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THE MEASUREMENT OF CAPITAL THROUGH A FIXED ASSET ACCOUNTING SIMULATION MODEL (FAASM)

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In this article the author describes a method of estimating the capital stock of the corporate sector which is being developed at Statistics Canada. The method uses a "Fixed Asset Accounting Simulation Model" or FAASM. FAASM provides estimates of the capital stock by inferring the actual service lives of fixed assets, and using these with price indexes to revalue assets on a constant price basis. FAASM is thus an alternative to the widely used Perpetual Inventory Method. By also inferring accounting lives using the depreciation accounts, it has other important outputs. These latter get only passing mention here. Since FAASM exploits the available data in a comprehensive, systematic way, its service life and capital stock estimates may eventually, after system development and improvement in operation, approach the limits of attainable accuracy.

1. Introduction

The factor of production capital, in contrast to the factor labour, is not now measured with reasonable accuracy. The method used by virtually all countries that publish capital stock estimates is the "perpetual inventory model" (PIM). It relies on three data inputs, capital expenditures, the capital goods price index, and service lives. There are problems with all three of them, although it is mostly the difficulty of accurately surveying lives that has raised doubts on the reliability of the present estimates.

Instead of requesting life data from companies, it is possible to infer lives from data from their fixed asset accounts, the account balances as well as the capital expenditures. This has been done in French and Canadian studies (Mairesse, 1972; Atkinson and Mairesse, 1978; Tarasofsky *et al.*, 1981; and Cette and Szpiro, 1988). What is new in the approach presented here is the systematic exploitation of this principle—extended to include changing vintage lives, and accountants' assumed lives as well as actual lives—in a simulation model. There are two versions. The partial version yields estimates of the capital stock. The full version also produces other outputs which, though important in their own right, receive only passing mention here.

Note: I am greatly indebted to my colleague, Terry Gigantes, who referred me to the work of Tarasofsky and his associates, the starting point for the present analysis, and who collaborated in internal Statistics Canada working papers; and to David Slater, for his indispensable support and valuable perspectives. Among the many others to whom thanks are due, space limits me to mention only Abe Tarasofsky and Jacques Mairesse, who discussed their prior work with me; Derek Blades, who drew my attention to the French work and reviewed early drafts; Julia Lelik of Peat Marwick; Fred Gault, Jack Wilson, Richard Landry, and Kuen Huang of Statistics Canada; Aly Elfar, Emil Asistores, and Marcel Uson of Bell Canada; and Michael McCracken, John Sargent, Bert Waslander, Derek Harris, John Caldwell, and Paul Ambrose.

FAASM's capital stock estimates are, by mathematical necessity, accurate under two main conditions: price index accuracy, and data accuracy. The important, but separate, question of the price index is not addressed here. Data accuracy requires an integrated annual survey of company fixed asset accounts, designed to screen out distortions and errors.

After a brief description of the PIM and a discussion of the nature of service lives, the author describes how the Fixed Asset Accounting Simulation Model (FAASM), now being developed at Statistics Canada, has the potential to generate up-to-date and reliable service life and capital stock estimates. Finally an example of the use of FAASM is given, employing data for the Canadian telephone utilities.

2. The Perpetual Inventory Model

In considering how the capital stock is to be measured, we should start with the fixed asset accounts of companies. These, practically speaking, are the sole source of data for any method of capital stock estimation, including the life data used in the PIM. For any group of fixed assets it chooses to distinguish, a corporation's fixed asset accounts show:

$$\left.\begin{array}{ll} & G_t = \text{gross fixed assets} \\ \text{less} & A_t = \text{accumulated depreciation} \\ \text{equals} & N_t = \text{net fixed assets} \end{array}\right\} \quad \text{at the end of year } t$$

at original (historic) prices. In principle, if accounting were at "current cost," gross and net stocks could be estimated by statistical agencies simply by aggregating, respectively, these G_t and N_t values. Practical problems would be the distortions in the accounts, described in Section 4, non-uniformity in companies' use of price indexes, and the fact that the net stock obtained, though a useful measure, would not be a "true net." Accounting net is based on each company's assumed lives and particular depreciation methods. Arriving at true net requires somehow determining actual lives, and deciding on some acceptable, uniform, depreciation rule.

The only practical way of estimating the capital stock is through some statistical agency model. This could be based on the basic perpetual inventory process of company accounts:

$$G_t = G_{t-1} + I_t - d_t \tag{1}$$

where I_t is capital expenditure and d_t is discards, during year t. But, for a statistical agency to use this to estimate the capital stock would impose a large data burden. Initially a survey of the age distributions of fixed assets would permit calculation of a revalued G_{t-1}. This would be updated annually through a survey of the age distributions of d_t, also revalued.

