A FEASIBILITY STUDY

DEFLATING EXPENDITURES
IN THE NATURAL SCIENCES

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by

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SUMMARY AND COMMENTS*

Each year, Statistics Canada surveys federal establishments to provide information pertaining to the current and historical trends in federal support of research, development and related scientific activities in the natural and human sciences. For the past three years, the results of this survey have been published by the Ministry of State for Science and Technology in an annual publication entitled "Federal Scientific Resources, Natural and Human Sciences". This publication is carried out in cooperation with Statistics Canada and members of the Interdepartmental Committee on Scientific Expenditures, and without whose assistance the preparation of this report would not be possible.

The Ministry and Treasury Board Secretariat use this information as an input for policy planning and program evaluation. Additionally, international agencies such as OECD and UNESCO, provincial agencies, the academic community, various associations and the general public are provided with expenditure data.

The first two Ministerial publications for the years 1971 and 1972 contained comparative expenditure estimates for a fourteen year period and a ten year period respectively. In part it became increasingly apparent to senior officers of the Ministry that inter-temporal comparisons of current dollar expenditures over a long period of time may not be particularly useful for long-term planning because of the inflationary component. As a result, the latest publication contained estimates for only a three year period.

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It has just recently became apparent that even a three year comparison may also result in an illusionary inter-temporal indicator of the real cost of Federal scientific efforts. Initially, it was thought that dollar expenditures on Federal scientific activities could be deflated using an overall index such as the Consumer Price Index (CPI) or a "cost of research index". The results of this preliminary paper suggest that this type of aggregative approach although quite simple and straightforward is unacceptable to the policy planning and program evaluation needs of the Ministry. The main operational reasons for objecting to this approach are basically twofold. Firstly, the component inputs required to generate an aggregated index are not proportionately the same inputs of scientific expenditures. For example, the CPI may be rising by 10% due mainly to the proportionately increasing price of clothing, housing and transportation, whereas the prices of scientific research and development may be rising at an annual rate of 15% due principally to the proportionately increasing price of wages and capital. Thus, deflating the annual increases of science expenditures by 10% would not in this case properly reflect the true inflationary price increases.

The second reason for rejecting the aggregate approach is of direct concern to the Ministry and especially Treasury Board in determining the relative departmental increases in scientific expenditures over time. The example provided in Figure I of this summary clarifies this point. In current dollar terms the Scientific Expenditure of Department "A" increased by 8.4% between 1971 - 1972 and 1972-1973; whereas the real increase was -2.0%. In the case of Department "B" current expenditures rose by 12.1% whilst real expenditures increased by -4.0%. In essence, although the current expenditures rose more for department "B" than for department "A"; in real terms department "B" displayed a more profound decrease than department "A". This illusionary effect is created by the weights assigned to each component in addition to the different expenditure patterns of both departments.

The objective of this paper is to investigate the feasibility of constructing a set of price deflators for Federal expenditure in the Natural Sciences which would provide a measure of the effects of inflation as shown in the example above. This preliminary study attempts to use intramural expenditure information as it relates to Natural Sciences which is outlined in the "Statistics Canada Survey Federal Government Activities in the Natural Sciences". Should this approach be deemed worthwhile, then an investigation of extramural costs and expenditures on humanities can be initiated. In essence, an attempt is made to construct a separate index for the following broad classifications; personnel, expendable research equipment, other current operating expenses, and capital outlays. Very briefly this analysis concludes that:

(1) The presently available information is sufficient to develop a reliable personnel price deflator for natural science expenditure. It should be noted however that this index would not include quality considerations. This finding is particularly important since personnel costs are by far the largest component of R&D expenditures.

(2) At this present time it is not possible to construct a price deflator for expendable research equipment for basically two reasons;

(a) there does not appear to be a common interpretation of the term "expendable research equipment" among Federal departments. Irrespective of the indexing problem, this specific aspect should be investigated thoroughly;

(b) as well, several departments contacted agreed that actual items included as "expendable research equipment" could not be supplied for past years.

(3) Lack of definition with respect to "other current operating expenses" and "intramural capital" imply that it is difficult to place any significance to the total government expenditure on these items and as a result the construction of a price index would not be feasible at this time. Again, this problem should be thoroughly investigated irrespective of the indexing aspect.

(4) It is possible to correct the problems outlined in (2) and (3) by defining "expendable research equipment and capital in terms of "line objects" and "other current expenditures" in terms of "standard objects". Once consistent definitions of "expendable research equipment", "other current operating costs" and "capital" have been adapted;

(a) it is possible to construct an index for "expendable research equipment" and "capital";

(b) a"proxy index" could be constructed for "other current operating expenses".

(5) No attempt was made in this paper to construct an index for the funding of extramural performers in the natural sciences. Should the Ministry consider it worthwhile the next step to this investigation will be to analyse the Federal expenditure patterns as they relate to Canadian industry, Canadian non-profit institutions and Foreign institutions.

FIGURE I

Dept. A	1971-72 $Millions	1972-73 $Millions	Index	Real Expenditure $Millions
Personnel	43.5	48.0	110	43.6
Exp. Research	0.0	0.0	110	0.0
Other current	10.0	12.0	110	10.9
Capital	5.0	3.5	115	3.0
Canadian Ind.	0.0	0.0	115	0.0
Canadian Univ.	1.0	1.0	125	0.8
Other Canadian	0.0	0.0	110	0.0
Foreign	0.0	0.0	110	0.0
TOTAL	59.5	64.5		58.3

Dept. B	1971-72 $Millions	1972-73 $Millions	Index	Real Expenditure $Millions
Personnel	33.0	41.0	110	37.3
Exp. Research	3.0	3.0	110	2.7
Other Current	18.0	18.0	110	16.4
Capital	6.0	9.0	115	7.8
Canadian Ind.	11.0	11.0	115	9.6
Canadian Univ.	60.0	65.0	125	52.0
Other Canadian	0.0	0.0	110	0.0
Foreign	1.0	1.0	110	.9
TOTAL	132.0	148.0		126.7

NOTE: The indicies employed are arbitrarily selected.

INTRODUCTION

In the past few years total federal expenditures in the Natural Sciences have been increasing at a rate of almost 10% per annum. This yearly increase in expenditures in the Natural Sciences should not be perceived as a true measure of the increase in scientific effort for several reasons.

First, the forces of inflation affect input prices of labour, materials and supplies and other overhead costs. Thus, some, if not all, increases in expenditures in the Natural Sciences merely cover the increased costs of research.

Second, changes in productivity and output must be taken into consideration. For example, increased expenditures on new sophisticated instruments which reduce the time to carry out experiments or increase the quality of the output, would reflect increased costs devoted to increased scientific effort. What this means is, that if one were interested in determining the costs of maintaining a constant level of scientific effort, one must take into account changes in prices, productivity, output, and quality plus changes in expenditure patterns due to price changes with respect to science expenditures[1/].

