# STRUCTURAL CHANGE IN THE AMERICAN ECONOMY, BY FUNCTIONAL INDUSTRY GROUP

BY ROGER H. BEZDEK*

*U.S. Department of Energy Washington, D.C.*

AND

CONSTANCE R. DUNHAM*

*Stanford University Palo Alto, California*

In this paper, we reclassify U.S. input–output data along functional lines by analyzing the use of products represented in the detailed coefficients of the 1967 interindustry study. Our new categories comprise 11 producing "industries," services (nonproduction), energy (nonproduction), marketing, distribution, other general, crude materials, semi-finished materials, energy production, service production, and machinery replacement, furnishing products to 80 consuming industries. This functional input–output system is then used to analyze postwar structural change in the American economy. Distinct shifts in the uses of different types of inputs are indicated and the implications of these results are discussed.

## I. INTRODUCTION

In reviewing studies of changes in U.S. input–output relationships published in the past decade, one interesting impression which emerges is that postwar structural change has been largely unpatterned, erratic, and unpredictable. There are several possible explanations for this, one of which may be that even at the 80-order level of industry detail, the industry numbering scheme generally utilized is too detailed to identify continuous and ongoing shifts in the use of inputs which were occurring among and between general types of industries. For example, in the past three decades there may have been occurring a gradual and continuous increase (decrease) in the use of raw materials or energy sources per dollar of output. However, at the two digit (SIC) industry level of detail this perhaps clearcut pattern of change may have been obscured by various shifts which occurred among uses of different types of raw materials and different energy sources. To study this problem, we reclassified U.S. input–output data, coefficient by coefficient, into eleven functional industries and then used this classification scheme to re-examine postwar changes in the structure of the American economy. Section II reviews similar previous studies, Section III describes our regrouping of U.S. input–output coefficients, and Section IV discusses the empirical findings derived here.

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## II. Results of Earlier Studies

Previous studies of changes in U.S. input–output coefficients have reported a "disconcerting" degree of unpatterned and almost random coefficient change at the 80-order (two-digit SIC) level of detail.[1] To isolate the broad shifts in industrial structure which may have been in progress, Anne Carter grouped industries into five broad types of inputs: General Inputs, Material Inputs, Metalworking Inputs, Chemical Inputs, and All Other.[2] She then computed the intermediate output requirements for delivering 1961 final demand with 1947, 1958, and 1961 input–output structures:

$$Z_t = (I - A_t)^{-1} y_{61} - y_{61} \quad (1)$$

where:

$Z_t$ = is the vector of derived intermediate output levels for years $t = 1947, 1958, 1961$

$(I - A_t)^{-1}$ = is the Leontief inverse matrix for years $t = 1947, 1958, 1961$

$Y_{61}$ = is the 1961 final demand vector.

Carter's findings are summarized in Figure 1. This figure indicates that between 1947 and 1961 there were some discernable shifts in the distribution of intermediate output requirements among these general types of inputs. Inputs