Fortunately we can circumvent these problems by replacing equation (1) with the exactly equivalent age distribution equation:

$$G_t = \sum_{k=0}^{t} I_k S_{kt} \tag{2}$$

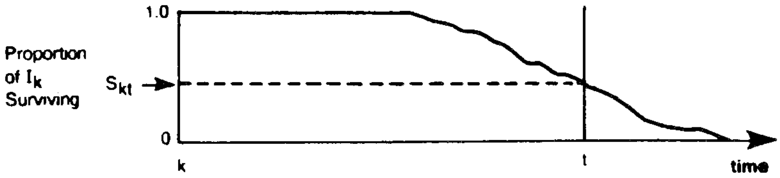


Figure 1. Survival Curve

where S_{kt} is the proportion of the vintage of capital goods, I_k, surviving at time t. As can be seen from the diagram above, S_{kt} is in fact the survival curve of I_k. The PIM uses an approximation of this, replacing the irregular and changing S_{kt} with some survival function ϕ, usually expressed in terms of a fixed mean value, L:

$$G_t = \sum_{k=0}^{t} I_k \phi_{kt}(L). \tag{3}$$

Sometimes statistical agencies make the further approximation of zero-dispersion of lives (all items in a group of assets have the same life), in which case equation (3) assumes the simple form

$$G_t = \sum_{k=t-L+1}^{t} I_k \tag{4}$$

Given the commonly used assumption of straight-line depreciation, the corresponding equation for accumulated depreciation is

$$A_t = \frac{1}{L} \sum_{k=t-L+1}^{t} (t-k+1) I_k \tag{5}$$

Using some assumed value of L, and the deflated I_k series, equations (4) and (5) give estimates of the gross and net capital stocks (net stock is gross stock less accumulated depreciation).[1]

3. The Nature of Service Lives

Before proceeding further it is necessary to clarify the concept of service life. To avoid unnecessary complexity, zero-dispersion is assumed. Figure 2 shows two types of life: actual, L_k, (period in service); and accounting, LA_k (predicted by corporations). Lives, shown as falling here, may change in either direction. The subscript "k" refers to the vintage of capital goods whose life is indicated.

Actual Lives: The interval from t' to t encompasses the vintages of capital expenditure comprising the present stock. J_t is the age of its oldest marginal item, about to be discarded. It is clearly the life, $L_{t'} (= L_{t-J_t})$ of capital goods of the t' vintage – "cohort" in the parlance of human mortality statistics. Figure 2(a) shows the curve, L_k, of such vintage lives. $L_{t'}$ is its latest measurable value. The BC part of the curve is unknowable. It must be predicted in order to calculate depreciation required for estimating the net stock.

[1]For simplicity, the equations of this paper use a conventional notation based on integer lives. A somewhat more complex notation has been developed for FAASM in terms of non-integer values.

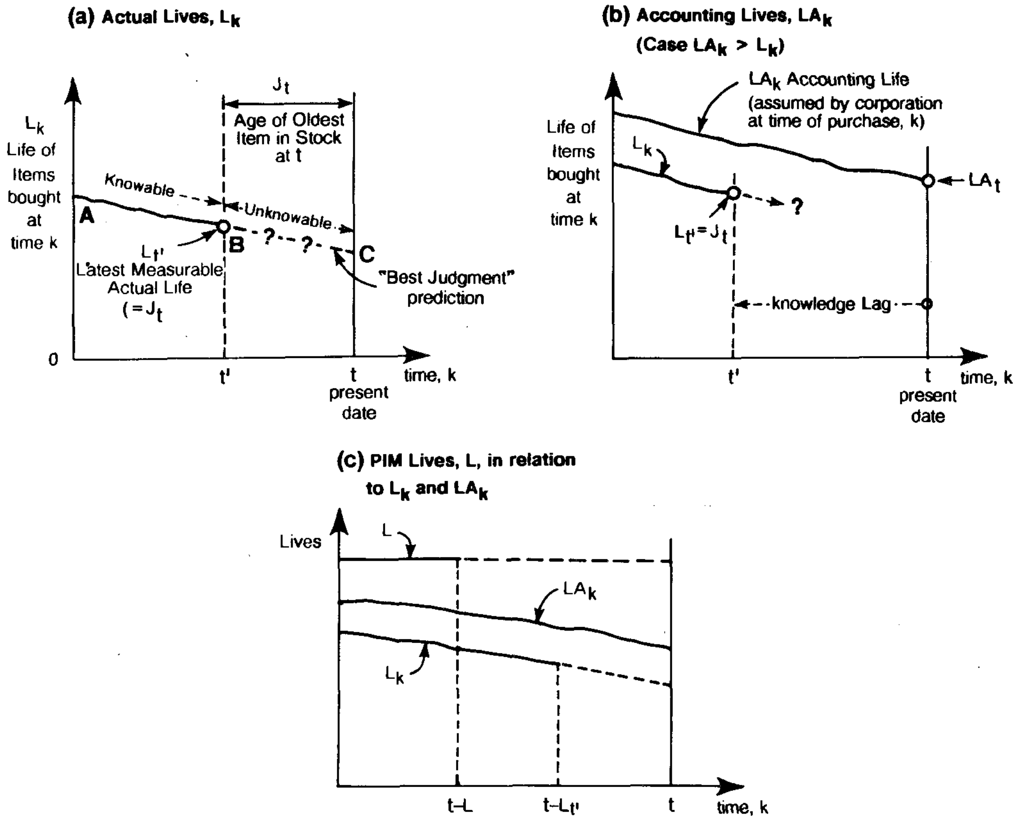


Figure 2. Service Lives

J_t might, alternatively, be plotted on a graph as the age of capital goods "dying" now, at t. It is only at t that the value of $L_{t'}$ is determined, through the discard decision, under present economic and technological conditions, to discard, and possibly to replace or expand, with modern equipment. (Note that when lives are dispersed, J_t and $L_{t'}$ are means which are only approximately equal.)

