1981	2.46	61.09	73.38
1982	2.36	51.86	72.80
1983	1.66	64.70	71.55
1984	5.33	57.12	74.02
1985	4.17	58.36	75.22
1986	3.73	56.22	75.95
1987	-0.26	49.83	72.65
1988	-0.38	48.63	69.36
1989[b]	3.98	70.57	70.57
1990	1.21	75.04	68.96
1991	0.00	75.14	66.20
1992	0.51	73.62	64.06
1993	2.63	73.62	64.13

[a] NA signifies no data.
[b] The benchmark year is 1989.

Appendix 2: Supplementary results

Table A2a. Aggregate capital stock of Machinery in Pulp and paper. Implications of different depreciation rates. Mill. 1991-NOK

Year	Depr. 8%	Depr. 6%	Depr. 4%	NNA[a] 8%
1972	64244	42567	28368	5513
1973	59965	40872	28089	5597
1974	56163	39414	27960	5782
1975	53015	38385	28170	6496
1976	49769	37077	28038	6678
1977	46483	35524	27564	7110
1978	43300	33826	26803	7681
1979	40447	32332	26186	8049
1980	43882	35806	29582	9804
1981	41977	35183	29841	10894
1982	38672	33076	28601	10619
1983	35888	31362	27684	10215
1984	33374	29779	26810	10005
1985	31541	28826	26570	9721
1986	30333	28397	26792	9927
1987	29324	28052	27013	10289
1988	28219	27572	27089	10305
1989	26944	26885	26955	9879
1990	25831	26289	26867	9642
1991	24888	25834	26912	9439
1992	23129	24396	25811	9249
1993	21393	22973	24739	8964

[a] National Accounts.

Table A2b. Aggregate capital stock of Buildings in Pulp and paper. Implications of different depreciation rates. Mill. 1991-NOK

Year	Depr. 4%	Depr. 3%	Depr. 2%	NNA[a] 4%
1972	8852	7616	6579	5279
1973	8837	7726	6785	5196
1974	9048	8059	7214	5291
1975	9158	8285	7533	5346
1976	9297	8541	7887	5403
1977	9208	8562	8001	5502
1978	9116	8564	8082	5729
1979	9125	8666	8267	6102
1980	10205	9846	9534	6374
1981	10486	10225	10005	6731
1982	9993	9819	9679	6531
1983	9552	9472	9422	6308
1984	9263	9268	9299	6140
1985	9366	9461	9583	6086
1986	9259	9442	9652	5988
1987	9262	9523	9815	6012
1988	9231	9566	9934	5928
1989	9372	9784	10237	5902
1990	9824	10305	10832	6221
1991	10351	10915	11534	6626
1992	12196	12814	13495	8759
1993	11982	12685	13461	8807

[a] National Accounts.

Table A3a. Aggregate capital stock of Machinery in Chemicals. Implications of different depreciation rates. Mill. 1991-NOK

Year	Depr. 13.5%	Depr. 10.13%	Depr. 6.75%	NNA[a] 13.5%
1972	118129	57502	27546	6370
1973	103577	52669	26460	6248
1974	90104	47846	25183	5993
1975	78731	43792	24272	6684
1976	68921	40170	23442	7983
1977	63280	39559	25130	9404
1978	74937	48912	32462	9579
1979	65925	44969	31224	8792
1980	57870	41259	29958	8127
1981	51153	38176	29031	7790
1982	45140	35204	27964	7359
1983	39552	32085	26453	6976
1984	35359	29882	25645	6727
1985	31493	27764	24821	6492
1986	28325	26032	24219	6499
1987	25895	24742	23886	6537
1988	23628	23465	23502	6456
1989	21735	22379	23198	6356
1990	19696	20966	22444	6050
1991	18669	20466	22543	6050
1992	17252	19468	22062	5760
1993	15972	18525	21580	5315

[a] National Accounts.

Table A3b. Aggregate capital stock of Buildings in Chemicals. Implications of different depreciation rates. Mill. 1991-NOK

Year	Depr. 4%	Depr. 3%	Depr. 2%	NNA[a] 4%
1972	7502	6153	5041	6952
1973	7426	6182	5146	6818
1974	7380	6247	5294	6962
1975	7435	6410	5538	7430
1976	7549	6621	5824	8063
1977	11480	10067	8856	8838
1978	13747	12424	11272	9613
1979	13682	12533	11527	9395
1980	13619	12642	11781	9197
1981	13653	12841	12124	9065
1982	13620	12970	12395	8914
1983	13238	12734	12292	8709
1984	13216	12859	12553	8756
1985	13277	13064	12892	8764
1986	13294	13219	13181	8770
1987	13390	13446	13536	8863
1988	13531	13718	13940	8973
1989	13619	13934	14287	8956
1990	13721	14145	14612	9108
1991	14132	14681	15279	9338
1992	14097	14768	15498	9213
1993	14108	14894	15751	9125

[a] National Accounts.

