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Background Paper

REFORM OF THE MEASUREMENT
OF ALL ASPECTS OF FIXED
CAPITAL

Michael Jaffey, Statistics Canada
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The national estimates of fixed capital comprise four vital measures: investment, the most dynamic component of GDP; the gross capital stock, which determines national output capacity; the net stock, the value of future capacity and a large part of measured national wealth; and capital consumption, the annual amount by which the latter shrinks, through wear-and-tear and obsolescence.

Yet, it is contended here, by an anomaly of national accounting, the means of producing these statistics are flawed. The annual investment survey lacks vital data categories, and the so-called perpetual inventory method (PIM), using assumed values of service lives, estimates the capital stock and capital consumption with gross inaccuracy.

A good system of fixed capital statistics is not possible without a correctly designed survey questionnaire. Unfortunately, present questionnaires generally do not adequately capture the logic of capital accumulation, routinely entered in the company accounts. These contain three distinct investment components, capital expenditure on off-the-shelf items directly adding to the producing stock; capital expenditures for work-in-progress that will enter service only in the sometimes distant future; and large account transfers, from time to time, when completed work enters service. Further, most agencies' questionnaires do not include reconciliations, to ensure accuracy and to screen out accounting distortions.

The three components can be combined to give two definitions of investment, what might be called the national accounts and capital stock definitions, abbreviated, respectively, 'N' and 'C'. Most agencies now survey only the N definition, capital expenditure, the sum of the first two components. The C definition is the sum of the first and third items, and is the annual addition to the productive or in-service stock. The Netherlands surveys only this definition. While over, say, ten years, the cumulative values of the two definitions are approximately equal, in individual years, one definition may be a small fraction of the other.

One consequence of the present defective data base is investment statistics, both as a component of GDP, and for monitoring the economy, that are less accurate and informative than they should be: During the year, how much was added to the stock of in-service capital? Of this, how much was direct off-the-shelf additions, how much fruition of decisions made years ago? How much was spent to create future capacity?

Acknowledgments. Without the support over the years of Derek Blades and Terry Gigantes, this work would probably never have been done. They early recognised that capital stocks could be directly estimated from company accounts. Appreciation is also due to my superiors at Statistics Canada who allowed me time to develop these ideas. I am indebted to Chris Jackson, whose suggestions much increased the clarity of presentation, and to Mary Coughlan, for meticulous copy-editing.

Of this how much was recently started, how much the latter stages of projects started years ago? Did the inventory of capital work-in-progress increase or decrease, and by how much (a decrease might suggest pessimism)? All we now have is an undifferentiated total annual capital expenditure. These deficiencies alone are sufficient reason to redesign the questionnaires.

Further, because the PIM must use the N definition of investment, its estimates may be quite wrong, for example, showing a substantial increase in the stock when there was, in fact, a drop. But even if a redesigned survey gave the C definition, gross errors would remain. The PIM is inherently unreliable because accurate life assumptions are simply not possible. The large spread, from 11 to 26 years, in the average lives assumed for machinery and equipment by similar industrial countries, seems symptomatic of this, and suggests that some of their estimates must be seriously incorrect.

The published literature Making the situation surprising is that the published literature has clearly shown the shortcomings of the PIM. Further, affordable alternatives have also been described. The main literature, discussed in the present paper, is Lock (1985) and Frenken (1992), of the Netherlands Central Bureau of Statistics (CBS); Mayes and Young (1994), consultants to the U.K. Central Statistical Office (CSO); and Jaffey (1990), and unpublished papers by the same writer, from Statistics Canada.

There seems little awareness of the investment survey problems. The only published description of a survey correctly reflecting company accounts appears to be by Jaffey (1990), who has taken the matter further only in unpublished work. There is nothing arcane here, and the present unsatisfactory questionnaire design is difficult to explain.

Alternatives to the present methods

The fixed asset accounting simulation model (FAASM), proposed some years ago (Jaffey, 1990) is a total, integrated system that yields all categories of capital statistics. A new reconciliation-based survey provides a correct data base, and a computer model infers the survival functions implicit in the data, and calculates capital stocks and capital consumption with a high degree of accuracy. The investment statistics are free of the deficiencies described above.

The Direct Observation of Capital (DOC), pioneered by the CBS since the early 1980s, precisely measures the gross stock. Its principle is clear: age distributions are obtained of the company gross fixed asset accounts, and these are revalued with the price index. This same principle underlay the abandoned international initiative to implement company current cost accounting. CBS use DOC in the manufacturing industries, to get benchmark values at four year intervals (Lock, 1985; Frenken, 1992; Jaffey, 1995a), and are planning to extend it to the other industries. For other capital statistics, they use various procedures (Jaffey 1995a), including a model with some features shared by FAASM, to estimate lives both for their National Accounts to calculate capital consumption, and for models of the Dutch National Planning Agency.

Anchored FAASM: In the course of recent collaboration with the CBS, the writer developed an "anchored" version of FAASM that uses occasional DOC benchmarks to keep the system precisely on track. Advantage was also taken of the availability of the accurate DOC estimates to provide empirical confirmation of FAASM accuracy (hitherto only theoretical).

At the same time, the CBS have been considering adoption of the FAASM form of survey, in order to improve their investment and capital stock statistics. If CBS follows through on this course, and Statistics Canada were to adopt the anchored FAASM, the two systems would end up much alike.

The CSO have a study underway, considering the replacement of the PIM with the Dutch method of direct measurement (Mayes and Young, 1994).

International standards. The present methods of producing fixed capital statistics are in accordance with international guidelines (System of National Accounts, 1993, and the European System of National and Regional Accounts). If the arguments of this paper are correct, these guidelines must be changed radically.

The purpose of this paper. Not helping the present situation is the piecemeal and diverse nature of the literature. The aim here is to produce a clear, comprehensive statement of the issues: what is wrong and what needs to be done. The paper is structured in the form of an argument, as follows:

Part 1: Proof of the PIM's shortcomings:

- A. The PIM lacks a sound theoretical basis: Its estimates are sensitive to assumed values of "service lives" which are of necessity highly inaccurate.
- B. Empirical evidence, in the form of independent measures of the stock, confirms this theoretical inaccuracy.
- C. Further, sometimes gross errors result from the use of the N instead of the C definition of investment. Though the investment survey could be redesigned, the life error would remain unacceptable.

Part 2: The defects of the Investment Survey

- A. Present questionnaires fail to capture vital data from the company accounts.
- B. A correctly designed reconciliation-based survey would solve this difficulty.
- C. Manifold benefits would flow from the new survey.

Part 3: A Brief Outline of Good Alternative Systems of Capital Measurement.

A good fixed capital statistical system must include the following components:

- A. The reconciliation-based survey providing the data base for both investment statistics and the simulation model.
- B. The computer simulation model which converts the fixed asset data into accurate estimates of the capital stock and capital consumption. A and B together are the minimum requirements for a good system.
- C. Direct measurement surveys (DOC) which give precise values of the gross stock, and provide benchmarks to increase the accuracy of the model estimates.

Appendices. Three matters are discussed further in appendices:

1. The mystery of the PIM's continued use, despite its quite evident shortcomings.
2. Rigorous theoretical analysis of the PIM difficulties.
3. The integration of fixed asset statistics within a FAASM framework.

PART 1: PROOF OF THE PIM'S INACCURACY¹

A. The PIM's Weak Theoretical Basis.

The PIM's inherent difficulty is its dependence on life assumptions. Strictly, one should refer to "survival curves", as in the rigorous treatment of Appendix 2. "Life" usually refers to the mean value of a life distribution, and the little attention given to this distribution is surely an indication of the methodology's crudeness.

There are two steps in arriving at conclusive proof of the PIM's inherent inaccuracy: first, to show that its estimates are highly sensitive to service life assumptions; and then to demonstrate that accurate such assumptions are impossible.

(i) Stock Estimate Sensitivity to Life Assumptions.

The following demonstrations draw on studies at the CSO and Statistics Canada.

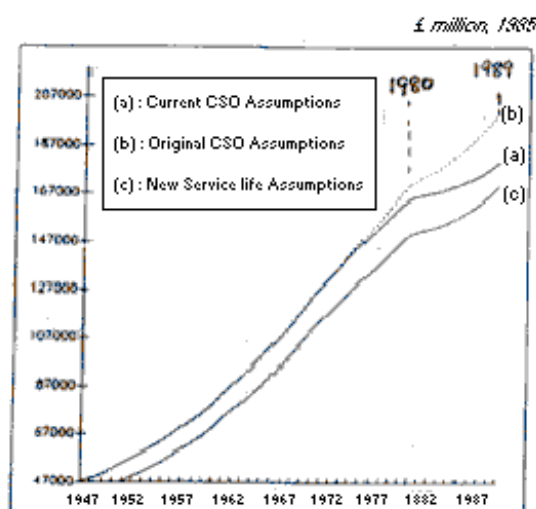
The CSO.

In 1983 the CSO revised its lives. How much this affected the capital stock estimates is discussed in a study by the U.K. Institute of Economic and Social Research, for the CSO (Mayes and Young, 1994). Until then, the CSO assumed constant lives for every category of capital good. The new estimates, still in force, retained the old lives for the pre-1950 vintages, but assumed that lives then declined gradually to a new constant value an arbitrary 25% lower, starting with the 1970 vintage.

Figure 1a is from the Mayes and Young paper. Estimate (a) is the present CSO estimate of the gross stock, embodying the new life pattern, and curve (b) what the stock would have been if the old lives had continued in use. The new estimate reduces the stock growth rate from 1980 to 1989 by 1.1%, a large amount, about half the long term economic growth rate. Normally the stock growth rate approximates to the economic growth rate. (Curve (c) is the stock based on the new reduced lives throughout, and it is readily seen that the present slow estimated capital stock growth after 1980 is simply due to the transition from the original constant lives to the new, lower, constant lives).

Based on Jaffey (1995c).

Figure 1a: U.K. Gross capital stock, plant and machinery in manufacturing



In the consultant's view, all this " . . . illustrates how bad these estimates can become when the asset life assumptions that underlie them are incorrect". But, he asked, which estimate is the most accurate? -- independent evidence would be required to settle this, and he sought other sources of data, as discussed in Section B(ii) below.

Statistics Canada

Initial Assumptions

Statistics Canada, too, revised its capital stock estimates, in 1990. Originally a pattern of life change like that used by the CSO was planned: the old constant lives until 1947, dropping to new constant lives from the 1975 vintage. Unlike the CSO's new lives, which were an arbitrary 25% reduction of the old lives, the Statistics Canada new values were companies' expected lives of new capital goods. These lives have been requested in the questionnaire, from about 1985. Often the reduction was far greater than 25%.

Figure 1b is from a study performed of the effects of these original assumptions. It shows the gross stock growth rate for different assumed life falls. For example, a life drop from 29 years to 15 years, a gradient of 0.5 years per year, reduces the 1990 growth rate by 3% below what it would have been under the old estimate, substantially more than the CSO's 1.1%. Many capital good categories had proposed gradients larger than 0.5.

Figures 1a and 1b shows a strong sensitivity to life assumptions, and intuitively incorrect estimates when life falls precipitously from one "plateau" to another.

The present pattern of lives.

