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ABSTRACT

This study relates to price trends affecting research and development (R&D) activities at academic institutions. Part I of this report provides the overall results of the study with limited discussion of measurement concepts, methodology and limitations. Part II deals with price indexes and deflation-general concepts and methodology. Part III discusses methodology and data base and Part IV describes alternative computations and approaches. Statistical tables and charts are included. (Author/CS)

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A price index for deflation of academic R&D expenditures

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FOREWORD

THIS STUDY RELATES to price trends affecting R&D activities at academic institutions. These activities are of special interest to NSF because the academic sector performs more than one-half of total basic research, and because NSF allocates most of its research support to institutions of higher education.

Readers of this report will recognize the complex problems faced in the development of a price index for academic R&D expenditures and the limitations of the index because of an inadequate data base. There are conceptual problems as well—R&D expenditures data correspond to inputs rather than to outputs; therefore, the price index presented here is a measure of the price trends of inputs. The problem of measuring outputs of R&D is unresolved, although progress in this direction at some future date is not precluded. Notwithstanding these difficulties, which are not peculiar to the R&D "industry," a price index developed on the basis of secondary source data adds a useful statistical tool for the analysis of academic R&D trends.

Part I of this report provides the overall results of the study with limited discussion of measurement concepts, methodology, and limitations for those readers who wish a brief overview. A preliminary version of this was published as a *Science Resources Studies Highlights*, NSF 71-32. Parts II, III, and IV are intended to provide a more technically oriented discussion for those more interested in rationale and methodology.

Data that have become available since this report was completed indicate a slowdown since fiscal year 1971 in the increase in prices affecting academic R&D activities. Recently released information on faculty compensation and other information on price trends indicate the increase in academic R&D prices from fiscal year 1971 to fiscal year 1972 to be in the range of 4.0 percent to 4.5 percent. This compares with the 5.5-percent annual increase in the several preceding years presented in this report.

May 1972

CHARLES E. FALK
Director, Division of Science Resources Studies

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Various contributions of the following individuals in supplying and interpreting data for this study are greatly appreciated: Maryse Eymonerie, Survey Director, American Association of University Professors; Howard P. Wile, Executive Director, Committee on Governmental Relations, National Association of College and University Business Officers; Thomas W. Gavett, Deputy Commissioner, Bureau of Labor Statistics, U.S. Department of Labor (formerly Assistant Commissioner for Wages and Industrial Relations); Allan D. Searle, Special Assistant, Office of Prices and Living Conditions, Bureau of Labor Statistics, U.S. Department of Labor; Martin L. Marimont, Assistant Director of Economic Accounts, Bureau of Economic Analysis (formerly Office of Business Economics), U.S. Department of Commerce. Responsibility for the way in which the data were used for this study rests, however, with the NSF staff.

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PART I

STUDY FINDINGS

General

Institutions and Government agencies concerned with the funding and performance of academic research and development as well as individual researchers must necessarily be concerned with the effects of inflation on these activities. There are no precise measures of price change in the R&D area; general-purpose price indexes are often used as expedients for analysis. The estimates presented here are the result of developing a price index series based on existing data sources for academic R&D expenditures. Users of this index should bear in mind the limitations which stem from the approach and the data utilized.

Federal agencies now provide about 60 percent of the R&D funds for academia. For fiscal year 1971, R&D expenditures at universities and colleges were estimated at $2,950 million (table 1).

Interest in a price index for academic R&D expenditures is related to changes in the "real" level of funding for R&D activities. Through use of suitable price indexes, expenditures data such as those cited above can be converted to a constant dollar basis, that is, the effects of inflation can be removed.

A meaningful price index must be referenced to a specific set of transactions or dollar outlays. The NSF's estimates of expenditures for research and development at universities and colleges provide such a reference point. These estimates are for current account expenditures and exclude separately budgeted capital equipment and expensive instruments. They are based on NSF's biennial Survey of Scientific Activities of Institutions of Higher Education.[1] Activities of departments in the physical, life, mathematical, and social sciences, and engineering are within scope of the academic R&D expenditures estimates and of the price index described here.

1961–71 Price Trends

Price inflation is estimated to account for about a 50-percent increase in the direct costs of academic research and development performed over the 10 fiscal years ending in June 1971. Most of this rise occurred in the last 5 years when the compounded annual increase rate was 5.0 percent. Estimates for fiscal year 1971 indicate an increase from 1970 of approximately 5.5 percent, about equal to the change over the preceding year.

TABLE 1.—*Current expenditures for research and development in universities and colleges, by source of funds, fiscal years 1961–71*
[Dollars in millions]

Academic year	Total expenditures [a]	Sources		
		Federal Government [a]	Universities and colleges [b]	Other [c]
1961	$ 969	$ 500	$ 371	$ 98
1962	1,143	613	424	106
1963	1,359	760	485	114
1964	1,595	916	555	124
1965	1,822	1,073	615	134
1966	2,085	1,262	673	150
1967	2,329	1,409	753	167
1968	2,599	1,572	841	186
1969	2,705	1,600	900	205
1970	2,856	1,658	970	228
1971 (prel.)	2,950	1,700	1,020	230

[a] Excludes R&D expenditures at Federally Funded Research and Development Centers.
[b] Includes State and local government funds and private gifts not specifically designated for research and development.
[c] Includes other nonprofit institutions and industry.
Source: National Science Foundation.

[1] See reference 14 which presents summaries of 1967–68 funding. The more recent survey covering 1969–70 funding is not yet available although some of the results are used in this study. Extrapolations from the latest survey results (and interpolations between survey years) are made on the basis of other NSF surveys.

Increases in personnel compensation, which accounts for about 65 percent of academic R&D direct costs, were principally responsible for the increase in costs. Payments to personnel increased about two-thirds over the decade. Prices of equipment, expendable supplies, and miscellaneous services, on the other hand, increased only about one-fifth.

TABLE 2.—*Estimated trends in academic R&D prices, fiscal years 1961–71* [a]
(1967 = 100)

Fiscal year	Total direct costs	Personnel compensation	Nonpersonnel direct costs
1961	82·5	76·2	94·3
1962	85·1	79·9	94·8
1963	87·5	83·4	95·2
1964	89·8	86·6	95·8
1965	92·7	90·4	96·9
1966	95·9	95·1	97·3
1967	100·0	100·0	100·0
1968	104·8	105·9	102·7
1969	110·0	112·5	105·4
1970	116·0	119·8	109·1
1971	122·5	126·8	114·3

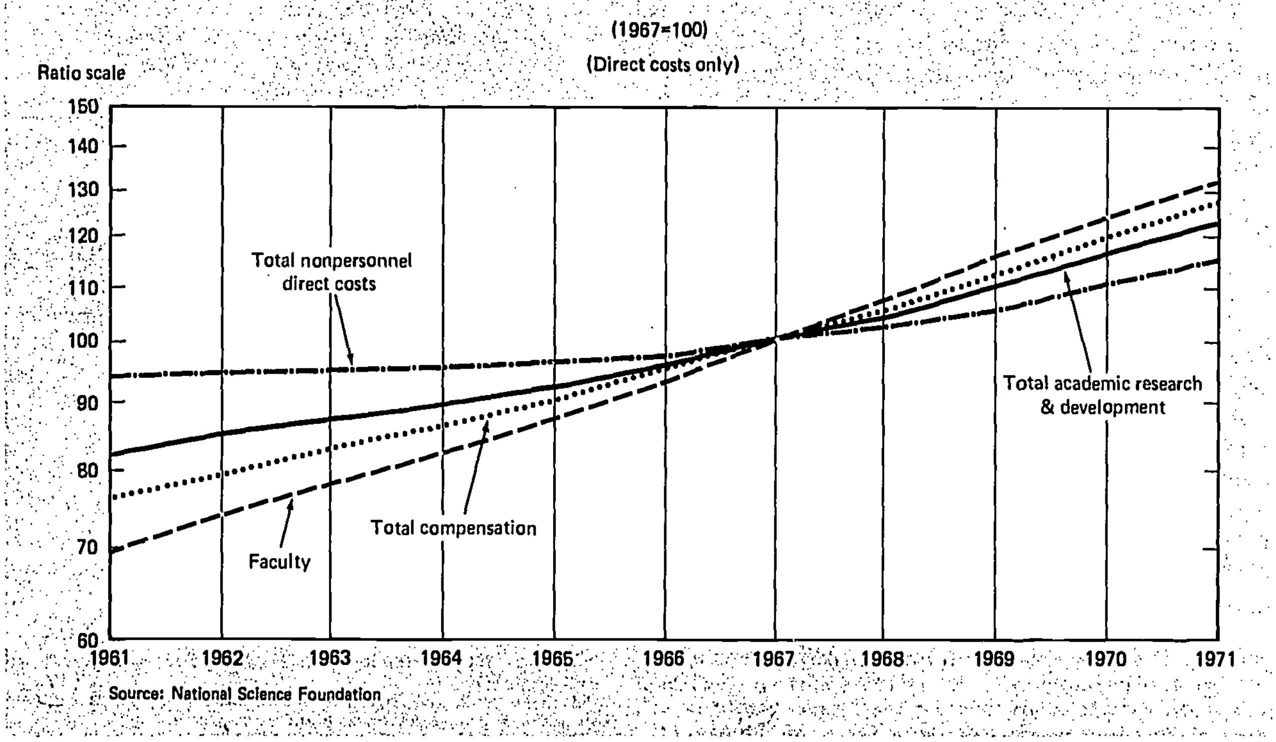
[a] An input price index corresponding to current account R&D expenditures.
Source: National Science Foundation.

Nature of Computations

These estimates were developed from an analysis of the composition of academic R&D expenditures and price trends relevant to R&D costs. The results are summarized in the form of a price index designed to represent the trend of input prices to academic research and development for fiscal years 1961 through 1971 (table 2 and chart 1). Direct costs of R&D activities include such expenses as personnel compensation and purchases of small or expendable equipment, supplies, and services which can be directly related and charged as current costs to research projects. Overhead charges, or indirect costs, are conceptually within scope but are excluded from the price index framework because of data limitations. The implications of this omission are discussed later in part I.

The price index series is constructed in the conventional manner by applying a pattern of cost weights to price trend series. The weights are estimated proportions of direct academic R&D expenditures during the 1967 base period. Thus, the index portrays estimated changes in prices of an R&D expenditures aggregate with a fixed composi-

Chart 1. Academic R&D price trends, fiscal years 1961-71



tion of inputs. In the absence of data specifically applicable to R&D, the price trends embodied in the price index are surrogate series selected from secondary sources as most similar in trend to prices of specified R&D cost categories.