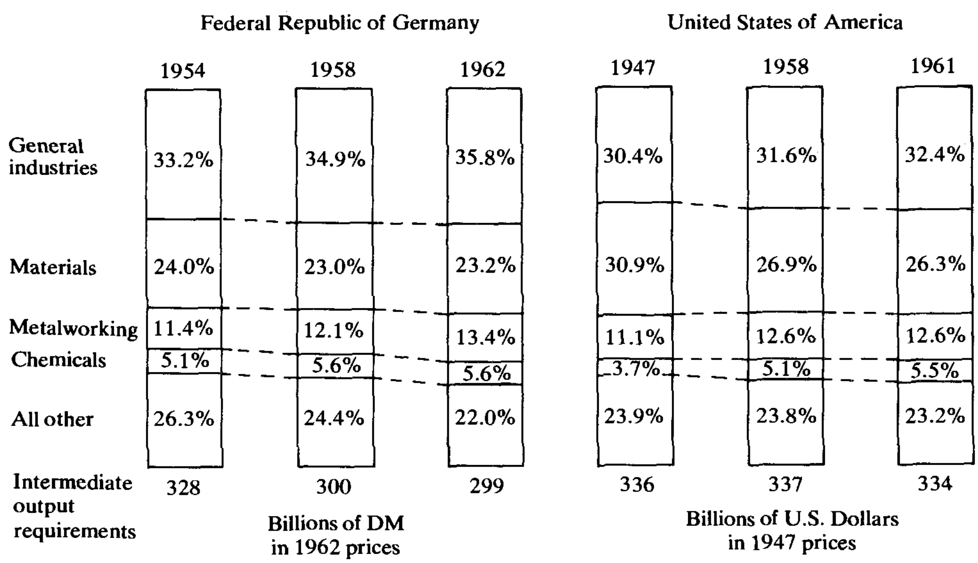


Figure 1. Intermediate output requirements for delivering 1962 final demand with 1954, 1958, and 1962 technology in the Federal Republic of Germany and intermediate output requirements for delivering 1961 final demand with 1947, 1958, and 1961 technology in the U.S.

*Source*: Staglin and Wessels, [9], page 391.

[1]See, for example, Bezdek [2], Bezdek and Wendling [3], and Vaccara [12], [13].
[2]See Carter [5], [6].

from (outputs of) general industries, metalworking, and chemicals steadily expanded while materials and all other industries tended to decline. Thus:

> While the total level of intermediate input requirements remains relatively stable, requirements from some groups of industries expand and from others, contract. Thus, inputs from the general industries—producers of fuels, transportation, trade, communications, and other services—have been expanding steadily, as have requirements from the chemicals sectors. Metalworking inputs rise as the complexity of these products increases and as specialization within the metalworking block grows. However, materials inputs tend to decline as the size and weight of many different equipment items decrease, as waste of materials is reduced, and as cheaper materials are substituted for more expensive ones.[3]

Reiner Staglin and Hans Wessels conducted a similar analysis for the West German economy for the period 1954–62 and found a marked similarity in the pattern of structural change in the U.S. and West German economies.[4] This reported similarity is also illustrated in Figure 1. Staglin and Wessels state that their findings indicated:

> "... a surprising correspondence in intermediate output requirements for Germany and the U.S. In both countries, all five industry groups show the same tendency in intermediate output change: inputs from (or outputs of) general industries, metalworking, and chemicals are expanding steadily during the period examined, while materials and all other industries tend to decline in intermediate output levels. The differences in the shares of the five industry groups for West Germany and the U.S. are narrowing during the periods observed, resulting in a relatively similar distribution in the most recent year."[5]

While the Carter classification is useful in grouping industries into broad types, it suffers from at least one serious deficiency. Within any single industry, the inputs delivered to different industries often serve different functions, and it is impossible to classify most industries exclusively into any single category. For example, under the Carter classification the output of the Coal mining industry is classified as an energy input, which it is in most cases. However, practically all of the coal input into the Chemicals industry (27) goes into the production of Industrial organic and inorganic chemicals (SIC 281 except 28195) and this cell should more properly be regarded as a basic production input rather than as a general energy input. Another example is that under the Carter classification the output of the Glass industry (35) is classified under Materials inputs. However, in a number of industries the requirements from the Glass industry represent primarily requirements for Glass containers (SIC 3221) and for these industries glass serves more as a packaging input than as a basic materials input. These examples could be repeated for most industries and they illustrate the difficulty of classifying the entire output of any single industry into one exclusive broad functional category.

[3]Carter [5], p. 37.
[4]Staglin and Wessels [9].
[5]Ibid., p. 391.