So a totally new pattern of life change was required, still using the available data, the old lives and the new, surveyed, lives, but in a way which would not produce these impossible stock growth rates. The pattern adopted is shown **Figure 2**, and applies for every asset class, in every industry. It has four elements:

- (1) "New Life". The surveyed expected life applies only to the 1987 vintage, and is simply a defining point in the life trajectory, defined in (4) below.
- (2) "Old Life". The old constant value is retained for vintages before year 'A', which varies as explained under (3).
- (3) The year that the age at discard started to drop, assumed to be 1947. In the original pattern it was assumed that vintages installed from this date would have falling lives. This new assumption is more reasonable: service lives are primarily determined by the economic conditions at the time of discard, not at the time of installation. The date 'A' when vintage lives start to fall, is determined by subtracting the old life from 1947. In this example, where the old life is 40 years, 'A' is 1907. Obviously the more gradual vintage life change between 1907 and 1987, rather than the originally assumed drop from 1947 to 1975, will produce a far less violent change in the estimated growth rate.
- (4) The shape of the curve between 'A' and 1987 was assumed geometric, that is, the life falls by a constant percentage annually, in this example, at a rate 0.863% per year. The previously assumed new constant life plateau was abandoned: the same rate of fall continues after 1987.

This was an arbitrary pattern, proposed by the writer, *faute de mieux*, in the absence of statistical evidence. Geometric fall has a neutral quality, and 1947 was thought to be as good a year as any to assume that age at discard started to fall. The prime virtue of the chosen pattern was that it obviated the obviously impossible growth rates of the earlier pattern, but in fact one was merely "making the best of a bad job", given the lack of data.

Figure 1b: Sensitivity of the Growth Rate of the Gross Capital Stock to Vintage Lives falling sharply from Old to New Levels

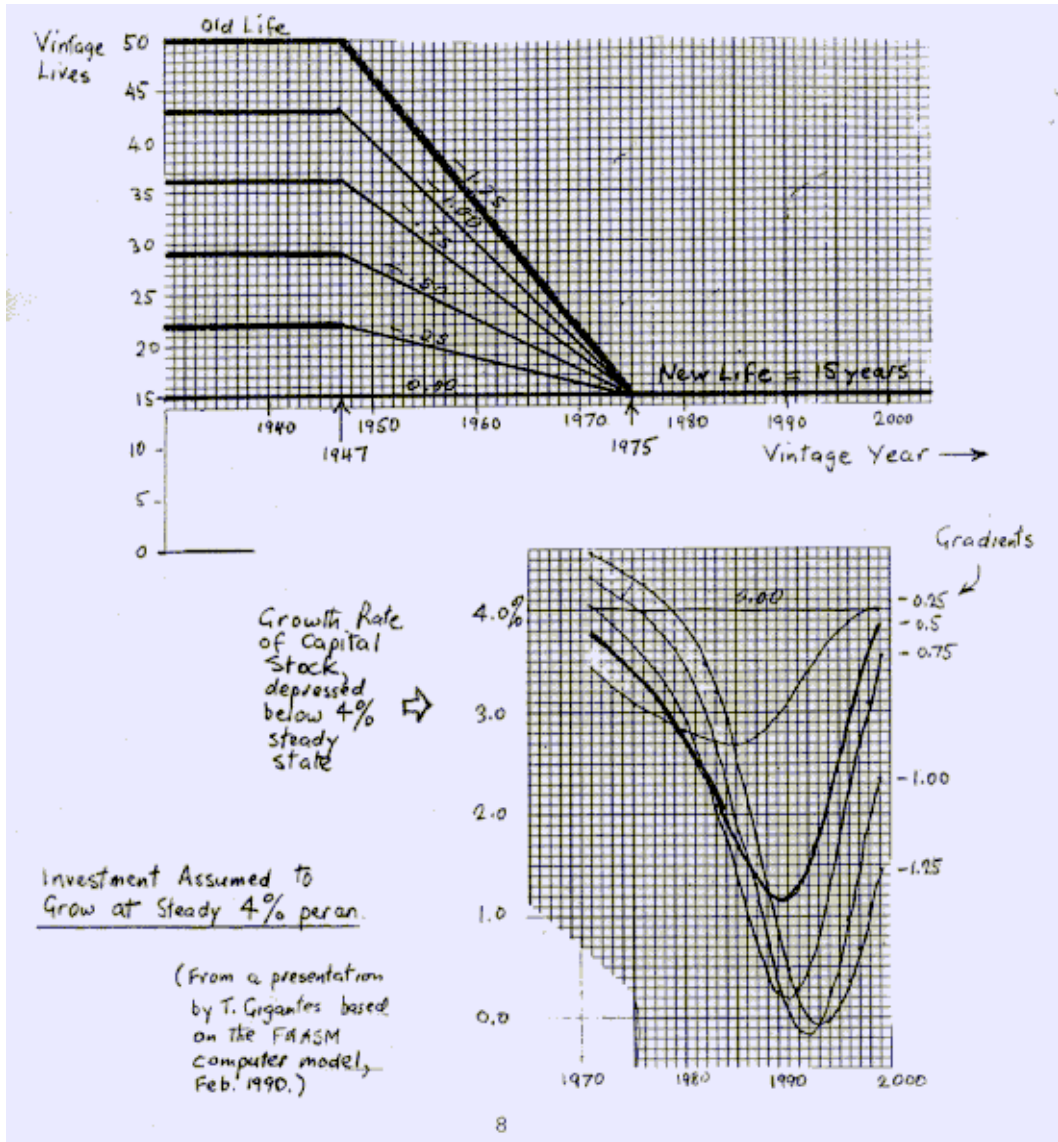
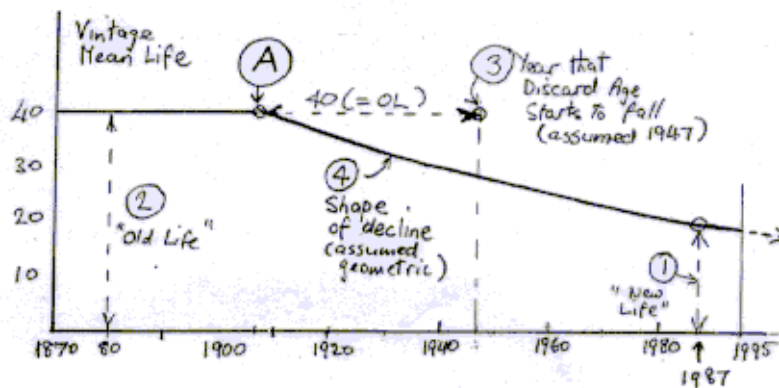


Figure 2: Statistics Canada Assumed Pattern of Vintage Mean Service Lives



The obvious shortcomings of this pattern

Consider how wrong each of these assumptions may be, for any particular industry and/or class of capital good:

(1) **The new lives** are companies' *expected* lives used for charging depreciation. There is evidence, from a FAASM study of Canadian enterprises, that some companies are conservative, assuming short lives, while other companies do the reverse. In any case, it is difficult to forecast lives, especially in today's economic climate. It will only be known many years hence what the actual service life will be.

(2) **The old lives** were set by T.K. Rymes (Rymes, 1967), for Statistics Canada's first capital stock estimates. He wrote "Satisfactory data, which would reveal how long various types of capital good have remained in production . . . do not exist in Canada [these are virtually the words, given later, used by Lock for the Netherlands]. The "life" data used in this report must be regarded as very imperfect". The lives were largely based on the so-called 1942 US "Bulletin F", and were essentially for the calculation of tax depreciation. As Rymes points out, their status is highly ambiguous: "It is not clear whether [they] represent "true lives" or those which will permit rapid equipment replacement to conform to fiscal policy objectives."

The Bulletin F lives were, in fact, until recently, the basis of the official U.S. capital stock estimates. They were already viewed in the U.S. with scepticism when adopted by Rymes (Wealth Inventory Planning Study, 1964). Rymes writes that "because of their weakness, it was decided to produce capital stock and flow estimates based on a range of lives. It is hoped that [thereby, users] will be able to appreciate fully what biases in levels and, more importantly, what differences in trends . . . result from changed assumptions with respect to average economic lives . . . when the estimates are prepared using the 'perpetual inventory' method".

Clearly, the original edifice of the old estimates was built on sand, and the defective old lives remain a pillar of the new estimates.

(3) **Year in which discard age starts to fall.** Not only was the choice of 1947 entirely arbitrary, there is no evidence that there was ever a level plateau from which there has been a descent. Some FAASM estimates, using corporation financial statistics, indicate that the age of

discards, in some industries, started to plunge much later than 1947.

(4) **The geometric rate of decline** also may be very wrong. The shape of the curve is likely to differ strongly from industry to industry. This, too, is indicated by the FAASM studies just referred to.

High sensitivity to errors in these assumptions.

A study has been done (Jaffey 1991) of the sensitivity of the PIM estimates to the four elements of the adopted life pattern. Five cases were examined, assuming erroneous assumptions as follows :

Test 1: Old life 15% too high.

Test 2: Both old and new lives 15% too high

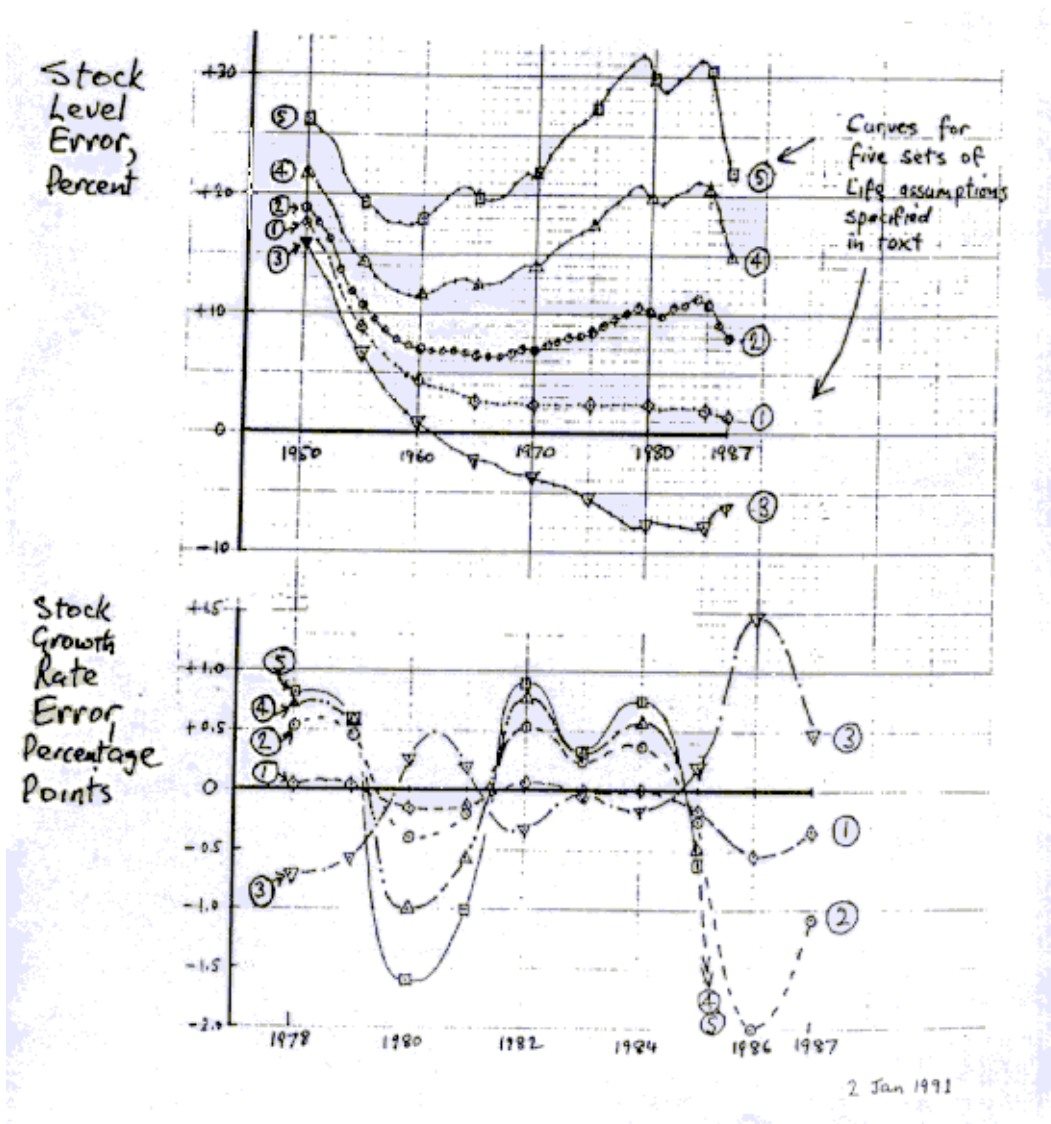
Test 3: Old life 15% too high, new life 15% too low.