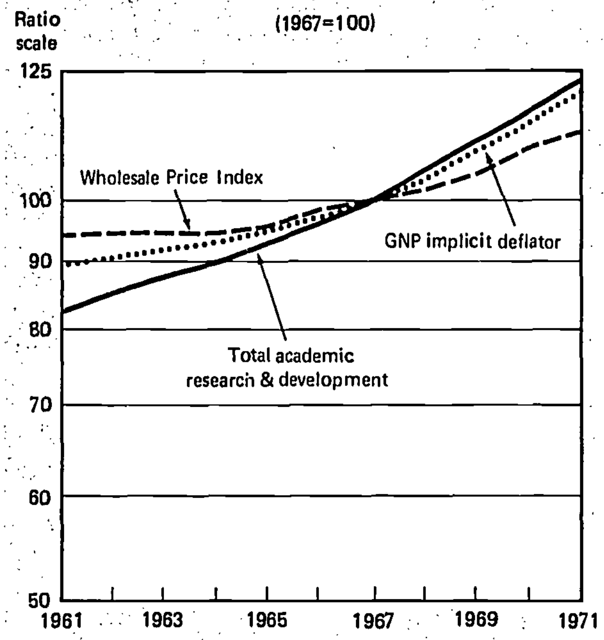
Comparisons With General Trends

The increases in prices of academic research and development over the past decade were considerably higher than price increases in the economy at large. Thus, the 10-year compounded annual increase in R&D prices was 4.0 percent compared with corresponding rates of 2.9 percent for both the Consumer Price Index (CPI) and the gross national product (GNP) implicit deflator. The R&D increase can also be compared with 10-year annual increase rates of 2.6 percent in the GNP implicit deflator limited to the private economy and of 1.7 percent in the Wholesale Price Index (WPI) (table 3 and chart 2).

Differentials between academic R&D and general price level changes were particularly marked in the first half of the decade. R&D prices increased 3.0 percent per year while general price levels increased by 1.5 percent according to the GNP implicit deflator, or by 0.7 percent if the WPI is the measure. The differentials narrowed as the decade progressed. Over the last 2 years the rate of increase of R&D prices appears about the same as the increase in the GNP implicit deflator and the CPI. However, there was still a large differential as compared with the WPI.

The large increases in salaries paid R&D personnel, particularly faculty, combined with heavy weighting factors explain the differentials. Salary and wage trends in other sectors of the economy increased at a lower rate during the first half of the decade as compared with academic research and development. Annual rates of change in compensation in academic research were higher in the last part of the decade than in the first 5 years, reflecting in addition to continued increases for faculty large increases for other professional and nonprofessional staff. However, the GNP implicit deflator had a considerably higher rate of increase in recent years reflecting general inflationary pressures and general wage increases. In effect, salary and wage increases in the general economy lagged behind academic salary increases in the first part of the decade but caught up with the pace in the latter part.

Chart 2. Comparison of trends in price change in academic research and development with the general economy, fiscal years 1961-71



SOURCE: Departments of Labor and Commerce; National Science Foundation.

TABLE 3.—*Estimated average annual rates of price change, academic R&D price index compared with general economy indicators*
(Fiscal year basis)

Price indicator	(Compounded percent change)			
	1961–66	1961–71	1966–71	1969–71
Academic research and development:				
Total direct costs	3·0	4·0	5·0	5·5
Compensation	4·5	5·2	5·9	6·2
Nonpersonnel direct costs	·6	1·9	3·3	4·1
General economy:				
GNP implicit deflator:				
Total economy	1·5	2·9	4·4	5·4
Private	1·2	2·6	4·0	4·9
Consumer Price Index	1·4	2·9	4·5	5·5
Wholesale Price Index:				
All commodities	·7	1·7	2·6	3·7
Industrial commodities	·5	1·7	2·8	3·7

Source: National Science Foundation, Bureau of Labor Statistics, and Department of Commerce.

Trends Within Research and Development

Professional personnel on academic research projects received significantly higher compensation increases during the decade than nonprofessional staff, 73 percent versus 50 percent. Survey data[2] show a 10-year increase for faculty (all ranks) of 88 percent. The increase for nonprofessional staff, including technicians, skilled craftsmen, and secretarial-clerical workers cited above was estimated on the basis of trends for related occupations in private industry.[3] Trends for professional personnel other than faculty, primarily research associates and graduate students, were estimated in a manner that imputes an increase to these groups about midway between nonprofessional and faculty trends.

The annual increases in prices paid for direct-cost items of a nonpersonnel nature are estimated at less than 1 percent in the first half of the decade and at approximately 4 percent in the last several years. In the absence of price trend data directly representative of the equipment, materials, supplies, and services utilized in academic R&D projects, the national income accounts implicit deflator for the corporate sector of the economy, excluding financial corporations, was selected as the price trend proxy. This corporate sector embraces the manufacturing and service industries that provide the diverse items required for academic research.

TABLE 4.—*Comparison of academic R&D expenditures in current dollars with constant dollars, 1961–71*

[Dollar amounts in millions]

Fiscal year	Academic R&D expenditures		R&D price index (1967 = 100)
	Current dollars	1967 dollars	
1961	$ 969	$1,175	82·5
1962	1,143	1,343	85·1
1963	1,359	1,553	87·5
1964	1,595	1,776	89·8
1965	1,822	1,965	92·7
1966	2,085	2,174	95·9
1967	2,329	2,329	100·0
1968	2,599	2,480	104·8
1969	2,705	2,459	110·0
1970	2,856	2,462	116·0
1971	2,950	2,408	122·5

Note: Column 2 is derived by deflation, i.e., by dividing each entry of column 1 by the price index in column 3 and multiplying by 100.

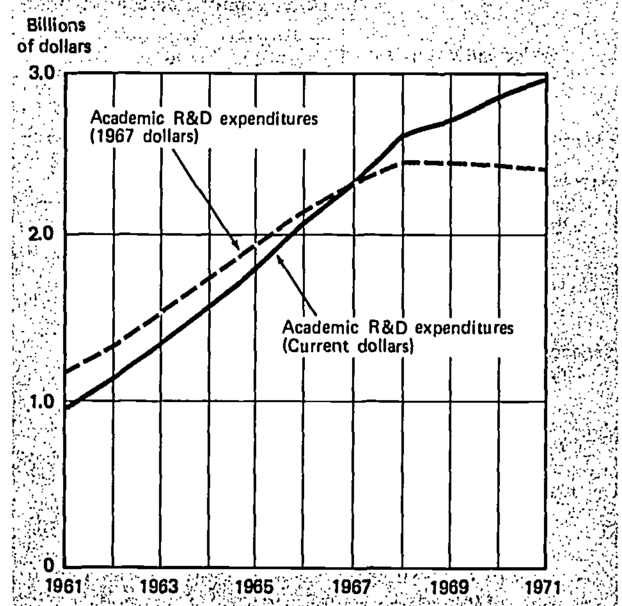
Source: National Science Foundation.

Uses and Interpretation

The price index series is intended to measure the effects of price change, and price change only, on the real quantities of resources that can be purchased with a given funding aggregate for academic research. For example, if the index series shows that the price increase between 2 consecutive years is 5.5 percent, this result can be interpreted as follows: To offset the effects of inflation and to be able to purchase the same kinds and amounts of resources inputs for R&D activities in the second year as in the first would require an expenditures increase of 5.5 percent. Alternatively, $1 million spent for research in the second year would be equivalent to $948,000 in prices of the previous year. Taking a longer perspective, $1 million spent in 1971 would be comparable in purchasing power to $673,000 in fiscal year 1961 dollars.

The importance of price changes in R&D expenditure levels is demonstrated in table 4 and chart 3. Over the decade academic R&D expenditures in current dollars rose at an annual rate of 11.8 percent. When converted to constant dollars the rate becomes 7.4 percent. More significantly,

Chart 3. Comparison of academic R&D expenditures in current dollars with deflated dollars, fiscal years 1961-71



SOURCE: Current dollars—National Patterns of R&D Resources, Funds and Manpower in the United States, 1953-72 (NSF 72-300). Deflated dollars—obtained by deflating current dollars by index as shown in table 4.

[2] See table 9 and reference 26.

[3] See table 9 and references 28 and 30.

an apparent annual increase for the period 1968–71 of 4.3 percent becomes a decrease of 1.0 percent.

The constant dollar expenditure series approximates the "real" resources expended in academic R&D work. This is based on the assumptions that there are no important coverage or conceptual differences in the current expenditures data, that the mix of resources used is unchanged, and that the resource elements are substantially equivalent over time. The fact that these assumptions may not conform to the real situation could, for some purposes, affect the usefulness of price index series and the deflated dollar series. This situation is no different from that faced by users of the widely known price indexes. A particular problem results from the increasing proportion of expenditures accounted for by indirect costs as discussed later.

Qualifications and Limitations

The index series will not always answer the question "What would it have cost to do the research of year 'a' if it were performed in year 'b'?" In year "b" for example, the researcher might have a choice of different instruments, equipment, and materials, or might employ a different mix of personnel to accomplish the same research objectives. If the question were asked retrospectively, the answer might be that the research of period "b" could not have been performed in earlier period "a" because the state of knowledge and technology would not have permitted it.

The price index series presented here will contribute to answering such questions as what dollar levels of R&D support correspond to employment of a given number of scientists or engineers, but other factors ought not be ignored. In addition to prices, changes in the nature of research programs, in the amount of capital or supporting personnel per scientist, in indirect costs, and in productivity and the underlying technology also affect in important ways the average cost of R&D performance on a per scientist basis.

The fact that the price index is based on direct costs limits its usefulness for deflation of aggregate academic R&D expenditures, which include indirect costs. Unfortunately, the information on hand does not provide a sufficient basis for explicit inclusion of indirect cost changes in the price index. Consequently, the use of the price index series for deflation of R&D expenditures data implies that indirect costs have changed proportionately to direct costs.

Considering the composition of indirect cost expenses as compared with direct costs, it seems likely that indirect costs have not increased, on the average, more than direct costs and may in fact have increased less. This reasoning follows from the large weight of professional compensation in direct costs, and their higher rate of increases as compared with salary and wage trends of administrative and service personnel usually charged to indirect costs. Salaries and wages of nonprofessional personnel and prices of nonpersonnel expenses in the direct and indirect cost categories probably follow the same general pattern. It appears, therefore, that the price index for direct costs would not err to an important extent as an indicator for total R&D costs.

There is a difficulty, however, in deflating R&D expenditures by the price index for direct R&D costs which stems from the nature of the expenditures data. Indirect costs, particularly for federally funded projects, have been assuming increasing importance in the expenditures estimates. Thus, over the period 1964 through 1970 the ratio of indirect costs to wage and salary direct costs for federally funded projects increased from an estimated 27 percent to 32 percent. An important portion of this increase may be due to changes in Federal regulations which have allowed greater reimbursement of indirect costs and, it is hypothesized, led to more complete reporting of indirect costs. This possibility would be consistent with the NSF survey request for reporting of indirect costs attributable to sponsored research projects only to the extent that these indirect costs are "reimbursed or reimbursable."

A fixed weighted index fails to correct for changes in the scope and composition of the expenditures estimate, whatever the cause. Thus, the reported greater amount of indirect costs in current expenditures tends to overstate the increases in real R&D resources. Over the six-year period 1964–70, the annual increase in constant dollar terms of direct cost components of R&D project funds is 5.2 percent. The apparent annual increase in constant dollar terms of total academic R&D expenditures would be 5.6 percent, when total expenditures are deflated by the price index for direct costs. The lower estimate is believed to be the better approximation of the change in "real" resources available for academic R&D activities.[4]

Since the price index series combines estimated input price trends with input expenditures distribution weights, it can be described as an "input price index." For some purposes, an input price index should take account of productivity changes.