Another problem with Carter's analysis of structural change is the manner in which she derived intermediate output requirements. As illustrated in equation (1), she derived the vector of intermediate output requirements, $Z$, by generating a vector of gross output requirements, $(I-A)^{-1}y$, and then subtracting from this the final demand vector, $y$. It would have been preferable for her to derive the vector of intermediate output requirements directly by multiplying the direct requirements matrix, $A$, by the gross output vector:

(2) $$Ax = Z.$$

This derivation avoids the introduction of the effects of the inverse coefficients, and is the methodology we utilize in the empirical portion of this study.[6]

## III. Reclassification of U.S. Input–Output Industries

To be able to study structural change over time by functional industry group, it is necessary to analyze the detailed uses of the output of every industry as an input into every industry. This was accomplished by utilizing the information contained in the two digit (80-order) and the four digit (370 order) transactions and direct requirements input–output tables. First of all, those flows representing only a negligible portion of intermediate output of the producing industry and of the input to the consuming industry were ignored. The remaining nonzero cells of the input–output table were then carefully analyzed and placed in the appropriate category. In some cases, this could be done at the two digit SIC level, although in most instances it was necessary to analyze the detailed flows at the four digit SIC level. In cases where the use of the output or product in question was still unclear, either the input–output documentation material or the interindustry analyst in charge of that sector was consulted. Nevertheless, in some cases, where input usage was widespread and heterogeneous, subjective value judgments had to be relied upon to place the flows in the proper category.

We classified the input–output flows into 11 major categories which were, in turn, grouped under three functional types of inputs. These classifications are given in Table 1. The first broad type of input we called General Inputs, and are those which are used by most industries and which are not directly related to production requirements—"overhead" type inputs. These are the type of inputs which would not be expected to vary to any major extent with the scale of production, such as the energy used to heat buildings, certain types of advertising and business services, maintenance and cleaning inputs, and so forth. We divided these inputs into five major types: Services, Energy (nonproduction related), Marketing, Distribution, and Other.

The second functional group of inputs is Packaging Inputs, and this category is self-explanatory and contains no further subdivisions. The third group of inputs is Production Inputs and includes those inputs directly related to production activities which may be expected to vary with the scale of production. There are five subcategories of this type of input. Crude Materials refers to natural resources and unprocessed agricultural products. Semi-finished Materi-

[6] For a more detailed discussion of these problems, see Carter [5], pp. 25-27.

TABLE 1

RECLASSIFICATION OF U.S. INPUT–OUTPUT INDUSTRIES[a]

I. General Inputs (used by most industries; not directly related to the physical requirements of production; "overhead" type inputs)
   A. Services
      12; 26 [except (26,26), (26,73), (26,39)]; 66; 70; 71; 72; 73 [except (73,2), (73,11), (73,12)]; 75 [except (75,65)]; 77 [except (77,77)]; 78; 82
   B. Energy (used for heating, lighting or nonproduction vehicles)
      7 [except (7,27), (7,7), (7,37), (7,68)]; 31 [except (31,1), (31,2), (31,3), (31,11), (31,12), (31,27), (31,31), (31,65)]; 68 [except (68,2), (68,5), (68,6), (68,7), (68,8), (68,9), (68,10), (68,11), (68,16), (68,24), (68,27), (68,31), (68,35), (68,36), (68,37), (68,38), (68,68)]
   C. Marketing and Distribution
      65 [except (64,65)]; 69; 81
   D. Other General Inputs
      29 [except (29,29), (29,72), (29,77)]