Test 4: Ditto, plus straight line instead of geometric shape

Test 5: Ditto, plus starting year of discard age fall 1965 instead of 1947

There is a build up from only one wrong assumption in Test 1 to wrong assumptions for all four elements in Test 5. It is difficult to believe that some such combinations of assumption errors do not quite often occur -- sometimes worse. **Figure 3** shows the severe consequences for the stock level and growth rate.

Figure 3: Sensitivity of PIM Growth Rate Estimates to Service Life Assumptions
 (For Transport'n Equip. Mfg. Industry, Mach & Equip)



Assumptions regarding distribution about the mean

In addition, there is the question of the distribution of lives about the mean. Here, too, an arbitrary assumption was made: a normal distribution, with dispersion limits 50% above and below the mean, and two standard deviations, uniformly, for every asset class and industry. Obviously this must be very incorrect in particular cases. For example, the Netherlands direct stock survey data showed a far wider dispersion of lives of buildings in the base metals manufacturing industry. Wrong distribution assumptions cause substantial stock estimating errors, for example, if actual distributions are skewed rather than an assumed bell-shaped, or actual dispersion is much greater than assumed.

This section has shown that the lives assumed critically affect PIM capital stock estimates.

Therefore, for the method to be useable, we must be assured that accurate life data are available. This is the question now examined.

(ii) **The inherent difficulty in arriving at accurate life assumptions**

The most common complaint regarding the PIM is the dearth of statistical data on lives. The following quotations are typical:

Ward (1976): "In most countries no recent, comprehensive and empirically based set of capital asset lives has been compiled"

Faucett (1980): "No comprehensive measures of actual lives exist". At the conference where this remark was made, Young and Musgrave, on behalf of the Bureau of Economic Analysis, stated "We endorse the comments of . . . Faucett . . . on the need for . . . better empirical evidence on service lives".

Lock (1985): "Hardly any statistical data about the lifetime of capital goods are available in the Netherlands". Regarding an inquiry made at companies: "The question on expected and realized lifetime . . . was badly answered. The reason is . . . that it is very difficult to reply to a question regarding expected lifetime . . . For the question regarding the realized lifetime . . . it was not easy to produce the necessary information".

Triplett (1992): ". . . the retirements data actually available consist of a small quantity of (usually not very current) service lives and a large quantity of assumptions"

Large differences among countries

That there is a lack of life data is reflected in the large spread in assumed values among similar countries, shown on **Figure 4** from the Mayes and Young study.

Figure 4: Average Services Lives of Machinery and Equipment in Manufacturing Activities in Various Countries, in 1990

Japan	11 yrs;	Belgium	15 yrs;	Germany	15 yrs;	Finland	17yrs;
Italy	17 yrs;	USA	17 yrs;	Austria	18 yrs;	France	18yrs;
Australia	19 yrs;	Ireland	22 yrs;	Canada	22 yrs;	Sweden	23 yrs
Norway	25 yrs;	U.K.	26 years				

Mayes and Young comment that this comparison is not very informative as the assessment of lives in all countries tend to be "based on very soft estimates", and that the bunching of lives may simply reflect the fact that some countries have adopted the values of other countries. As observed in the main text, the Canadian "old lives", which still partly govern the capital stock estimates, were simply U.S. values.

A study of the publications of Statistics Canada and the Bureau of Economic Analysis (BEA) shows that these two very similar countries have very different life assumptions. For example, for machinery and equipment in textiles products manufacturing, the U.S. assumes a constant value of 16 years, while Canada assumes a constant 26 years until the 1921 vintage, and falling values thereafter until life is 9 years in 1994. For the tobacco products industry, the U.S. life is 21 years, while the Canadian life falls from 15 years to 11 years. Office buildings in the U.S. are assumed to have lives of 36 years, while in Canada the assumed lives fall from 50 years to different values, depending on the industry: for example, 43 years in finance, insurance and real estate, 35 years for

federal government buildings, and 27 years in wholesale and retail trade.

Constant life assumptions because of lack of data.

The lack of good data may oblige many countries to settle on some constant value. For example, according to the methodology section of the official US capital stock estimates (BEA, January 1993), "service lives should be varied over time to account for changes in business conditions and technology; however, [for most types of asset and industry] . . . lives are held constant over time, because the information necessary to estimate such changes is not available". As already discussed, while Canada and the UK assume life change, the assumed pattern of change is quite arbitrary, with little empirical support. Such arbitrary assumptions probably sometimes produce greater errors in stock growth rates than are obtained from constant values.

Why is the acknowledged lack of life data endured? Why do not countries collect accurate values? The reason, it is argued here, is that there is an inherent, insuperable, difficulty in gathering such data. A study by the writer, included as Appendix 2, shows that to arrive at accurate statistical measures of life would require the use of techniques analogous to those used for the human population. Unfortunately this is not feasible. While the population of capital goods, like that of humans, comprises millions, capital goods are far more diverse, and, further, are component parts of larger facilities, whose birth and death dates are not the same as those of the individual components.

B. Empirical Confirmation of PIM Inaccuracy

Section A demonstrated the theoretical inaccuracy of PIM stocks. In this section, empirical evidence is given that confirms this, including independent estimates made by non-PIM means.

(i) The Netherlands.

As discussed in the Introduction, the CBS get accurate DOC benchmark values of the gross stock at four-year intervals. These have turned out to be very different from the corresponding PIM estimates. Until recently the conventional PIM was used for estimating the annual between-benchmark stocks, but unacceptably large "drifts" were found even in four years. So the PIM had to be replaced with another procedure. These large between-benchmark "drifts" are illustrated by **Figures 5a and 5b.**²

² Whether this method, whose main feature is a newly implemented annual discard survey, is accurate will not be known for some time. See Jaffey (1995a)

Figure 5a shows the published CBS capital stock estimate for the base metal manufacturing Industry (CBS, 1994). DOC benchmark surveys were made in 1982, 1986 and 1990. For 1986 and 1990 both estimates are shown, the between-benchmark PIM values followed by the DOC value. In this industry there has been little PIM error for the large buildings class, but for the other large category, other machinery and equipment, the stock is 16% too low in 1990. This represents the huge growth rate error of 4% annually over four years. For many classes there are even larger errors.

Figure 5a: CBS Gross Capital Stock, Base Metal Industry (1995 prices)

Tabel 33.2
Basis metaalindustrie
Waarde van de KGV in prijzen 1985, verdeeld naar soort

Code Soort	1 januari									
	1985	1986	1986 (1)	1987	1988	1989	1990	1990 (1)	1991	1992
'Aantal bedrijfseenheden	129	118	118	127	121	125	130	130	131	140
	min gld									
'Totaal	19 043	18 928	20 156	19 705	19 467	19 212	19 138	20 786	22 103	22 340
1. Grond en terreinen	916	936	1 104	1 107	1 089	1 074	1 074	1 119	1 133	1 140
2. Bedrijfsruimten	4 446	4 495	4 703	4 668	4 631	4 617	4 658	4 588	4 637	4 653
3. Grond-,water-en wegebouwkundige werken	399	419	426	449	458	452	442	536	523	511
4. Vervoermiddelen voor extern transport	258	225	230	206	175	138	113	67	61	59
5. Middelen voor intern transport	357	351	407	401	392	378	372	836	817	807
6. Computers	166	182	215	258	262	346	425	497	512	599
7. Overige machines, apparaten en installaties	12 196	12 021	12 701	12 259	12 105	11 847	11 698	14 002	14 266	14 411
8. Overige kapitaalgoederen	306	299	369	357	355	360	357	138	154	160

1) Herziening ten gevolge van directe waarneming.

Between benchmark "drift": PIM estimate percent over DOC

Benchmark year	1986	1990
Years from previous benchmark	4	4
1. Land	-15%	- 4%
2. Buildings	- 4	+ 2
3. Engineering works, utilities	- 2	-18
4. External transport equipment	- 2	+69
5. Internal transport equipment	-14	-56
6. Computers	-15	-14
7. Other machinery and equipment	- 5	-16
8. Other capital goods	-19	+159
Total, all capital goods	- 6%	-12%

Figure 5b: CBS PIM Between-Benchmark Drift

Table 5. Comparison of tangible capital stock estimates in manufacturing industry in the Netherlands by type of goods and activity group conform two methods Actual value January 1, PIM/DOC								
activity groups	type of goods							
	Land	Industrial buildings	Other non-resid buildings	External transport equipment	Internal transport equipment	Computers	Other machines, devices and installations	Other tangible capital stock
334 Basic non-ferrous 1986	0.95	0.81	0.92	0.80	0.68	0.30	0.69	0.65
334 Basic non-ferrous 1990	0.95	0.98	1.13	1.44	0.82	0.81	0.81	1.98
261 Paper and board mills	0.54	1.01	1.18	1.92	0.96	0.52	0.88	0.94
311 Rubber products	0.59	0.86	1.10	0.94	0.98	0.34	0.88	1.03
271 Printing	1.02	0.98	1.10	1.36	1.11	0.84	1.00	0.94
291 Synthetic fertilisers	1.00	1.01	0.81	0.46	1.01	0.44	0.87	1.00
292 Synthetic resins	0.99	0.91	0.50	0.80	0.92	2.60	0.95	1.06
294 Other basic ind. chemicals	0.97	0.95	1.06	0.71	0.90	0.41	0.88	1.00
300 Artificial filaments	0.98	0.98	0.31	0.73	1.00	0.70	0.94	0.88
202 Dairy products	0.84	0.81	0.84	0.79	0.58	0.82	0.78	0.83
205 Sugar factories	0.72	0.84	1.01	0.69	0.73	0.77	0.87	0.82
211 Starch industry	0.47	0.68	3.73	2.07	2.06	0.44	1.62	1.73
212 Animal stock feeds	0.79	0.88	0.90	0.71	0.85	0.64	0.86	0.84
281 Petroleum refineries	0.99	0.77	1.27	0.90	0.32	0.67	0.94	1.61
331 Basic iron and steel ind.	0.95	1.03	0.77	2.82	0.31	0.85	0.82	11.66
369 Other electrical engineer	1.09	1.07	1.03	0.82	1.48	1.49	1.28	1.34