At a disaggregated level it is also necessary to determine the cost of maintaining a constant level of scientific effort by department or agency. From the point of view of the

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1/ For a more complete discussion of changing expenditure patterns using the CPI as an example see: Abner Hurwitz, "Constants and Compromise in the Consumer Price Index", American Statistical Journal LVII (1962).

individual department or agency, increased funds could be requested in order to maintain existing programs. Moreover, if new programs are to be initiated, then additional funds over and above those required to sustain present scientific effort are needed. From the viewpoint of overall science policy and evaluation, a measure of the increasing costs of scientific effort would be very useful. If a measure of output for scientific effort were developed, one could evaluate the effect of a real increase in expenditure (i.e. increased expenditures over and above that which could be attributed to an increase in the costs of scientific effort) in terms of increased output.

The purpose of this paper is to study the feasibility of constructing a set of price indices which would provide a measure of the effects of inflation on science expenditures in Canada. This would be the first step in the construction of an index of the cost of maintaining a constant level of scientific effort.

The basic approach and rationale is outlined below. Each department or agency allocates it's expenditures in the Natural Sciences, with varying weights, under the following broad classifications; personnel, expendable research equipment, other current operating expenses, capital outlays and funding of extramural performers[2/]. For example, the Department of Agriculture and Energy, Mines and Resources allocated

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2/ Canada, Ministry of State for Science and Technology, Federal Government Resources (Ottawa: Information Canada). See also: Canada, Statistics Canada, Cat. No. 13-202, Federal Government Activities in the Natural Sciences (Ottawa: Information Canada various issues).

79.8% and 59.5% respectively, of their total current intramural expenses to personnel in the fiscal year 1972-73. During the same fiscal year, Industry, Trade and Commerce allocated 96.8% and the Department of Agriculture allocated 0% of current expenditures on activities in the Natural Sciences to Canadian industry. Not only is there a diversity in the weights assigned to the various classifications of expenditure from one department to another, but also the components of expenditure within classifications vary between departments. For example, in the fiscal year 1972-73, the Department of National Defence and NRC allocated 19.4% and 28.2% respectively of their total man-years to scientific and professional personnel.

A basic premise of this paper is that the effect of inflation is different for each of the classifications listed above. Furthermore, since departments allocate funds differently within classifications it is necessary to construct a set of indices by classification for each department.

Section one of this paper will review the major work that has been completed in the area of cost-of-research indicies. Specifically, this section will summarize the work done by E.A. Johnson, H.S. Milton and E.D. Brunner on a cost-of-research index. The price indices constructed by A. Searle will be discussed in detail since many of the problems he encountered are similar to problems in developing a set of price indices for science expenditures in Canada.

Section two will deal with a discussion of the theory and practice of index numbers. This section will provide the necessary background to discuss the feasibility of constructing the indices and the reliability of the indicies.

Section three will discuss the feasibility of constructing a set of price indicies for each of the intramural classifications above for each department which has expenditures in the Natural Sciences.

SECTION I

Discussion of Previous Literature

During the early 1960's there was some concern in the United States regarding the increasing R&D budget. Expenditures were doubling every six years and need was expressed to find a measure of the true increase in R&D effort. In particular, information useful for planning and budgeting was required. As a consequence work began in the United States to construct a cost-of-research index. Ellis A. Johnson and Helen S. Milton of the Operations Research Department of the Johns Hopkins University undertook to develop a cost-of-research index.[3/] The cost-of-research index was to provide a measure of the relative cost of technical man-years[4/], supported by Research and Development (R&D) funds in the United States. With the use of this index, a measure of the increase in actual R&D was to be derived.

The index was based on the expenditures of seventeen research organizations, ranging from the most sophisticated industry to small private laboratories. At this point it is significant to note that the actual construction of the index based on the seventeen organizations is not discussed, that is to say, was it a Laspeyres or Paasche index? The year 1950 was used as the base year and the index was constructed for the years 1920-1960.

It would seem that the basic rationale for the construction of the cost-of-research index was to explain the rate of growth of R&D expenditures in the United States with respect to the increasing costs of research. In an attempt to illustrate the increasing costs

3/ Ellis A. Johnson and Helen S. Milton, A Proposed Cost-of-Research Index, Staff Paper ORO-5P-142 (Revised) (Maryland: Operations Research Office, Johns Hopkins University, 1960).

4/ Here, the "Technical Man" is the professional scientist or engineer, together with his supporting staff and capital equipment.

of research, the cost-of-research index was compared to the consumer price index (CPI) for the period 1920-1959. By making this comparison, the authors completely overlooked several important facts. Firstly, in order to take into account quality changes and changing consumer behaviour, the CPI in the United States was revised no less than three times during the period under consideration[5/], while the cost-of-research index does not take changing patterns and quality into consideration. Secondly, the consumer price index is based on a "fixed basket" of goods; the cost-of-research index does not provide a fixed base from which to compare price changes. Thirdly, the authors did not take into account a complex, two-way causal effect between the CPI and the cost-of-research index. That is to say, the increasing R&D effort may result in lower prices for consumers through technical advancements in production techniques or new and cheaper products. Moreover, the R&D effort may increase the quality of products and thus lower the CPI after adjustments for quality have been made. As well, it should be noted that a general increase in prices will affect input prices for the R&D effort.

The weaknesses of the cost-of-research index outlined above are further amplified by A. Searle:

> "... the purpose of the index makers seems to be to measure the combined effects of changes of product mix (even with price change), changes in man-hour mix (scientists and non-scientists), and prices and wages. An increase in these indexes can occur (1) if prices rise (and we therefore get less than our money's worth);(2) if more costly and efficient equipment is

5/ For a review of the revisions made during this period see Julius Puscha, "Overhauling the CPI", New York Times, July 28, 1974, Sec. 3, pp 2-3.

purchased (and we get more than our money's worth), or (3) scientists become more efficient (and we get more than our money's worth). What I am saying is that a rise in the index can be viewed either with joy or alarm, depending on its cause"6/.

Essentially Searle's agrument is that the cost-of-research index does not have a "fixed basket" of goods and thus does not hold anything constant. For example, even a man-year changes with the changes in productivity. Another problem with the concept of the cost-of-research index is that the cost-of-research index may reflect political and not economic considerations. For example, if the United States Government cuts back on its expenditures on space exploration and other sophisticated areas (requiring expensive equipment), the cost-of-research index may in fact drop even though the prices of inputs into R&D are rising. One may conclude that the cost-of-research index cannot be viewed as a deflator but rather of needs to be deflated.

E.D. Brunner7/ attempted to discover the real level of research effort financed by the U.S. Air Force of Aerospace Research. Essentially, Brunner used the same method as Johnson and Milton. Brunner defined a man-month of a scientist's time as the unit of measurement of scientific effort. Costs were defined as wages and salaries to scientists and supporting staff, capital equipment and other items necessary for research. Due to the similarity between Brunner's analysis and that of Johnson and Milton, the criticisms are the same as those discussed above.