[4] This computation can be made only for the period 1964 through 1970, for which R&D direct and indirect expenditures are available.

But in common with many service activities, no satisfactory measure of the productivity of research workers exists which might serve to introduce a productivity adjustment.

The form of the index holds constant all factors other than price change that might affect the level of expenditures. As noted earlier, the mix of inputs, and implicitly the mix of programs, is held constant by fixed weights corresponding to the various categories of inputs in the base period. The salary and wage trend series selected as representative of research compensation costs attempt, imperfectly, to standardize qualifications of personnel by rank or occupational categories and levels. The trend series used as representative of nonpersonnel costs is itself a composite of price series, for the most part WPI components, which are standardized to eliminate nonprice changes to the extent possible.

Other important questions relate to the validity of the data for use in the index computations. The problems are relatively more important with respect to data on compensation and other direct costs than with respect to the weights. The following sections on index methodology and data problems discuss these subjects in more detail.

Part II

PRICE INDEXES AND DEFLATION—GENERAL CONCEPTS AND METHODOLOGY

Price Index Formulas

The concept of a price index—a complicated system like the Consumer Price Index (CPI) or Wholesale Price Index (WPI) or a relatively simple one such as the present R&D price index—can be generalized by discussing it in terms of the dollar aggregate to which it is intended to apply. A change in dollar levels of this aggregate over time can be considered to be the combined effect of changes in price and quantity levels, holding the scope of the aggregate unchanged. This relation can be expressed as $V = P \times Q$ where V, P, and Q are value aggregate, average price and quantity ratios for the periods compared.

In order for the identity above to hold, the units for price and quantity measurement must be consistent. In addition, the algebraic form of the price ratio is related to the algebraic form of the quantity ratio. For a binary comparison of periods "i" and "o", if the price ratio is weighted by earlier period "o" quantities (Laspeyres) the quantity ratio must be weighted by current period (Paasche) unit prices for the product of the ratios to satisfy the identity. Reversing the quantity weights requires reversing the price weights. This illustrates the importance of a clear definition of the quantity units which are valued in the summation to the aggregate under analysis. For this it is necessary to have an unambiguous demarcation of the scope of the value aggregate and the nature of its components.

The R&D price index series is computed by the weighted average of price relatives formula derived from the simple aggregative form of price index as follows:

1. $$I_{i:o} = \frac{\sum_j p_{ij}\, q_{oj}}{\sum_j p_{oj}\, q_{oj}} \times 100$$

or

2. $$I_{i:o} = \sum_j \left[\frac{p_{oj}\, q_{oj}}{\sum_j p_{oj}\, q_{oj}} \right] \left(\frac{p_{ij}}{p_{oj}} \right) \times 100$$

The expressions above represent the price index for period "i" with respect to period "o" taken as the reference period equal to 100. Ideally such an index number should be based on a sample of well-defined items "j" representative of the composition of the aggregate under study. The price relatives or ratios, $p_{ij} \div p_{oj}$, will reflect actual price change to the extent that the items whose prices are compared are in fact equivalent and are priced under corresponding market conditions in time periods "i" and "o". Defining and maintaining equivalence in the actual collection and use of price data is the heart of the index number problem.

In formula 2, the weighted average of price relatives form, the weights (in brackets) are expressed as proportions of the total value aggregate which each priced item represents in a specified weight base period. This is derived from the sampling plan or imputation design. Thus, priced items "carry" not only their own weights but share the total weight of unpriced items.

For the academic R&D price index the summation is over expenditures categories "j", rather than over individual purchases. In formula 2, the weighted average of price relatives, the weights are, therefore, proportions which the categories comprise of the base year expenditures aggregate corresponding to the index scope. These are the index weights shown in percentage terms in table 5 of part III. Likewise the price relatives of the academic R&D price index, or ratios $p_{ij} \div p_{oj}$ of (2), are averages for the expenditures categories. For indexes such as the Consumer Price Index (CPI) the latter are derived by a sampling of item prices combined with appropriate internal weights within categories of expenditures. For purposes of the R&D price index, price relatives derived from sources described in part III, and referred to as "proxies" or "surrogates," are imputed to the expenditures categories.

Once the weights of a fixed weighted price index are determined and the sample of items to be priced (or proxies to represent them) are selected, the index structure may remain substantially unchanged for a long time. When price levels of two recent periods are compared by means of such indexes, neither period being the weight base period, the user should understand that the system of weights originally derived is still in control.

The remark above applies literally to the quantity weights of the weighted aggregate form but requires a further interpretation with regard to formula 2. For example, the price levels of periods "i" and the preceding period "i-1" can be compared using the price indexes calculated with period "o" quantity weights. When the algebra of this comparison is written out using the average of price relatives form, the proportionate value weights are seen to have taken account of changes in relative prices subsequent to the original base period. However, the implicit base period quantity components of these proportions are unchanged. Thus, the derived index for period "i" with respect to period "i-1" is:

$$3. \quad I_{i:(i-1)} = \sum_j \left[\frac{p_{(i-1)j}\, q_{oj}}{\sum p_{(i-1)j}\, q_{oj}} \right] \left(\frac{p_{ij}}{p_{(i-1)j}} \right) \times 100$$

These comments refer to index number mechanics but the mechanics are not trivial: they determine the meaningfulness of the resulting price change measure. For example, items priced for the Consumer Price Index are chosen to be representative of the purchases of urban consumers—the so-called "market basket"— and the CPI is therefore considered to reflect changes in purchasing power of income of urban consumers.[5] The fixed weighted index structure pinpoints the limitations of such a measure—it cannot adequately reflect consumers' adoption of new products or shifts in purchases in response to differential price changes, considerations which are fundamental to a more theoretically oriented cost-of-living measurement. And of course there is the always present problem of matching prices from one period to another taking correct account of quality changes. All of these problems are present in measurement of price change for research and development as well.

Deflation of Value Aggregates

Deflation is the process of converting a value aggregate with defined scope expressed in dollars of the period in question to the price level of a reference period. When a time series of value aggregates is deflated this may be referred to as conversion to constant dollars since the data for all periods are reduced to the same (reference period) money standard. Comparison of constant dollar estimates for several years can also be said to reflect differences in real physical quantities in the sense that the variable effects of price change on the dollar estimates are removed.

Conversion to constant dollars may be accomplished by deflating with a single composite price index series or separately for detailed components of the value aggregate. Deflation of components is the preferred procedure since it provides the opportunity to select separate price index series that best match individual components. When the latter procedure is employed, the byproduct is a current weighted (Paasche) price index corresponding to the composition of the aggregate under consideration. This is calculated as the ratio of the original current dollar aggregate to the sum of the deflated components (and multiplied by 100 to convert it from the ratio to the index form).

In algebraic notation the objective of deflation is to convert a value aggregate of a current period, $\sum_j p_{ij}q_{ij}$, into $\sum_j p_{oj}q_{ij}$. Performing the deflation in detail is expressed:

$$\sum_j \frac{p_{ij}\, q_{ij}}{\left(\frac{p_{ij}}{p_{oj}}\right)} = \sum_j p_{oj}\, q_{ij}$$

[5] See reference 19.

Using the appropriate Paasche price index for direct deflation of the value aggregate would give the identical result:

$$\frac{\sum_j p_{ij} q_{ij}}{\left(\frac{\sum_j p_{ij} q_{ij}}{\sum_j p_{oj} q_{ij}}\right)} = \sum_j p_{oj} q_{ij}$$

A price index which embodies fixed quantity weights will provide an acceptable deflator for a time series of value aggregates when there are no significant shifts in composition of the aggregate. As demonstrated above, Paasche weighted price indexes that are individually tailored to the data of each time period satisfy the requirements exactly. In actual practice, Paasche price indexes are not available; however, index weights are usually revised periodically to bring them in line with changing conditions.

As described in the index number algebra above, division of the current dollar GNP by the sum of the deflated GNP components produces the GNP implicit deflator for that period, in concept a current-weighted price index.[6] Comparisons of implicit deflators for years other than the 1958 dollar base now in effect reflect changes in the composition of the GNP as well as price changes. This presents a problem in using implicit deflators as measures of quarterly price changes, but for annual price changes the shifts in weights are not an important factor.[7]

The implicit deflators of the gross national product (GNP) have been receiving increasing attention as measures of changes in general price levels because of their comprehensive framework within which price trend data from many sources are synthesized. Deflation of the GNP is accomplished in considerable detail, elements of current dollar GNP being deflated by price indexes selected from the CPI, WPI, other price data sources, and special indexes constructed by the BEA staff. In some cases the deflation is by relatively homogeneous products, in other cases the deflation is by large categories using summary indexes—the detail of the GNP and of available price trend sources determines how the deflation process is accomplished.[8]

[6] Pragmatically, this is a hybrid Paasche index since the price indexes used for the deflation of components embody weights of earlier periods.

[7] See reference 34.

[8] See reference 20.

Government payments to private academic institutions to finance expenditures for research and development are classified in the national accounts as government purchases of research services. These research expenditures are included as part of the broader government sector category "services including compensation" whose components are deflated by various combinations of CPI and employment trends data. Non-Federal research at private universities is included in the "private education and research" component of GNP personal consumption expenditures and is deflated by an index which gives the major weight (75 percent) to the trend in average annual earnings for private higher education and the remaining weight to the Industrial Commodities component of the WPI. Expenditures for research at public universities, including activities funded by the Federal Government through grants in aid, are intermingled with other State-local expenditures. Estimates of personnel compensation in constant dollars are secured by extrapolating base year compensation data by trend data on State-local employment in education, rather than by deflation. Nonpersonnel R&D expenditures (not separately identified) in other segments of the State-local accounts are deflated by a variety of price indexes from secondary sources.[9]

R&D Price Indexes

In the case of R&D expenditures all of the considerations discussed earlier apply. We are most interested in deflating current (or prospective) expenditures and therefore want price index series that reflect the composition of current (or prospective) R&D expenditure aggregates. The difficulty is twofold: lack of information on the composition of the current (or prospective) aggregate and lack of information on price change directly relevant to R&D activities.

In the absence of published and authoritative price indexes for research and development, analysts have had to adopt convenient expedients. A frequently used expedient has been the GNP implicit deflator, or a major component of it, selected on the basis of its comprehensive scope. Other more ambitious expedients have involved combining (weighting) several major components of the CPI or WPI with some measure of trend in cost of personnel compensation.[10]

[9] The remarks in this paragraph are based on information supplied by the Bureau of Economic Analysis, U.S. Department of Commerce.

[10] An early use of this approach is described in reference 1.