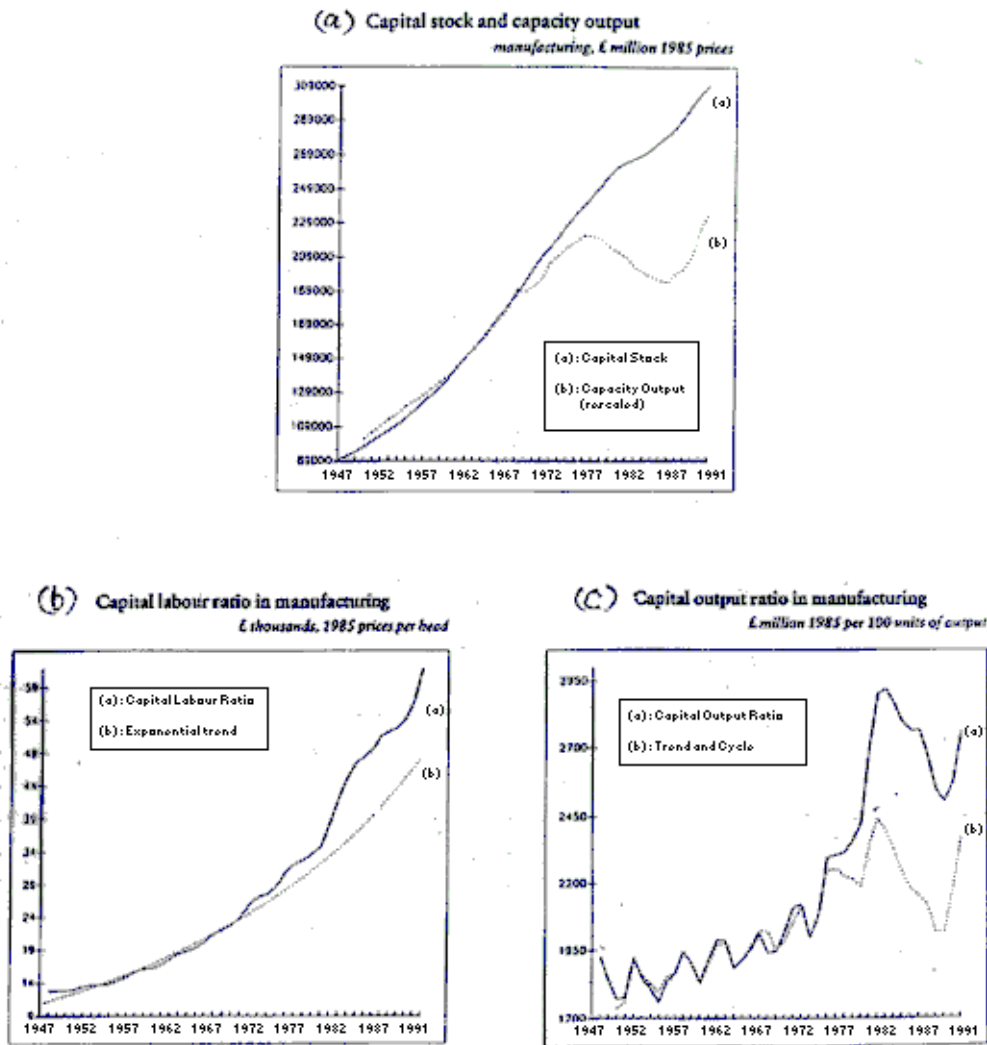
Figure 5b. This table (Frenken, 1992) assembles results of the type just described, for a number of manufacturing industries. Only 33% of the PIM estimates are within 10% of the DOC value, 13% are more than 33% above it, and 17% are more than 33% below it. The majority of the PIM estimates, 69%, are too low, suggesting that the CBS PIM service life assumptions tended to be too short. The CSO consultant, (Mayes and Young, 1994), assessed the CBS evidence thus:

" After careful study of results produced by the Netherlands statistical office over a period of more than a decade we are convinced that the simple use of the perpetual inventory method leads not only to an inaccurate baseline for the capital stock but also inaccurate updating, which can lead to estimates as much as 10% adrift over a period as short as five years."

(ii) The UK

This section gives evidence of inaccuracy of the CSO capital stock estimates presented in Mayes and Young (1994). **Figure 6a** compares the CSO capital stock, using the old constant lives, with an alternative stock estimate derived from the Chamber of British Industry (CBI) survey of capacity utilisation. If the latter is correct, then the official estimate was 44% too high in 1986. If the CSO estimate is based on the new, falling pattern of lives instead, the difference is smaller, but is still large. The CBI data suggest a severe contraction of the manufacturing capital stock in the decade to 1986. Even if the CBI data exaggerate this degree of scrapping, it seems difficult to have confidence in the CSO official PIM stock estimates.

Figure 6: Macroeconomic Evidence on Accuracy of CSO Capital Stock Estimates



Figures 6b and 6c show the change over time of the capital / labour ratio and the capital / output ratio respectively. The capital value used is the CSO capital stock estimate. An anomaly is evident in both cases. In about 1980, the beginning of the recession, both ratios increased sharply above the pre-1973 trend line. According to Mayes and Young, this suggests "that much of the capital stock that was included in the measured stock was scrapped . . . that the measured capital stock (on the basis of constant original lives) overestimated the true stock by about 25% in 1986".

Figure 6 has presented what Mayes and Young call macroeconomic evidence. They write: " The difficulty with this type of . . . evidence is that it can never be conclusive as it is really testing the evidence provided by the CSO against particular theories of production [which are not necessarily right]. It is fortunate therefore that there are other sources of evidence . . . "

Evidence from Company Current Cost Accounting

One such source of evidence used by Mayes and Young is the current cost accounting estimates of their fixed asset stocks drawn up by many companies in the early 1980s (presumably as part of the same international initiative that resulted in Canada's similar efforts at that time) As already observed, the method of these alternative estimates is similar to that used in CBS direct measurement.

Mayes and Young draw on two studies. The first, Smith (1987), calculated that the official 1983 estimate of the stock of equipment in manufacturing exceeded the current cost accounting based estimate by 36%. The disparity in non-manufacturing was 16%.

The second study, Wadhvani and Wall (1986), involved 333 companies in manufacturing. They estimated the stock change from 1972 to 1982, taking the 1972 CSO stock as a starting point. Their estimates varied from 10% to 35% below the CSO stock 10 years later. In other words, the growth in the stock estimated by current cost accounting was below the CSO estimated growth by these amounts.

All the evidence given above points the same way: the official CSO PIM estimate of the stock was far too high in the 1980s.

(iii) Canada

Two sorts of evidence are given:

(a) Capital stock values that appear not to "make sense".

Sometimes simple inspection shows that estimates are obviously wrong. The particular errors discussed here stem from the difficulty of the PIM, discussed in Appendix 2, in showing sudden changes in the discard rate. The PIM estimates discards to change gradually, year over year, reflecting assumed smoothly changing vintage survival functions. If investment increases sharply in a particular year, the PIM shows a corresponding large rise in the capital stock. In the "real world", a sudden surge in investment might, for example, be offset by a correspondingly large increase in discards, as companies replace outdated equipment under the forces of international competition.

A look at Statistics Canada's official capital stock estimates quickly unearths cases which reflect this inherent PIM characteristic. For example, for the chemical and chemical products industry, the PIM estimate of the gross capital stock increased 21% in the two years 1981-82, versus 11% in the previous two years. The reason is obvious: investment increased 81% in these two years, and in the absence of an offsetting large discard volume, there was a large increase in the estimated stock. The PIM-estimated discards increased only 12%, continuing their predetermined increase of only 6% annually.

An even more striking example exists in the transportation equipment manufacturing industry: Did the stock of machinery and equipment really increase 44% in the two years 1986-7, as estimated by the PIM, or was the three-fold increase in investment, at least partly, offset by increased discards?

A few simple enquiries with companies would quickly show whether in fact they did discard heavily³. We may be witnessing here the same difficulty that bedevilled the UK official estimates, discussed in the preceding section, the failure of the PIM to reflect a surge of discards in the 1980s.

(b) Alternative FAASM estimates of the Canadian Capital Stock.

Alternative estimates have been made of the corporate sector capital stock, with the FAASM computer model. They use, in addition to the same investment series used for the official PIM estimates, Statistics Canada's corporation financial statistics, which aggregate data from company financial statements. The two sets of estimates, compared on **Figures 7a and 7b**, differ greatly from each other. Although for the whole corporate sector industry differences cancelled out to average only about 10% for stock level and about 0.2 percentage points for growth rate, for individual industries the respective differences were as high as 40% and three percentage points.

Given accurate data FAASM stock level errors are only about +/- 2%. The data used here, without the benefit of the new survey, are far from perfect. Even so, the consequent errors in the FAASM stock are probably far from large enough to account for the gross differences. Already it is possible to state with confidence: there is a high probability that some of the official estimates are very inaccurate.

C. Inaccuracy due to Use of the 'N' Investment Definition

As already observed, PIM estimates are based, incorrectly, on the N definition of investment, which, on a year-on-year basis, may differ greatly from the C definition, especially where projects to create new facilities are of long duration. This is illustrated by CBS data (Jaffey, 1995a). The following is an example of a comparison of the two series³, for buildings in one industry, for the years indicated, in millions of guilders:

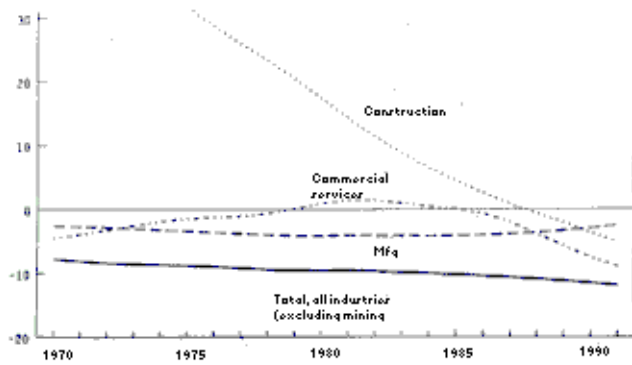
<u>Year</u>	<u>'N'</u>	<u>'C'</u>
1972	146.1	178.2
1973	240.3	98.6
1974	184.5	272.4
1975	240.4	90.6

³ Because the official PIM capital stock estimates are also produced in historic price terms, a comparison was possible with the agency's corporation financial statistics, and this appears to confirm the analysis presented here.

⁴ These FAASM estimates were preliminary runs, and could be considerably improved on. The potential of the corporation financial statistics has yet been far from fully exploited.