6/ Allan Searle, "Measuring Price Change in Research and Development Purchases", Proceedings of the Business and Economic Statistics Section (American Statistical Association, 1965, p.21).

7/ E.D. Brunner, The Cost of Basic Research Effort: Air Force Experience, 1954-64, Memorandum RM-4250-PR (Santa Monica: Rand Corporation, 1965).

Allan Searle[8] attempted to construct a set of price indicies based on information from U.S. army laboratories and private laboratories with large army contracts. The following indicies were constructed; personnel, material supplies and equipment, overhead and other costs, and total costs. Since there is no universal definition of a laboratory, no attempt was made to segregate expendable and non-expendable research equipment. The weights used in the construction of the indicies(Laspeyres) were obtained from surveys submitted by each laboratory in the study. Payroll data were broken down into four categories; scientists and engineers, technicians, craftsmen and unskilled employees; for materials, supplies and equipment, army laboratories reported total expenditures, a 2-digit code of sufficient supply classification groups to account for at least 50% of expenditures. With respect to wages, Searle pointed out that the purpose was to "price" the job content, i.e. the amount paid for the same work from year to year. No attempt was made to follow careers of individuals. Further, Searle considered wage increases in each job classification as a "price" increase rather than as a result of quality change. He used an example of the practices of the Public Service in the U.S. to substantiate his reasoning. Another problem Searle encountered was that R&D was changing so rapidly that it was necessary to revise the weights after three years. Moreover, items change in specification and sophistication over time and consequently it was difficult to obtain strictly comparable prices from year to year.

8/ Allan Searle, op.cit., p. 21.

Although the indexes Searle constructed were based on weights and prices from army and related laboratories[9/], the general approach and method is worth noting. In later sections of this paper we will return to a discussion of Searle's paper, when some of the problems in constructing a Canadian index are discussed.

In Canada, total Federal Government expenditures in the Natural Sciences, have been deflated by an "Inflation-sophistication Factor" (I-S Factor)[10/]. Actually, the I-S Factor was originally designed in order to project R&D expenditures in Canada. However, Statistics Canada until recently used the I-S Factor to express scientific expenditures in constant dollars. In reality, the I-S Factor is a cost-of-research index based on past trends in Canada and other countries. Instead of calculating the cost-of-research index each year, an annual rate of increase of six percent was suggested. The problems associated with a cost-of-research index have already been discussed earlier in this section. Recently, Statistics Canada has used the GNE implicit price index in order to express science expenditures in constant dollars. Essentially, there are two basic problems with using the GNE implicit price index. Firstly, there may be a source of bias in the implicit price index arising from the personal expenditure group. The bias could result from either an upward bias of the CPI or from the extension of a price index derived from a specific target group to cover personal

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9/ The sample represented 10% of R&D expenditures in the U.S.

10/ R.W. Jackson, D.W. Henderson and B. Leung, "Background Studies in Science Policy: Projections of R&D Manpower and Expenditure", Science Council of Canada, Special Study NO. 6, (Ottawa: Queen's Printer, 1969), p. 31-42.

expenditures of a much larger target group. A second problem with using the GNE implicit price index is that the weighting pattern does not necessarily describe the weighting pattern for expenditures in the Natural Sciences.

SECTION II

THEORY AND PRACTICE OF INDEX NUMBERS

The index number problem arises whenever one wishes to obtain a quantitative expression for a complex that consists of individual measurements for which no common physical unit exists. The problem of how to construct an index number is not only one of economic theory but also of statistical technique. That is to say, there are two basic concepts with respect to index numbers; theory and practice. In general, the theory of index numbers deals with the concept and choice of formulae in the context of economic theory; the practice of index numbers deals with deciding weighting patterns, carrying out price collections and making allowance for the factors such as seasonality and quality variations over time.

In the following section we will deal with the theory of price indexes, and in particular discuss which formulae will be used in the construction of the price indexes developed in this paper. The purpose of this section is twofold, firstly; this section will acquaint the reader with the general theory of price indexes, and secondly; provide a justification for the formulae chosen in the paper.

The most basic form of a price index is the simple equi-weighted arithmetic mean:

$A_o = \frac{1}{n} \sum_{i=p}^{n} P_{oi}$; the subscript "o" refers to the base year.

The arithmetic mean suffers from three basic faults. Firstly, the arithmetic means of prices are not invariant under changes in units and neither is their ratio. Secondly, the arithmetic mean of price relatives is not equal to the ratio of the arithmetic mean of prices:

$$A_o = \frac{1}{n}\sum_{i=1}^{n} P_{oi} \qquad A_1 = \frac{1}{n}\sum_{i=1}^{n} P_{1i}$$

$$J_{01} = \frac{1}{n}\sum_{i=1}^{n} \frac{P_{1i}}{P_{oi}} \neq \frac{A1}{Ao}$$

Moreover, the arithmetic mean of price relatives depends on the choice of the base year, i.e.

$$J_{12} \neq \frac{J_{02}}{J_{01}}$$

A second form of a price index is the geometric mean of the price relatives; i.e.

$$G_O = \left(\prod_{i=1}^{n} P_{oi}\right)^{1/2} \quad \text{and} \quad G_1 = \left(\prod_{i=1}^{n} P_{1i}\right)^{1/2}$$

which is not invariant under changes in units, but a ratio of means is invariant. Further, it should be noted that the geometric means are independent of the base period chosen. Although the geometric mean is superior to the equi-weighted arithmetic mean there are problems. F.Y. Edgeworth[11/] suggested that the change in the general price level could be estimated from a probability sample of all price quotations. Edgeworth further suggested that an appropriate estimator of the change in the general price level is the simple geometric mean of price relatives.

The basic problem with Edgeworth's suggestion is that it is difficult to perceive of a universe of all price quotations. Consequently one may ask, "what is the economic definition of the general price level in the context of the universe of prices?".

11/ F.Y. Edgeworth, Papers Relating to Political Economy (London MacMillan and Co. Ltd. 1925), I, papers H and I.

In other words, to say that the general price level is the geometric mean of all prices and estimated as the geometric mean of a sample of prices is a statement devoid of economic content. Thus, it can be argued that the geometric mean is an inappropriate measurement of the general price index.

An alternative approach to a price index as a measure of a general movement in prices, while at the same time having a precise economic meaning, is to base the concept on a specified money aggregate[12/]. One essential feature of such index numbers is that they are arithmetic means and weighted by the distribution of the money aggregate over the individual items priced. This approach discussed above leads us to the familar Laspeyres and Paasche forms:

Laspeyres $$L_{ot} = \frac{\sum p_t q_o}{\sum p_o q_o}$$

Paasche $$P_{ot} = \frac{\sum p_1 q_t}{\sum p_o q_t},$$

each comparing prices in situation "t" with those at time "0" with time "0" prices as 100%.