Accounting Lives: LA_k, shown in Figure 2(b), is corporations' predictions made at purchase—"life expectancies at birth"—of L_k, for calculating depreciation expense in their main accounts. (For large corporations in Canada, these are generally different from lives used for tax purposes, which are irrelevant here.) Though shown here as above L_k, it may be below. Prediction errors are understandable: When LA_t is set, the latest knowable life is L_t, J_t years in the past. "Knowable" does not mean "known", and corporations may not have analyzed their discards to determine trends in actual lives.[2] Knowledge of LA_k is not essential for estimating the capital stock, but has a variety of uses discussed later.

[2]Such analysis is performed by, for example, telephone utilities, for which depreciation expense is of great importance. Marston, Winfrey, and Hempstead (1953) is a leading reference work on retirements analysis.

PIM Life, L: Figure 2(c) compares the PIM's L with L_k and LA_k. (L is shown above here, but it could be below.) L is intended to be actual life, L_k. The distinction between knowable and unknowable presumably has no meaning in the PIM, since lives are assumed not to change. The PIM does not concern itself with accountants' depreciation lives, LA_k, as such, though statistical agencies may sometimes be guided by these values in assuming L, for lack of better data.

The PIM's constant life, L, seems clearly unsatisfactory: "Estimates of economic lives are regarded as the weakest aspect of the simulation exercise. In most countries, no recent, comprehensive and empirically based set of estimates of capital asset lives has been compiled" (Ward, 1976). The U.S. Bureau of Economic Analysis depends mainly on data compiled in connection with the administration of federal income tax laws, specifically on the 1942 edition of Bulletin *F* (Ward, 1976, and Bureau of Economic Analysis, 1987).

The imprecise practice of assuming a constant life is perhaps explained by the difficulty of the PIM approach in measuring life directly. It seems especially inappropriate now, given the apparently rapid introduction of new technologies. The assumption of constancy may greatly affect the estimates of capital stock growth rates.

If we could survey lives accurately, annually, we could improve the PIM by replacing L in equations (4) and (5) with J_t and L_k, to give

$$G_t = \sum_{k=t-J_t+1}^{t} I_k \tag{6}$$

$$A_t = \sum_{k=t-J_t+1}^{t} (t-k+1)\frac{I_k}{L_k}. \tag{7}$$

An acceptably close measure of J_t might be the weighted average age of discards, d_t, obtained from their age distribution. However, surveying this age distribution may impose a large data burden. A large company's annual discards, d_t, in a single asset class, has an average magnitude in the millions of dollars. This total would generally comprise a number of assets, acquired at different dates, each in turn including a possibly large number of parts replaced, or added, (renovations, retrofits, capacity increases) over the years.[3] In the first year of implementation, surveyed J_t would permit estimation of only a single, year t, gross stock. Until the system had operated for some years, it would be difficult to establish the L_k trend (see Figure 2(a)), necessary for estimating the net stock from equation (7), and for re-estimating past stocks. Compounding these difficulties would be the accounting distortions described in Section 4c.

4. The Fixed Asset Accounting Simulation Model (FAASM)

In this section I describe a method which circumvents the difficulties of direct life measurement by means of a model that simulates corporate accounts, through life inference.

[3]Where company practice is to charge replacements to expense rather than to capitalize them, the survey burden is reduced.

4a. *Prior Use of Company Accounts to Determine Service Lives*

There is a widely-held view (e.g. Ward, 1976, p. 26) that company accounts are of little value in capital stock estimation, both because accounting is at historic prices, and because of variations and anomalies of accounting practice. In fact, they can be used indirectly, to determine lives which can then be used to estimate stocks. As Blades (1983) notes in a review of life determination methods, historic price accounting need be no obstacle to life determination, provided data anomalies are removed.

The study by Tarasofsky and his associates (1981) brought to the writer's attention the possibility of inferring lives. These researchers estimated a value of accounting life, assumed to equal actual life, L, for the total business sector, all asset categories combined, of 19 years, in comparison with about 28 years assumed in the Canadian capital stock estimates. (Interestingly, all the studies of lives based on company accounts, those reviewed here, as well as the present telephone utilities study, seem to indicate service lives shorter than current PIM assumed values.)

French work, discovered only later by the writer, used life inference methods more like those of this paper. Mairesse (1972), in establishing the lives assumed in the French PIM capital stock estimates, relied to some extent on company accounts, despite a severe shortage of suitable data. In his later study with Atkinson (1978), equipment lives in manufacturing were determined using an equation similar to (3). Though coherent and consistent results were arrived at, the exercise had to be limited to a relatively small number of firms, judged to be largely free of data distortions. The values of L determined were sufficiently close as to confirm those established by Mairesse in 1972, so the latter remain in force for the French PIM estimates.

Cette and Szpiro (1988) studied the recent trends of lives in French industry, using the simple form of life inference described below, based on equation (6). The extent to which data distortions were excluded is not clear.

All the prior work reviewed here measured only actual lives, not, in addition, accounting lives. The equations used a constant mean life parameter. The importance of data problems in limiting the use of company accounts is emphasized by Mairesse, in his 1972 study particularly, and he identified categories of data distortions similar to those discussed below in Section 4c.