⁵ The N definition is from the investment survey, before the CBS recently changed it to the C definition. This they did to meet capital stock requirements, in particular the new procedure to replace the PIM for between-benchmark estimates. This procedure adds, to each year-end's gross stock estimate, the following year's investment and net acquisitions, and deducts discards. The latter required introduction of a discard survey. The N values, required for national accounts purposes, must now be calculated from data in several surveys (Jaffey 1995a). The C definition in this table, is from the DOC survey of the 1986 capital stock, broken down by vintage. The amounts for each year are only approximately equal to the C definition, as there may have been some changes in the stock since 1986, eg a sale of buildings of a particular vintage, or purchases from other industries of old buildings. But the discrepancies are relatively small for long lived assets of this sort.

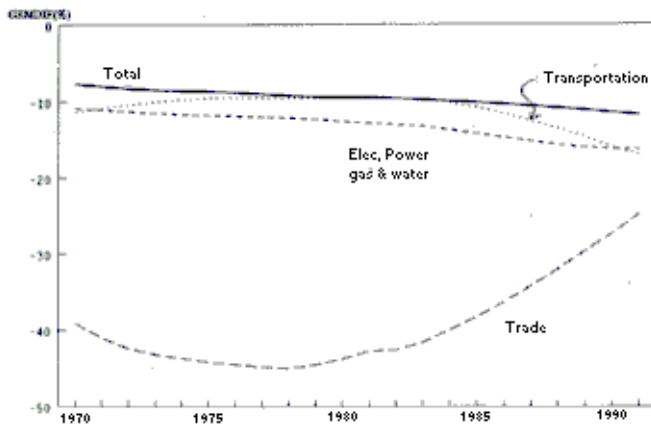
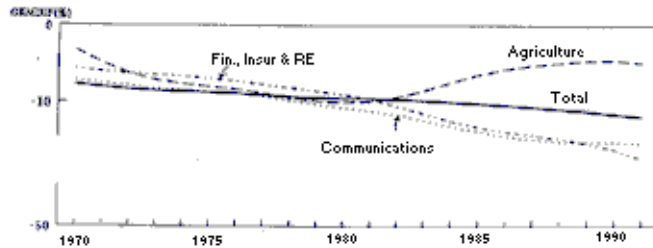
Figure 7a: Statistics Canada Gross Capital Stock (1986 prices)
FAASM percentage above Official PIM Estimates
 (Preliminary only, possibly subject to some substantial revisions)



(Inaccuracies shown by later model runs)

- Commercial Services about 4% too low, probably falls faster overall
- Manufacturing: Aver level OK, but growing a little faster
- Construction: OK

- Fin, Insur, & RE: about 7% too low (needs rerun)
- Agriculture: Aver level OK, but higher over-growth rate
- Communi: OK

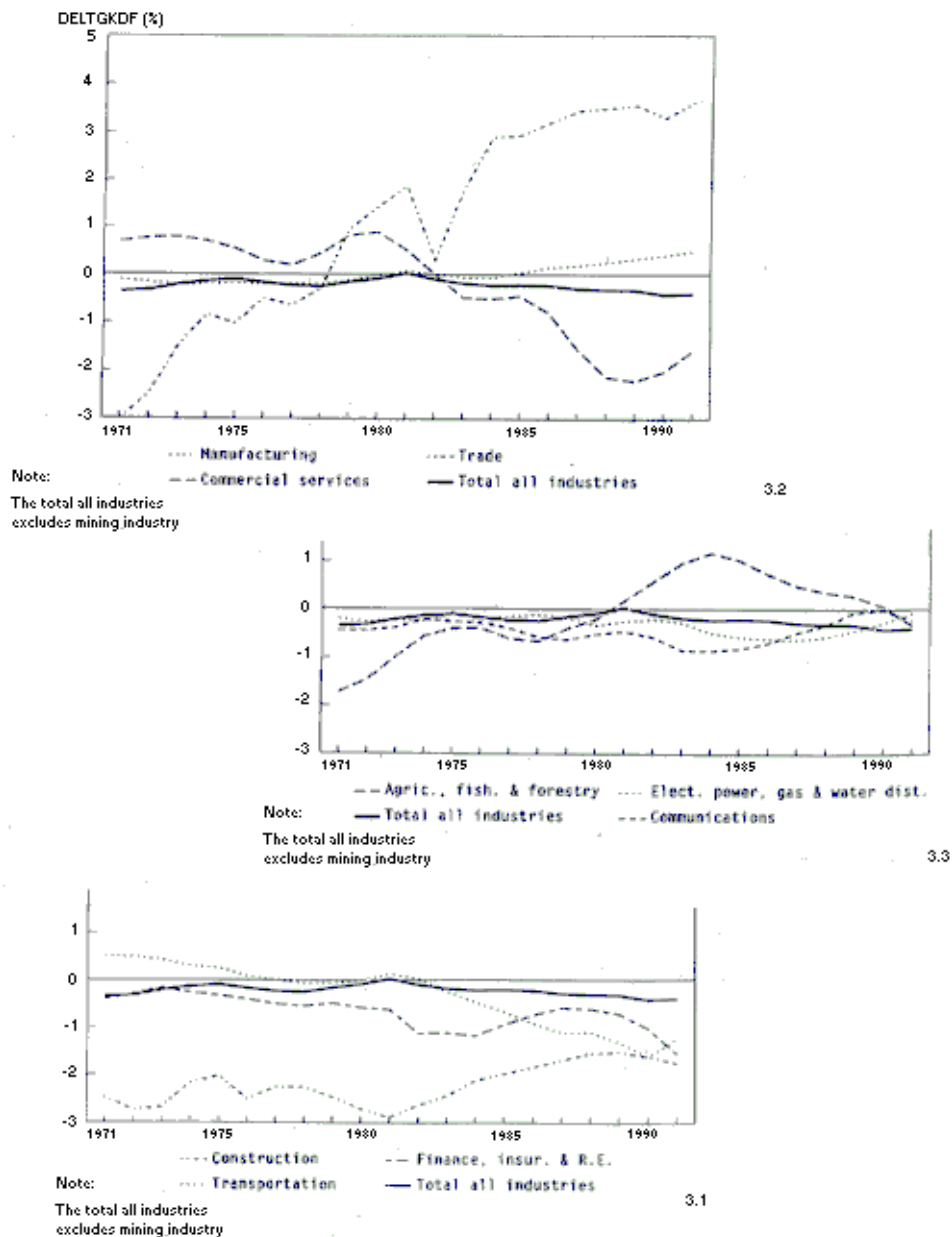


Transportation: OK (little higher?)

Elec Power, etc: About 2% too high, falls a little faster

Trade: Aver. Level OK, Aver. GR probably higher (needs rerun)

Figure 7b: Gross Capital Stock Growth Rate
FAASM percentage points above official PIM estimates
(Preliminary only, possibly subject to some substantial revisions)



The following hypothetical case, based on the above table, illustrates how use of the N definition in PIM estimates may totally misrepresent the true situation. Suppose, for example, that the capital stock was 3000.0 million at the end of 1974. Suppose further that discards in 1975 were 100.0 million. Using the N investment value of 240.4, the 1975 year end stock will be 3140.4, and using the C value of 90.6, it will be 2990.6. In the first case it grows by 4.7%, and in the second it falls by 0.3%.

Statistics Canada recognises this problem in estimating multi-factor productivity. They make an arbitrary, rule of thumb correction, using the capital stock estimate of one year back, to exclude some of the work in progress. This is very hit and miss, and clearly the only satisfactory solution is to redesign the investment survey questionnaire, to give both the C and N definitions, as discussed below, in Part 2.

Summary of the Evidence for PIM Inaccuracy

The evidence and arguments given in the preceding sections can be summarised as follows.

Section A shows how very sensitive estimated stock levels and growth rates are to the life assumptions. It also shows how these life assumptions *must* be inaccurate. It is inherently difficult to measure service lives; this accounts for the dearth of life statistics lamented by experts in the field; the situation is reflected in the very large differences in the life assumptions among similar industrial countries. For example, Canadian assumptions are very different from US assumptions. An analysis of assumed Canadian life patterns confirms the inherent difficulties: the large number of assumptions that have to be made with no supporting evidence makes it virtually certain that the stock estimates contain many errors of the grossest sort.

The empirical evidence given in **Section B** confirms these findings. Alternative measures of the stock from independent, that is non-PIM, sources, indicate grossly inaccurate results from the PIM. For example, alternative FAASM estimates of the Canadian capital stock show large differences from the corresponding official stock estimates. While this work is only preliminary, and there are shortcomings in the data used, the results indicate that almost certainly, there are some serious inaccuracies in the official estimates. In Holland, the precise direct measures show conclusively how incorrect the corresponding PIM estimates are.

Sometimes simple inspection can show there is something wrong with the PIM estimates. For example, could the machinery and equipment stock of the transportation manufacturing equipment industry really have increased 44% in 1986-87? This type of error occurs because the PIM cannot take account of the effect of current economic forces, in this case, a high degree of scrapping by the industry in 1986-87, which offset the large investments (the PIM assumed the predetermined low level of discards due to their fixed life assumption, applied automatically to vintages bought many years previously).

Finally **Section C** shows, without a doubt, that there are sometimes serious growth rate errors in the PIM stock as a result of use of the N, instead of the C, definition of capital investment. This could be remedied by the new form of survey described in Part 2. However, there would remain the unacceptable capital stock errors due to the PIM life problem.

The Overall Assessment of the PIM. While individual parts of the evidence given in this section may be discounted, taken together, surely, they demonstrate beyond doubt, that PIM estimates are unacceptably inaccurate.

It is surely a mystery that agencies have not moved to remedy the situation. Appendix 1 speculates on the reasons.

PART 2: THE FLAWED DESIGN OF THE INVESTMENT SURVEY

A. How company fixed asset accounts are structured

For each category of asset, there is a gross account, at cost, before depreciation; and a depreciation account, embodying accountants' assumptions. Only the gross account, which records all acquisitions and discards, is necessary for the production of the main fixed capital statistics discussed in this paper⁶. It is shown on **Figure 8**.

As can be seen, the gross account has two sub-accounts, in-service assets, and work-in-progress. Its three logically different investment components referred to in the Introduction, are evident: A, expenditure on work-in-progress (progress payments to contractors, and payments for in-house work); B, expenditure on off-the-shelf equipment; and C, transfers on completion into the in-service account -- not an expenditure, but an event, a stroke of the pen. A + B is the N definition of investment, and B + T is the C definition⁷.

These categories and relationships all seem rather obvious, which makes all the more surprising their present lack of recognition in statistical agency survey questionnaires. The consequence is the uninformative investment statistics, and inaccurate capital stock estimates due to use of the N definition of investment, already discussed.

Incorporating a reconciliation in the questionnaire has important accuracy advantages. L'INSEE and the Bureau of Economic Analysis now do this for this purpose, though they do not take the further step of making the split between the work-in-progress and in-service accounts, which provides the three investment components and both the N and C definitions.

⁶ The depreciation account is not without some interest for national economic statistics. Appendix 3 of this paper mentions the additional benefits of "full" FAASM, which includes this account. This version provides further types of statistic, beyond those which are our present subject matter. Full FAASM is viewed as of lower priority, for consideration in the more distant future.