Contrary to what many individuals sometimes think, the Laspeyres and the Paasche are simply two variants of one concept; the comparison of the costs of a fixed "basket" of commodities. Hence,there is no need for an "uncomfortable" choice between the two indexes or a compromise between the two. The distinction between the Laspeyres and the Paasche forms becomes relevant in comparisons over successive time periods. A run of Laspeyres index

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12/ Some examples are; consumption expenditure of a particular group of consumers. government scientific expenditures.

numbers"i"is pair-wise comparable. That is to say any two indexes L_{ok} and L_{ot} can be compared directly by means of the fixed "basket" of data"0". 13/ Unlike the Laspeyres form, the run of Paasche index numbers is valid for comparison of time"t"with the selected base. Thus P_{ot} is valid for"t"prices in comparison to"0"prices and P_{ok} is valid for"k"prices in comparison to"0"prices. Since the two comparisons use different "weights", they provide no way of comparing"k"prices with"t"prices directly by means of the ratio $\frac{P_{ot}}{P_{ok}}$ 14/. In fact it can be demonstrated that all prices may rise from time"k"to"t"but P_{ot} is less than P_{ok}.

There are other differences between the Paasche and Laspeyres forms. For example, if new weights are selected and applied to the Laspeyres form a new run of index numbers results. Moreover, if one changes the comparison base,the run is merely rescaled. Since the Paasche form has no fixed weights, and a fixed comparison base, a different index is obtained, not by selecting another "basket" of commodities, but by selecting another comparison year.

13/ Select"k"as the comparison base and express the original run in percentage of L_{ok} to give a rescaled run

$$L_{kt} = \frac{\sum p_t q_o}{\sum p_o q_o} \Big/ \frac{\sum p_k q_o}{\sum p_o q_o} = \frac{\sum p_t q_o}{\sum p_k q_o}$$

i.e. L_{kt} uses the same fixed "basket" of"0"quantities.

14/ $$P_{kt} = \frac{\sum p_t q_t}{\sum p_o q_t} \Big/ \frac{\sum p_k q_k}{\sum p_o q_t} = \frac{\sum p_t q_t}{\sum p_k q_k} \times \frac{\sum p_o q_k}{\sum p_o q_t}$$

i.e. the rescaled run cannot be expressed in terms of prices at dates"k"and"t" nor in terms of a single "basket"of quantities.

Although in terms of basic formulae and reliability of the indexes there is little to choose between using a Paasche or Laspeyres form, the latter allows the researcher to change the comparison base at will and make pair-wise comparison of the price levels at any two points of time.

More sophisticated price indexes have been constructed. In most cases these price indexes were "crosses" of the Paasche and Laspeyres forms 15/. Fisher, in his last book 16/, classified a great number of index numbers into seven classes; worthless, poor, fair, good, very good, excellent and superlative. The indexes were ranked using the following tests:

(1) The identity test: $P_{oo} = 1$

(2) The point reversal test: $P_{o1} \cdot P_{1o} = 1$

(3) The circular test: $P_{o1} \cdot P_{12} = P_{o2}$

(4) The commensurability test: P_{o1} will not change by changing the unit of measurement for any of the individual goods.

(5) The determinateness test: P_{o1} shall not become zero, infinite or indeterminate if an individual price or quantity becomes zero.

(6) The proportionality test: if all individual prices have changed in the same proportion from period "0" to period "1", P_{o1} shall be equal to the common factor.

15/ Some examples are the Drobisch arithmetic cross, Fisher's geometric cross and the Marshall-Edgeworth arithmetic crossed-weight aggregative.

16/ Irving Fisher, The Making of Index Numbers (New York: Houghton Mefflin Co., 1923).

On the basis of the six tests above, Fisher ranked the "crosses" as superlative and the Laspeyres and Paasche forms as very good. Mudgett[17/] points out that Fisher's selection of the Ideal Formula (geometric cross) as the "best", was largely due to the fact that it satisfied the point reversal test whereas the Laspeyres and Paasche did not. R.G.D. Allen[18/] suggests however that the "crosses" have no great advantage over the Laspeyres and the Paasche forms. It should be noted that since the "crosses" include the Paasche form, the arguments relating to the shifting of the base and pair-wise comparison are valid.

The indexes to be constructed or discussed in this paper will be of the Laspeyres form. Essentially, the choice was based upon the following considerations. Firstly, the equi-weighted arithmetic mean and the geometric mean were not chosen due to the arguments discussed above. Although there is little choice between the Paasche and Laspeyres forms, the Laspeyres form was chosen because: the base is shiftable; pairwise comparison at any two points in time is possible; maintaining a run of Laspeyres index numbers is cheaper than a run of Paasche numbers since only prices at time "t" need to be collected; and finally the indexes constructed here would be compatible with the Laspeyres indexes published by Statistics Canada. The "crosses" between the Laspeyres and Paasche forms were not chosen since they would be more expensive to maintain.

17/ Bruce Mudgett, Index Numbers (New York: John Wiley and Sons, Inc., 1951) p.42.

18/ R.G.D. Allen, Statistics For Economists (New York: Hutchinson University Library, 1963), p.107.

We now move to a discussion of the practice of index numbers in an effort to lay the background for later discussion on the quality of index numbers constructed.

When one is constructing an index, one usually takes a sample of "n" commodities from a population of "N" commodities. The index based on the "n" commodities in the sample includes what is termed a sampling error. The sampling error is the standard deviation of the sampling distribution of the mean. In dealing with the index numbers and a discussion of their sampling errors, one must take into account four effects:

1) Error of an average of a random sample;
2) Effect of weighting;
3) Effect of sampling from a finite population;
4) Effect of sample stratification.

In general the sampling error of a simple random sample varies inversely with the size of the sample. That is to say, as the sample becomes larger the theoretical sampling error becomes smaller. When the indexes are weighted averages, the sampling error also becomes a function of the weighting pattern.

The problem of calculating the sampling error with respect to index numbers becomes more complex due to the fact that samples of index number data are typically not simple random samples. Samples of index number data differ in two respects from simple random samples. Firstly, they are drawn from a finite population (results in sampling without replacement) and secondly, they are stratified. In the case of sampling without replacement the theoretical sampling error of a simple random sample is multiplied by a factor of $1 - \frac{n-1}{N-1}$, where "n" is the sample size and "N" is the population size.

One can readily see that as $\frac{n-1}{N-1} \rightarrow 0$ the sampling error approaches the theoretical sampling error of a simple random sample. In either case, to reduce sampling errors, one should endeavour to obtain the largest sample possible. Stratified samples increases accuracy over random sampling for a given size of sample. For example, the personnel price index is a stratified sample. Federal or departmental expenditures fall into several categories: scientific and professional, technical, operational, and so on. A simple random sample of "n" persons could be without any representatives in a particular category, but a stratified sample would give proportional representation to each category.

