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CONCEPTUAL AND STATISTICAL PROBLEMS IN ESTIMATING CAPITAL COEFFICIENTS FOR FOUR METAL FABRICATING INDUSTRIES

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1. *Introduction*

This paper deals with the conceptual and statistical problems associated with the derivation of capital coefficients for industries characterized by wide variability among establishments in products, manufacturing operations or processes, and degree of integration. Some numerical values measuring the different kinds of capital used per nuit of an industry's output can always be obtained whenever a body of data exists which purports to give the quantities of capital assets, or their values, and the outputs associated with their use. The problem is to obtain, from available data, coefficient values in which sufficient confidence can be placed so that they may be called *the* capital coefficients for a specific industry usable to forecast the investment needed in that industry for an output in excess of its capacity.

The comments set forth are based upon experience derived from the study of four industries: (1) machine tools, (2) metalworking machinery, not elsewhere classified, (3) machine tool accessories, and (4) ball and roller bearings. Securing coefficients which will provide sufficient accuracy for their contemplated uses in input-output analysis involves three major conceptual problem areas: (1) the industry problem, (2) the gross output problem, and (3) the problem of capacity and of balanced or unbalanced use of capital facilities. Each of these problems will be discussed in the next section and will provide a basis for the presentation of the statistical problems in the third and last section.

The assumption underlying the choice of these three problem areas is that industrial relationships existing at any given time are grounded in a technology that changes only slowly, or if rapid technological changes take place in certain segments of the economy, these will, at least in the short period, affect only certain aspects of the economy for which adjustments may be made.

If this assumption is granted, the various production sectors of the economy at a given time may be considered to reflect a particular technology and thus have stable input-output requirements. This is reasonable, if the level of disaggregation of production sectors is not carried too far. However, many industrial relationships are not technical in the usual sense of this term even though technical considerations influence cost and demand and help to establish the institutional arrangements among and within industry sectors. The purely technological requirements may not be the most important determinants of many interindustry relationships. To the extent that nontechnical or only indirectly technical factors influence the coefficients, they may be less stable for numerous production sectors than for a few. One problem is to determine the best level of aggregation and another to ascertain, at that level, appropriate and stable coefficients for an industry with widely variable constituent elements.

The problem of gross output stems from these same stability considerations. Similarly the idea of capacity and of the balanced use of facilities is directly related to the expectation of stability contained in the assumptions concerning the relationships among industrial sectors.

2. *Conceptual Problem Areas*

The Industry Problem

In our paper, "The Capacity Concept and Induced Investment,"[1] we attempted to show that there was meaning to the term "industry" as an interdependent production sector. We found that there was a core group of establishments which were persistently classified in only one industry and that, even though the number of such plants was small in relation to all the plants which make an industry's product, these core plants produced a large and stable share, and might be considered typical of the industry. Nonetheless the methods used to classify industries, at least in the manufacturing field, covers plant with such diverse characteristics that any measures which purport to be representative of an industry must recognize these internal differences.

Tables 1 and 3 illustrate some of the differences among the establishments which were classified by the Census of Manufactures

[1] R. T. Bowman and A. Phillips, "The Capacity Concept and Induced Investment," *Canadian Journal of Economic and Political Science*, May 1955, pp. 190–203.

TABLE 1

Establishments in the Machine Tool Industry,[a] by Size and Operations Performed, 1947

	Employment by Size Classes			
	All Sizes	*Under 150*	*150–629*	*Over 629*
All establishments	316	225	66	25
Establishments not reporting number of operations	54[b]	52	2	
Establishments reporting number of operations:[c]				
1 or 2	170	147	23	
3 or 4	60	22	30	8
5 or 6	23	4	6	13
Over 6	9		5	4

[a]Standard Industrial Classification 3541.

[b]The note to census Table 8 (*Census of Manufactures, 1947*, Bureau of the Census, Vol. II, p. 664) indicates that forty-nine establishments did not report number of operations. The special tabulation found fifty-four such establishments.

[c]The data collected on metalworking operation by the *Census of Manufactures, 1947*, are described on p. 19 of Vol. II. The published data on metalworking operations for the machine tool industry are given in Table 8 on p. 664 of Vol. II. The data presented above and in Tables 2 and 3 are based on a special census tabulation which related the operations information to other data. Twelve separate operations were reported: (1) foundry, (2) die casting, (3) forging—presses, hammers, or upsetters, (4) electroplating, (5) galvanizing and other hot.dip coating, (6) heat treating or annealing of metals, (7) automatic screw-machine department, (8) machine shop, (9) tool and die room, (10) pattern shop, (11) plate or structural fabrication, (12) stamping, blanking, forming, or drawing. Establishments reporting only one operation almost always specified a machine shop. Two operations were generally machine sbops combined with (in order of frequency) heat treating or annealing of metals, tool and die room, pattern sbop, or plate or structural fabrication. When the number of operations reported is more than two, the exact combination becomes variable. Operations 8 and 9 as numbered above are almost always present, but the third, fourth, fifth, etc., operations vary rather widely. For example, of thirteen establishments reporting six operations, nine had different combinations while the remaining four had two different combinations of operations.

in the machine tool industry in 1947. That census included a survey of selected metalworking operations carried on in metal-processing plants. Although one might imagine that the producers in this industry would have very similar operations, this does not appear to be the case. On closer scrutiny of the technique of classification, it is not so surprising.[2] Table 1 indicates that

[2]*Ibid.*

there is some positive correlation between size and number of operations but it is not without exception. Some small plants have several operations and some large plants have only a few. Table 2 indicates that in general the proportion of value added to shipments[3] increases as size and number of operations increase. Again this relationship is not very strong.