II. Packaging Inputs
   (17,14); 21; (24,14), (24,36), (24,69); 25; (28,14); (35,14); (35,29), (35,69); 39

III. Production Inputs
   A. Crude Materials
      1; 2; 3; 5; 6; (7,27), (7,37), (7,68); 8; 9; 10; 15; (20,20), (20,24); 80A
   B. Semi-finished Materials and Components
      13; 14 [except (14,69)]; 16; 17 [except (17,4), (17,14)]; 18; 19; 20 [except (20,20), (20,24)]; 22; 23; 24 [except (24,14); (24,36), (24,69)]; 27; 28 [except (28,14)]; (29,29), (29,72), (29,77); 30; (31,27), (31,31); 32; 33; 34; 35 [except (35,14), (35,29), (35,69)]; 36; 37; 38; 40; 41; 42; 43; (44,44); (45,45); (46,46); (47,47); (48,48); 49; 50; (51,51); (52,11), (52,12), (52,40), (52,52), (52,54), (52,59), (52,73); 53; (54,11), (54,54), (54,72); 55; 56 [except (56,66)]; 57; 58; (59,59), (59,75); (60,60); (61,61); 62; 63; 64; 83
   C. Energy Production Inputs (power used in production or gasoline used in production vehicles)
      (31,1), (31,2), (31,3), (31,11), (31,12), (31,65); (68,5), (68,6), (68,7), (68,8), (68,9), (68,10), (68,11), (68,16), (68,27), (68,31), (68,35), (68,36), (68,37), (68,38), (68,68)
   D. Service Production Inputs (services used in production)
      4; (26,26), (26,39), (26,73); (65,65); 67; (68,2), (68,24); (73,2), (73,11), (73,12); 76; (77,77)
   E. Machinery Replacement Parts (except intraindustry)
      46 [except (46,46)]; 47 [except (47,47)]; 48 [except (48,48)]; 51 [except (51,51)]; 52 [except (52,11), (52,12), (52,40), (52,52), (52,54), (52,59), (52,73)]; (56,66); 59 [except (59,59), (59,75)]; 60 [except (60,60)]; 61 [except (61,61)]

[a]Industry numbers correspond to those published in the 1963 U.S. interindustry study [10]. Industries 11 and 80B, transfers to dummy industries 81, 82, and 83, and all other industries or parts of industries not mentioned specifically are excluded here.

als and Components includes those partially processed materials and components used in production. Energy here includes those energy flows directly required for production, such as the energy used to run machinery and fuel used to run transportation equipment. The Service category here includes those services directly used in production, such as the rental of farm machinery. Replacement parts includes the flows of replacement parts to the capital using industries. Parts used by capital producing and repairing industries are treated as production inputs.

## IV. Empirical Findings

We wished to determine the changes in intermediate output requirements between 1947 and 1963 (as measured by direct coefficients) for the functional industry groups listed in Table 1. We first aggregated the 1947, 1958, and 1963 U.S. primary direct 83-by-83 coefficient matrices (expressed in constant 1958 dollars) to 11-by-83 matrices, the 11 rows corresponding to our 11 industry groups.[7] We then multiplied each of the three aggregated matrices by the 1958 primary gross output vector:

$$A_t x_{58} = z_t \tag{3}$$

where:

$A_t$ = is the aggregated 11-by-83 direct coefficient matrix for $t = 1947$, 1958, and 1963

$x_{58}$ = is the 83-order 1958 primary gross output vector

$z_t$ = is the vector of derived intermediate output requirements for each of the industry groups for the years $t = 1947$, 1958, and 1963.

This analysis allows us to measure the changes over time in derived primary intermediate output requirements for each of the industry groups computed using direct coefficients, and equation (3) yields the intermediate output that would have been required directly from each of the 11 industry groups to produce 1958 output levels with 1947, 1958, and 1963 input–output structures. The percent distribution of intermediate output requirements for each year and the average annual rate of change in intermediate output requirements for the periods 1947–58, 1958–63, and 1947–63 are summarized in Table 2 and our results are graphed in Figure 2. This figure shows the changes in intermediate output requirements expressed as a percent of intermediate output excluding value added (since the ratio of intermediate output to value added changes from year to year).

Figure 2 illustrates that between 1947 and 1963 there was a remarkable degree of stability in the relative distribution of intermediate output requirements from each of the 11 industry groups. Looking first at the three most aggregate groupings, general inputs, packaging inputs and production inputs, we see that there was a slight though continuous decrease in the share of intermediate output accounted for by general inputs, from 37.8 percent in 1947 to 37.0 percent in 1958, and 36.4 percent in 1963. The relative share of packaging inputs remained about constant, comprising in the three years 1.7 percent, 1.5 percent, and 1.7 percent, respectively. The relative share of production inputs increased slowly from 60.5 percent in 1947 to 61.5 percent in 1958, and 61.9 percent in 1963.