A number of years ago the Bureau of Labor Statistics undertook to develop and test the methodology for a price index representative of Army R&D activities. This work was sponsored by the National Science Foundation at the request of the Department of the Army. The BLS studied the patterns of expenditures of intramural Army R&D activities and contractors' laboratories and selected a large sample of items and services representative of these expenditures for pricing. Price data were compiled for the period 1961–65 on the basis of purchase data (including personnel compensation) provided by the laboratories or secured from vendors. Many difficulties were encountered but the conclusion was that such an index system was feasible, but expensive. No other attempt has been made on this scale to develop an R&D price index. The BLS report on this work is recommended for its careful discussion of methodological, conceptual and operational problems.[11]

Several published reports have presented indexes of changes in R&D costs per scientist or engineer engaged in R&D work.[12] These results may be described as price indexes—the definitions of price and cost are flexible—but they do not satisfy the objective described in this paper, namely, isolating the effect of inflation on R&D funding levels. The change in cost per scientist combines the inflation effect with the effects of changes in the proportions of different types of research performed with disparate cost patterns. Also important are the effects upon such an index of advances in science and technology which make available more versatile and powerful instrumentation and change personnel and other costs. To determine the change in "real" R&D costs per scientist, the inflation effect should be removed, i.e., the index of R&D costs per scientist or engineer requires deflation by an R&D price index.

The two kinds of indexes have one point in common: They can be used to derive estimates representing levels of effort. Deflating current R&D expenditures estimates by price indexes results in dollar funding levels, which are proportional to the "real" resources utilized or consumed in the R&D activities of the periods compared (on a basis corresponding to the assumptions built into the price index mechanism). The indexes of R&D costs per scientist or engineer can be used to deflate R&D expenditures data to equivalent levels of effort in terms of scientific and engineering manpower.[13]

The R&D price index approach, in detail as in the BLS study of Army R&D activities, or in gross terms as in the present study, has been criticized on the grounds it does not measure changes in prices of R&D outputs. This is obviously true: the expenditures aggregates to which the price index series corresponds represent outlays or expense charges for inputs to R&D activities and not values of R&D outputs. In the current state of economic statistics there are no satisfactory direct ways to measure the total outputs of R&D activities. This parallels the government sector of the economy for which expenditures are also used as indicators of level of activity. It is conceivable that at some future date techniques for measuring output of such sectors will be developed.[14]

The fixed weighted R&D price indexes have limitations even as measures of changing costs of inputs. Research project directors can choose new mixes of personnel, materials and equipment to perform essentially the same kinds of research work as earlier projects. The changes could be made to take advantage of favorable relative price changes and of the availability of improved or new materials, instruments, and equipment. Just as cost-of-living theory suggests with regard to personal consumption, the real costs of performing R&D work might be reduced by adjustments of purchases to the new conditions even when prices for exactly comparable cost items have not changed. The difficulties of trying to introduce such considerations into index computations are also parallel. Since the accomplishments or outputs of R&D activities cannot be quantified (just as consumer welfare or satisfaction cannot be measured), it is impossible to calculate the costs of changed sets of inputs that will achieve equivalent results or outputs in different periods. Thus, while not ideal, an input price index approach, with fixed weights, is a pragmatic way to measure effects of inflation on R&D funding levels.

Another operational approach to measuring historical change in R&D prices over some past period

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[11] See reference 4.

[12] See references 3 and 5.

[13] Estimates of full-time-equivalent (FTE) scientists and engineers employed in all R&D work have been developed by the NSF on the basis of its periodic sectoral studies of R&D funding (reference 11). Thus there is no need to derive estimates of total scientist/engineer manpower effort level by the deflation route. The technique described may be useful for providing manpower estimates for component groups and for making projections.

[14] Preliminary results of a study of government productivity were announced as this report was being completed. The study utilized some 600 measures of output for selected kinds of government operations. *New York Times*, May 24, 1972.

is to select a sample of recent R&D projects and attempt to secure from the project managers or business directors of their organizations retrospective estimates of what the costs would have been several years back. This is analogous to repricing a specified structure to produce a construction cost index. The rules of the game are that the estimates be in terms of current resource requirements for the project (i.e., as of the period the projects were actually performed) and realistic prices as of the retrospective pricing period. This is couched in terms of retrospective pricing because of the availability of necessary project expense detail to provide a basis for such estimates. If this could be done and the results properly aggregated (weighted) one would have a measure of input price change. Having established benchmarks, presumably the same projects could be repriced in subsequent periods.

The National Association of College and University Business Officers (NACUBO) attempted an experimental project along the lines briefly sketched above. A sample of two or three departments in over 40 universities (representing 10 science and engineering fields) was surveyed to develop retrospective cost information for 1966 for approximately 400 designated research projects active in 1969. The National Science Foundation was interested in this as a methodological effort and provided some technical assistance. The results of the NACUBO effort were not encouraging. It appears that a very limited amount of information on retrospective or current project inputs or prices can be secured through a survey relying completely on mail responses; however, as more institutions expand their computer systems, it is likely that additional detail would be available. Nevertheless, the questionnaires returned in the survey were useful, on a selective basis, in resolving questions concerned with developing the present price index.

Part III

METHODOLOGY AND DATA BASE

The Index Weights

The index weights in table 5 have been estimated for the fiscal year 1967 reference period from data derived in the NSF biennial surveys of universities and colleges covering R&D funding for academic years 1965-66 and 1967-68.[15] Summaries of NSF survey information on R&D expenditures in academia appear in tables 6 and 7.[16] Data tabulated from proposals to NSF for Scientific Research Project Support grants contributed to estimating subcategories not reported in the surveys.

Excluding indirect costs, wages and salaries comprised 64.5 percent of direct costs in 1965-66 and 65.1 percent in 1967-68. For the 1967 weighting pattern rounded figures of 65.0 percent for wages and salaries and 35.0 percent for nonpersonnel direct costs were used. Some institutions not allocating personnel fringe benefits to research projects may have reported them as overhead costs. Likewise uniform treatment for charging costs of various services performed by universities for R&D projects cannot be assumed. For example, clerical services, university computing, printing and duplicating, and similar services may not always be directly charged to research projects; in some cases they may be included in overhead costs. It does not appear that possible differences in reporting would have important effects upon the 65 percent-35 percent division of direct costs between personnel and nonpersonnel charges.

TABLE 5.—*Percentage weights of academic R&D price index, fiscal year 1967*

Category	Percent of direct costs
Total	100·0
Personnel compensation	65·0
Professional	48·3
Faculty	20·2
Research associates	16·7
Graduate students	8·0
Other professional, nondoctoral	3·4
Nonprofessional	16·7
Technicians	9·9
Shop-craftsmen	3·4
Secretarial-clerical	3·4
Nonpersonnel direct costs	35·0

Source: National Science Foundation.

The next stage of development of the weighting pattern was to derive personnel subcategories that are meaningful in relation to functions performed and the manner of organization of academic R&D projects and that are also relatively homogeneous in terms of compensation trends. The term "compensation" is used rather than "salary" or "wage" because the objective is to measure trends in compensation including fringe benefits, although for some categories of personnel this was not possible.

[15] Almost all of the academic R&D expenditures are for research described in the NSF survey questionnaire as ". . . a systematic, intensive study directed toward fuller knowledge of the subject studied. Research may be either basic or applied . . ." Approximately 5 percent of expenditures is for development which embraces ". . . the systematic use of knowledge directed toward the design and production of useful prototypes, materials, devices, systems, methods, or processes . . ."

[16] The NSF surveys and R&D expenditures estimates cover all separately organized research activities at institutions of higher education, including medical schools and agricultural experiment stations. In addition, part of expenditures for regular operations of science and engineering departments reported in these surveys as "instruction and departmental research" is added to the estimates of expenditures for academic research on the basis of more detailed reports secured some years ago. Data on R&D activities at Federally Funded Research and Development Centers (FFRDC's) administered by universities and consortia are collected through the biennial surveys but are excluded from the estimates of academic R&D expenditures discussed in this paper.

If an academic R&D price study were to be performed on a large scale, individual specializations would be identified and their shares of the total compensation weight estimated. For measuring compensation trends, the specialization would in some cases be further identified by professional level, years of experience, or educational requirements (or a combination of these criteria) to confine the intertemporal comparisons within narrow bounds. The BLS annual National Survey of Pro-

TABLE 6.—*Current R&D expenditures in universities and colleges, by principal cost categories and source of funds, academic years 1964, 1966, 1968, and 1970* [a]

[Dollars in millions]

Cost item	Total		Federal Government		Other sources	
	Amount	Percent distribution	Amount	Percent distribution	Amount	Percent distribution
	1964					
Total	$1,594·9	100·0	$ 917·3	100·0	$ 677·6	100·0
Direct wages and salaries	870·6	54·6	458·0	49·9	412·6	60·9
Other direct costs (materials, supplies, expendable equipment, etc.)	489·5	30·7	334·0	36·4	155·6	23·0
Indirect costs [b]	234·8	14·7	125·4	13·7	109·5	16·2
	1966					
Total	2,084·7	100·0	1,261·0	100·0	823·7	100·0
Direct wages and salaries	1,133·6	54·4	636·0	50·4	497·6	60·4
Other direct costs (materials, supplies, expendable equipment, etc.)	625·4	30·0	442·5	35·1	182·9	22·2
Indirect costs [b]	325·7	15·6	182·5	14·5	143·2	17·4
	1968					
Total	2,598·7	100·0	1,572·1	100·0	1,026·6	100·0
Direct wages and salaries	1,422·2	54·7	802·7	51·1	619·5	60·3
Other direct costs (materials, supplies, expendable equipment, etc.)	761·5	29·3	534·7	34·0	226·7	22·1
Indirect costs [b]	415·0	16·0	234·6	14·9	180·4	17·6
	1970					
Total	2,856·4	100·0	1,658·3	100·0	1,198·1	100·0
Direct wages and salaries	1,597·0	55·9	870·4	52·5	726·6	60·6
Other direct costs (materials, supplies, expendable equipment, etc.)	778·5	27·3	512·6	30·9	265·9	22·2
Indirect costs [b]	480·9	16·8	275·2	16·6	205·7	17·2

[a] In addition to separately budgeted R&D expenditures, figures include estimated expenditures for departmental research and other R&D activities for which universities and colleges do not maintain separate records, which amount to about one-sixth of the overall total for each of the years. The estimates do not include R&D expenditures of university-administered FFRDC's.

[b] Includes overhead costs incurred in R&D performance, such as expenditures for general administration, operation and maintenance of physical plant, etc.

Note: Details may not add to totals because of rounding. Percentages were computed on the basis of unrounded figures.

Source: National Science Foundation; based on Surveys of Scientific Activities of Institutions of Higher Education.

TABLE 7.—*Direct wages and salaries for separately budgeted research and development in universities and colleges reporting such information, academic year 1966* [a]

Item	All institutions	All units except medical schools and experiment stations	Medical schools	Agricultural experiment stations
	Thousands of dollars			
Direct wages and salaries, total	$578,528	$312,398	$138,709	$127,421
Instructional staff (instructors or higher	177,223	89,919	46,172	41,132
Research professors and associates	146,872	78,800	36,237	31,835
Employed graduate students	72,574	53,054	6,060	13,460
All other personnel	181,859	90,625	50,240	40,994
	Percent distribution			
Instructional staff (instructors or higher	30·6	28·8	33·3	32·3
Research professors and associates	25·4	25·2	26·1	25·0
Employed graduate students	12·5	17·0	4·4	10·6
All other personnel	31·4	29·0	36·2	32·2

[a] Direct wages and salaries in respondent institutions totaled $579 million, or 63 percent of the estimated $912 million for separately budgeted research and development in all institutions in the survey.