Another type of error which arises is the homogeneity error. Since the construction of most price indexes involves collecting data for a specific list of items for both the base period and period "t", (binary commodities) the price index derived from these data is not the true index of the measure of the change in the price level. In order to obtain a true measure of the change in the price level, an index must be constructed in such a way as to include all items, both binary and unique to the two periods. The homogeneity error is then the difference between the index using all items and the index using only binary commodities. In order to obtain some idea of the magnitude of the homogeneity error the following formula is suggested[19/]:

$$R = \frac{\text{number of unique commodities}}{\Sigma\,(\text{unique} + \text{binary})\text{commodities}};$$

19/ Bruce Hudgett, *op.cit.*, p.56

where "R" is the measure of homogeneity. Thus, if R=0 we have perfect homogeneity and R= 1 we have perfect heterogeneity.

Another consideration in the practice of index numbers is to account for quality changes:

> "if a poll were taken of professional economists and statisticians, in all probability they would designate (and by a large majority) the failure of the price indexes to take full account of quality changes, as the most important defect in these indexes and by almost as large a majority they would believe that this failure introduces a systematic upward bias in the price indexes - that quality changes have on average been quality improvements".20/

Generally, the discussion of quality changes and changes in tastes or preference centres around the concept of measuring the increased costs associated with maintaining a constant level of utility[21/]. For example, an increase in the quality of a product may increase satisfaction, welfare or utility characteristics of goods. Thus one can see that an increase in quality must be accounted for within the framework of constant utility. Another consideration is changes in tastes. For example, if consumers change their budget to avoid the purchase of those products whose prices have risen and at the same time find equally desirable and less expensive substitutes, the actual cost of living may decrease, while the cost of living index may in fact increase since the price of the "fixed basket of goods" has increased. A further problem in maintaining a run of index numbers is that product changes cause the item to fall outside the original specifications.

20/ National Bureau of Economic Research, The Price Statistics of the Federal Government (NBER General Series No.73, 1961) p. 35. (reprinted in R.A. Loyns, CPI and IPI as Measures of Recent Price Change, Price and Incomes Commission, (Ottawa: Information Canada, 1972) p.9.

21/ For a discussion of indifference map analysis and the price index number problem see: Ragnar Frisch, "Annual Survey of General Economic Theory: The Problem of Index Numbers", Econometrica, IV (1936) 13-27. See also: R.G.D. Allen, Price Index Numbers, (Ottawa: International Statistical Institute, 1963) pp.39-41.

There have been suggestions made regarding methods to overcome the problems outlined above. A few of these methods will be reviewed below to provide a background for later discussion on how the problems dealing with quality and taste could be dealt with in the construction of each price index.

One of the most popular methods of adjusting for quality is the "nedonic" or multiple regression approach to price indexes. In practice the following questions arise in formulation of the model for price change:

1) What are the relevant characteristics?

2) What is the relationship between price and characteristics?

3) How does one estimate "pure" price change from such data?22/

To account for product changes several methods are used. If there is overlap (model A and B appear in the market simultaneously), the difference in quality is estimated by taking the price differential between model A and model B. Thus when model B replaces model A, it is spliced into the index at the relative level of the last quotation used for model A. If two items do not appear in the market at the same time three procedures can be used:

1) bumping - direct substitution of the price of the new item with that of the old item. Thus the price relative used to "bump" B into the index is:

$$y_t = \frac{P_t}{PA_{t-1}}$$

22/ Z. Griliches, Price Indexes and Quality Change (Cambridge: Harvard University Press, 1971) p.5 (for an excellent bibliography see also pp.278-281).

2) splicing - a full splice consists of having a price relative equal to unity. In order to do this, the new item is introduced with no price change under the assumption that the price increase matches the quality increase;

3) adjustment by a quality factor - here explicit quality adjustments are made in calculating the price relative:

$$y_t = \frac{P_{B_t}}{P_{A_{t-1}}} \times Q^{-1},$$

where "Q" is some measure of their relative qualities 23/.

With the background discussion above we are now in a position to critically assess the quality of the indexes to be constructed and to decide what information is needed to construct reliable price indexes for the costs of scientific effort in Canada.

22/ R.A. Loyns, op.cit., pp. 56-57

SECTION III

In the Statistics Canada survey, Federal Government Activities in the Natural Sciences, current operating expenses are divided into three components:

1) personnel;

2) expendable research equipment;

3) other current operating expenses.

In the following section, the feasibility of constructing a price index for the first of these, namely personnel costs, will be discussed.

Personnel in the federal government can be defined within several broad categories: executive, scientific and professional, administrative and foreign service, technical, administrative support, and operational. At this point it would be useful to outline the types of personnel included in each category. The executive is defined as all personnel in the senior executive group, that is to say, those persons who are responsible for managing an agency or department and for providing advice on the development and conduct of government programs. Those classified as scientific and professional would be those individuals engaged in the application of a comprehensive body of knowledge acquired through university graduation. Also included as scientific and professional are those individuals in groups controlled by legal licensing bodies. The administrative and foreign service category includes those groups engaged in the planning, execution, conduct and control of programs serving the public interest and relations between Canada and other countries and the requirements of internal management in the Public Service of Canada. Technical personnel are those engaged in conducting analytical, experimental and investigative duties which require knowledge acquired through completion of secondary school and specialized training. Personnel such as clerks, secretaries and data processors would be included in the administrative support category. Operational personnel would include those engaged in the performance of a craft or unskilled work. For example, this group would be responsible for general services, postal operations and printing operations. From the discussion above, it is clear that each of the categories contain a wide variety of sub-classifications called units or occupational classes. 24/ The wage settlement for each occupational class may be quite different. Consequently, in order to construct a price index for each of the categories listed above, one must take into account the number of personnel used and the wage within each occupational class. Moreover, as discussed earlier, the distribution of persons employed in the Natural Sciences by occupational class varies from one department to another. Thus, there is a case for constructing a separate index for each department.

The general approach to the construction of the personnel price index is discussed below. For each department a Laspeyres price index can be constructed for each of the following categories: scientific and professional, administrative and foreign

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24/ For a detailed breakdown of each category by unit or occupational class see Appendix A.

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service, technical, administrative support and operational.[25/] The base year weights for each index can be derived as follows; the number of personnel[26/] allocated to each occupational group within the categories listed above is available for all departments hired by Treasury Board. The average wage for each occupational class is not available for each department but across all departments. Hence the base year weights for occupational class "j" within category is "i" for department "k" is:

$$W_{ijk} = \frac{P_{oijk} \, \ell_{oijk}}{\sum_{j=1}^{n} P_{oijk} \, \ell_{oijk}}$$

where; P_{oj} is the average wage in the base year for occupational class j;

ℓ_{oijk} is the number of manpower units in the base year devoted in occupational group j within category i for department k;

n is the number of occupational groups j within category i for department k.