4b. *The Principle of Life Inference*

That lives can be inferred from fixed asset accounts, despite their being at historic cost, is simply demonstrated. For example, equation (6) has three variables, G_t, I_k, and J_t. If G_t and I_k are known, the single unknown, J_t, can be calculated. We therefore do not need to attempt to gather data on lives if, instead, we survey the readily accessible G_t total in the accounts.

In practice we would probably use more accurate expressions for G_t, based on the equation (2) given earlier. G_t no longer depends on a single life, $L_{t'} = J_t$, but on a series of survival curves, S_{kt}. To permit life inference, an approximate form of equation (2) is used, assuming some specified survival shape, and some functional form for the trend of the mean life, L_k, for example,

$$G_t = \sum_{k=0}^{t} I_k \phi_{kt}(\alpha, \beta, \gamma, \delta) \tag{8}$$

where α and β are the L_k parameters (assuming some two parameter trend like a straight line, S-curve, or negative exponential), and γ and δ are the dispersion parameters, fractions of L_k representing the lower and upper dispersion limits respectively. Assuming γ and δ, and some survival shape based on empirical evidence, we can solve for the L_k trend parameters, α and β. Whereas before, to determine the single unknown, J_t, a single year's data value, G_t, sufficed, now two years' such values, G_t and G_{t-1}, are required.

Instead of assuming a specific survival shape, we may treat γ and δ as the parameters of some assumed standard functional form for such a shape, e.g. a normal distribution. Now, given four years of G data, we can solve not only for the trend of L_k, but also for the approximate life distribution. Theoretically then, we can infer something about survival functions without the need for direct observation. Given more years of data, we might solve for more than four parameters, allowing greater accuracy of trends and distributions. Econometric estimation methods might be employed.[4]

Equation (8), unlike equation (6) for zero-dispersion, by embodying the life trend, appears to facilitate re-estimation of the past stock.

Just as it is possible to infer actual lives and survival functions from G_t equations and data, we can infer accounting lives, LA_k, if we have, in addition, the corresponding depreciation equations and data, both A_t, accumulated depreciation, and D_t, annual depreciation. Now the situation is more complex. While there is only one, universally used, G_t equation, (1), there is a variety of A_t and D_t equations, reflecting the particular depreciation methods used by corporations. Moreover, the equations are more elaborate. Accounting life inference is not discussed in this paper.[5]

In the present study, both L_k and LA_k have been inferred from data using zero-dispersion equations. For LA_k a straight-line trend was assumed. A programme of experimental simulation is required to develop inference techniques based on equations like (8). This must then be extended to the more complex situation where accounting lives are involved.

4c. *The Errors to which Inferred Lives are Subject*

The errors to which inferred lives are subject can be seen from the equations from which they are determined. In the inference of actual lives from equation (8), there are three sources of error: (i) Deviation of equation (8) from the rule governing corporate accounting equation (1); (ii) G_t data distortions due to corporations' own deviations from equation (1); and (iii) I_k data distortions.

[4]Since submission of this paper, equation (8) has been successfully used for the inference of α and β, given assumed survival shape and γ and δ values. The inference of γ and δ has not yet been tried, but may raise some theoretical questions and require more than the four years of G data here indicated.

[5]However, see Jaffey and Gigantes, 1987, for discussion of inference of accounting lives.

In addition to these distortions of G_t and I_k in corporation accounts are the errors in surveying them, ignored here, familiar survey errors in an area of readily accessible information. The three error categories are discussed in turn.

(i) Deviation of Equation (8) (Survival Curve Approximations)

Under the zero-dispersion assumption, when equation (8) becomes equation (6), simulation experiments by the writer show that if actual, real world lives have a normal distribution, gross capital stock is estimated with a small downward bias, say 3 percent, given the rates of price increase and investment growth of recent decades. If, however, some irregular, say, bimodal, distribution exists, this bias may be considerably larger. The corresponding net stocks, as calculated using equation (7), have substantial upward biases.

To eliminate these biases, in practice the equations discussed above, incorporating dispersion and life trend, would be used. Then, with some empirical knowledge of actual survival functions in each industry, most of the error due to the equation approximations could probably be eliminated. Even assuming simple, rule-of-thumb, distributions will substantially reduce the bias. The accuracy improvements theoretically possible through inference of distributions without empirical knowledge, have not yet been investigated.

(ii) Distortions of Gross Fixed Assets, G_t

It can be seen from the basic equation (1) that G_t may suffer errors from three sources: "extraneous" alterations of the G_t value in the accounts, outside the basic process of equation (1); errors in the d_t data; and errors in the I_k data. The most important extraneous alteration of the G_t value is owing to revaluations, for example, in the course of company acquisitions. Due to inflation this produces an upward bias in G_t.

There are two main sources of discard error. The more important is "unrecorded discards," resulting from the failure to remove from the accounts difficult-to-estimate parts of facilities, e.g. a replaced roof or a road surface. Unrecorded discards give an upward bias to G_t in the accounts. This bias cannot be exactly eliminated even in principle, because, unlike all the other distortions mentioned here, there is no record of them. The best one can hope for is to estimate approximately their importance, industry by industry. Unrecorded discards constitute, in effect, a breadkown in accounting procedure—and there are others—that set an ultimate limit to the accuracy of capital stock estimation by any method. This includes the attempt to improve the PIM approach of direct measurement of lives, discussed in Section 3.