Source: NSF Survey of Scientific Activities of Institutions of Higher Education.

fessional, Administrative, Technical, and Clerical Pay (PATC) specifies jobs by category and level to produce comparable trend data. Similar techniques were also employed in the Army R&D price index project conducted by the BLS. The personnel categories established for the present work are rather broad. However, the individual compensation trend series that are used as proxies for the academic R&D price index are standardized at their sources somewhat in the manner suggested here. The major question about their use here is the appropriateness of selection.

There are problems in defining personnel categories for academic research and development which are unique to this sector. The faculty staff—both tenure and nontenure—play important roles in academic research as project directors, principal investigators, and faculty associates. Because there is a structured system of faculty salaries and fringe benefits and changes can be followed through established surveys of academic institutions this is a natural point of departure. It should be noted, however, that the price index is concerned with changes in compensation for time charged to R&D projects and included in the expenditures estimates. Whatever time faculty members contribute to research work when carrying a full-time teaching load without receiving additional compensation for their research efforts would not enter the expenditures estimates or affect the price index.

The research associates engaged in academic research are also a unique factor. These are professional scientists or engineers, usually with doctoral status (Ph.D. or M.D.) but usually without faculty rank or perquisites. Their attachment to the university is generally marginal although research appointments may be stepping stones to more permanent affiliations. The research associates group includes both senior research associates and postdoctorals. The senior research associates are more experienced, have more prestige, and receive higher salaries than their junior colleagues. The postdoctorals are usually within five years of their doctorate and are for the most part engaged in research projects to gain additional experience, competence and recognition. Although there are differences in salary level, NSF data for research grant proposals processed over recent years suggest that somewhat similar patterns of change prevail.

A major reason for universities' participation in research projects is to further the education of graduate students and to provide opportunities for dissertation work. Although these graduate students are working at the professional level as scientists and engineers they are generally separately reported as in table 7 because of the interest in graduate education. Graduate students employed as technicians are included in the latter group according to survey instructions.

Other professional level staff are included in a category "other professional, nondoctoral." The difficulty is distinguishing such professionals from "technicians" who are nonprofessional level research staff. Technicians are working ". . . in positions which involve technical work at a level requiring knowledge . . . such as that obtained at technical institutes and junior colleges or through on-the-job experience . . ."

Comprehensive estimates of full-time-equivalent research scientists and engineers, graduate students, and technicians have been developed through the NSF surveys. These estimates are shown in table 8 for universities and colleges inclusive of medical schools, and for medical schools separately. The ratios of graduate students and technicians to scientists and engineers in medical schools are significantly different from the ratios for all academic institutions. Medical schools employ few graduate students but have large numbers of auxiliary technical staff.

The remaining categories of personnel are shop-craftsmen—who are skilled employees but not research technicians—and secretarial-clerical staff. Information on these categories is rather scanty but they are shown as separate components of the weighting structure to indicate the outlines of a meaningful classification system.

To recapitulate, the proportions of the total personnel weight assigned to faculty, research associates, and graduate students are based on the 1965-66 NSF survey data for separately organized academic research, recognizing that the survey categories do not exactly correspond to those used. The weights for the remaining categories are crude estimates suggestive of magnitudes rather than of precise dimensions. Because of different ways of classifying auxiliary personnel the distribution of the weights among the "other professional, nondoctoral," "technician," and "shop-craftsmen" categories could be significantly altered. It will be seen, however, that the salary trends that will be associated with these categories for the index computations are very similar. Therefore, the composite R&D price index would be little altered if these weights were to be distributed somewhat differently.

The nonpersonnel direct costs weight could be approximately suballocated to budget categories such as permanent equipment, expendable supplies and equipment, travel, computing costs, printing and publication, and miscellaneous costs. This could be done on the basis of NSF grants data or the returns to the NACUBO survey described earlier. The reasons for treating nonpersonnel costs on an aggregate basis are discussed below in the context of price trend "proxies" or "surrogates."

TABLE 8.—*Full-time-equivalent numbers of professional and technical personnel in academic research and development,*[a] *January 1971 and selected prior dates*

[In thousands]

Category	March 1958	March 1961	January 1965	January 1967	January 1969	January 1971
Universities and colleges, including medical schools:						
Scientists and engineers	29·2	33·6	40·4	47·5	50·4	49·8
Graduate students[b]	7·3	8·8	13·0	16·6	17·9	18·6
Technicians[c]	N.A.	N.A.	28·1	30·9	32·3	31·9
Medical schools:						
Scientists and engineers	N.A.	N.A.	13·0	13·8	15·6	16·3
Graduate students[b]	N.A.	N.A.	·9	1·4	1·3	1·5
Technicians[c]	N.A.	N.A.	11·5	13·8	14·3	15·3

[a] Excludes health professionals engaged primarily in patient care and other clinical activities and personnel employed at Federally Funded Research and Development Centers.

[b] Full-time equivalent of graduate students receiving compensation for part-time services as scientists and engineers.

[c] Defined as ". . . persons employed in positions which involve technical work at a level requiring knowledge . . . such as that obtained at technical institutes and junior colleges or through on-the-job experience . . ."

N.A.—not available.

Source: Based on NSF Surveys of Scientific Activities of Institutions of Higher Education.

Compensation and Price Trend "Proxies"

It would be desirable to match the index components with price trend series that reflect actual changes in salaries, fringe benefits, and prices paid by the academic sector. However, specific index series representing price trends for R&D input costs are not available. This makes necessary reliance on secondary sources and selection of trend data considered most relevant.

The American Association of University Professors (AAUP) conducts annual surveys of faculty salaries and compensations in universities and colleges, and publishes an annual report on the economic status of the profession.[17] The report includes data on salaries, fringe benefits, compensations, increases in salaries and compensations for full-time faculty members (on a 9-month basis). The survey has grown over the years from less than 400 institutions in the early 1960's to more than 1,300 for the 1970-71 survey.

The AAUP, in calculating salary and compensation increases for institutions reporting comparable data in consecutive years, uses what amounts to a Paasche index in which the numbers of faculty members in each rank in the most current year are used as weights. Percentage changes computed by AAUP have been linked together for the R&D index computations in the form of a chain index with 1967 as 100.

The Paasche-chain computation described above provides a better indication of changes in compensation than do unadjusted data for whatever institutions have reported for the different years. A comparison of survey results, i.e., of averages based on the total respondents of each year, shows lower increases as the AAUP sample was enlarged through the addition of small universities and colleges with lower pay scales.[18]

An index, compiled on the Paasche-chain basis, with AAUP data for changes in compensation in all faculty ranks, all institutions, has been used as representative of the trend of compensation for faculty participants in academic research. The compensation data include, in addition to salary payments, such fringe benefits as are reportable for purposes of the AAUP survey; for example, the institution contribution to retirement is included only if it is vested in the faculty member within five years. The AAUP surveys indicate a somewhat larger relative increase over the last decade for total compensation than for salaries alone.

With about 95 percent of academic R&D expenditures accounted for by universities, including associated medical schools, trends relating to faculty compensation in universities only would be more directly relevant for the R&D price index. However, information for universities was not available separately in a consistent manner over the period so that the preferred selection could not be used. Comparisons of the limited published university data available, and unpublished AAUP data for 94 universities for which survey returns are available for academic years 1960-61 through 1968-69, with the published information for all institutions indicate that any error resulting from this factor would not be important.

Since medical schools are excluded from the AAUP trend data the possibility of developing a different compensation trend proxy for medical school faculty was explored. Published data indicate that the average salary received by faculty in clinical departments is higher at all ranks than that received by their counterparts in other parts of academia, including nonclinical departments of medical schools. However, suitable trend data for medical school faculty are not available for use in this study.[19] For the present AAUP data must be assumed as representative of all academic faculty, including medical.

The most important concern with regard to the AAUP data is whether the trend in compensation of all faculty, computed separately by faculty rank and weighted on a Paasche basis, is the appropriate surrogate for science faculty engaged in research. This concern arises because science and engineering departments have been relatively affluent in recent years, the inference being that promotions in faculty rank have come more easily to members of science and engineering department faculties. If this is true, the AAUP compensation comparison, constrained within faculty levels, would miss part of a real rise in compensation that may have occurred for a faculty engaged in R&D projects.

Somewhat related to the question above is the appropriateness of the "all ranks" compensation trend reflecting total faculty composition weights. The AAUP data reweighted with faculty counts by rank which correspond to R&D participation would be more appropriate. However, data do not exist

[17] See reference 26.

[18] The AAUP technique of comparing data for matched institutions in consecutive year surveys is especially advantageous because the AAUP approach has been to build up coverage of academic institutions rather than to employ probability sampling methods.

[19] Surveys of medical school faculty salaries have been conducted since 1960 by the Association of American Medical Colleges (AAMC). However, the AAMC data are not available in the detail needed for this study. See reference 25.

for this reweighting. As a practical matter, this is unimportant since the differentials between compensation trends of the various faculty ranks are small.

Selection of a compensation trend to "represent" research associates presents a difficult problem. These persons are academically oriented, many of them planning a career in universities. It therefore seems appropriate to assume that their compensation is related to the salary and compensation scales of faculty. Such an assumption may be particularly cogent with respect to senior research associates who account for about a tenth of the research associate dollars in recent NSF grants proposal data. On the other hand the research associates, particularly the postdoctorals whose research participation represents a continuation of their educational training, are, in a sense, "captives" of the universities which provide the research opportunities they require. Research associates may therefore not share equally in compensation advances with faculty.

There is a similar problem with regard to graduate students. If it can be said that research associates are "captives" of their institutions, this would be true to a greater degree for graduate students employed as part-time research assistants. For example, the payments received by graduate students as research assistants may be regarded as stipends which are oriented to changes in tuition and living costs rather than to university salary trends. Continuing this line of thinking, payments to graduate students might be affected by the availability of research project funds—as funds become tight the academic institution has the flexibility to apply less liberal stipend policies.

The NSF grants data indicate a considerably lower increase over the period 1966 through 1970 in average planned monthly payments (calculated on a full-time basis) for both research associates and graduate students than for faculty members. However, the data extend back only to 1966 and reflect changes in institutional and research components which could affect the results. Other information relevant to these questions are returns to the NACUBO survey. Examination of reported salary changes for research personnel over the 3-year period 1966-69 showed some similarity of change for faculty and research associates but a smaller increase for graduate students.

With only fragmentary and inconclusive information as guides, the final selection of proxy trends to represent compensation of research associates and graduate student research assistants must be judgmental. The assumption was made that compensation of research associates paralleled the trend indicated by AAUP data for instructors; the graduate student compensation trend proxy was derived by imputing one-half the annual increase in the instructors' compensation trend to graduate students. Over the 1961-71 period the instructors' compensation increase imputed to research associates was 82 percent, the decade increase imputed to graduate students was 36 percent. For research associates and graduate students combined the decade increase in the price index computations was 65 percent compared with 88 percent for faculty engaged in academic R&D work.