Looking at the individual industry groups, we see that there was a continuous gradual decline in the proportion of intermediate output composed of

[7] These data were published in [7], [10] and [11]. The 1963 data were deflated to 1958 prices.

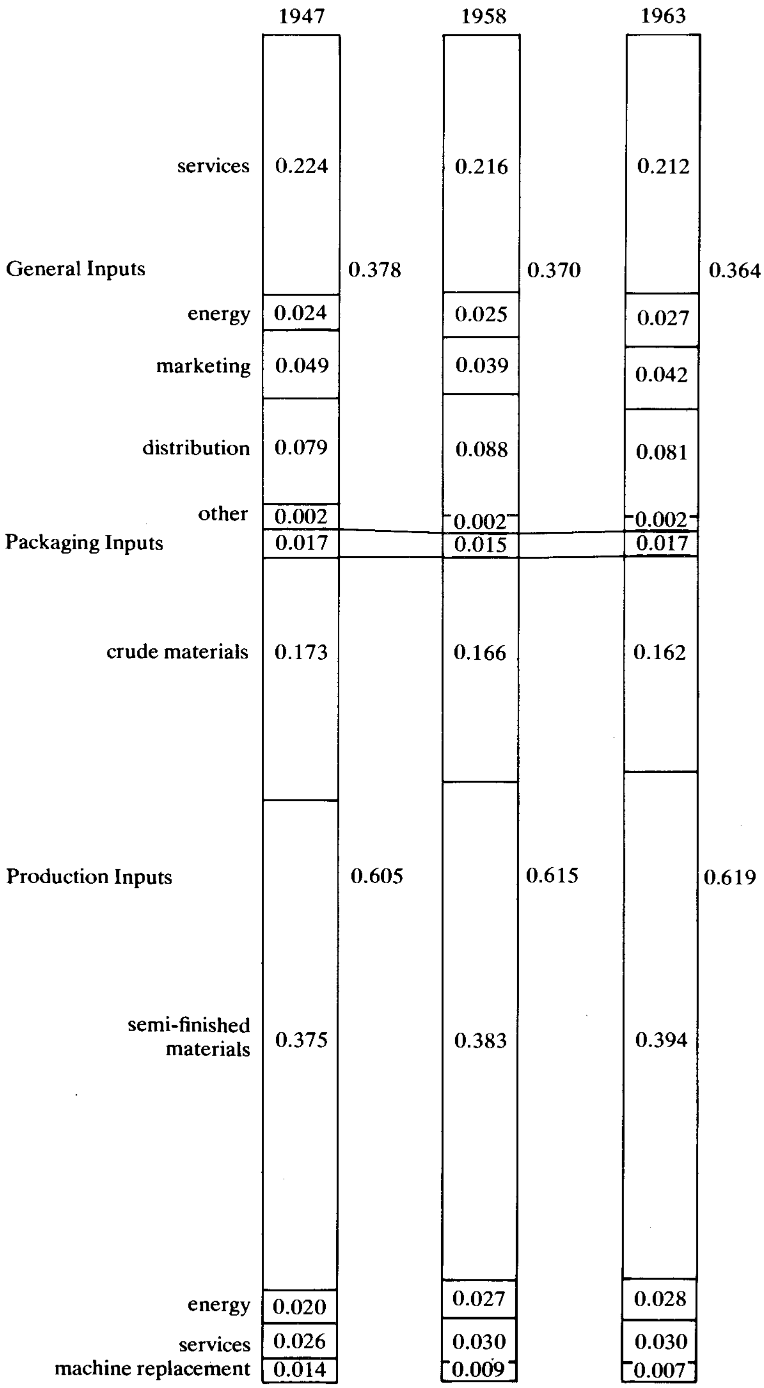


Figure 2. Changes in U.S. Intermediate Output Requirements

TABLE 2

CHANGES IN INTERMEDIATE OUTPUT REQUIREMENTS BY FUNCTIONAL INDUSTRY GROUPS

| Functional Industry Groups | Average Annual Rates of Change in Intermediate Output Requirements (Percent) | | | Distribution of Intermediate Output Requirements | | |
|---|---|---|---|---|---|---|
| | 1947–58 | 1958–63 | 1947–63 | 1947 | 1958 | 1963 |
| *General Inputs* | | | | 0.378 | 0.370 | 0.364 |
| (1) Services | −0.37 | −0.06 | −0.27 | 0.224 | 0.216 | 0.212 |
| (2) Energy | 0.58 | 1.15 | 0.87 | 0.024 | 0.025 | 0.027 |
| (3) Marketing | −1.98 | 1.67 | −0.86 | 0.049 | 0.039 | 0.042 |
| (4) Distribution | 0.91 | −1.23 | 0.24 | 0.079 | 0.088 | 0.081 |
| (5) Other | 0.53 | 0.18 | 0.42 | 0.002 | 0.002 | 0.002 |
| (6) *Packaging Inputs* | −1.14 | 2.55 | 0.0 | 0.017 | 0.015 | 0.017 |
| *Production Inputs* | | | | 0.608 | 0.615 | 0.621 |
| (7) Crude Materials | −0.43 | −0.14 | −0.34 | 0.173 | 0.166 | 0.162 |
| (8) Semi-finished | 0.15 | 0.89 | 0.38 | 0.375 | 0.383 | 0.394 |
| (9) Energy | 2.70 | 1.36 | 2.28 | 0.020 | 0.027 | 0.028 |
| (10) Service | 1.22 | 0.09 | 0.87 | 0.026 | 0.030 | 0.030 |
| (11) Mach. Replacement | −3.85 | −3.66 | −3.79 | 0.014 | 0.009 | 0.007 |
| Total Interindustry Output Requirements | | | | 1.000 | 1.000 | 1.000 |

general service inputs (22.4%–21.6%–21.2%). This is somewhat surprising, and may have resulted from firms conducting more of these types of services, such as maintenance and cleaning, "in-house" rather than contracting them out. General energy inputs accounted for a small, but gradually increasing share of intermediate output (2.4%–2.5%–2.7%), and this is consistent with the increased use of energy per unit of output in the U.S. in recent decades. Marketing activities showed no definite trend, declining from 4.9 percent of intermediate output