The second discard distortion is "retirements pending disposal," for which there is a delay before sale or scrapping, at which time they are deleted from the G_t account.

The third of the three sources of distortion in G_t, errors in I_k, is also an independent source of error in estimating life, discussed in the next section.

(iii) Distortions in the Capital Expenditures Series, I_k

Two types of I_k error are frequently referred to as major sources of PIM inaccuracy, inter-industry sale and leasing of fixed assets. Four other I_k problems are noted here as potentially important. In Canada, corporations may enter into their accounts the value of fixed assets purchased, net of government subsidies and investment tax credits, instead of at the gross value relevant for capital stock estimation. Other significant distortions may lie in the charging of large replacement parts as expense, and in mergers. Finally, there may be definitional problems, as between "annual capital expenditures", "annual additions to fixed assets in service," and "year-end balance of construction-in-progress," entities which may differ greatly in magnitude.

It is possible that I_k errors will not have a major effect on life inference, because the two I_k effects on life, the indirect effect through G_t, and the direct effect, tend to be mutually compensatory. If, for example, companies' I_k values are downward biased, so will be their G_t values. Then when lives are inferred from equation (8), the downward bias of G_t will tend to offset the downward bias in I_k. I_k errors probably have a more important effect in the final step of capital stock estimation, step (ii) described in Section 4h.

The errors to which the inference of accounting lives, LA_k, is subject are not discussed here. They are analagous, but more complex.

4d. *The Principles of the Simulation Model*

Occasional studies, like those described in Section 4a, are rendered difficult not only by the account distortions just discussed, but also by the gaps and inconsistencies in existing data series, some of which may be gathered in separate, difficult-to-reconcile surveys. Moreover, such episodic study cannot provide comprehensive, up-to-date coverage. Full exploitation of life inference is made possible by embodying it in a simulation model, in conjunction with an annual data survey that screens out the distortions.

The rationale of the simulation system is as follows. It has three components: *A*, account values; *B*, equations representing the fixed asset accounting procedures that yield those values; and, *C*, service lives, which are the equation parameters. If the model is an analogue of the corporate fixed asset accounts, the three elements will simultaneously replicate their real world counterparts. Further, given their mutual dependency, if the model is capable of replicating any two elements, then it should reproduce the third element. Simulation in this way appears to be no more than the expression of scientific method, linking variables, laws, and parameters.

In FAASM, initial investigation of corporations determines accounting procedures, *B*. An annual survey transfers data values, *A*, to the model. The model then finds the values of *C* that will cause equality between model-calculated *A* and data *A*. The same model could, in principle, achieve the analogue condition in the "PIM-mode," i.e. through *B* and *C* replication, and calculating account totals, *A*. However, as already explained, the accurate observation of *C*, lives, is difficult.

We can see that there are three conditions for the accuracy of FAASM-determined lives: accurate survey of data, *A*; accurate formulation of the model's equations, *B*, in terms of lives; and stating the equations in a form soluble for lives. The latter is possible only by imposing regularities on the myriad diversity of actual lives, reducing them to a handful of life distribution and trend parameters.

Through continuing simulation, FAASM is a learning system, its life parameters becoming more accurate with time. It should be economical in its data requirements. Even at initial implementation, using zero-dispersion equations and a single year's data, a considerable amount is learnt. From equation (6) we arrive at a single L_k $(=J_t)$ value, and from the corresponding A_t and D_t equations a trend of LA_k values, from which we can also guess at the L_k trend [see Figure 2(a)]. By repeating the process for only a few succeeding years, our trends become considerably more accurate. In practice, using equations like (8), embodying trend and distribution, we learn even more, including some direct knowledge of the past L_k trend at the outset.

4e. *Partial and Full FAASMs*

The simulation model has two versions. The partial version uses the G_t and I_k accounts, and embodies only actual lives, L_k. The full version adds the A_t and D_t accounts, and accounting lives, LA_k.

Partial FAASM suffices in the estimate of true stocks, both gross and net, which depend only on L_k. True net stock has two parts, a known true value which can be calculated only in retrospect for the years preceding t', and for later years, a "best judgment" true net, at least partly using the best judgement predicted L_k [see Figure 2(a)]. Partial FAASM will also provide estimates of true capital consumption, hence, residually, of true profit, for use in the GDP estimates. (These components in the Canadian national accounts are now based on depreciation expense reported by companies, which may be substantially different.)

Full FAASM can complement the partial version in estimating true stocks. By providing LA_k, corporations' own predictions of life, it helps establish the "best judgment" part of the L_k trend, needed for estimating the true net stock. Full FAASM also permits a second net stock measure, or "accounting" net, based on LA_k, of what would appear on the corporate balance sheets if current cost accounting were in force. True and accounting net capital stocks yield, respectively, true—for recent years, best judgment—and accounting rate of return on capital. The former is presumably the underlying long-term return. However, perhaps in the shorter run, accounting return may better relate to decisions on investment and output.