TABLE 2

Ratios of Value Added to Shipments in the Machine Tool Industry, by Size and Operations Performed, 1947

	Employment by Size Classes			
	All Sizes	*Under 150*	*150–629*	*Over 629*
All establishments[a]	0.69	0.65	0.68	0.71
Establishments not reporting number of operations	0.56	0.49	0.63	
Establishments reporting number of operations:[b]				
1 or 2	0.67	0.66	0.68	
3 or 4	0.68	0.71	0.69	0.67
5 or 6	0.71	0.55	0.61	0.72
Over 6	0.73		0.71	0.74

[a]For number of establishments in each size class, see Table 1.
[b]See note c to Table 1.
Source: *Census of Manufactures, 1947,* Bureau of the Census.

Table 3 compares the ratio of value added to shipments when both the number of operations and the type of principal product of the plants are considered. This further subdivision shows not only differences in the proportion of value added by products but also great variation within the product groups as the number of operations varies. No close association is apparent between the number of operations and the type of product manufactured. In fact although the detail is not presented here, there does not seem to be recognizable relationship between the specific operations of a

[3]The census measure of value added is only an approximation of income originating. It is usually calculated "by subtracting the cost of materials, supplies, and containers, fuel, purchased electric energy, and contract work from the total value of shipments." Value added as a percentage of shipments varies widely among individual establishments in the same industry. For ninety-six important establishments in the machine tool industry (Standard Industrial Classification 3541) the percentage of value added to shipments varied from 22.5 to 98.4. The interquartile range was 17.4 per cent.

TABLE 3

Ratio of Value Added to Shipments in the Machine Tool Industry, by Product Produced and Operations Performed, 1947

		Ratio of Value Added to Shipments					
				Establishments Reporting Number of Operations[b]			
Product[a]	*Number of Establishments*	*All Establishments*	*Establishments Not Reporting Number of Operations*	*1 or 2*	*3 or 4*	*5 or 6*	*Over 6*
All products	316	0.69	0.56	0.67	0.68	0.71	0.73
Boring machines	10	0.74		0.80	0.65[c]		
Drilling machines	25	0.74	0.28[c]	0.73	0.74	0.81[c]	
Gear cutting and finishing machines	9	0.78	0.47[c]	0.69			0.81[c]
Grinding and polishing machines	38	0.63	0.29	0.66	0.66[c]	0.67[c]	
Lathes	28	0.71	0.56[c]	0.64	0.70	0.74	
Milling and key seating machines	7	0.65	0.53[c]	0.76[c]	0.63[c]		
Planers, shapers, and slotters	10	0.58	0.60[c]	0.57	0.62[c]		
Others, including rebuilt and parts	50	0.60	0.63	0.62	0.55[c]	0.59	
Not classified into a single product class	139	0.69	0.65	0.67	0.68	0.71	0.72

[a]An establishment was classified under a single product class if 50 per cent or more of its shipments were in that product class.

[b]See note c to Table 1.

[c]Ratio is based on less than five establishments.

Source: *Census of Manufactures, 1947,* Bureau of the Census.

plant and its principal product. Nearly every establishment reported a machine shop, but the other operations were not explained by the product which was shipped.

The fact that many manufacturing industries are composed of plants which differ greatly is important in deriving and interpreting capital coefficients. The technological character of the industry coefficients must be understood in a very broad sense. It is clear that no single technology dictates the values for the coefficients. Capital coefficients for an entire industry must represent properly weighted averages of the capital requirements of all the various elements of that industry. And even then their reliability may be doubtful. For with all the factors which may influence capital coefficients—location, product, size, degree of integration, labor market conditions, customs, etc.—even very accurate information on capital stocks and rates of output would reveal little evidence of a marked central tendency of the capital requirements among the plants in an industry. It must be expected that large differences will appear which cannot be explained simply by an absence of balance in the plants. Choosing those coefficients which best represent the industry is an extraordinarily difficult averaging process, and the meaning of the result is not usually clear because of the heterogeneity of the items from which it is obtained.

The Output Problem

To estimate capital coefficients an output denominator is required. This denominator is generally shipments, taken as the gross output of the industry. But the gross output of each industry will be a good index of the industry's need for stocks of capital facilities only if these are used to capacity and the value added in the industry is a technically determined and unvarying proportion of the capacity gross output.

It is fairly obvious that if an industry's gross output can be achieved with varying portions of such output originating in the industry, capital coefficients, flow coefficients, and the industry's capacity can be variable without indicating any necessary change in the capital stocks required to produce the economy's final bill of goods. Put somewhat differently, if the proportions of value added can and do change, the output of each industry required to produce a specific final bill of goods may vary.

Any shift in either the intraindustry or interindustry relationships may affect the capital coefficients. If there is more specialization and less integration among the individual establishments in an industry, more shipments will be counted more than once in the industry's gross output, and its capital coefficients will seem to diminish. On the other hand, if certain processes are contracted out in greater amounts to firms in other industries, a similar distortion of the capital coefficients will appear because of the gross output denominator used to obtain them.

This point is aptly illustrated by the remarks which appeared on a transcript of a certificate of necessity for an establishment in the machine tool industry. The applicant stated that he expected no increase in shipments but that the new facilities would permit him to do less subcontracting. In essence his remark meant that he expected to add more value within the establishment but that the gross total product would not increase. Presumably it was the expectation of more profit which induced the investment. It is easy to see, then, that the capital coefficients of this establishment, when computed in the usual way, would rise and that its marginal coefficients would be infinite. But what about the capital coefficients of the industry? They would appear to rise also since the activities of the one establishment did not change the capacity outputs of other establishments. If their capacities and capital facilities remained unchanged, their individual capital coefficients would be unchanged, but the rise in the capital coefficients for the one plant would raise the coefficients for the group as a whole. Looked at in terms of gross outputs, all establishments, including the one that increased its facilities, would have the same potential outputs but they would, as a group, have more capital facilities. Yet in terms of value added there may have been no change in capital requirements. The net potential output of the economy would be larger as a result of the new facilities. The same results would appear even if the subcontracting had been with an establishment outside the industry.