in 1947 to 3.9 percent in 1958 and then increasing to 4.2 percent in 1963. The same observation holds true for distribution, which rose from 7.9 percent of intermediate output in 1947 to 8.8 percent in 1958 and then declined to 8.1 percent in 1963. Taken together, marketing and distribution activities declined from 12.8 percent of intermediate output in 1947 to 12.7 percent in 1958, and 12.1 percent in 1963. This gradual though continuous decline in marketing and distribution activities is also surprising because it is generally assumed that expenditures on these types of activities have tended to increase faster than total output or sales in recent decades. Other general inputs remained small and constant at 0.2 percent of intermediate output in each year. Packaging inputs remained a relatively constant proportion of intermediate output (1.7%–1.5%–1.7%), but one would have probably expected packaging inputs to increase as a percent of intermediate output.

Looking at production inputs, we find that crude materials decreased continuously as a fraction of intermediate output (17.3%–16.6%–16.2%) while semi-finished materials and components increased (37.5%–38.3%–39.4%). This is consistent with the shift towards greater specialization and roundaboutness which has characterized postwar technological change in the American economy. There was a consistent increase in the use of energy production inputs (2.0%–2.7%–2.8%). This is consistent with the increased use of energy in the American economy, and it is interesting to note that energy production inputs increased considerably faster than general energy inputs. Service production inputs increased from 2.0 percent of intermediate output in 1947 to 3.0 percent in 1958, and then remained at 3.0 percent in 1963. Finally, machinery replacement parts, though accounting for a small portion of intermediate output, declined sharply from 1.4 percent in 1947 to 0.9 percent in 1958 and 0.7 percent in 1963. This decline may have been due to the fact that replacement parts were difficult to obtain during World War II and after the war there was a pent up demand for them.