Full FAASM's outputs go beyond the capital stock estimates just discussed. Graphs like Figure 2(b), by perpetually monitoring accounting versus actual life trends, provide insights into industry technological change, market forces, and accounting policies. Measures of the over- or under-statement of profits because of under- or over-charging of depreciation, respectively, are also shown. The extent of old, fully depreciated, plant (perhaps because of stagnation), or of plant disposed of not yet fully depreciated (perhaps because of rapid technological change and competition) would also be indicated. Full FAASM could also serve as an aid in setting corporation tax lives, by making available to government more accurate estimates of both actual and accounting lives.

4f. *The Annual Data Survey*

FAASM requires an annual survey of the totals in companies' fixed asset accounts, G_t, I_t, D_t and A_t. Partial FAASM, whose survey is described here, gathers only G_t and I_t. (The additional survey features for full FAASM are analogous.) To meet FAASM's data accuracy condition, the survey is in the form of an annual reconciliation statement, based on the G_t equation, (1). Owing to the distortions or adjustments in the accounts, described in Section 4c, the values in the corporate accounts are not our "true" G_t, but instead G'_t, such that

$$G'_t = G'_{t-1} + I_t - d_t + X_t \tag{9}$$

where X_t is the total of distorting entries in the G_t account during the year (the sum of G_t, I_t and d_t distortions). By using a survey form that employs this equation we can screen out the distortions, thereby arriving at true G_t and I_t. At implementation of FAASM, an initial survey would be required to permit an approximate estimate of inherited distortions. The importance of inherited errors would diminish with time.

This reconciliation form of survey would not entirely eliminate errors, as some of the corrections supplied by corporations would surely be approximate, especially for d_t. In addition to screening out distortions, the reconciliation would also increase accuracy by imposing mutual consistency of all the data items. The long-standing difficulties of I_k reporting, described in Section 4c, with regard to capital leases, government capital assistance, and definitional problems, would be resolved. Study of the remaining difficulties, second-hand assets, operating leases, and expensed capital items, would be facilitated by FAASM's integrating framework.

Solution of the definitional problems would be sought by supplementing the equation (9) reconciliation with a similar construction-in-progress reconciliation. G_t would be defined as including only fixed assets in service, and I_k as additions to this stock. I_t then would have two components, IP_t, items directly entering service on purchase, and T_t, completed construction work, transferred from the construction-in-progress account. The latter is expressed thus:

$$W_t = W_{t-1} + C_t - T_t \tag{10}$$

where W_t is the balance of construction-in-progress, and C_t is construction in year t. Note also the relationship:

$$CE_t = IP_t + C_t \tag{11}$$

where CE_t is annual capital expenditure. It should be possible through a further "retirements pending disposal" reconciliation, similar to equation (10), to segregate these items from the G_t data. There is a view that capital stock estimates are sometimes upwardly biased through inclusion of these permanently inactive items.

How practical is it to perform this annual reconciliation type of annual survey? The French statistical agency, INSEE, already uses a relationship similar to equation (9) at the enterprise level, broken down by asset class, solely for the purpose of improving accuracy of reporting (they do not in addition utilize the data in a simulation model). Preliminary investigation indicates that Canadian enterprises perform such reconciliations in preparing their annual financial statements. In order to provide industry detail, FAASM would need this at the level of the constituent establishments. This could probably be provided by most companies, but further investigation is required. Where gaps exist, the statistical agency would need to interpolate from the available data.

The asset class breakdown of FAASM capital stock estimates will depend upon the detail in which establishment fixed asset accounts are kept. In Canada, for large companies, this is probably more detailed than the present breakdown of the capital stock estimates, into buildings, engineering construction, and machinery and equipment. This also needs to be investigated further.

4g. *Formulating FAASM Equations*

The other condition for FAASM accuracy is the formulation of equations that faithfully reproduce company accounting processes, in a form soluble for lives. This should present no serious problems with partial FAASM, with its simple, universal, G_t equation.[6] However, for full FAASM, with its A_t and D_t equations, reflecting diverse company depreciation methods, a substantial effort will be required. This is not discussed here.

FAASM's development, operation, and continuing improvement—and updating to reflect changing accounting procedures—will require consultation with accountants and service life analysis specialists, now usually employed only by utilities. The national professional accounting body might play a role.

4h. *The Accuracy of FAASM Estimates of the Capital Stock*

The precise factors affecting accuracy can be seen from the equations used. Consider the estimate of the gross stock, using equation (8) to determine the life parameters, and then using the same equation including the price index, P_k, to calculate the stock:

$$KG_t = \sum_{k=0}^{t} \frac{I_k}{P_k} \phi_{kt}(\alpha, \beta, \gamma, \delta) \tag{12}$$

This is subject to the following types of error:

(i) Errors in the lives inferred from equation (8), discussed in Section 4c, due to
  (a) Approximations built into the equation; and
  (b) Errors in I_k and G_t data.

(ii) Errors in the capital stock estimated from equation (12), due to
  (a) Errors in the I_k data
  (b) Errors in P_k.

To what extent will it be possible to eliminate these errors? Following FAASM's initial development stage and continuing improvement in operation, it should be possible to reduce (i) and (ii-a) type errors to quite a low level. The

[6] Possibly FAASM adaptations will need to be devised for industries with atypically volatile investments and discards, and for new industries without clear mortality patterns.

main remaining errors in gross capital stock estimates will be due to (ii-b), the price index. Estimates, using full FAASM, of accounting net stocks, based on accounting lives, would probably have larger errors, owing to the greater complexity and diversity of equations and data.