Table A4a. Aggregate capital stock of Machinery in Basic metals. Implications of different depreciation rates. Mill. 1991-NOK

Year	Depr. 8%	Depr. 6%	Depr. 4%	NNA[a] 8%
1972	76030	46109	27011	8789
1973	71137	44531	27120	8912
1974	68037	44076	28015	9427
1975	64514	43302	28730	9970
1976	61020	42370	29247	10291
1977	58043	41672	29876	10681
1978	54869	40637	30143	10852
1979	51824	39535	30264	10915
1980	49409	38886	30770	11058
1981	47765	38860	31846	11728
1982	45974	38548	32579	12400
1983	43735	37595	32564	12204
1984	41603	36692	32600	12249
1985	41885	38037	34782	12964
1986	40783	37962	35548	14296
1987	40582	38644	36987	14526
1988	39130	38114	37291	14161
1989	38094	37747	37545	13821
1990	36061	36402	36861	13636
1991	34879	35895	37026	13453
1992	33252	34889	36677	12939
1993	31774	33977	36390	12206

[a] National Accounts.

Table A4b. Aggregate capital stock of Buildings in Basic metals. Implications of different depreciation rates. Mill. 1991-NOK

Year	Depr. 4%	Depr. 3%	Depr. 2%	NNA[a] 4%
1972	10912	8841	7141	8229
1973	11057	9158	7580	8200
1974	11400	9637	8156	8275
1975	11876	10173	8813	8453
1976	12267	10734	9502	8611
1977	12648	11276	10171	8729
1978	12786	11581	10610	8768
1979	12917	11872	11031	8687
1980	13671	12782	12073	9038
1981	14959	14230	13661	9907
1982	15209	14647	14227	10026
1983	15320	14918	14643	10039
1984	15278	15036	14910	9947
1985	16462	16379	16405	10300
1986	16686	16755	16928	10750
1987	16535	16721	17007	10873
1988	16624	16963	17405	10807
1989	16703	17156	17716	10845
1990	16352	16918	17594	10837
1991	16216	16913	17726	10653
1992	16079	16915	17878	10554
1993	16025	16995	18108	10318

[a] National Accounts.

Appendix 1: Capital stock calculation. An example

In this appendix, we examplify the method applied to calculate capital series in Section 4 by considering a specific plant. The observed gross investment and fire insurance value and the calculated capital value are shown in Tables A1a and A1b.

The plant we consider is observed in 22 years and, in accordance with Table 1, the reference year is given as the fifth largest observation in the sorted time series. The fifth largest value of the deflated fire insurance value occurs in 1986 for Machinery, and in 1989 for Buildings. Let H_{kt} denote the (deflated) fire insurance value of capital type k in year t ($k = M$ for Machinery and $k = B$ for Buildings) and let J_{kt} denote gross investment of capital type k and K_{kt} the stock of capital type k for the plant in year t. The constants δ_M and δ_B denote depreciation rates for Machinery and Buildings, respectively. We have chosen $K_{M1986} = H_{M1986}$ and $K_{B1989} = H_{B1989}$. For the calculation of the capital stock of Machinery in the remaining years we can utilise the following forward and backward recursions, cf. eqs. (7) – (10) in the main text:

$$K_{Mt} = (1 - \delta_M)K_{M,t-1} + J_{Mt}, \qquad t = 1987, 1988, \ldots, 1993,$$
$$K_{Mt} = (1 - \delta_M)^{-1}(K_{M,t+1} - J_{M,t+1}), \qquad t = 1985, 1984, \ldots, 1972.$$

For the stock of Buildings the recursions are

$$K_{Bt} = (1 - \delta_B)K_{B,t-1} + J_{Bt}, \qquad t = 1990, 1991, \ldots, 1993,$$
$$K_{Bt} = (1 - \delta_B)^{-1}(K_{B,t+1} - J_{B,t+1}), \qquad t = 1988, 1987, \ldots, 1972.$$

This procedure cannot be used for all plants because it sometimes produces negative values – depending on the value of the depreciation rate. For the plants for which this is the case, other reference years have been chosen (usually corresponding to the lowest values in the ordered series).

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