⁷ These distinctions, to the writer's knowledge, are not explicitly recognised at statistical agencies. They were found invaluable in communicating with the different groups, at one agency, concerned with the various aspects of fixed capital (Jaffey, 1995a) Confusion is surely unavoidable without these terms, and perhaps their absence is symptomatic of the present unsatisfactory state of affairs.

**Figure 8: The Basic Fixed Asset Accounting Relationships:
Depreciable Assets at Cost, before Depreciation***

	Opening Balance	Changes during year			Closing Balance
		Capital Expenditures	Transfers of Completed Facilities into In-Service Acct	Disposals (Sold or Scrapped)	
Fixed Assets-in-service Account	G	Acquisitions of smaller and used items directly entering service + B	+ T	- D	G ₊₁
Work-in-Progress Account	W	Additions to Work-in-Progress: large facilities on contract or by own forces + A	- T		W ₊₁
Total Fixed Asset Account	FA	+ E	nil	- D	FA ₊₁

Only E is now reported in CES & Quarterly Surveys. A, B, and C are not reported. (National Accounts definition of investment)

F (=B+T), addition to fixed assets in service, is therefore not available. (Capital stock definition of investment).

An aspect of accuracy might be called "definitional". Questionnaires usually contain guidelines, defining what is to be included in each item. Problems of interpretation arise for company clerical staff, sometimes "in a hurry". That the guidelines may not be fully read or understood is suggested by a case where a radical change in definitions produced little change in the data reported. A reconciliation minimizes definitional requirements: "a reconciliation is worth a thousand words".

Figure 8 shows the accounts in an ideal form, at pure historic, market price. An actual survey form must screen out what are accounting distortions from a national accounts viewpoint, and provide asset class detail, as discussed in the next section.

B. The Reconciliation Based Annual Investment Survey

The considerations to be borne in mind for a questionnaire that puts into effect the principles just discussed were summarised in the original FAASM paper in the Review of Income and Wealth (Jaffey, 1990): The following is the relevant excerpt:

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

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

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 dt distortions). By using a survey from 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 dt . 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, 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. It 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:

$$W_t = W_{t-1} + C_t - T_t \quad (10)$$

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

$$CE_t = IP_t + C_t \quad (11)$$

where CE_t is annual capital expenditure. It should be possible through a further "retirement 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.

* G_t = gross fixed asset balance; I_t = investment; d_t = discards

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 building, engineering construction, and machinery and equipment. This also needs to be investigated further.

Figure 9 shows one possible design for a questionnaire that applies these principles. Part 1 shows the gross fixed assets, in aggregate, of the company, or of each separately-reporting division of the company. It controls the accuracy of Part 2, which gives the detailed breakdown, by asset category, major categories such as buildings, engineering construction, and machinery and equipment, which may be further subdivided. The column totals, A, B, C and D of Part 2, are the same as the values in the corresponding boxes of Part 1.

Part 1 is identical to Figure 8, with the addition of columns for the accounting distortions: "credit adjustments" and "revaluations". The first and last columns, the opening and closing balances, should be exactly what appears in published company balance sheets. Companies in Canada make all their entries into the accounts in *net* terms, that is, the *gross* values (what they pay in the market, relevant for national fixed capital statistics), *less* credit adjustments for such items as government assistance, grants, donations, investment tax credits, and flow through share credits. They must add these to the net values appearing in their accounts to give the gross value columns of the survey form. The "revaluations" column refers to reappraisal of fixed assets, likely to occur mainly in the course of company acquisitions, write-downs, and the like.

There should not be serious difficulty implementing a new questionnaire⁸ like Figure 9. Companies now routinely make reconciliations of this type for preparing their own financial reports, and possibly filling out the new questionnaire could be tied in with this process. The help of national accounting standards bodies, like the Canadian Institute of Chartered Accountants, might be enlisted. At the same time the present practice of making net entries in the company accounts might be reviewed. If companies were required to enter gross values, the national statistical problem would be much eased. The writer has been told by a senior member of one of the major accounting firms that the present practice lacks sound logic.

⁸ A committee at Statistics Canada has designed a survey form like Part 1 of Figure 9, to add to its present questionnaire to control its accuracy, though this has not yet been field tested. The committee, set up for the purpose, was broadly based, and included Statistics Canada's senior accountant.

Creating an idealised fixed asset data base.

The aim of all the foregoing is the creation of an "idealised set of national fixed asset accounts, at historic, market price". This would equal the sum of what would appear in company accounts if all adhered to the purest form of historic accounting principles.

This data base would be like Figure 8 broken down by industry and asset class. It would provide, free of accounting distortions, an accurate investment series, in both the N and C definitions, and an accurate in-service account year-end balance series. The simulation model uses C definition investment and the in-service balance to estimate capital stock and capital consumption.

Figure 9: The Reconciliation-Based FAASM Annual Investment Survey

Part 1. Aggregate Account, Reconciliation

	Opening Balance	Changes during year							Closing Balance
		Additions		Transfers from W-in-P		Disposals		Revaluations	
		Gross	Credit Adjustments	Gross	Credit Adjustments	Gross	Credit Adjustments		
In service	2500	+170	-9	+150	-7	-60	+3	-300	2447
Work-in-progress	500	+130	-6	-150	-7			0	481
Total	3000	-300	-15	nil	nil	-60	+3	-300	2928
	*	*	*	*	*	*	*	*	*

Part 2. Changes during year, by asset Category, Gross Values

Asset Categories	Additions to W-in-P	Direct Additions to In-Service Fixed Assets	Transfer from W-in-P to in-Service Status	Disposals
1.				
2.				
Etc.				
Totals controlled by Part 1.	130	170	150	-60

E = Total Cap. Expend. = 300

F = Total Additions to In Service Assets = 320

Note: The shaded (*) areas in Part 1 are annual distortions, and the distorted company balance sheet totals which contain accumulated past distortions. All these distortions must be removed for the corresponding fixed capital series to meet national accounting or capital stock estimation requirements.

The accuracy of the data base will depend on successful determination of the distortions. Some distortions will be difficult to report accurately in the annual survey. The credit adjustments for new capital goods can be readily identified, but it will be less easy to determine them for discards, second hand goods, and company acquisitions. Estimates will probably be required.

The starting and closing balances cannot be used for the data base. Being the values appearing in the company accounts, they contain inherited distortions, all the credit adjustments and revaluations in companies' pasts. The undistorted balances required must therefore be estimated by the agency. At the launching of FAASM, some form of base survey is required, to purge these inherited distortions. Thereafter, each year's gross balance will be calculated by the agency, adding the year's accurate gross additions and deducting gross discards, from the investment survey. It was originally assumed, for cost reasons, that the starting survey would be only approximate, but that the importance of the inherited errors would decrease over the years.

Now CBS' experience with DOC changes this view. In the proposed anchored version of FAASM, DOC can provide not only an accurate starting balance, but also occasional future benchmarks to keep the system on track.

For its fixed asset data base to be accurate, the statistical agency will probably need to use other information⁹, and various imputations, to supplement the distortion data reported in the new annual survey. Much of the distortion problem would disappear if accounting guidelines were changed to require the use of gross values.

Rationale for the Proposed System

Given that the proposed idealised data base is imperfect, like the PIM, requiring assumptions and judgments, why adopt it? The case is made as follows: The errors in measurement of the capital stock due to the assumptions for the proposed system will be substantially smaller than those resulting from the grossly wrong life assumptions of the PIM. Further, the new data base will allow major improvements in investment statistics. The proposed route, despite some practical difficulties, is the scientific, rational, way of using the available data, in company accounts.

One can argue from another perspective. The new form of survey can be justified solely on the grounds of better investment statistics. But, once the new survey exists, there is little extra cost in creating the idealised data base and using it in a computer simulation model, to produce accurate estimates of the capital stock and capital consumption.

⁹ Such information might include, for example, statistics on government capital assistance, investment tax credits, mergers and acquisitions, and second hand sales. One possibility is collaboration with the accounting standards body, in Canada, the Canadian Institute of Chartered Accountants, whose charter is not only meeting the needs of corporations and accountants, but also pursuing matters of national concern. This might include the quality of fixed capital statistics.

C. Potential Benefits from Adopting the new form of questionnaire.

To show how extensive are the benefits of the new survey, they are listed on **Figure 10a** (Jaffey 1993b). All categories of fixed capital statistics are improved, and because the data base mirrors the structure of the companies' core accounts, the several surveys involving aspects of fixed assets can be rationalised, and respondent burdens reduced. **Figure 10b** illustrates how investment reporting might be improved, using both the N and C definitions.

Figure 10a: Summary of Benefits from the Reconciliation-Based FAASM Questionnaire

1. Reconstruction of an idealised, pure historic cost, set of fixed asset accounts. This would constitute the national accounting fixed asset data base. It would show all three capital formation components, both the annual flows and year end accumulated balances. This data base would allow the following improvements.
2. Identifying the three capital formation components would permit:
 - More meaningful fixed capital investment statistics. Our present single investment figure could be broken down in two ways: (1) "additions to the productive stock" plus the change during the year in the inventory of work-in-progress; and (2) "of-the-shelf" items directly entering service plus expenditure on work in progress during the year. The "additions to the productive stock" would include, in addition to the off-the-shelf purchases, transfers of completed facilities from the work-in-progress inventory (eg a billion dollar nuclear station when commissioned). All this would surely help in understanding the state of the economy.
 - The series "additions to fixed capital in services" is needed for accurate estimates of the capital stock and replacement cost capital consumption. The present use of the investment series results in inaccuracy, particularly in estimates capital stock growth rates and capacity utilisation rates.
 - Reconciliation of demand-side, supply-side and international trade fixed capital investment data, increasing accuracy and helping compilation of IO tables.
3. Integration of the CES and the IOFD quarterly survey.*
4. Increased data accuracy through company reconciliation statements (the French agency, INSEE, already uses a reconciliation statement for this purpose).
5. Increased accuracy through better reporting of the distortions in the fixed asset accounts (essentially capital expenditure credits and revaluations)
6. Reduction in inaccuracy due to leasing, by showing account balance ownership as well as annual acquisition and capitalised leases.
7. Accurate capital stock and replacement cost capital consumption estimation. This would be provided by running the FAASM computer simulation model with the new national accounts fixed asset account data base. Further accuracy would be obtained if FAASM could be linked to periodic direct measurement benchmarks as now used by The Netherlands CBS.

* Statistics Canada's surveys, respectively, of capital expenditure and of company financial statements.