It is next necessary to consider whether our findings are actually the result of our reclassification of industries or are due primarily to the use of a more aggregate input–output table. While in some cases the coefficients in a relatively disaggregated table may show less instability due to the phenomena of changing product mix, aggregation usually increases coefficient stability by canceling out the impact of substitutions among related materials. To test whether it was the aggregation alone which resulted in the consistent pattern of structural change reported here, we aggregated the 83 industries randomly into 11 "industries." We then conducted the same type of analysis using the 11-by-83 matrices. The results derived using this random aggregation indicated little evidence of structural stability or consistent patterns of change in intermediate output requirements, with respect to either the intermediate output required from industry groups in different years or in the average annual rate of change of intermediate output requirements. Thus, the results illustrated in Table 2 and in Figure 2 are not the result solely of aggregation, and our regrouping of industries and coefficients is apparently meaningful.

We have thus far used the data generated using formula (3). The question arises of whether using the Carter formula (1) instead would have produced significantly different results.

Formula (1) can be rewritten as

$$z_t^b = A_t x_0 \tag{4}$$

where $t$ and 0 refer, respectively, to the base year and the index year

Formula (3) can be rewritten as

$$z_t^c = (I - A_t)^{-1} Y_0 - Y_0. \tag{5}$$

The understanding of the differences between the weighting systems used in the two indices can be facilitated if (5) is rewritten in the following form:

$$\begin{aligned} Z_t^c &= (I - A_t)^{-1} Y_0 - Y_0 = (I + A_t + A_t^2 + \dots A_t^u) Y_0 - Y_0 \\ &= A_t (I - A_t)^{-1} Y_0 = A_t X_t. \end{aligned} \tag{6}$$

Thus it is observed that each row of $A_t$ is "weighted" in (4) by an appropriate element of the base year gross output vector, $X_0$, while in (6) the corresponding elements of the gross output vector $X_t$ of the index year, $t$, are used as weights.

A change in the industrial classification scheme (without a corresponding change in actual technology) with emphasis on vertical integration or disintegration would affect (4) more than (5). Further, in the context of global inputs-minimization or output-maximization (Pareto maximum) formula (6) may also be preferable to (4). More generally, indirect effects might either cancel or reinforce the findings reported thus far. To investigate this possibility we computed the changes in U.S. intermediate output requirements between 1947 and 1963 using formula (1). These results are summarized in Figure 3.

The findings given in Figures 2 and 3 are similar. While there are a few minor exceptions, it can be concluded that the changes in U.S. intermediate output requirements between 1947 and 1963 are in the same direction and of the same overall magnitude whether measured by the Carter formula (1) or the Bezdek–Dunham formula (3).

In conclusion, it appear that our classification of industries into 11 broad groups provides useful information on two aspects of coefficient changes. First of all, the high degree of coefficient instability we have observed previously with respect to industries at the 80-order level of detail is clearly not present when the industries are aggregated to 11 groups. Figures 2 and 3 illustrate that the intermediate outputs required from each industry group to produce 1958 final demand with 1947 technology were very similar to those required to produce 1958 final demand with 1963 technology. Second, we were able to observe some gradual but apparently consistent trends in structural change. Intermediate use of general service inputs, marketing and distribution inputs, crude materials inputs and machinery replacement inputs all declined over the period, while intermediate inputs per unit of output from energy services, semi-finished materials and components, and energy production all increased. It would be useful to extend this analysis to 1967 and later years to determine if these trends are continuing and to ascertain whether the findings reported here are valid.[8] The type of classification scheme given in Table 1 also has potentially useful applications in related areas of economic research. For example, these input–output data could be readily incorporated into the type of aggregated input–output forecasting model developed recently by Hudson and Jorgenson[9] and Berndt and Wood.[10] These data can also be used to examine the stability of current and constant dollar interindustry coefficients. While many coefficients would be expected to be more stable in constant dollars than in current dollars, it is possible that some, such as those we identified here as representing general overhead types of inputs, may be more stable in current dollars.[11]

[8] When this research was conducted, the 1967 input–output table was not available in 1958 prices.