Auxiliary research personnel in the categories "other professional, nondoctoral," and "technicians" are necessary to provide backup services to the principal investigators and research associates. The need for the types of services they provide varies with the nature of research performed. For example, referring to table 8, it is estimated that one technician was needed for every scientist or engineer (excluding graduate students) engaged in research at medical schools. In other university research there appeared to be one technician for every two scientists or engineers.

Technicians and nondoctoral professional personnel provide the continuing services that generally are outside the professional interests (or training) of the faculty, research associates, and graduate students. It is stated this way because a major justification of research activities at universities is to provide opportunities for participation by the latter groups. It seems logical, therefore, to assume that compensation paid to such auxiliary research personnel would be determined by competitive conditions for their specializations in the general labor market. As an approximation of these market conditions a composite trend of salaries for five scientific, engineering, and technician occupations as published in the BLS reports on its annual National Survey of Professional, Administrative, Technical and Clerical Pay (PATC) was used as a surrogate for both the "other professional" and "technician" categories. Although the same trend was imputed to each class of personnel they have been maintained as separate categories in this study to call attention to the need for more definitive information on compensation trends for the range of occupations each embraces.

For the residual nonprofessional categories of "shop-craftsmen" and "secretarial-clerical" personnel, the assumption was again made that compensation is determined by competition in the open labor market. Although this might not be entirely true of secretarial and clerical personnel because of the opportunity to utilize part-time services of students, or relatives of students and university personnel, a composite of industry wage trends for nine clerical occupations based on the PATC surveys was used to represent the secretarial-clerical group. For the "shop-craftsmen" category a composite of wage trend for six maintenance and toolroom occupations was used as a proxy series, developed from the annual BLS Area-Wage Surveys in metropolitan areas.

The BLS surveys on which the trend proxies for nonprofessional and other professional personnel are based insure comparability of data from one period to the next by detailed specification of target occupations and by scientific sampling and careful weighting.[20] The jobs for which wage or salary data are collected are defined ". . . to identify the essential elements of skill, difficulty, and responsibility that establish the basic concept of the job."

The PATC survey data are available as of June of each survey year from 1961 through 1971 and fiscal year trends were derived for purposes of the study by interpolation. The same procedure was followed with published calendar year data for years 1961 through 1970 from the BLS Area-Wage Surveys. To complete the 10-year trend series on a fiscal year basis, the fiscal years 1969-70 changes of the proxy series were extrapolated forward through fiscal year 1971, the fiscal years 1962-63 changes backward through fiscal year 1961. These extrapolations are supported by data on trends of earnings in manufacturing industries.

The compensation, salary or wage trend series described in the preceding paragraphs are shown in table 9. Despite the different occupations represented in the three salary and wage trend proxies developed from the BLS surveys to represent the "other professional" and technician, shop-craftsmen, and secretarial-clerical categories, the trends are very similar. They differ, however, as compared with faculty compensation trends. The validity of the assumptions underlying the selection of compensation trend proxies for nonfaculty personnel therefore appears to depend upon the extent to which university policies with regard to faculty salaries carry over to determination of salary and wage scales for other university personnel. The missing factor here is a set of university sector salary and wage surveys relating to research personnel and comparable with the BLS industry surveys to provide definitive information and eliminate the need for conjecture.

There are, of course, other sources of data that were considered for selection as compensation trend

[20] See references 28, 29, and 30.

TABLE 9.—*Selected compensation and price trend series used as proxies for R&D index analysis, fiscal years 1961–71*
[1967 = 100]

Fiscal year	Faculty compensation trends		Industry salary and wage trends			Nonfinancial corporations
	All ranks (1)	Instructors (2)	Selected S/E/T occupations (3)	Clerical occupations (4)	Maintenance and tool room occupations (5)	Implicit deflator (6)
1961	69·6	72·0	N.A.	N.A.	N.A.	94·3
1962	74·1	76·4	85·4	86·7	85·0	94·8
1963	78·4	80·5	88·2	89·0	87·8	95·2
1964	82·3	84·1	91·1	91·4	90·4	95·8
1965	87·3	88·6	93·8	93·7	92·9	96·9
1966	93·6	94·3	96·6	96·2	96·1	97·3
1967	100·0	100·0	100·0	100·0	100·0	100·0
1968	107·4	106·9	104·5	105·1	104·8	102·7
1969	115·1	114·4	110·2	110·7	111·1	105·4
1970	123·3	123·1	116·6	117·1	118·2	109·1
1971	130·9	131·2	123·3	124·7	N.A.	114·3

Note
Columns (1) and (2) based on all institutions reporting to AAUP, matched in consecutive years.
Column (3)—salary trends in industry for chemists, engineers, engineering technicians, draftsmen, and accounting clerks, based on National Survey of Professional, Administrative, Technical, and Clerical Pay by BLS.
Column (4)—salary trends in industry for nine clerical occupations based on PATC survey by BLS.
Column (5)—wage trends in industry for carpenters, electricians, automotive mechanics, painters, and tool and diemakers surveyed by BLS in metropolitan areas.
Column (6)—Bureau of Economic Analysis (formerly Office of Business Economics).
N.A.—not available.

proxies. For example, the National Education Association provides biennial data on median annual salaries of faculty personnel in 4-year colleges and universities. Between 1962 and 1970 the NEA surveys show a 6.4-percent annual average compounded rate of increase in median salaries of professors and 5.3 percent for instructors and lecturers. The corresponding annual rates of increase for compensation of professors and instructors based on the AAUP surveys are 6.7 percent and 6.1 percent, respectively. The differences are reasonable in view of the compensation-salary trend differential and differences in survey and statistical methods.

Possible alternatives to the selected proxies for nonprofessional categories are data on changes in earnings for broad classes of employees derived from such sources as the Census' Current Population reports and BLS' Industry Employment Series. These might merit consideration for ad hoc use in the absence of more directly relevant occupational wage trend data. Over long periods of time the trends may correspond but there could be shifts in relative occupational wages from time to time. For example, between 1962 and 1970, the average annual compounded rates of increase of the proxies used for technicians and shop-craftsmen were 4.0 percent and 4.2 percent, respectively. Over this period the average hourly earnings of production workers in manufacturing industries, adjusted to exclude premium pay and shift differentials, showed an annual increase of 4.0 percent. However, from 1962 through 1966 the earnings of manufacturing production workers increased 2.6 percent annually as compared with 3.1 percent for technicians and shop-craftsmen as used in this study. From 1966 through 1970 the comparison is 5.4 percent for production workers, 4.8 percent for technicians and 5.3 percent for shop-craftsmen.[21]

An alternative technique for measuring changes in compensation of professionals that might have been considered if the necessary data had been available is the "age-wage" or maturity approach. The Battelle Memorial Institute has been collecting data on this basis since 1967 for the Atomic Energy Commission.[22] Aside from the shortness of the time span for which data are available, the sample is not in sufficient depth to provide information separately for academic R&D participants. The National Register of Scientific, Technical and Professional Personnel, conducted for biennial years 1962-70, could conceivably have provided "age-wage" data for the academic sector but extensive tabulations would have been required, without confidence that the results would be more useful.

In the "age-wage" or maturity approach salary data can be compared, sample size permitting, for similar classes of scientists or engineers, grouped separately by degree level, field of scientific specialization, and function, and stratified by age or years since receipt of highest degree. A hypothetical advantage of such a technique for the academic R&D price index is that by bypassing the formal rank structures of academia it may provide better compensation comparisons in the sense that the groups compared are chronologically or professionally at the same stage of their careers and presumably equivalent in professional competence. This approach, however, would seem to raise, at least for purposes of this study, as many questions as it purports to answer. The AAUP method of measuring changes in faculty compensation, while not directly applicable to faculty engaged in research, offers the advantage of preventing shifts in importance of institutions from affecting the results and takes account of level of responsibility by making comparisons separately by faculty rank. It would be interesting to see how the "age-wage" technique would be applied here but it is unlikely that the necessary data will be available in sufficient depth in the foreseeable future.

Materials and supplies, equipment, and services produced and sold by a wide range of industries are necessary for a broad program of research and development. Some purchases are relatively commonplace items and services typical of the operation of many industrial organizations, e.g., office supplies and equipment; ordinary chemicals and medicines; printing and duplication services; postage, telephone and travel costs, etc. Other purchases are specialized in relation to the research performed, e.g., laboratory glassware and other supplies; scientific instruments, measuring devices, and equipment;[23] specially bred animals for experimental use, etc. If the study were on a larger scale, e.g., in the manner of the BLS study of Army research and development, a representative sample of these purchases would be selected, and priced periodically by contacting vendors servicing the academic sector of university purchasing agents. The emphasis here is severalfold: a representative sample sufficiently large to deliver the desired accuracy; repricing of the same or equivalent items so that changes in intertemporal price ratios reflect

[21] For an analysis of differences in occupational pay trends, see reference 31.

[22] See reference 27.

[23] Charges for the use of large equipment items are generally made through the indirect cost accounts. The less expensive equipment items purchased for specific projects are charged as direct costs.

price changes only; collection of price data in a manner to reflect prices paid by the academic sector, which may differ (at least on a short-run basis) from prices paid by other sectors.

Faced with the impracticability for this study of deriving a price index for nonpersonnel direct costs in the manner described above, there were three alternatives that could be considered: (1) select price index series for individual commodities or services from existing statistical systems and combine them with weights representative of direct costs, (2) select a number of composite or summary price indexes from secondary sources and combine as described and (3) select a single composite index available through an existing statistical system and use it alone as a proxy for nonpersonnel direct costs. The first two alternatives have appeal in terms of producing proxies specially adapted for this purpose. The third alternative has a pragmatic appeal and, after checking to see that it was not inferior to the second approach, was adopted. The first alternative described could not be seriously considered on two counts: lack of detailed knowledge of academic R&D input elements and limited availability of secondary source price data for items that are distinctly R&D oriented.

Selection of the implicit deflator for nonfinancial corporations,[24] a series developed through the national accounts structure of the Bureau of Economic Analysis, as the surrogate price trend series for nonpersonnel direct costs can be justified on grounds other than pragmatism and convenience. The performance of academic R&D work requires purchases of materials and services corresponding to the production or sales of practically every private industrial sector of the economy as is the implicit deflator in question. The deflator for nonfinancial corporations has the advantage, as compared with more inclusive implicit deflators from the national accounts, of excluding price effects within sectors entirely or in greater part irrelevant to academic R&D costs, for example, government, agriculture, personal services, and, obviously financial corporations. The differences that these exclusions make can be seen in table 3.

In the early stages of this study NSF staff developed a price index series for nonpersonnel direct costs, based on budget category information tabulated for NSF grants proposals. Various price indexes from the CPI, WPI, as well as special indexes developed for deflating the national accounts were selected judgmentally as representative of these budget categories and a composite index computed with NSF grants weights. It is interesting that this composite was, for all practical purposes, indistinguishable from the trend of the implicit deflator for nonfinancial corporations. This is probably not accidental: the set of indexes used for the alternative computation covers the wide range of industrial activities represented in the deflator for nonfinancial corporations. Another price trend series considered as a surrogate to represent nonpersonnel direct costs was the BLS Industrial Commodities Price Index, i.e., the Wholesale Price Index for all commodities less farm and food products. The implicit deflator for nonfinancial corporations is compared, on a calendar year basis, with these alternatives in table 10; the basis for the special computation by budget categories is shown in table 11.