Figure 10b: GDP Statement Illustrating Improvements to Fixed Capital Investment Reporting

(StatsCan, Catalogue 13-001 Q2, 1990, table 2, hypothetical detail added)

Personal Consumption		398.7
Government Current expenditure		131.8
Investment in Fixed Capital		
(N Definition, Capital Expenditure)		142.6
Machinery & Equip. Off-the -shelf Equip	27.0 *	
Large Equip.		
Work-in-progress	<u>17.6 *</u>	44.6
Structures: Construction expenditure		98.0
Investment in increased Inventories		-3.3
Exports		168.9
Imports		-166.9
Statistical discrepancy		<u>-0.2</u>
Gross Domestic Product at Market Prices		<u>671.6</u>
<u>Capital investment, C definition *</u>		
Additions to stock of) Off-the-shelf *		27.0
in service)		
machinery and) Large equipment deliveries		<u>21.1</u>
* equipment) Total *		48.1
Increase in M & E Work in Progress Inventory *		-3.5
Investment, mach & equip		<u>44.6</u>
Structures: Completed projects entering service *		104.5
Increase in Construction-in-Progress Inventory *		<u>-6.5</u>
Investment, structures		<u>98.0</u>
Total investment in Fixed Capital		<u>142.6</u>

* Hypothetical figures

PART 3: AFFORDABLE, ACCURATE FIXED CAPITAL SYSTEMS

There is a widely held view that there is no affordable alternative to the PIM. For example, the Chief Economist of the U.S. Bureau of Economic Analysis writes that "Despite the difficulties, the perpetual inventory method remains the primary procedure . . . owing to the cost of a census of capital goods, which is the major alternative" (Triplett, 1992). In fact, there are other alternatives, the good fixed capital systems already mentioned in the Introduction. **Figure 11** shows the components of each. It is largely self-explanatory, as most parts have already been touched on. The following remarks elaborate further.

Figure 11: Four Good Fixed Capital Estimating Systems

	(1) Reconciliation- Based Investment Survey	(2) FAASM or extended CBS Model	(3) Direct Survey of Gross Stock	(4) Annual Discard Survey, and Estimates of Inter-Industry Mergers
A FAASM System (Review of income and Wealth, March 1990)	Yes	<i>For</i> Gross Stock Net Stock Capital Consumption	-	-
B Anchored FAASM System	Yes	<i>For</i> Gross Stock Net Stock Capital Consumption	<i>For</i> Occasional Accuracy Checks	-
C Cost-Unconstrained Ideal System	Yes	<i>For</i> Net Stock Capital Consumption	<i>For</i> all Gross Stocks	-
D "Improved CBS System"	Yes	<i>For</i> Net Stock Capital Consumption	<i>For</i> Benchmark Gross Stocks	<i>For</i> Between-Benchmark Gross Stocks

1. All four alternative systems use the first two components, the survey and the model. A simulation model provides the only way to arrive at the accurate survival functions necessary for reliable estimates of capital consumption and the net stock. Company depreciation values cannot be used, being at historic price, and based on expected lives which are merely forecasts, and may also depend on company accounting policy.
2. Component (3), Direct Survey, or DOC. Teams from the CBS visit all 1500 large Dutch companies to take the age distribution from the company accounts, relieving company staff of the burden. (Almost all other CBS surveys use conventional questionnaires filled in by company personnel). Over the years the procedures have been improved. The visit to the company which originally took five days, is now completed in one day. Using a laptop computer, the visiting CBS employee converts the historic price age distributions, with the price index, into current price estimates which are then aggregated at CBS head office, to

become the estimates of the gross capital stock.

The system was originally developed by Mr. J.D. Lock, now a member of CBS top management. The original study is described in the Review of Income and Wealth (Lock, 1985). A more up-to-date description of the system was presented at the IARIW General Conference of 1992 (Frenken, 1992). In 1995, the writer visited the CBS for meetings on the various aspects of fixed capital. A report (Jaffey, 1995a) provides a current description of the methodology, and also evaluates its accuracy.

3. System D, "Improved CBS System": DOC gives only benchmark measures of the gross stock. A complete fixed capital system requires the addition of components (1) and (2) of the table. Following the meetings referred to in the last paragraph, the CBS have been considering adopting these items. Component (4) is the procedure referred to earlier, adopted to replace PIM for between-benchmark estimates of the gross stock. However, the simulation model, needed for capital consumption and the net stock, at the same time estimates the gross stock probably just as accurately. If component (4) were therefore found unnecessary, System D would become much the same as system B, anchored FAASM.
4. Description of the FAASM computer model. The computer model is described in detail in Jaffey (1994). The simulation of the company accounts, to infer survival functions and use these to estimate the stock, is a complex process. The model involved has many pages of equations, and requires a high speed computer, often running for many hours. The most accurate version yet implemented defines the survival functions with seven parameters, five for a five-degree polynomial mean life curve, and two for the shape of the distribution about the mean. Input into the model are the fixed asset data and the price index, output from it the estimated capital stocks and capital consumption, and other capital statistics, as required. Survival functions are inferred as an intermediate process, and are output only if especially desired, for example, to study the evolution of lives over the years. The paper, Jaffey (1994) also discusses the conceptual underpinnings of FAASM, including its application of universal scientific method, analogous to that of physics.

The FAASM computer model has also been employed to study individual large Canadian enterprises, using Statistics Canada's survey of company financial statements. The results were interesting, indicating, for example, that some companies overdepreciate, while other underdepreciate, respectively understating and overstating their profits. One may observe that FAASM rose to the challenge of delivering the current cost values of company fixed assets that the companies themselves preferred not to do, in the failed accounting initiative.

5. FAASM and Anchored FAASM. System A is the FAASM version described in the original published paper, Jaffey (1990), with no anchoring from direct measurement such as DOC, thought at the time to be unduly costly. System B, which adds DOC, should be significantly more accurate. How frequent the benchmark surveys need to be will be discovered through experience over the years. It is possible that they can be quite widely spaced, that the model and the investment survey alone will give sufficiently good results over a considerable number of years. The CBS performs direct measurement on a rotating basis, visiting each company every four years. Possibly anchored FAASM could have longer intervals.
6. Accuracy of the three systems.
Owing to a lack of resources, there has been little systematic testing of FAASM accuracy. Such testing as there has been used Dutch DOC data, and this is the source of the +/- 2% error of the next paragraph. Only through DOC-type enquiries can the accuracy of estimates of the capital stock be empirically tested -- apart from highly costly censuses or inventories of capital goods.

System A: This depends on two data series, investment and gross fixed asset balance. If both are accurate, the FAASM estimate of the gross stock should be accurate within about +/- 2%. The error arises because the model-inferred survival functions are smoothly shaped and smoothly changing, while in reality survival curves have irregularities.

We shall assume for present purposes that the investment series, provided by the new survey, is precisely accurate (in fact, it will contain small errors). As System A lacks anchoring DOC surveys, the gross balance data will not be precisely accurate, and so the estimated stock will have errors larger than +/- 2%, but probably much smaller than PIM errors.

System B. Anchored FAASM should have errors in the gross stock, in the between-benchmark years not much different from the +/- 2% value referred to above. The error may be less than this because lives will be inferred from not only the data used by System A, but also the age distributions from the benchmark surveys. The foregoing assumes that the DOC gross stocks are precisely accurate, but, in fact, they will have some, probably small, errors of the type discussed in Jaffey (1995a).

System C. Its annual DOC survey should produce highly accurate gross stock every year.

Errors in Net Capital Stock and Capital Consumption. We have talked only of errors in the gross stock. To estimate capital consumption and the net stock, all three systems depend on model-estimated values of survival functions. For the same type of reason that System B should estimate these more accurately than System A, System C should estimate them more accurately than System B. While all the systems will have small errors in estimated capital consumption and net stock, owing to the use of smooth functions, the errors will be smallest for System C. The net stock accuracy of the latter will also benefit from the accurate annual gross stocks, as net stock equals gross stock *less* accumulated capital consumption.

7. Totally integrated, FAASM-based, fixed capital systems

All three systems are unified, integrated systems, within the framework of a simulation of the fixed asset accounts of the nation's corporations. System A incorporates a single survey, the investment survey, while Systems B and C also include DOC surveys of the gross stock. This total system nature of FAASM is discussed in Appendix 3, written in 1989 when FAASM was originally proposed. Appendix 3 also says something about benefits of the "full FAASM" version, which contains the company depreciation accounts as well as the gross accounts.

8. The most suitable system for present use.

At present this appears to be B, which combines the economy of FAASM with the precision of direct measurement. The best course might be to implement the pure FAASM system, A, first, and upgrade it to B, as resources become available.

Concluding Remarks

The case for adoption of a FAASM-type system can be briefly stated as follows. The present investment survey is poorly designed, compromising the quality of all categories of fixed capital statistics. It should be replaced by a reconciliation-based survey, distinguishing all three components of investment, and providing both the N and C definitions of investment. This will make possible immediate important improvements in investment statistics. Once a correct data base exists on the basis of the new survey, one can then take the further, low cost, step of replacing the grossly inaccurate PIM model. The new data, fed into a computer simulation model, will give reliable estimates of the capital stock and capital consumption. Preferably, a DOC benchmark survey should also be incorporated, increasing the accuracy of the model estimates.

If we are ever to achieve a high quality of fixed asset statistics, it is difficult to see what alternative course exists. And the way looks clear. There should be little serious difficulty in implementing the new questionnaire; the computer simulation model has already been developed and used; and DOC is already well established at one agency.

It does not seem unsuitable to conclude by quoting from the CBS paper presented at the 1992 IARIW General Conference (Frenken, 1992) :

" . . . at the end of the twentieth century no reason exists any more to leave capital in the rear of statistical development."

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APPENDIX 1: .

THE MYSTERY OF THE PIM'S CONTINUED USE

One can speculate why the PIM continues to be used despite obvious shortcomings:

- (i) Simple organizational and academic inertia. This is not an unusual phenomenon. It has been observed, for example, that medical practice has lagged, say, twenty years behind the latest knowledge.
- (ii) The PIM is virtually cost-free, as can be seen from its equation given earlier. It uses a data series already collected for other purposes -- investment in real terms. Alternative methods involving even modest costs are viewed as an unjustifiable burden. Yet a more balanced perspective might be: "One of the two factors of production, capital, is not now properly measured. We should be prepared to spend some money on this".
- (iii) Agencies have not been faced by sufficiently strong pressures to improve the capital stock measures. One can only speculate why this is so. It has been suggested that economic modellers, having little confidence in official estimates, have instead incorporated their own, alternative, estimates of the stock in their models. Another reason might be that the consequences of using inaccurate capital stock measures are not obvious. Capital stock estimates are, for example, used in estimating multi-factor productivity. Perhaps the estimates of the latter are thereby inaccurate, but how would one know? It has been said that if the official capital stock estimates used in econometric models were inaccurate, this would show up in a poor model fit with the data. But would it always? I believe there is a view that econometric models can be made to have good overall fits by appropriate adjustments to the economic theories embodied in their equations.
- (iv) It has been thought that there is no low-cost alternative to the PIM. This is discussed in the main body of this paper.
- (v) The lack of a multi-disciplinary approach to designing the capital stock model and investment survey may have played a part. Procedures might now be better if the efforts of engineers and accountants had supplemented those of economists.

APPENDIX 2

INHERENT PROBLEMS OF THE PERPETUAL INVENTORY METHOD OF CAPITAL STOCK ESTIMATION (PIM)¹⁰

This appendix examines the difficulty of the PIM in arriving at accurate life assumptions. It shows that the problem is inherent in the model, and cannot be remedied. It also touches on several other difficulties of the method. Consider the model's equation:

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

where G_t is the gross stock at the end of year 't', I_k is the constant price investment series, and S_{kt} is the fraction of each vintage's investment, I_k , at constant price, surviving in the stock at 't'.

This simply expresses a truism: The stock is the sum of what remains of past years' investments. As can be seen from the diagram later in the paper, S_{kt} is the value of the survival function of the 'k' vintage of capital goods at 't' (the term "service life" is often used loosely for the mean value of this survival curve).