[9] Hudson and Jorgenson [8].

[10] Berndt and Wood [1].

[11] See the discussion in Bezdek and Wendling [4].

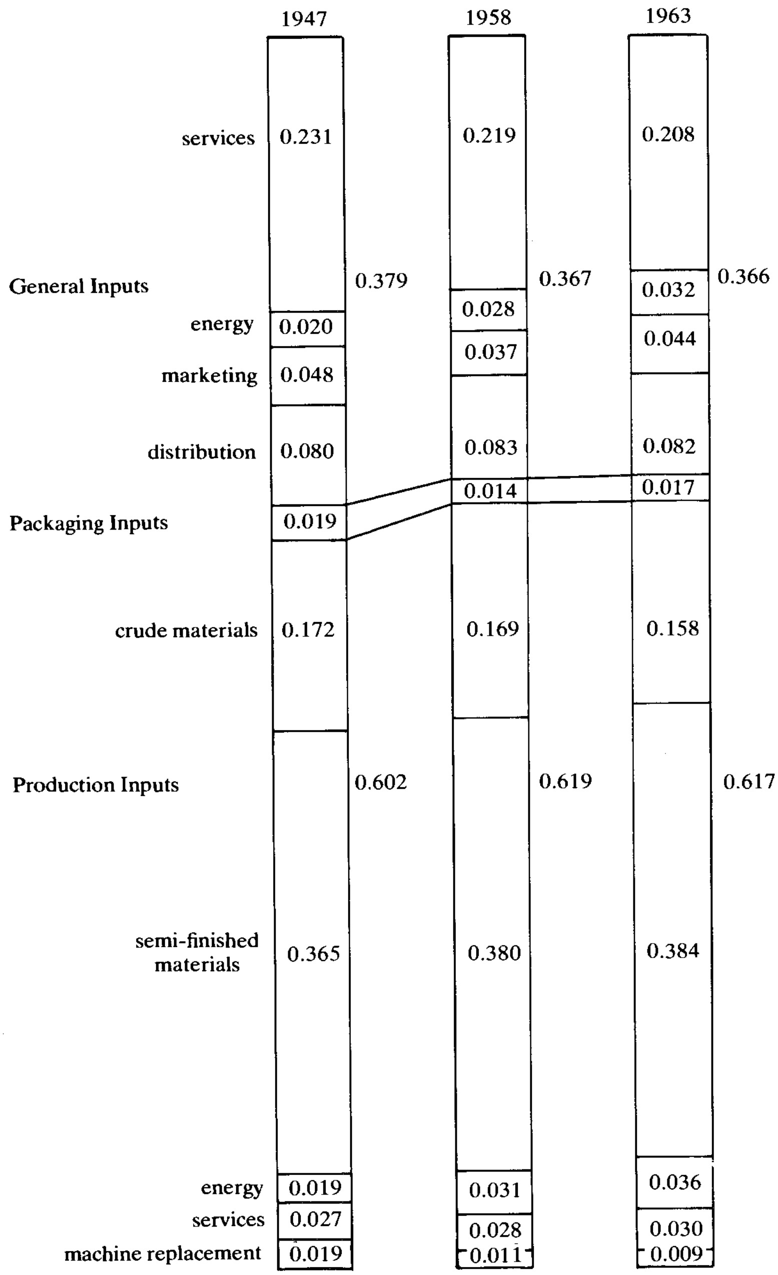


Figure 3. Changes in U.S. Intermediate Output Requirements. Computed using the Carter formula (1)

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