It may be argued that the intraindustry and interindustry relationships themselves are determined by the general character of the over-all technological avenues open and that cost and revenue considerations would determine the pattern of relationships within and among industries. This is a fairly satisfactory explanation for the static case but not for the dynamic, except under certain conditions. The dynamic case looks to the adjustment of the economy to varying final bills of goods. In the historic transition, however, the path taken by many of the economy's segments will depend not only on the final bill of goods but also on the initial circumstances before the change. The economy's new product mix may be obtained in different ways depending upon the characteristics of the economy before the change and the general level of output experienced by the economy and its individual industries during the period of change. The more radical the contemplated shift in the final bill of goods, the more likely it is that intraindustry and interindustry shifts may take place which significantly change the relationships measured by the coefficients of an earlier period when these coefficients have gross output denominators. This may happen even without any change in technology.

This possibility is apt to be less significant the fewer the industrial sectors used in the model or the smaller the contemplated shifts in the final bill of goods. While our analysis does not attempt to determine directly the most appropriate level of aggregation, it does suggest that, within the industry aggregates selected for study, further disaggregation may not be appropriate even though differences are known to exist within the industry aggregate. Combinations of even more diverse elements might be quite germane if stable historical coefficient values were desired.

The Capacity Problem and Capital Coefficients

A further conceptual difficulty in estimating capital coefficients arises from their possible uses. Basically their measurement provides a means of estimating induced investment. The coefficients therefore must be ratios of the stocks of various capital items to the "capacity" output rate of the respective industries. Capacity, used in this sense, implies the rate of output of an industry beyond which additions to those stocks will tend to be made. The output problem is further complicated by the necessity of estimating the capacity to which the capital stocks are appropriate. In general it is possible to measure the capacity of an industry if one can ascertain the rate of output which is "best" for existing industry facilities at some point in time. It seems less obvious that such a measure will be useful in dating the time at which investment takes place. If it does not, the usefulness of the capital coefficients for anything other than a description of the past may be severly restricted.

3. *Statistical Problems*

Capital Coefficients from Tax Amortization Certificates

A principal source of data for the derivation of capital coefficients is the records of the several government agencies connected with war and defense facilities expansions. These records are in the form of applications for certificates of necessity for accelerated tax amortization or for public financing and leasing of facilities constructed and equipped by the government. They pertain almost invariably to individual establishments rather than firms so that the problem of industrial classification of the data provided is less difficult than with accounting information for whole firms. Information which may be available includes:

1. Name and address of the plant and parent company
2. Product or products of the plant
3. Product or products for which the expansions are made
4. Capacity of the plant prior to and after expansion, either in physical or value terms or both
5. Actual employment at the plant before expansion, capacity employment before expansion, and capacity employment after expansion, all by shifts
6. Dates of acquisition of materials, date construction was started or equipment was ordered, operation date or estimated production beginning date for the new facilities
7. The type, materials, and dimensions of new construction.
8. Cost of new construction by type
9. Cost of equipment items by item, including whether the items are new, used, repaired or leased

If reliable data were available for all the expansions which take place in an industry, and for the entry of new plants, the problem of deriving capital coefficients—at least coefficients which describe historical experience—would seem easily feasible. Use of the information described, however, leads to the belief that certain aspects of it are especially weak. Some of these merit attention.

There is a possibility that expansions carried on under governmental tax help or direct financing do not represent all expansions of an industry even during the period for which the data are gathered. The government records may give extraordinary weight to those expansions which stress the production of goods of special military importance. Since the data most frequently apply to expansions of existing plants, the purchases are apt to represent the specific additions required for these goods rather than the more general additions which might be needed for the more usual products of the particular industry. In other words even the bottlenecks which are broken by unbalanced expansions may not be representative of unbalanced expansions for the whole industry's peacetime products. In addition government records may give undue weight to larger expansions, omitting small capital expenditures for which no tax relief or public financing was requested.

Moreover, the validity of the reporting still presents many problems. Beginning and ending capacity information have proven especially troublesome. Many reports do not give the necessary data and even those which do cannot be used without adjustment. In many cases, establishments had more than one application and the increases in capacity reported on separate applications for the same plant were quite obviously not independent. Expenditure data on the several certificates really referred to the same capacity increase or to some combined increase. Thus consolidation of the data is required before use and may introduce additional errors. Furthermore the lack of consistency in the labor and value information raises questions about their accuracy. On the other hand the reporting of capital expenditures seems generally good. Descriptions of equipment purchases are usually in adequate detail for classification by producing industry. However, the dating of the expenditures is not always clear so that price deflation is difficult. It is also impossible to determine from the records the extent to which capital was purchased for replacement rather than expansion purposes.

The nature of the data, the conceptual problems mentioned above, and the distinct possibility that many expansions were of the bottle-neck-breaking variety indicated that there would not be great uniformity in the coefficients among the plants of an industry, or stability of the coefficients through time even for the same plants.