25/ A price index for the executive class will not be constructed for several reasons. Firstly, this category is quite small and hence wage data may conflict with the confidentiality of individuals. Secondly, since this category is quite small, its weight in terms of an overall index, by department would be insignificant. Thirdly, the executive class does not fall under collective bargaining and hence wages and wage changes are based on individual situations as opposed to group situations.

26/ The number of personnel is used as opposed to the number of man-years since the number of personnel represents number of man-years <u>used</u> at a particular time rather than the number of man-years <u>allocated</u>.

The price relatives for each occupation group would be the ratio the wage rate at time "t" to the wage rate in the base year. Thus, the general formula for the price index for category "i" and department "k" at time "t" (Lotik) is:

$$L_{otik} = \sum_{j=1}^{n} \left(\frac{P_{otijk}}{P_{ooijk}} \right) W_{ijk}.$$

The next step is to construct an overall personnel price index for each department. This can be accomplished by constructing a Laspeyres price index using the indexes calculated for each individual category as price relatives. The relevant weights for the ith category and kth department are derived as follows:

$$W_{ik} = \frac{\sum_{j=1}^{n} P_{ooijk} \, Q_{ooijk}}{\sum_{i=1}^{l} \sum_{j=1}^{n} P_{ooijk} \, Q_{ooijk}} \quad ; \; l \text{ is the number of categories}$$

However, this weighting scheme does not take into account the weight of each category with respect to activities in the Natural Sciences. A first step in achieving the appropriate weights would be to use the total continuing employees engaged in scientific activities by category as reported in the Statistics Canada Survey, Federal Government Activities in the Natural Sciences. The price data would be the average wage for each category,

i.e:

$$P^{A}_{ooik} = \frac{\sum_{j=1}^{n} P_{ooijk} \, Q_{ooijk}}{n}$$

The weights for the ith category for the Kth department using the above method, is:

$$W_{ik} = \frac{P^{A}_{ooijk} \, Q^{1}_{ooik}}{\sum_{i=1}^{l} P^{A}_{ooik} \, Q^{1}_{ooik}}$$

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where;

p^A_{ooikj} is the average wage in the base year for personnel in category i,

q^1_{ooikj} is the base year number of personnel engaged in scientific activities in the Natural Sciences.

The problem with using this weighting scheme is the inconsistency between the prices and quantities. The price data is <u>not</u> the average wage of those engaged in scientific activities in the Natural Sciences.

The overall personnel price index for the Kth department at time t (Lotk) is:

$$L_{otk} = \sum_{j=1}^{\ell} (L_{otik})(W_{ik}).$$

In order to assess the personnel costs of one department relative to the rest of the departments, a Laspeyres price index should be constructed for each category using the price indexes for each department as the price relatives. The weights for department "K" in category "i" could be derived as follows:

$$W_{Ki} = \frac{\sum_{j=1}^{n} P_{ooijK}\, Q_{ooijK}}{\sum_{K=1}^{m}\sum_{j=1}^{n} P_{ooijK}\, Q_{ooijK}}$$

m is the number of departments.

The overall government index for category "i" at time "t" would be:

$$L_{oti} = \sum_{K=1}^{m} (L_{otiK})(W_{Ki}).$$

The grand government personnel index, that is, the index across categories and departments is a Laspeyres price index using the overall government index for each category and weights as follows:

$$W_i = \frac{\sum_{k=1}^{m} \sum_{j=1}^{n} P_{ooijk}\, q_{ooijk}}{\sum_{i=1}^{\ell} \sum_{k=1}^{m} \sum_{j=1}^{n} P_{ooijk}\, q_{ooijk}}$$

In order to approach the true weights for activities in the Natural Sciences, one could use:

$$W_i = \frac{\sum_{k=1}^{m} P^{A}_{ooik}\, q'_{ooik}}{\sum_{i=1}^{\ell} \sum_{k=1}^{m} P^{A}_{ooik}\, q'_{ooik}}$$

The grand government personnel index at time "t" (Lotg) would then be:

$$L_{otg} = \sum_{i=1}^{\ell} (I_{oti})(W_i)$$

It is suggested that the fiscal year 1973-74 be used as the base year. The main reason for this decision is a data constraint. Treasury Board was unable to supply the wage bill for each occupational class within categories for each department for previous fiscal years.

The indexes as constructed above have some problems within the framework of the practice of index numbers. Firstly, the weights used in the calculation of each price index represent the weight attributed to the various categories by a given department as a whole. In actual fact one should have the departmental weights attributed to the Natural Sciences. That is to say, one should have the number of personnel used in each occupational class within categories for those individuals performing activities in the Natural Sciences rather than the average wage by occupational class for all those hired through Treasury Board and the Public Service Commission. Some departments indicated that this type of data could be available if advance notice were given and proper and concise definitions were outlined. Thus, a formal request to obtain the number of personnel by occupational class and the corresponding wage data could be drafted in order to receive the information required to construct the appropriate weights for the indexes. The data compiled above could be used in the formulae above in order to obtain the relevant indexes. The only change that would be required would be to include the wage data by department instead of across all departments, i.e.

$$P_{ojk} \longrightarrow P_{oijk}$$

A second problem is that Crown Corporations and other agencies such as the International Development Research Council (IDRC) do not hire through the Public Service Commission and have internal classifications as opposed to Treasury Board classifications and occupational grouping. Consequently, in order to obtain a price index for personnel costs for Crown Corporations, the number of personnel used in each internal classification and the average wage for each classification is needed. The next step would be to cross-reference the occupational classes, as defined by a particular Crown Corporation, with the categories defined by Treasury Board. For example, in the case of AECL, chemists would be cross-referenced with the scientific and professional category. This information would be needed when constructing

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the overall government index for each category (Loti), the grand government personnel index (Lotg), and the index for each agency by category (LotiK) and the overall index for each agency (LotK).

In terms of sampling theory the set of personnel indexes outlined above would be reliable. The data used in the construction of the price indexes is highly stratified. The index for each category takes into account the weight allocated to each occupational group within each category. The overall index for each department takes into account the weight allocated to each category. The overall government index for each category and the grand government personnel index would be reliable since we have a universe in the sense that all departments which have expenditures in the Natural Sciences are given their appropriate weight. As discussed earlier in the section dealing with the practice of index numbers, the variance of the price index becomes less as the sample size approaches the size of the universe.

With respect to quality changes, it is difficult to determine quality changes in personnel and in their output. Some work began in the early 1960's in the United States in order to define output and quality of scientific effort (particularly inventive activity). Simon Kuznets[27/] attempted to summarize the key issues in the definition of inventive activity. With respect to the magnitude of an invention (here we will consider magnitude as quality), there are four

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27/ National Bureau of Economic Research, The Rate and Direction of Inventive Activity - Economic and Social Factors (Princeton:PrincetonUniversity Press, 1962), pp.19-43.

considerations:

1) The technical problem - a view of the past;
2) the technical potential - the effect on future advance;
3) the economic cost;
4) the economic potential.