Even for countries where the quality of company accounting is not high, it seems likely that results from a FAASM approach would be more accurate than those based on the under-utilization of the same source data through the intermittent, piecemeal PIM approach of direct measurement of service lives.

5. A Case Study: Application of FAASM to the Canadian Telephone Utilities

A simple version of full FAASM was applied to this industry, using already available, published, Statistics Canada data.[7] The zero-dispersion assumption was used, which may produce large biases when applied, as here, to undisaggregated industry totals. The data were uncorrected for distortions, though there is some evidence that these are small in this industry. Despite these shortcomings, the results seemed sufficiently tantalizing to present here.

Figure 3 shows the lives arrived at. Owing to the zero-dispersion assumption, the gap between actual and accounting lives is exaggerated, especially in the earlier years.[8] Nonetheless, there is evidence from data on expected lives in the 1985 and 1986 *Capital Expenditures Surveys*, from the composite depreciation rates given in Bell Canada's *Annual Report*, and from discussions with Bell Canada, that these results have considerable validity.[9] Actual lives are about half those now assumed in the PIM. Lives of vintages from 1959 onwards have been falling at a considerable rate, reflecting decisions since 1976 to discard assets progressively earlier.

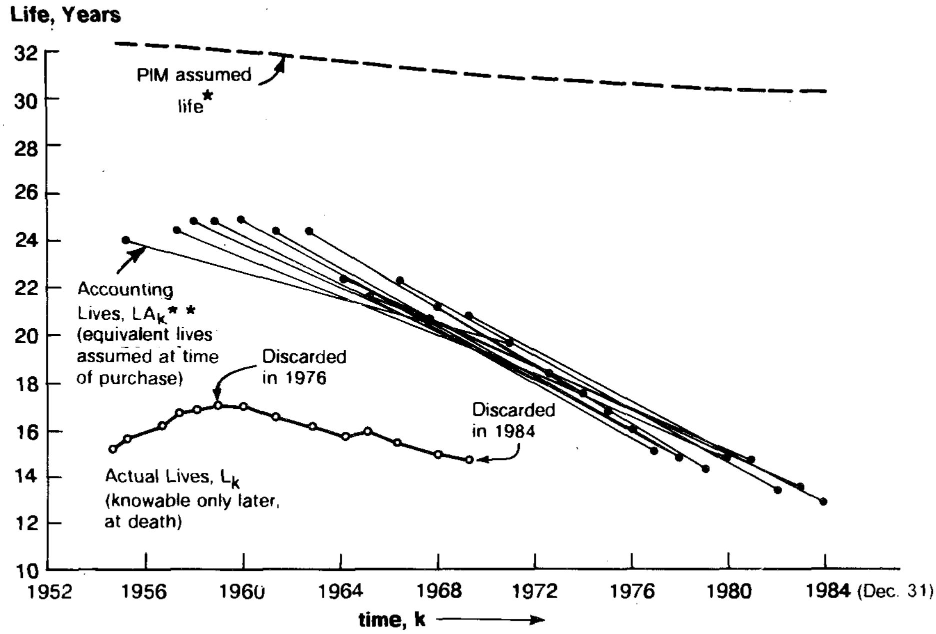
Figure 4 shows the gross and accounting net capital stocks estimated by FAASM, compared with the published PIM values. The differences, especially as regards recent growth rates, are large. (The zero-dispersion simplification does not produce much error in the gross stock, but for the net the error may be substantial.)

Despite this case study's shortcomings, its results are encouraging. Notable are their coherence, internal consistency, and clear patterns and trends, and their support by independent empirical evidence.

[7]This version contains equation (6) for G_t, and corresponding equations for A_t and D_t, assuming standard straight-line depreciation, plus equations reflecting telephone utilities' depreciation procedures, incorporating changing group lives. The standard equations were required to determine equivalent accounting lives, LA_k (see note 7).

[8]The more elaborate inference techniques discussed in Section 4b should permit replacement of the set of LA_k trends with a single non-linear trend. Figure 3 shows, in fact, "equivalent" vintage accounting lives; what they would have been if telephone utilities used standard, straight-line depreciation.

[9]The relatively high LA_k indicates undercharging of depreciation. This, in fact, has been true of some telephone utilities, though probably not Bell Canada. For U.S. telephone utilities, such under-depreciation resulted in a "$26 billion time bomb on (the utilities') balance sheets", for which the Federal Communications Commission awarded rate relief. This shortfall was the result of faster obsolescence of facilities occasioned by deregulation, which exposed the utilities to competition. (Forbes Magazine, July 29, 1985.)



NB: L_k is too low, LA_k is too high in early years, because of the zero-dispersion assumption.

* Falling because of increasing proportion of machinery and equipment.
(constant lives assumed: mach. & equip. 25 yrs; bldgs 50 yrs; eng. constr. 55 yrs).

* * The set of straight line trajectories which satisfy the At / Dt data pairs for t = 1971 to t = 1984.