Other research units have used somewhat the following method in their attempts to derive capital coefficients from such data:[4] The certificates are analyzed to make sure that they provide the essential information on the change in capacity and capital expenditures. The various plants are examined for "balance" with a priori criteria and the unbalanced ones are rejected. In some cases the expenditures are broken down by processes within plants as well as by supplying industry. For the remaining expansions the individual expenditures are divided by the change in capacity to which they pertain to secure capital coefficient estimates for the expansions of

[4]See, for example, Sidney Sonenblum, "A Report on Capital Purchases by the Copper Mining and Milling Industry," Bureau of Mines, Inter-Industry Analysis Branch Item 21, processed, February 20, 1953; Robert L. Winestone, "Capital Coefficients for the Iron and Steel Forgings Industry," Bureau of the Budget, processed, July 1, 1953; "Capital Coefficients for the Chemical Industry," Harvard Economic Research Project, hectographed, May 1952.

the selected plants. Extreme items, including zeros, are then eliminated. The remaining coefficients are averaged, usually by an unweighted arithmetic mean, and these averages are taken to represent the whole industry's capital requirements. Depending on the research unit and the industry studied, various tests may be made of differences in the coefficients due to size of expansion, size of plant, time of expansion, age of plant, product being made, etc., but the results of such tests are usually neutral, i.e. they do not indicate what causes the differences in the coefficients which remain after the culling. Some final industry coefficients have been based on only one and most on only a very small number of plants.

It is possible that such a method is applicable to the industries to which it has been applied. Our reservations concerning this method for the industries we have investigated may be summarized as follows:

1. The metal-fabricating industries are characterized by a very heterogeneous group of establishments. Even the hard-core plants have differences in products made, materials used, technologies employed, labor practices followed, locations, degrees of integration, etc. which affect their capital-output ratios. No small sample of plant expansions is likely to cover all the attributes of such industries and give them their appropriate weights.

2. Computing capital coefficients for individual plant expansions in these industries and then eliminating the extreme items as being unbalanced would be very hazardous. This appears to be tantamount to accepting the capacity information as accurate and the expenditure data as responsible for the variability in the results. Our studies indicate almost the reverse to be the case.

3. Using unweighted averages of the selected coefficients may produce some bias. We have found almost universally that larger expansions tend to have lower capital requirements per unit change in capacity so that an average weighted by the changes in capacity is smaller than the unweighted mean. The weighted average can be computed directly by adding all the purchases from a given industry and dividing by the sum of the capacity changes to which they apply. The resulting difference between such coefficients and the unweighted ones have been found to be as great as 100 per cent, based on the smaller coefficient. The weighted average can be justified quite simply; it gives the actual expenditure per unit change in capacity for the whole group of plants included. On the other hand, the unweighted mean gives the average of the plant coefficients without regard to the differences in capacity changes among

them. As an example suppose one plant spends $100 to get an increase in capacity of $500 and another spends $1,000 to get an increase of $10,000. The unweighted over-all capital coefficient is $0.15, whereas the weighted is only about $0.105. The latter indicates the expenditure actually required per unit change in capacity for the combined plants.

The method which we have followed in the derivation of capital coefficients has been designed to overcome these limitations. In order to get as good coverage as possible for the industry, it attempts to use as much information about as many establishments as seems accurate and time and expense will allow. Variation among the establishments is expected in view of the character of the industry. Variability per se is never used as a reason for the deletion of any information. Final estimates of capital requirements are based on many applications which, we hope, tend to cancel out errors in the capacity data.

TABLE 4

Certificate of Necessity Data in the Machine Tool Industry, January 1950–December 1952

Number of establishments for which certificates were received	137
Total number of certificates received	222
Total capital expenditures on certificates received	$90,167,000
Estimated total of authorized expenditures for all establishments[a]	$163,781,000

[a]This is a rough estimate computed from a machine listing prepared by the Defense Production Administration.

To illustrate the method in more detail, the derivation of capital coefficients for the machine tool industry from data pertaining to the Korean defense period is presented here. General information on the amount and type of data is shown in Table 4. Of a total of approximately $163.8 million of applications for rapid amortization by establishments in the industry up to January 1, 1953, certificates totaling $90.2 million were received. The coverage for the industry is fairly good. The difference is accounted for in part by the exclusion of expansions of less than $50,000 and expansions of plants in the industry to produce products of other industries.

The initial editing of all certificates showed that an estimated dollar increase in capacity was often lacking. Of 222 certificates received, only 62 provided such an estimate. These covered only 32 establishments, some of which were not persistent members of the industry. On the other hand, capacity employment both before and after the expansion was reported by 79 establishments. Therefore it was decided to investigate the possibility of using the labor information to measure the dollar change in capacity.

Several methods are available for estimating the relationship between the change in employment and the change in capacity. Information on shipments, man-hours, and employment for 86 of the 137 plants was obtained from reports to the National Production Administration on Form NPAF-1. Table 5 shows that the unweighted mean output per man-year corrected to 1950 prices is $15,056. There are, of course, large plant-to-plant differences and smaller differences between the averages of the several product classes into which the establishments can be grouped.

TABLE 5

Output per Man-Year in the Machine Tool Industry

Product	*Number of Establishments*	*Unweighted Mean Output per Man-Year* (1950 dollars)	*Range* (1950 dollars)
All products	86	$15,056	$ 5,411 - 28,731
Boring and broaching machines	8	17,363	9,457 - 23,264
Drilling machines	14	17,568	7,694 - 27,189
Gear cutting, finishing, and hobbing machines	5	14,630	9,069 - 23,789
Grinding, buffing, and polishing machines	12	14,457	9,210 - 25,632
Lathes and automatic screw machines	24	13,663	5,411 - 22,240
Milling machines	8	14,096	10,561 - 18,019
Planers, shapers, and slotters	11	15,820	7,198 - 28,731
Rebuilt machine tools	4	12,736	7,432 - 20,884

Source: Estimated from National Production Administration Form 1 reports.

Two other means of estimating the output per man-year are afforded by the certificates themselves. One is the ratio of capacity output to capacity employment *before the expansion*; the other is the ratio of the reported change in capacity output resulting from the investment to the reported change in capacity employment. Of the 32 plants which reported dollar capacity figures, 26 had labor data for the first comparison and 28 for the latter. The weighted mean output per man-year was estimated at $11,527 when computed from the before-expansion data. It was $16,911 when derived from the increase in capacity information. The range of the former was from $5,384 to $31,429, and that of the latter from $6,250 to $75,906. In many cases there was very little agreement between the two estimates for individual establishments. For example one plant reported an output per man-year of $11,616 before the expansion and of $75,906 for expansion labor alone. Several others had nearly as disproportionate reports.