The implicit deflator for nonfinancial corporations is used here as if it is a price index series with a fixed weighted structure. As indicated in the general discussion of price indexes and deflators, this is approximately, but not exactly, true for the annual series. The deflator relates to value added originating in nonfinancial corporations; the value added originating derived by subtracting aggregate purchases from aggregate value of production in nonfinancial corporations. Values of both production and purchases are deflated in considerable industry detail using price trend data selected from secondary sources, primarily the WPI system, and restructured for this purpose by the national accounts staff of the Bureau of Economic Analysis. In concept the price indexes used reflect actual mar-

TABLE 10.—*Comparison of alternative price trend proxies for academic R&D nonpersonnel direct costs, 1962–70*

[Calendar year basis, 1967 = 100]

Calendar year	Nonfinancial corporations, implicit deflator [a]	Industrial commodities, WPI [b]	Special calculation [c]
1962	93·7	94·8	93·9
1963	94·1	94·7	94·0
1964	95·1	95·2	94·8
1965	95·6	96·4	95·5
1966	97·2	98·5	96·8
1967	100·0	100·0	100·0
1968	102·5	102·5	103·2
1969	105·6	106·0	106·8
1970	110·1	110·0	110·8

[a] Bureau of Economic Analysis (formerly Office of Business Economics).

[b] Bureau of Labor Statistics, WPI all items, except farm and food products.

[c] Computation as outlined in table 11.

[24] See reference 33.

TABLE 11.—*Structure of a price index for academic R&D nonpersonnel direct costs calculated by budget category components* [a]

Budget category	Weight [b] (percent)	Selected price trend proxies
Permanent equipment [c]	34·8	BLS price index for Producer Finished Goods for Nonmanufacturing, a composite of 94 groups of commodities priced for the WPI.
Expendable supplies and equipment	37·2	(1) Same as above. (2) A BEA composite price index for the Glass Products Made of Purchased Glass Industry (S.I.C. 3231) based on WPI price data. (3) The price index for Chemicals and Allied Products, WPI. (4) A BEA composite price index for the Converted Paper and Paperboard Products, N.E.C., Industry (S.I.C. 2649) based on WPI price data.
Travel	14·0	A BEA composite price index based primarily on CPI data.
Publication and printing	6·8	A BEA composite price index representing price trends of inputs to the Commercial Printing Industry (S.I.C. 275).
Computing costs	7·2	A BEA composite price index for the Office, Computing, and Accounting Machines Industry (S.I.C. 357) based on assumption that quality and productivity changes completely offset price changes.
Total	100·0	The budget categories used for this calculation represent 77.5 percent of nonpersonnel direct costs.[b]

[a] An index series was computed with the weights and price proxies shown in this table, with 1968 equal to 100.0. The results, shifted to a 1967 base, are shown in table 10.

[b] Based on fiscal year 1968 NSF research grants proposal data.

[c] Less expensive permanent equipment charged to current R&D accounts.

ket prices and have been adjusted to eliminate the effect of quality changes—improvements or deterioration—and to maintain equivalence for price comparison purposes. This point is made to indicate that the implicit deflator for nonfinancial corporations takes account, in concept at least, of quality changes in products and of changes in productivity. The problems of making adjustments for quality changes, particularly for complex items which are changed frequently as a result of technological advances, can only be partially resolved. For a discussion of such issues the reader is referred to the literature on price index number theory and practices.

Part IV

ALTERNATIVE COMPUTATIONS AND APPROACHES

There are many questions left unanswered by the previous discussions of methodology and data limitations. Accepting a price index with fixed input weights as a reasonable approach, other analysts might prefer different assumptions on which to base development of the index and use alternative data sources. The question is how much difference in results such alternative choices would make. A more serious question—taking the methodology as given—arises from the omission of indirect costs from the price index. The following discussion attempts to put these questions in perspective.

Alternative Computations

The NSF Scientific Research Support Program is a convenient starting point for study of the effects of alternative choices of weights on the price index computations. The NSF supports research and development through other programs as well. However, the program cited has the most direct relationship with academic research since about 94 percent of grants (dollars awarded in 1970) were to academic institutions.

Tabulations of the NSF grants proposal data conform closely to the selected index weights in terms of the division between compensation and other direct costs. The major differences in the composition of personnel compensation when compared with all academic research and development are the smaller proportion for research associates appearing in NSF grants data (15 percent for NSF grants compared with 26 percent for all academic R&D expenditures) and the larger NSF grants proportion for graduate students (30 percent versus 12 percent). Applying the NSF grants weights to the trend proxies selected for this study produces a price index which increases less over the decade 1961-71, 44.2 percent as compared with 48.4 percent for the academic R&D price index.

A simpler test than that using NSF grants data was first performed by reweighting the composite compensation and nonpersonnel direct costs of the academic R&D price index with weights for these gross categories based on all federally funded academic R&D projects as estimated on the basis of NSF surveys. The recomputation, assigning a smaller weight for compensation—60 percent for Federal projects instead of 65 percent for all projects—produced a 46-percent increase over the years 1961-71. This is only slightly lower than the increase in the academic R&D price index since both computations depend on the same price trend assumptions. However, if the compensation trend derived with NSF grants data weights for personnel categories (and the same trend proxies) were used for this recomputation, the 1961-71 change would be lowered to 42 percent.

Since the greatest uncertainty exists concerning the relative compensation trends of nonfaculty professional personnel vis-à-vis faculty trends another computation was made to see the effect of a simplified and drastically different assumption for selection of trend proxies. For this purpose it was assumed that all professional personnel, including graduate students working at the professional level and other nondoctoral professional personnel, enjoyed the same rate of compensation increases from 1961 through 1971 as did faculty.

Applying the alternative assumption above using AAUP all ranks faculty compensation trends, changes the 10-year increase from 48.4 percent to 54.0 percent, and the annual rate of increase of the price index for total direct costs over the 10-year period from 4.0 to 4.4. Alternative assumptions as to the trends of nonprofessional personnel compensation and nonpersonnel direct costs that would change the index results significantly are not evident. In any event, the new assumption with regard to professional personnel appears extreme and may compensate for any understatement of the upward trend in compensation of nonprofessional personnel. If this is the case, and in the absence of new and different price trend proxies, it appears that the index could understate the annual percentage change by at most a tenth.

A Total Costs Approach

The description of the academic R&D price in dex has emphasized that it relates to direct R&D costs only. However, while an index representative of direct costs only can be appropriate for particular questions, use of such an index as a deflator for total R&D expenditures is wrong conceptually. Since the R&D price index will be applied to total academic R&D expenditures the reasons for excluding indirect costs, and the implications for use of the index in analysis of R&D trends, warrant further discussion.

Data on indirect costs cited in this study are in the context of the NSF estimates of academic R&D expenditures. The NSF survey questionnaire asks for the reporting of indirect costs on separately organized R&D projects only if reimbursed or reimbursable. Thus nonreimbursable indirect costs on sponsored projects and also on separately organized projects financed with institutions' own funds are not reported. This procedure is intended to be consistent with the financial accounting system for institutions of higher education published by the American Council on Education. The latter treats reimbursed indirect costs on sponsored projects as an income item. A more complete estimate of indirect costs for separately organized projects might be secured by using the indirect cost ratios for Federal projects as if they are applicable to non-Federal organized research as well. However, the only nonreimbursable indirect costs included in the NSF estimates of expenditures for academic R&D activities are estimated for the institutions' obligations under cost sharing agreements on Federal projects and for departmental research.

Indirect costs, calculated according to accepted accounting conventions, are real costs, just as are direct costs. In a study of greater depth it is conceivable that the various indirect costs chargeable to academic R&D projects could be examined, their relative importance measured statistically, and procedures for following their price trends developed. This was in fact the procedure of the BLS in the study of Army R&D price trends. In a short-cut approach such as that used in this study, once the elements of indirect costs are suitably classified, price trend proxies could be selected as has been done for the direct-cost categories. The statistical base for such an approach was not present. And, as it will appear later, a price index with the more comprehensive scope would not eliminate all problems stemming from the manner of inclusion of indirect costs in estimates of academic R&D expenditures.

Some statistical difficulties arise from the fact that decisions to classify some costs as indirect, others as direct, often stem from organizational arrangements and administrative convenience. Various classes of personnel and fringe benefits may be accounted for as direct costs in some institutions, as indirect costs in others. In some instances where the research installation is separate from other institutional facilities outlays for buildings operation and maintenance services might be classified as direct costs.

That the nature of the research organization affects the classification of costs can be illustrated with data on federally financed projects from the NSF survey of 1966 academic R&D expenditures. For 1966 the ratio of estimated indirect costs to direct wage and salary costs of R&D projects at agricultural experiment stations, which are often physically separated from other facilities of academic institutions, was considerably lower than the corresponding ratios for medical schools and other institutional components:

Institutional component	*Ratio of indirect costs to wage and salary costs, 1966 Federal projects*
Agricultural experiment stations	10.5%
Medical schools	28.3%
Academic institutions, excluding above	32.0%

The accounting for research projects has been greatly influenced over the past decade by the large amounts of Federal support for academic R&D activities. The Federal Government has promulgated various requirements on record keeping to insure that Federal funds are used in accord with the grant stipulations and to facilitate auditing. With the increased Federal support, institutions have become more cost conscious and have attempted to recoup more completely indirect costs as well as the more easily identified direct costs of research projects.

The question of reimbursement of indirect costs on federally sponsored R&D projects has often been a sensitive issue. Curently there are no general limitations on reimbursement of indirect costs. However, at various times there were ceilings imposed by individual Federal agencies or incorporated in legislation relating to particular agencies' research grants programs. More recently there have been provisions requiring academic institutions to "cost-share," that is to absorb some of the costs of federally supported projects. These matters are documented elsewhere and need not be discussed in detail here.[25]

The circumstances described above are reflected in responses to NSF surveys (table 6). The estimates for federally supported academic research derived from the biennial surveys indicate an increase in reimbursed, or reimbursable, indirect costs on Federal projects from a 1964 fiscal year ratio approximating 27 percent of wages and salary direct costs to almost 32 percent for fiscal year 1970 as follows:[26]

Fiscal year	*Ratio of estimated indirect costs to wage and salary costs, Federal projects*
1964	27.4%
1966	28.7%
1968	29.2%
1970	31.6%

The trend shown seems to reflect additional claims for reimbursement of indirect costs as changes in Federal regulations permitted as well as some shifts of expense charges from the direct cost category to the indirect cost accounts to simplify the accounting.

The indirect cost ratios reflected in the NSF data for nonfederally financed separately organized research are much smaller. For such research (i.e., not including departmental research) financed from other than Federal sources, the 1970 ratio of estimated indirect costs to wages and salaries costs is 13.0 percent. This seems to indicate that where the opportunities for reimbursement do not exist, survey responses of academic institutions and the R&D expenditure statistics will not fully reflect indirect costs of research projects. As noted earlier, the NSF surveys ask only for reimbursed or reimbursable indirect expenses on sponsored research, and the results cited are consistent with the survey instructions. Apparently a considerable portion of sponsored research does not provide reimbursement of indirect costs.