The capital stock estimate will be accurate if both of the two components¹¹ are accurate, the series of annual vintage survival curves, S_k , and the series of investments, I_k . Of the following problems, the first two relate to the survival function, and the second two to the investment series:

- (1) Inaccuracy of service life assumptions.
- (2) Sharp changes in the discard rate due to current conditions.
- (3) Inter-industry transfer of capital goods.
- (4) Charging of major replacements to expense instead of capital.

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As demonstrated in the main text of this paper, large errors in assumed lives and changes to the discard rate result in grossly inaccurate estimates of stock growth rate and level. How important items (3) and (4) are in practice requires investigation.

¹⁰ Revised version of Jaffey (1995d).

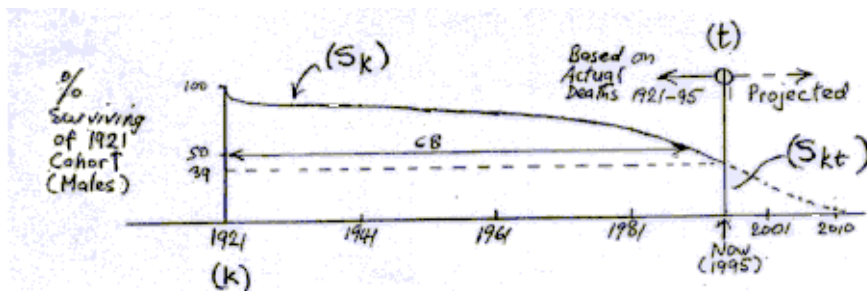
¹¹ One of the two components, investment, has two parts, the historic price investment series, and the price index series. The price index is important, and affects every method of capital stock estimation. It is not discussed here.

(1) The Virtual Impossibility of Directly Measuring Service Lives.

The main text showed that the most common complaint against the PIM is the absence of statistical data on which to base the method's service life assumptions; and that symptoms of this are the wide range of life assumptions among similar industrial countries, and the fact that countries are obliged to assume lives that do not change over time. It is demonstrated here that the shortage of data would be very difficult to remedy.

The accurate measurement of life spans, for large populations, involves the compilation of the survival curves of each vintage or cohort of the population. This applies to populations of capital goods just as it does to human populations. In each instance, we are dealing with populations of hundreds of thousands, or millions, of individuals.

For humans, the task is not difficult, as each individual functions as a separate entity. At the death of each individual, two dates, the year of death, and the cohort or year of birth are recorded. Using mortality data we can plot survival curves for every cohort, like that shown below (these are for the so-called "stationary" or natural population, excluding migration). This shows that of the 1921 cohort, 39% are still alive in 1995. The part of the survival curve for the 61% who have already died is based on recorded fact, and the remaining part, shown dotted, is projected under mortality assumptions. The median life of each cohort has been increasing. For the 1921 cohort it was 68 years. For the 1995 cohort it might be projected as, say 76, years. In principle, such survival curves



Based on Statistics Canada "Longevity and Historical Life Tables, 1921-81", Catalogue No. 89-506.
(For illustrative purposes, "now" is shown as 1995, though actually it was 1981)

can also be developed for capital goods (the vintage median lives have probably been falling, not increasing). Capital good populations, like human ones, include millions of individuals. This is shown by a study underway at the UK Central Statistical Office. It was found that large companies may have many thousands of fixed capital accounts -- pharmaceutical companies may have, say, 15,000 accounts, utilities over 100,000. Each account may constitute more than one "individual" of our population. It shows an original acquisition, and possibly, for subsequent years, replacements, additions, and improvements. Each of these expenditures, at each successive date, constitutes an "individual". Unlike human individuals, the capital good individuals tend to be component parts embedded in large capital facilities, perhaps with thousands of parts.

As for human populations, vintage survival curves are built up from mortality data, at the final scrapping of facilities. The fact that most of the individuals are component parts complicates the task. Consider a year's discard data. There are two categories, whole large facilities no longer

economic to operate; and individual parts of operating facilities that have worn out and been replaced. The record of each discarded large facility should be in the form of a tabulation by year of acquisition or vintage of its parts. The data on each individual worn-out part will show its vintage. To update the vintage survival curves with a year's discard data, all these records must be rearranged by vintage.

One interesting phenomenon is worthy of mention. Consider a particular piece of equipment, say a type of pump. There are two circumstances under which it may be discarded, the first when replaced after wearing out as part of a facility that continues in operation, and the second when it is part of a facility that is scrapped as a whole. This pump will in general have a longer life under the first circumstance -- its maximum, economic life span. Under the other circumstance, the pump discarded may be quite new. For example, the old car one scraps may contain quite new brakes.

The costly, time-consuming, activity of assembling survival curves ("retirements analysis") is not usually undertaken by companies. Capital-intensive companies, especially regulated utilities, where depreciation charges are very large, may perform it. Bell Canada has a department for the purpose, headed at one time by Dr. Ali Elphar, with a Ph.D from the University of Iowa, a centre of expertise in this particular area¹²

Companies thus do not, in general, know their true survival curves. The assumptions they make on lives (their "expected lives") are for calculating depreciation. For some companies, the assumptions may be rather rule of thumb. National accounting standards call on companies to be realistic in their life assumptions -- accurate reporting of profits depends on this. A FAASM study of a number of large Canadian enterprises showed that some companies conservatively assumed short lives, and hence "over-depreciated", while others did the reverse.

Michael Ward (1976) has encapsulated many of the difficulties discussed in this section:

" . . . it is difficult to attach any great precision to average asset lives. The life of a capital good is a composite of the lives of the component parts which have either been added or replaced in the capital since its initial construction. In some cases very little may be left of the original capital good other than its basic framework or superficial structure".

(2) Sudden Changes in the Discard Rate.

The point made here is in fact an aspect of the life assumption difficulty just discussed. The PIM assumes predetermined lives for each vintage, that are constant, or change smoothly. In practice, lives are determined partly at time of discard, under current economic, technological and competitive forces, and so may suddenly shorten, reflecting an increased discard rate -- or lengthen with a fall in discards. For example, during recessions, companies may go out of business and capital scrapped. Or investment in new facilities may be delayed, thus extending service lives.

The PIM cannot take account of such changes. The CSO study (Mayes and Young, 1994) concluded that the true UK stock was far below the PIM stock estimates, in the 1980s, as a result of substantial capital scrapping due to the recession.

¹² I have discussed these matters with Dr. Elphar and his department. His help was acknowledged in my Review of Income and Wealth paper of March 1990.

(3) Inter-Industry Transfers of Capital Goods.

The PIM assumes that capital goods remain in the industry of initial acquisition, rather than being exchanged through sale or merger. The PIM estimate of the stock of a particular industry is a summation of the historic investment series ending in the estimate year. To the extent that there have been net transfers in the past, the estimate will be inaccurate¹³.

Changing industrial classifications are often mentioned as a difficulty of the PIM, and this could be regarded as an aspect of this inter-industry transfer problem.

(4) Major Replacements not charged to Capital

The extent of this difficulty depends on accounting practice, both the national standard, and individual company. The problem exists in theory, but how important it is in practice requires investigation. Under Canadian Institute of Chartered Accountants guidelines, expenditures on a capital facility that are replacements, rather than improvements or extensions, are to be treated as expense. The PIM will have a downward bias, because the investment series will exclude items which should be regarded as capital in the PIM equation given earlier.

Are Alternative Capital Stock Measurement Systems Free of these Inherent Defects?

It is of little avail discussing these defects if they are shared by the alternative methods. Consider the improved systems described in the main text:

- A. FAASM
- B. FAASM anchored to DOC benchmark gross stocks
- C. Cost-unconstrained ideal (As B, except that DOC is used for gross stocks annually.
- D. Improved CBS system (As explained in the main text, this might eventually become much the same as B).

All of these systems are free of the most serious problem, (1), reliance on life data. With regard to the other three problems, sudden changes in discard rates, inter-industry transfers, and major replacements not charged to capital, System C is nearly free of these too (there are some intractable difficulties with used goods). System A compensates for them, though not totally. System B, anchored FAASM, is a compromise between the other two, combining FAASM economy with DOC precision.

¹³ For the PIM to be free of this difficulty, the historic investment series in each industry would have to be continually revised. Each time there was a merger, all past investments contributing to the part of present stock of assets transferred would also have to be transferred. This would require so-called micro-data storage by agencies. A feasibility study on this is, in fact, planned at the Netherlands CBS. .

APPENDIX 3

THE NATURE OF FAASM

FAASM should be seen as a concept, that of a model that simulates the fixed asset accounts and accounting processes of the corporate sector. It is not merely a specific technique, for example, for estimating lives or even capital stocks. It is probably without precedent anywhere else in the world. FAASM would run in parallel with companies' fixed asset accounting systems. It would be the repository of the aggregated data from these systems. It would contain the attached statement, which is the medium of survey used. (Companies prepare such reconciliations in order to prepare their annual financial statements).

FAASM would show not only the actual "distorted" values appearing in company accounts, but also the "true" values that it would calculate by removing the distortions. (The true values, incidentally, are what would appear in company accounts if they adhered to the purest form of historic accounting principles.)

FAASM would also carry another set of values, "real", or constant price values. That is, it would have the ability to revalue its fixed asset balances at current cost. Thereby it will be doing what has proved difficult for corporations themselves to do under the recently abandoned international initiative to institute current cost accounting. These constant price values are, of course, what we call the "capital stock". The model will contain "gross stock"; "true net stock"; "accounting net stock" (what would appear in corporate accounts if current cost accounting were in force); "true real capital consumption"; and "accounting real capital consumption". The accounting, as opposed to the true, values are produced by the full FAASM version. At present we are attempting to implement only the partial version.

FAASM will simulate company accounting processes not, of course, by repeating the myriad additions and deletions of everyday accounting, but through the approximation of inferring the life patterns implicit in the accounts. The model will contain a sophisticated inference mechanism. A study is now underway to develop this.

As an analogue of the corporate accounts FAASM should yield a variety of outputs in addition to the capital stock. Some have a direct impact on the SNA. The various types of output are briefly described in paragraphs following.

FAASM OUTPUTS

Primary Outputs, from partial FAASM, concerned only with the company gross fixed asset accounts, at cost, before depreciation:

The primary objectives of the Fixed Asset Accounting Simulation Method (FAASM) are the estimation of the capital stock, and of the business capital consumption component of the SNA (thereby also affecting the profit component of the SNA). Indirectly, through changes it requires in the CES, it increases the accuracy of the business fixed capital formation component of the SNA. FAASM also has secondary objectives briefly noted below.

Secondary benefits achieved by full FAASM: while partial FAASM depends on actual lives based on the evidence of discards, full FAASM determines in addition the accounting or expected lives, assumed by companies at purchase of assets for calculating depreciation. Additional FAASM outputs from the full version are expected to include the following: the measurement of accounting net stock, what would appear in corporate balance sheets if current cost accounting were in force. This would, in turn, permit estimation of an "accounting rate of return on capital" as opposed to the "true" rate based on the "true" net stock measured by partial FAASM. Other outputs of full FAASM should include the monitoring of accounting versus actual life trends, giving insights into industry technological change, market forces, and accounting policies; estimates of the over- or under-statement of profits because of under - or over-charging of depreciation respectively; and measures of 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). 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.