TABLE 6

Comparison of Estimated Increases in Capacity from Labor Data and Certificates in the Machine Tool Industry

Establishment Number (1)	*Labor-Based Estimate of Capacity Increase* (*1950 dollars*) (2)	*Capacity Increase from Certificates* (*1950 dollars*) (3)	(2) ÷ (3) (4)
All establishments	$44,552	$47,286	0.942
1	12,637	9,467	1.335
2	6,697	6,000	1.116
3	4,566	5,009	0.912
4	4,506	11,094	0.406
5	3,401	3,125	1.088
6	2,443	1,635	1.494
7	2,141	1,596	1.341
8	2,083	1,547	1.346
9	2,079	2,889	0.720
10	1,055	1,031	1.023
11	937	500	1.874
12	566	1,200	0.472
13	515	600	0.780
14	494	969	0.510
15	432	564	0.766
Arithmetic mean =			1.012
Median =			1.023
Q_3 =			.720
Q_1 =			1.341
$Q_1 - Q_3$ =			.621
$(Q_1 - Q_3)/Md$ =			.611

It is possible that some of these differences are due to the lack of balance in the expansion. This might also account for the fact that the change in capacity estimate was so much higher than the estimate before the expansion. The weighted average output per man-year is $12,003 when computed for only the ten balanced expansions before expansion, and $16,008 for the same plants based on the change in capacity. The ranges of the individual expansion output per man-year for the ten balanced expansions were $5,384 to

\$23,730 and \$11,161 to \$43,453 respectively for the two methods. Quite clearly the differences in estimates of output per man-year cannot be attributed entirely to the lack of balance.

There were fifteen establishments with an applicant's estimate of change in capacity which could be compared with the change in capacity estimated by the change in labor multiplied by the NPAF-1 calculation of output per man-year. Table 6 indicates that there is considerable variation in the fifteen individual plant estimates but that, taken together, the totals are surprisingly similar. Thus, even while there is evidence that the NPAF-1 method may give poor results for individual establishments, it seems quite good for the whole group.

In order to test whether a smaller core group of plants would give estimates of capital coefficients approximately the same as the whole 137 establishments for which some data is available, a sample of such core plants was chosen.[5] The sample contains 54 establishments and 115 separate certificates of necessity. Table 7 shows the ratios of purchases from particular four-digit industries to total capital expenditure for these establishments. If the sample is representative, this gives a picture of the distribution of capital purchases by the machine tool industry, by supplying industry, for the period January 1950 to December 31, 1952, with prices adjusted to 1950. These are not balanced capital requirements but an estimate of the actual distribution of purchases. Since they are based on the sample selected as a core group of plants, their representativeness seems likely but not assured. In order to check the hypothesis that the core group adequately represents the industry, forty-six additional plants from the machine tool industry were added to the original sample,[6] with the results shown in Table 8.

Only the two largest supplying industries, construction and machine tools, were tested. These account for 87 per cent of total capital expenditures so that any changes in other expenditure

[5]The sample consists of the plants for which we have expansion information and which were in the WPB-732 reports of World War II and the BLS 790C-1 reports of January 1951 and 1952. Practivally without exception, the same establishments are in the quarterly NPAF-1 reports since the last quarter of 1950, so that long histories of output, employment, and metal consumption are available as well as the capacity information provided by the BLS 790C-1 survey.

[6]These forty-six constitute all plants outside the sample for which certificates of necessity give information adequate for the computation of capital coefficients either from value or labor data on change in capacity. Deflating the expenditures of the other thirty-seven establishments did not seem warranted.

TABLE 7

Ratios of Purchases from Capital-Producing Industries to Total Capital Expenditures by Fifty-Four Core Establishments in the Machine Tool Industry

(1950 dollars)

SIC of Supplying Industries	*Ratios*	*SIC of Supplying Industries*	*Ratios*	*SIC of Supplying Industries*	*Ratios*
All industries	1.000000[a]				
Construction	0.405157				
2499	0.000004	3555	0.000041	3621	0.000041
2520	0.003937	3559	0.006655	3641	0.000084
2541	0.001412	3561	0.001700	3651	0.000056
2550	0.000273	3563	0.024538	3661	0.000101
2561	0.000152	3564	0.002757	3664	0.000062
2589	0.000004	3565	0.007179	3669	0.000044
2591	0.000067	3566	0.000192	3691	0.000085
2599	0.000566	3567	0.011741	3693	0.000014
3399	0.000004	3569	0.001225	3699	0.000138
3423	0.000066	3571	0.001906	3715	0.000366
3425	0.000002	3572	0.001072	3717	0.000586
3431	0.000062	3576	0.000434	3742	0.000017
3439	0.000839	3579	0.001030	3811	0.003507
3441	0.001482	3581	0.000009	3821	0.001517
3442	0.000018	3584	0.000715	3831	0.000215
3443	0.002327	3585	0.001425	3841	0.000085
3444	0.001148	3586	0.000018	3861	0.001172
3463	0.000009	3589	0.000302	3871	0.000026
3471	0.000023	3591	...	3954	0.000321
3492	0.000141	3593	0.000149	3981	0.000016
3494	0.000002	3594	0.000002	3998	0.000018
3499	0.000006	3599	0.000007	3999	0.000056
3522	0.000027	3611	0.000203	o.n.c.[b]	0.000605
3531	0.007937	3612	0.000017		
3541	0.469080	3613	0.000545		
3542	0.007763	3614	0.002697		
3543	0.019268	3615	0.000584		
3552	0.000010	3616	0.000086		
3553	0.000069	3617	0.000131		
3554	0.000049	3619	0.001604		