The four considerations above lead to the question of measuring quality of basic research in Canada.

Crude measures outlined in the Lamontagne Report[28/] such as the number of Nobel Prizes and other international awards, publications as a per cent of GNP and the "Citation Index" are really not sufficient to measure quality within the framework of the four conditions outlined above. Firstly, there may be some question whether attainment of a Nobel Prize satisfies considerations two, three, and four. Secondly, unless one carefully studies the nature and type of publications, an index of the number of publications as a per cent of GNP may not satisfy any of the four considerations above. The "Citation Index" may not be a useful measure of the quality of scientific output since a publication may be referred to quite often because it is interesting but it may have little technical or economic potential. Secondly, some work may be "ahead of its time" and it may take many years before the work and its potential are realized. Since there is not a reliable method determining the quality changes in scientific research, the argument used by A. Searle (see ff.1) will be used here. That is, any wage change in each classification will be assumed to be a "price" increase rather than a quality change.

28/ Report of the Senate Special Committee on Science Policy, A Science Policy For Canada (Ottawa: Information Canada, 1972), II, Targets and Strategies For the Seventies, p. 440-442. See also:
Andrew Wilson, Science Technology and Innovation, Economic Council of Canada, Special Study No. 8, Ottawa: Information Canada, 1968.

The indexes discussed in the previous section would be reliable indexes for personnel costs in the Federal Government. Future refinements dealing with quality considerations would further improve the indexes as constructed. Thus, one can conclude that a set of price indexes for personnel costs in the Federal Government is feasible.

In the previous section, the feasibility of constructing a price index for personnel costs was discussed. The next step is to consider the feasibility of constructing a price index for expendable research equipment and other current operating expenses. The first problem encountered was finding a definition for expendable research equipment.29/

Initially, various departments were approached in order to obtain a definition of expendable research equipment and its components. These discussions revealed two important facts. Firstly, there does not seem to be a common interpretation of the term expendable research equipment. Secondly, all departments contacted agreed that items actually included as expendable research equipment could not be supplied for past years. Later in this section of the paper this point will be discussed again and methods of obtaining the information in the future will be suggested.

29/ It is interesting to note that the word expendable is enclosed in quotes in the Statistics Canada survey (above). This would imply a lack of definition of the term expendable.

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Before any work can be done to obtain a list of items included as expendable research equipment, an appropriate and concise definition is needed. In order to illustrate the present situation and underline a need for a concise definition for expendable research equipment, the interpretation of the term expendable research equipment by several departments will be given. One department does not report any expenditures as expendable research equipment due to a lack of definition. In this case some equipment would be included in other current operating expenses. Another department reports very little expenditure as expendable research equipment since its accounting procedure places all equipment purchases as capital acquisitions. That is, most equipment purchases are reported under Standard Object 09 (Construction or Acquisition of Machinery and Equipment). Yet another department reports expenditures on expendable research equipment as a subset of expenditures reported in Standard Object 07 (Utilities, Materials and Supplies). In particular, expenditures associated with some of the line objects included under Parts and Consumable Tools (line objects 0775-0797) plus other selected line objects such as photographic equipment (line object 0763) and rockets (line object 0765) are reported as expendable research equipment. However, many of the line objects included as Parts and Consumable Tools could be included in Standard Object 09 (Construction or Acquisition of Machinery and Equipment). For example, both line objects

0775 and 0901 are General Purpose Industrial Machinery. This leads to a lack of consistency since the same item could be reported as expendable research equipment or capital depending on the interpretation of different individuals. This problem is further compounded since the application of a particular piece of equipment may determine whether it is listed as expendable research equipment or capital. Another department defines expendable research equipment as a piece of equipment which has an initial cost of less than $250.00 or a life expectancy of less than five years or has no scrap value. Thus, a piece of expendable research equipment could vary in price from $0.01 to over $100,000.00.

In summary there is a wide range of interpretations of the term expendable research equipment from one department to another. In fact the lack of consistency and interpretation may even occur within departments. The result of this lack of definition is, that even assuming departments supply accurate data, it is difficult to place any significance to the total government expenditure on expendable research equipment, other current operating expenses and intramural capital.

For the purposes of constructing a price index for expendable research equipment and other current operating expenses,proper definitions for the above terms are needed so as to eliminate overlap between the two types of expenditures. Concise definitions would also provide a necessary basis for obtaining items and weights for the constructing of the price indexes.

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Below is a suggested list of line objects which would be included as expenditures under expendable research equipment:

Line Object	Description
0763	Photographic equipment
0765	Firearms, weapons and ammunition (other than for Defence)
0770	Live animals
0776	Conveying, Elevating and Materials handling equipment
0778	Agricultural Machinery and Implements
0781	Heating, Air-conditioning and Refrigeration Equipment
0785	Measuring, Controlling, Laboratory, Medical and Optical Instruments
0787	Safety and Sanitation Equipment, Signals and Alarms

It is possible that the line objects listed above will not reflect the type of equipment used by particular departments in their research functions. However, the key issue is that expendable research equipment be accurately defined in terms of line objects.

Other current operating expenditures would then include all items under the following Standard Objects:

Standard Object	Description
02	All items included in Transportation and Communication
03	All items included as Information
04	All items included as Professional and Special Services

Standard Object	Description
05	All rentals
07	All items included as Utilities, Materials and Supplies with the exception of those line objects included under expendable research equipment.

At this point one can differentiate between the items included as expendable research equipment and other current operating expenses. Due to the overlap of items included in Standard Object 07 and Standard Object 09 (see ff. 36) there is still a problem with the definition of expendable research equipment. Since the same particular piece of equipment may be expendable or capital depending on its use there is the continual possibility that the same items would be charged as expendable research equipment or capital. This situation need not be a problem if all departments have a consistent method of segregating such items. For example, if all departments agreed to use the following definition to distinguish between items classed as expendable research equipment and capital, the expenditures reported as expendable research equipment and capital would be consistent across departments, and, as a result, some significance could be attached to expenditures in each of the two categories. The definition suggested is as follows:

> For each of the line objects included within the category expendable research equipment (see above), only those items with an initial cost of less than $250.00 or those which have no scrap value upon completion of the research project will be charged

as expendable research equipment. All other items will be charged to the appropriate line object within Standard Object 09.

Having obtained a set of consistent definitions for expendable research equipment and other current operating expenses, the next step is to obtain the information necessary to construct a set of price indexes. Ultimately, in order to construct a reliable price index for expendable research equipment and other current operating expenses a list of items and prices are required in order to calculate the appropriate weights. Moreover, since the indexes are to be used to measure price changes in the Natural Sciences, the items should be those associated with expenditures in the Natural Sciences.