We come now to the practical question: What is the relative magnitude of the error in the price index resulting from its omission of indirect costs? At first glance this appears to involve only the question whether prices of indirect cost items change over time in a manner reasonably close to the trend in prices of direct costs. For an index with a fixed composition of inputs, i.e., a fixed weighted index of the type developed in this study, this is indeed the only question. In considering the use of the price index for deflation, however, other questions such as the nature of the expenditures series, and the academic accounting procedures which are reflected in R&D survey statistics are also relevant.

With the limited information available one can reason, without statistical verification, that indirect costs have not increased in price more than direct costs, and may in fact have increased less. The basis for this thinking is primarily the heavy weight for compensation of faculty and research associates included in direct costs, and their higher rate of increase contrasted with salary and wage trends of administrative and service personnel representative of charges as indirect costs. Prices of materials and supplies necessary to maintain and operate academic institutions, and thus finding their way into indirect cost charges to R&D projects, are presumed to have moved in line with prices of nonpersonnel direct costs (i.e., in line with the price trend representing nonpersonnel costs in the price index for direct costs).

Some limited statistical exploration of error ranges resulting from the indirect cost problem can be performed on the basis of NSF biennial survey data over the period 1964-70. Thus if price changes of indirect cost items parallel exactly price changes of direct costs, the ratio of indirect costs to total direct costs would not change as long as the expenditures aggregate retains the same composition and is unaffected by accounting and other nonprice changes. Making the assumption that nonprice factors had no effect over the period 1964-70 is equivalent to assuming that all of the change in the relative importance of indirect costs in the academic expenditure aggregates results from differential price movements of direct and indirect cost items.

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[25] Prior to 1963 certain agencies chose to limit the amount of reimbursable indirect costs by applying a ceiling to their research grants. HEW had been using, by law, such a rate for a number of years. In 1963 legislation was enacted extending the concept of limiting rates for indirect costs incurred on research grants to other agencies, including DOD, NASA, and NSF. In 1965 the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics recommended that Congress eliminate ceilings on reimbursable indirect costs in future appropriation acts. Subsequent legislation imposed no ceilings for reimbursement of indirect costs incurred, but did establish a requirement for cost sharing. For a historical review of this subject see reference 7.

[26] Indirect costs in Federal projects for which an institution foregoes reimbursement as its cost-sharing contribution are excluded from these rates.

Over the period 1964 through 1970 prices of direct costs are estimated to have increased 29.2 percent. The ratio of indirect costs to direct wages and salaries increased 11.6 percent over this period while for federally financed projects alone the increase in the ratio was 15.5 percent. If the entire change in the ratio of indirect costs to direct wages and salaries costs resulted from higher prices of indirect expense items, the increase in academic R&D prices over the 1964–70 period would be 32.9 percent rather than the 29.2-percent increase indicated by the price index for direct costs alone. On an annual rate basis the adjusted increase would be 4.8 percent compared with the estimated price increase of 4.4 percent for direct costs alone. A slightly higher adjusted increase is obtained on the basis of the change in the indirect cost ratio for federally funded projects.

If the judgments expressed earlier about relative price movements of various components of direct and indirect costs are correct, the higher price index based on the increased importance of indirect costs over the period 1964-70 may not be due to price changes at all. An important explanation for the increase in the indirect cost ratios upon which the adjustments in the index are based may be the changes in institutional accounting practices. This is believed to have occurred in response to liberalized Federal regulations governing reimbursement of indirect costs. Other nonprice factors that might have contributed to the increase in relative importance of indirect costs are shifts in the distribution of R&D dollars. As noted earlier the importance of indirect costs is related to individual institutional practices and to the nature of the research facilities. Unfortunately, statistical examination of the importance of the factors noted here could not be made because of data limitations.

The previous discussion was intended to support the argument that the price index for academic R&D activities based on direct costs alone provides a reasonable approximation for price trends of total costs. However, at the same time it suggested that the scope of the estimates of academic expenditures may have changed as a result of different procedures of accounting and reporting indirect costs associated with academic R&D activities. The latter point is important, and cannot be separated from the first, because a prime objective of this study is to measure changes in real resources available for academic R&D activities by converting current dollar expenditures estimates to constant dollars. The NSF biennial survey data for the period 1964-70 again provide some basis for estimating the possible discrepancy arising from this problem.

The increase in total current dollar expenditures for academic R&D activities over the 6-year period 1964-70, including indirect costs, is estimated at 79.1 percent; the increase in expenditures for direct costs alone is 74.7 percent. When these expenditures estimates are deflated by the price index for direct costs, and the increases converted to an annual rate basis, the results are a 5.2-percent increase for direct expenditures as compared with 5.6 percent for total expenditures. Most of the difference between these two annual rates of increase is believed to result from changes in the scope of indirect costs included in the expenditures data. Assuming that the dominant factor here was the increase in claims for reimbursement as permitted by the liberalized Federal regulations on indirect costs, the smaller rate reflects more accurately the increase in equivalent real resources available for academic research.

Variations for Particular Problems

Analysts faced with the need for a price index for academic R&D activities can use the price index developed in this study either as is or with modifications appropriate for their particular problems. Some problems and procedures for application are suggested here:

1. The index through 1971 may be satisfactory but the need may be to project prices into the future, through 1972 and perhaps several years forward. Price expectations for the general economy would probably dominate such projections. It was noted earlier that the annual changes in the academic R&D price index for the last several years have been very similar to the movements of the GNP implicit deflator and the CPI. Thus, as an interim measure the academic R&D price index could be extrapolated to 1972 on the basis of these general price trend measures. However, as AAUP or other source data used as trend proxies become available, a more direct updating of the index, even if on a partial basis, would be preferable.
2. Those users who are concerned with special programs of academic R&D activities—e.g., an agency or institutional program, or R&D activities in a field of science—can develop their own price indexes by the techniques used for this study. They may be able to develop weighting patterns relating to these programs and some price trend proxies more relevant for their purposes than those used for this study. Such indexes can be calculated at varying levels of detail and can incorporate data elements of the academic R&D price index to

the extent necessary. Some examples of such adapted index computations are:

(a) Special program weights derived for major personnel categories, using price trend proxies from this study;

(b) Special weights for major personnel categories; independently derived price trend series for faculty, research associates, and graduate students; other compensation and price trends from this study.

The index calculations on the basis of formula (2) are simple. For those without experience in index number calculations the following step-by-step procedures are suggested:

1. Select basis for the weighting pattern. The most recent financial data available for the R&D program will probably serve best. If the interest is in a proposed program, use budget estimates as basis for weights. The remarks here are in the context of direct costs expenditures weights corresponding to formula (2) requirements, page 7.
2. Convert financial data to percentage weights corresponding to the detail in which the index calculations will be performed.
3. Compile data on compensation or price trends for each component of the weights taking pains to maintain comparability over time.
4. Adjust the scale of each compensation or price trend series so that the value for the reference period equals 100. These trend series correspond to the price relatives of formula (2).
5. Multiply price trend series values against corresponding percentage weights.
6. Sum products of (5) for each time period, keeping subtotals for each major category of interest, e.g., compensation.
7. Divide sums of (6) by sums for reference period and multiply results by 100 to establish on usual index scale. With steps 2 and 4 as outlined (and without step 8) this involves only correct placing of decimal points when computation is for summary index.
8. If index is intended to embrace indirect costs on basis of indirect cost experience of the agency or institution the following additional steps are necessary:
   (a) Estimate ratios of indirect costs to direct personnel compensation costs (or to total direct costs) for each period.
   (b) Apply these ratios to product sums of (6) to estimate supplements to product sums corresponding to indirect costs.
   (c) Derive adjusted product sums by combining indirect cost supplements above with sums of (6).
   (d) Proceed with computation of index as before. Note, however, that this may result in an adjusted index including indirect costs that will reflect more than changes in prices of indirect cost items as discussed earlier.

Analysts using the price index approach should define their questions carefully. If the interest is simply with the effects of inflation on dollars required for an R&D program the fixed weighted price index approach may be adequate. If the interest is more directly operational, i.e., concerned with a departmental or institutional program, the objective may be estimates of forward budget requirements on the basis of program plans and inflation expectations. In some cases it may be necessary and possible to vary the fixed weight approach to take account of changing proportions of the several types of personnel and other input costs at the expected future price levels. In fitting such information into index formulas a distinction must be made between prices per unit and price relatives, i.e., the correct form of the index number formula must be used, or a combination of formulas 1 and 2 for different segments of the calculations.

Future Work on Academic R&D Price Indexes

This study of academic R&D price trends is believed to have exhausted currently available sources of information. Significant improvements in the index presented here depend on improvements and enlargement of the data base.

It will be difficult and probably undesirable, to separate the work of developing a better price index from the task of improving the estimates of academic R&D expenditures. The NSF biennial surveys of scientific activities of educational institutions on which the expenditures estimates are based would be greatly strengthened by allocation of additional resources to improve reporting and permit response analysis followups in greater depth than currently possible. Additional itemization of some of the components of academic R&D expenditures in this survey would be desirable, although this may present a danger of overloading the survey and weakening response. Alternatively, occasional separate surveys might be conducted to develop special details needed for academic R&D price index work.

The NSF biennial surveys of scientific activities covering 1964 and 1966 requested estimates of departmental research expenditures, by area of science, but this request was characterized by a high rate of nonresponse. The high nonresponse was due to record-keeping procedures of universities and colleges that grouped instruction and departmental research expenditures in a single account. Notwithstanding past experiences, efforts to secure separate data on departmental research expenditures should be reactivated.

The major emphasis in the current work has been on personnel compensation trends. That is the dominant factor in R&D costs and there will probably be the most payoff in concentrating early efforts here. Additional information is needed on the personnel engaged in academic R&D activities—the numbers by academic and occupational specialization and institutional affiliation. For academically oriented staff—faculty, research associates and graduate students—more should be known about compensation practices in relation to participation in R&D activities. More generally, the research structure and R&D accounting practices in universities, which underlie the statistics, have to be better understood and documented.

Going beyond the expenditures and personnel characteristics data, it is desirable to develop sources of trend information on compensation of personnel specifically engaged in R&D activities. Information directly relevant to academic R&D should be substituted as soon as possible for the trend proxies used in this study. This can be done by periodic compensation surveys similar to the BLS surveys of Professional, Administrative, Technical, and Clerical Pay. If there is a conflict of priorities this would have precedence over efforts to develop price trend information on nonpersonnel direct costs.

Looking at the longer run, it will be necessary to learn more about the kinds of equipment, materials and services utilized in academic research and development and where they appear in the expenditures estimates. A periodic collection of price data for selected categories of expenses should be initiated to minimize dependence on secondary source data. It was evident in the earlier discussion of price proxies that the price statistics collection programs of the government have very poor coverage of R&D related items. A major reason for this is the difficulty inherent in collecting comparable price data for this changeable category. Recommendations for improving data in this area will depend on further exploration of concepts, techniques, and data sources.

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