[a]Actual total lies in the range 1 ± 0.000005.
[b]Other nonconstruction expenditures not classifiable by supplying industry.
... indicates less than 0.0000006.

ratios would necessarily have to be small. The small change in these two supplying industries is fairly easy to explain. Establishments in the original fifty-four establishment sample are the larger plants of the industry, with total expenditures amounting to $51.9 million, as contrasted with $11.4 million for the forty-six other plants added. Since the weighting of the original sample is more than four times as great as that of the added plants, any changes brought about by differences between the two groups is dampened. The slight increase shown on line 3 of Table 8 is accounted for by the relatively small size of the expansions added to the core group. Smaller expansions tend to purchase from fewer supplying industries, yet usually buy from both the construction and machine tool industries. This makes the ratios of these industries higher, on the average, for the small-expansion than for the large-expansion plants. Adding the smaller expansions to the sample tends to increase the larger and decrease the smaller ratios.

TABLE 8

Comparison of Principal Expenditure Ratios between the Original and the Augmented Sample

	Construction	*SIC 3541*
1. Original 54 establishment sample	0.405157	0.469080
2. Original samples plus 46 other establishments	0.408342	0.473268
3. Difference (2) – (1)	+0.003185	+0.004188

One other test of representativeness is possible. The core-sample distribution contains eighty-four supplying industries. Adding the forty-six other plants yields five additional supplying industries. However, the combined ratio of purchases from all five of these industries to the total purchases by all 100 establishments, is only 0.000248, so that it can hardly be said that a significant difference is found.

The evidence does not show that the original sample is unreliable. The distribution given in Table 7 seems to give a good picture of the historic purchases of the machine tool industry.

Of the fifty-four establishments in the sample referred to above, thirty-three had information adequate for the computation of the ratio of total capital expenditures to change in capacity estimated by use of NPAF-1 labor data for the separate plants. Table 9 indicates that the weighted average total expenditures per dollar increase in capacity, computed as the relationship between total plant expenditures and plant change in capacity, is 0.253 for all thirty-three establishments.

TABLE 9

Historic, Over-all Capital Coefficients from Thirty-three Core Establishments

Product (1)	*Establishment Number* (2)	*Total Expenditure* (3)	*Labor-Based Estimate of Capacity Increase (1950 dollars)* (4)	(3) ÷ (4) (5)
All products	1–33	$30,855	$122,125	0.253
Drilling machines	1–6	3,026	11,842	0.256
	1	677	2,443	0.277[a]
	2	590	3,973	0.149[a]
	3	525	566	0.928[a]
	4	371	2,141	0.173
	5	364	707	0.515
	6	499	2,012	0.248[a]
Grinding, buffing, and polishing machines	7–11	7,884	19,683	0.401
	7	5,351	12,637	0.423[a]
	8	1,825	4,566	0.400[a]
	9	467	1,179	0.396[a]
	10	187	937	0.200
	11	54	364	0.148
Lathes and automatic screw machines	12–22	12,502	57,456	0.218
	12	3,288	8,480	0.388[a]
	13	1,765	3,401	0.519[a]
	14	1,554	2,292	0.678[a]
	15	1,751	21,554	0.081
	16	1,126	2,441	0.461[a]
	17	911	6,060	0.150
	18	884	4,413	0.200
	19	506	6,697	0.076
	20	282	631	0.447
	21	274	432	0.634[a]
	22	161	1,055	0.153
Planers, shapers, and slotters	23–28	2,890	6,540	0.442
	23	1,046	765	1.367
	24	977	2,079	0.470[a]
	25	499	494	1.010
	26	213	352	0.605
	27	113	515	0.219
	28	42	2,335	0.018
All other products	29–33	4,553	26,604	0.171
	29	1,321	11,871	0.111
	30	1,119	6,421	0.174[a]
	31	969	4,506	0.215
	32	963	2,083	0.462[a]
	33	181	1,723	0.105

[a]Balanced expansions.

The historic, over-all coefficient may be computed in a number of ways without restricting the analysis to the core establishments. By one method, using thirty-two plants which reported their change in capacity directly in dollars, the coefficient is $0.319. However, only eighteen of these establishments are in the sample of larger and more persistent members of the industry. By another method the over-all coefficient may be computed by applying one of the estimates of output per man-year to the total change in labor reported by seventy-nine plants which provided appropriate labor data. One estimate, using the NPAF-1 output per man-year figure of $15,056, is $0.310. If the output per man-year figure of $16,911 is used, the estimate becomes $0.276. Several other estimates are possible. All these differences in coefficient value are attributable largely to the different methods used to estimate the value of the changes in capacity. The evidence does not indicate that adding plants to the original sample increases the reliability of the estimate.

Since there appears to be no significant difference between the distribution of expenditures made by establishments in the core sample and those outside the sample, the initial attempts to derive balanced capital requirements also relied upon the fifty-four establishments in the sample. The choice of balanced expansions—those unaffected by bottleneck eliminations—is very difficult in so complex an industry as machine tools. Letters were sent to all the plants in the sample, and on the basis of the replies received those plants with unbalanced additions were eliminated. Two of the replies specifying that the additions were balanced were rejected by our analysis because one had purchases from but a single industry and the other from only two. Several other plants not covered by letters were rejected as balanced expansions for other reasons; some had no construction expenses, others bought from only one or a few industries or purchased types of equipment which obviously were not adequate for the over-all production of the products of the plants. This culling determined that the expansions of twenty-six establishments in the sample were unbalanced. The remaining twenty-eight are not necessarily balanced, rather, they are not obviously unbalanced and no further testing seemed feasible.