Figure 3. Telephone Utilities Case Study: Lives Determined through FAASM

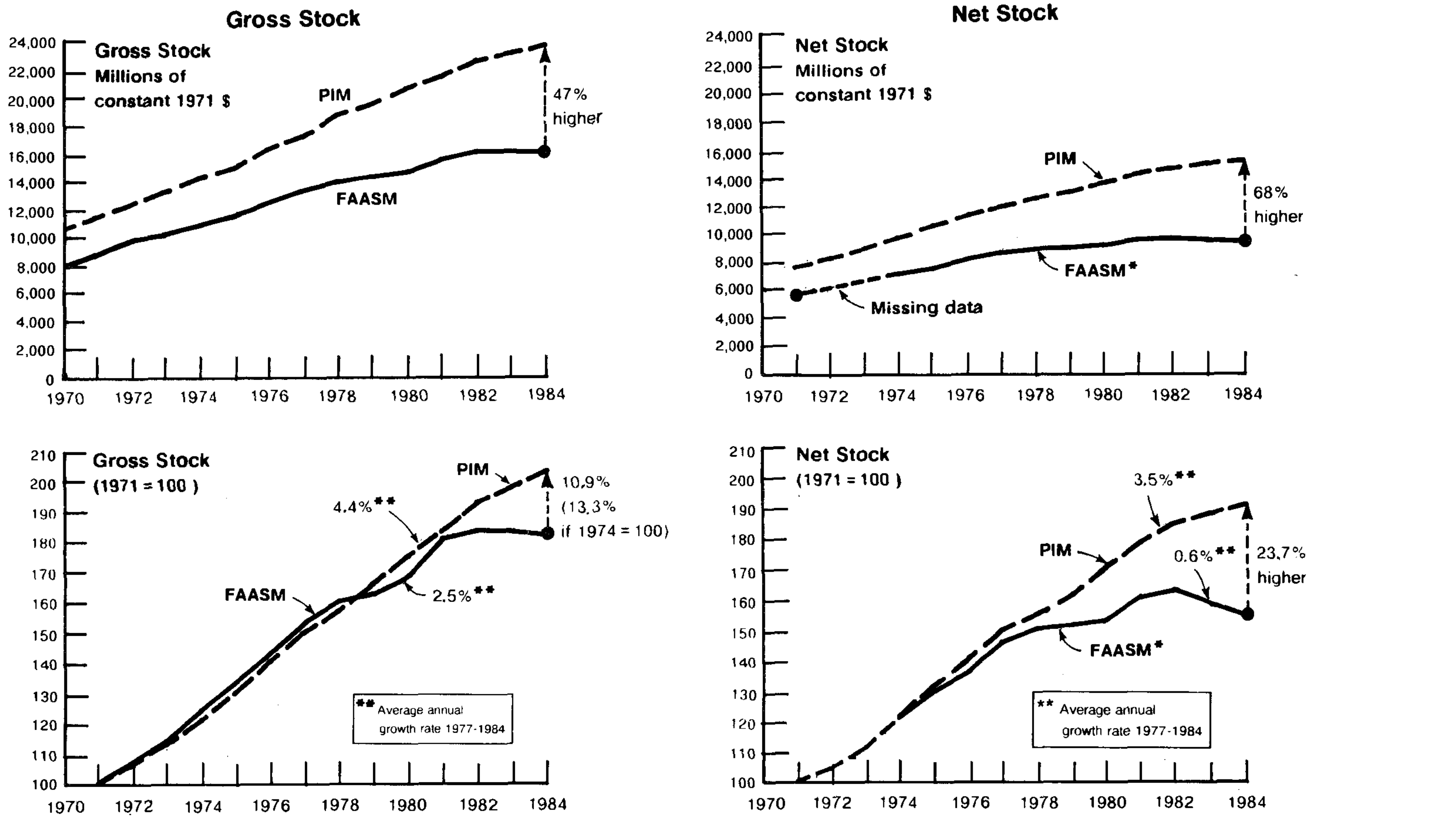
6. Summary and Conclusions

The present PIM approach of directly surveying lives has inherent difficulties. There is the "changing identity problem": each asset may have changed since original purchase as a result of replaced parts, additions, retrofits, and renovations over the years. To measure these in order to arrive at a correctly weighted average life may involve a large data burden.

Such weighted average lives may instead be inferred in a simulation model, FAASM. Through exploiting the available source data in a systematic, scientific way, FAASM life estimates may eventually approach the limits of attainable accuracy.

The partial form of FAASM, based on actual lives, suffices for capital stock estimation. The practical problems of implementation do not appear to be serious. Ultimately, if the problems of the price index are also addressed, it may be possible to measure capital, and the rate of return on capital, quite accurately.

Full FAASM offers important additional benefits. Though there appear to be no serious theoretical problems, the amount of effort to overcome practical difficulties may prove substantial. Further investigation is required. To what extent, and to what standards of accuracy, full FAASM will be implemented will surely be a question of cost effectiveness.



* Accounting net stock, based on LA_k. A more appropriate comparison would be with a best judgment, true net stock based on a projection of L_k on Figure 3. True net stock would be about 20% lower.

Figure 4. Telephone Utilities' Capital Stock, in 1971 Constant Dollars Comparison of PIM and FAASM Measures.

How FAASM might be extended from the corporate to the other sectors, unincorporated business and government, needs to be explored. One way would simply be to use corporate sector lives suitably adjusted.

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