Armed with concise definitions and advance notice, departments should be able to derive a method of obtaining a list of items and prices. One general method, would be to have cards (purchase cards) made at the time a requisition is initiated, which would indicate the item bought, its unit price, and the line object to which the item is charged. An additional piece of information could also be placed on the card - that is, whether the item was purchased for use in the Natural Sciences. The cards could then be sorted by line object. Since the definitions above for expendable research equipment and other current operating expenses are in terms of specific line objects, the cards sorted by line object could then be associated with either expendable research

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equipment or other current operating expenses. It should be noted from the outset that the information regarding items and prices will be required each year. The information will not only be used to construct the indexes each year but will also be used to revise the weighting pattern periodically for the price indexes. The information will also be used to take into account changes in quality and sophistication of particular pieces of equipment. As quality and sophistication of equipment change, these items will be introduced into the index using the methods for quality adjustments which were discussed earlier.

The final use of the information will be to obtain correct weights for items bought periodically, that is, those items not bought each year.

The general approach to the construction of the price indexes for expendable research equipment is outlined below.

A Laspeyres price index could be constructed for each department. Thus the expendable research equipment index for department "K" will be:

$$L^{E}_{otk} = \sum_{i=1}^{n} \left(\frac{P_{otik}}{P_{ooik}} \right) \frac{P_{ooik} Q_{ooik}}{\sum_{i=1}^{n} P_{ooik} Q_{ooik}}$$

Since the reference period is relatively "long" (one fiscal year) prices of particular commodities may change depending on when they were bought during the fiscal year. In order to maintain a consistent set of prices, the price at the beginning of the fiscal year will be used whenever possible. Indexes for each of the "n" items used in the index will not be constructed. It could be argued that the lack of indexes for each item would be a methodological flaw in terms of sampling theory. However, since we are pricing the actual items bought by government, item indexes are not required at the present time. If, over time, different "brands" of the same item are bought, then item indexes should be constructed. The information in order to construct the item indexes would be available from the purchase cards described earlier.

In terms of the practice of index numbers, the index for expendable research equipment will be reliable. Firstly, we have a universe of all items bought by each department. This eliminates the sampling error. Secondly, changes due to quality and sophistication of items can be accounted for over time. Thirdly, if needed, one can construct indexes for individual items.

The next section will deal with the feasibility of constructing a price index for other current operating costs. As discussed earlier, other current operating expenses include, transportation and communication, information, professional and special services, rentals and utilities, materials and supplies not included as expendable research equipment. For most departments the bulk of other current operating expenses would be included under utilities, materials and supplies. Consequently, there is some argument for using some sort of proxy price index for the rest of the components of other current operating expenses. The basic arguments are as follows. Firstly, the information required to obtain price and quantity data to generate the proper weights for the construction of the index would not be available from the purchase cards (discussed earlier). Thus, a great deal of expense would be incurred. In fact, in some cases the cost of data collection could be greater than the actual expenditure on the item. Secondly, in the case of professional and special services, there is some doubt that a reliable index could be constructed in the near future. The reason is that professional and special services not only include direct wages, but also overhead costs. Thus, in order to construct an index for professional and special services, one would have to obtain detailed information concerning prices for the various components of overhead costs. Professional and special services range from legal services to laundry services, which means that a study of overhead costs would be very expensive.

The use of a proxy price index for other current operating expenses (excepting utilities, materials and supplies) would not be reliable in terms of the practice of index numbers. However, since the relative weight of these components is quite small, the error introduced in using a proxy would be somewhat negated. In terms of the costs of obtaining a reliable index compared to the benefits of reducing the error associated with a proxy, the benefit cost ratio would be close to zero.

The index for utilities, materials and supplies excluding those included as expendable research equipment could be constructed from the purchase card data. For department "K," the price index would be:

$$L^{U}_{0tK} = \sum_{i=1}^{n} \left(\frac{P'_{0tiK}}{P'_{0tiK}} \right) \quad \frac{P'_{00iK}\, Q'_{00iK}}{\sum_{i=1}^{n} P'_{00iK}\, Q'_{00iK}}; \qquad \ldots 37$$

where "i" is the number of items included as utilities, materials and supplies, and p' and q' are the associated prices and quantities.

The price index constructed above would be reliable with respect to the practice of index numbers for the same reasons as discussed earlier concerning the price index for expendable research equipment.

In this section a case for a concise definition of expendable research equipment, other current operating costs and capital was presented. Once working definitions are adapted it is possible to construct reliable price indexes for expendable research equipment and utilities, materials and supplies could be constructed. The costs of constructing a reliable price index for the other components would be very large. It is suggested that a proxy price index be used since the expenditures on the other components is quite small and thus negate the errors introduced by not using the most reliable index.

APPENDIX A

EMPLOYER, CATEGORY, UNIT

Treasury Board

Scientific and Professional

AC	Actuarial Science
AG	Agriculture
AR	Architecture and Town Planning
AU	Auditing
BI	Biological Sciences
CH	Chemistry
DE	Dentistry
ED	Education
EN	Engineering and Land Survey
ES	Economics, Sociology and Statistics
FO	Forestry
HE	Home Economics
HR	Historical Research
LA	Law
LS	Library Science
MA	Mathematics
MD	Medicine
MT	Meteorology
NU	Nursing
OP	Occupational and Physical Therapy
PC	Physical Sciences
PH	Pharmacy
PS	Psychology
SE	Scientific Research
SC	Scientific Regulation
SW	Social Work
VS	Veterinary Science

Administrative and Foreign Service

AS	Administrative Services
CO	Commerce
CS	Computer Systems Administration
FS	Foreign Service
FI	Financial Administration
IS	Information Services
PG	Purchasing and Supply
PM	Programme Administration
TR	Translation
WP	Welfare Programmes

Technical

AT	Air Traffic Control
AO	Aircraft Operations
DD	Drafting and Illustration
EG	Engineering and Scientific Support
EL	Electronics
EU	Educational Support
GT	General Technical
PI	Primary Products Inspection

Technical (Continued)

PY	Photography
RO	Radio Operations
SI	Social Science Support
SO	Ships' Officers
SP	Ships' Pilots
TI	Technical Inspection

Administrative Support

CM	Communications
CR	Clerical and Regulatory
DA	Data Processing
OE	Office Equipment Operations
ST	Secretarial, Stenographic, Typing
TE	Telephone Operation

Operational

CX	Correctional (SU-NS)
FR	Firefighters (SU-NS)
GL	General Labour and Trades (SU-NS)
GS	General Services (SU-NS)
HP	Heating, Power and Stationary Plant (SU-NS)
HS	Hospital Services (SU-NS)
LI	Lightkeepers (SU-NS)
PO	Postal Operations - Supervisory
PO	Postal Operations - Non-supervisory
PO	Postal Operations - Non-supervisory, P-T Letter Carriers
PO	Postal Operations - Part-time
PR	Printing Operations - Supervisory
PR	Printing Operations - Non-supervisory
RMC	Railway Mail Clerks
RV	Revenue Postal Operations
SC	Ships' Crews (SU-NS)
SR	Ship Repair

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