Table 10 gives the ratios of purchases from capital-producing industries to total capital expenditures for the twenty-eight balanced expansions. To test whether there are significant differences from those obtained when no attention was paid to the balance aspect, a correlation was run of the logs of the highest twenty ratios of

TABLE 10

Ratios of Purchases from Capital-Producing Industries to Total Capital Expenditures for Twenty-eight Balanced Expansions, in the Machine Tool Industry

(1950 dollars)

SIC of Supplying Industries	*Ratios*	*SIC of Supplying Industries*	*Ratios*	*SIC of Supplying Industries*	*Ratios*
All industries	1.000001				
Construction	0.437642				
2499	0.000005	3542	0.007621	3599	0.000008
2520	0.004743	3543	0.020427	3611	0.000250
2541	0.001485	3552	0.000013	3612	0.000021
2550	0.000337	3553	0.000085	3613	0.000652
2561	0.000187	3554	0.000060	3614	0.003174
2589	0.000005	3555	0.000050	3615	0.000640
2591	0.000083	3559	0.002709	3616	0.000106
2599	0.000580	3561	0.001756	3617	0.000161
3399	0.000005	3563	0.024628	3619	0.001636
3423	0.000038	3564	0.003113	3621	0.000051
3425	0.000002	3565	0.006212	3641	0.000104
3431	0.000042	3566	0.000042	3651	0.000069
3439	0.000854	3567	0.006907	3661	0.000124
3441	0.000933	3569	0.001136	3669	0.000054
3442	0.000022	3571	0.001740	3691	0.000069
3443	0.001976	3572	0.000517	3693	0.000017
3444	0.000885	3576	0.000393	3699	0.000132
3463	0.000011	3579	0.000934	3715	0.000451
3471	0.000029	3584	0.000053	3717	0.000722
3492	0.000173	3585	0.001636	3811	0.004310
3494	0.000002	3586	0.000022	3821	0.001484
3499	0.000008	3589	0.000345	3831	0.000169
3522	0.000033	3591	...	3841	0.000105
3531	0.007740	3593	0.000184	3861	0.001443
3541	0.444418	3594	0.000003	3871	0.000032
				3954	0.000395
				3981	0.000020
				3999	0.000069
				N.N.C.	0.000707

[a]Other nonconstruction costs not classifiable by supplying industry.
... indicates less than 0.0000006.

Table 10 with those of the corresponding ratios for the twenty-six unbalanced expansions. If there were no difference, the coefficient of correlation (r) would be unity, the regression constant (A), zero, and the regression coefficient (b), unity. The actual result was that $r^2 = 0.690$, $A = 1.707$ and $b = 0.422$. The difference between A and zero and the difference between b and unity are both significant

Also, forty-three capital-supplying industries represented in the balanced expansions are not included in the unbalanced.

Of the thirty-three expansions and their respective over-all coefficients presented in Table 9, only fifteen remained when the obviously unbalanced expansions were eliminated. These fifteen balanced expansions have a weighted average over-all coefficient of $0.382 when computed by using the output per man-year of the individual establishments as shown by NPA data. This compares with $0.253 when no attention was paid to balance and the same method was used for thirty-three expansions in the sample. Thirteen balanced expansions, using the applicants' estimates of the value of the change in capacity, yield a weighted mean coefficient of $0.435 as compared with $0.319 for the similarly computed historical coefficient for thirty-two expansions. Eleven of the thirteen and eighteen of the thirty-two are in the sample. Thirty-two balanced expansions which report a change in capacity employment have a coefficient of $0.472 when the NPAF-1 mean output per man-year of $15,056 is used to estimate dollar increase in capacity and a coefficient of $0.420 if the $16,911 figure is used. The corresponding historical coefficients by the latter two methods are $0.310 and $0.275. As would be expected, the balanced requirements are higher. Since applicants' estimates seem preferable for obvious reasons, the $0.435 value seems the best selection.

The question again arises whether the difference between the balanced and unbalanced coefficients is significant. To test this, the thirty-three coefficients of Table 9 were separated into the fifteen balanced and eighteen unbalanced ones and the unweighted mean coefficient of each group determined. These are $0.440 for the balanced and $0.322 for the unbalanced expansions. Since the unweighted mean of the unbalanced expansions is much greater than the weighted mean of $0.147, there was an inverse relationship between the change in capacity and the size of the capital coefficient. This inverse relationship is not nearly so strong among the balanced expansions. A probabilistic test indicated that the difference between the unweighted means of the balanced and unbalanced expansions, using the 0.05 level as the criterion, should not be considered significant. However, an F-test indicated that there was significant difference between the variability within the two parts. The relative dispersion among the unbalanced expansions, measured by the relationships of the respective means and standard deviations, is almost 2.5 times as great as for those not clearly unbalanced. It was decided that the difference between the weighted means is significant: (1) because of this significant difference in relative dispersion and the different amount of correlation with the changes in capacity; (2) because the several methods of estimating historical and balanced coefficients gave about the same relative difference; (3) and finally because a priori considerations indicate a difference between balanced and unbalanced expansions in line with the measures derived. Since Table 9 indicates that balanced coefficients still vary from 0.149 to 0.928 when computed by the labor productivity method, and since even those coefficients based on applicants' estimates range from $0.143 to 0.638, it would be desirable to know the extent to which such differences are accounted for by principal product classification, location, integration, etc. However, there are too few cases to warrant classification beyond the balanced and unbalanced. A test of the thirty-three expansions given in Table 9 indicated that the means of the product classes were not significantly different, though their variances were. By consolidating the coefficients into two groups composed of the three product classes with the highest average coefficients and the two product classes with the lowest, a significant difference between means can be found. Still, these thirty-three expansions are heterogeneous because they contain both balanced and unbalanced capital expenditures. Furthermore, some of the differences in individual coefficients are due to the use of labor productivity data rather than direct estimates. Thus, while no quantitative conclusions can be drawn, the remaining differences, after the balanced expansions have been selected, reinforce the conclusion that the sample must be large. The greater the number of plants covered the more likelihood that appropriate weights are given to the heterogeneous industry, even though the proper coefficients for each of its many facets is not known.

It may be that, given appropriate data, more homogeneity would be found within product groups or within size groups within product groups, etc. If capital coefficients are sought which are to represent technical requirements of but one production process, such a further narrowing of classification may be necessary for many industries. Nevertheless the evidence indicates that even this further subclassification will not produce sufficient homogeneity and that it can be carried all the way to the individual establishments without finding markedly similar capital requirements.

Table 11 presents the final capital coefficients for the machine tool industry by supplying industries. These are computed by multiplying the ratio values of Table 10 by the over-all balanced coefficient estimate, $0.435. Since the amount of confidence in the latter is not high, only those coefficients which were equal to or greater than 0.0005 are presented.[7] There is some evidence to indicate that this over-all capital coefficient is too high. Construction during the period under survey seems excessive for normal balance and, in addition, some new facilities are largely more productive replacements of older ones.

TABLE 11

Balanced Capital Coefficients for the Machine Tool Industry

SIC	*Balanced Capital Coefficients (1950 dollars)*
Total balanced coefficient	$0.435
3541	0.195
Construction	0.191
3563	0.011
3543	0.009
3531	0.004
3542	0.004
3567	0.003
3565	0.003
2520	0.001
3811	0.001
3614	0.001
3564	0.001
3559	0.001
3443	0.001
3561	0.001
3571	0.001
3619	0.001
3583	0.001
Other industries[a]	0.005

[a]See Table 10 for other industries. None of these was as great as 0.0005.

Capital Coefficients From Accounting Data

The use of accounting data adds another element to the industry problem since the firm, the usual accounting unit, may have establishments in different industries. In addition to the differences which may exist among establishments in the same industry, there is an added possibility of interindustry diversity within and among

[7]The remaining supplying industries are noted in Table 10.

firms. Furthermore the use of balance sheet data to obtain the value of plant and equipment requires that a choice be made between the depreciated and undepreciated values, and also raises questions concerning the character of either valuation since the property was acquired at different times. Similarly, sales values from income accounts pose price problems if capital-to-sales ratios at different points in time are to be compared. It is the price change corrections with respect to capital asset values, however, which present the more difficult problem.

The use of accounting data also involves capacity problems. Capital-to-sales ratios can easily be computed, but these are not capital coefficients unless the outputs involved are considered to be capacity outputs. It might be presumed that the problem of unbalanced use of facilities would not be involved in accounting data if the firm is presumed to be operating at capacity. This is not necessarily true. There may be no output of the usual product mix of a firm that will completely utilize all of its existing facilities. If capital coefficients for this product mix are desired, some deletions of capital items becomes necessary. The averaging problem also exists if capital coefficients for individual firms turn out to be widely dispersed.

Another very important shortcoming of such data in the form usually available is the lack of detail with respect to the individual items of plant and equipment. It is necessary to know the amount of each type of capital in terms of its supplying industry to obtain capital coefficients.

Moreover accounting data make it necessary for capital coefficients to be stated in money terms. This does not prevent conversion into real units if the price per unit for each coefficient is known. By using money as the common unit for the capital facilities, the industry's capital coefficients can be added to give an over-all coefficient. If accounting data included not only the over-all relationship of total capital and capacity output but also the individual values of each kind of capital facility for that output, it would be possible to describe the industry's capital requirement in two somewhat different ways. First, the over-all coefficient for one industry might be contrasted with that of another to indicate the differences that exist in the amounts of capital required. Any differences would not necessarily mean that the relative quantities of the various kinds of capital were different. Second, industries might be contrasted in terms of the kinds of capital facilities they use, neglecting the over-all capital requirements.

It is not difficult to visualize an ideal set of accounting information on asset and capacity sales values. Such an ideal would be realized if firms could be induced to provide an analyst with the detail of its plant and equipment facilities (1) classified by the industry which produces them, (2) deleted of any items or facilities not required for a stipulated product mix which will use all facilities to capacity, and (3) valued at the cost of replacing such facilities with the best current ones. Then with the current sales value of the capacity output, the establishment coefficients could be computed for the given point in time. Comparisons with similar data for another time point would, however, still require price adjustments if the prices of sales items and capital items changed disproportionately. Furthermore if the proportion of value added to gross sales changed, another element of noncomparability between the coefficients over time would be introduced.

In the absence of ideal data some general results for the machine tool industry are included here. The information provides only very restricted coverage for the year 1951. The plant and equipment values used were the undepreciated amounts averaged for the beginning and end of the year without any correction for price changes. The capacity output was based on sales increased to a capacity level by using BLS studies for January 1951 and January 1952. The relationship between current and maximum potential employment at the two dates as shown by the studies allowed the computation of an average percentage of capacity utilized for the year 1951 which could be used to expand sales to a capacity level. This was done for each of the firms for which balance sheet and income account data and BLS information on maximum potential employment were available. The requirement that both types of information be available restricted the use of accounting data. An attempt was made to determine from available information the extent to which the firms included had more than one establishment. Firms which had one or more of their establishments producing relatively large amounts of products other than those included in the industry being studied were excluded from the analysis.

Table 12 summarizes the information derived from the accounting and capacity information at our disposal. The heavy weight placed on estimates of capacity in determining the over-all capital coefficients is apparent from the supporting footnote, which indicates the differences between capital-to-sales ratios and capital coefficients. The wide variability of firm over-all coefficients is indicated by their range.

TABLE 12

Over-all Capital Coefficients from 1951 Accounting Data for Twelve Machine Tool Producing Firms

Percentage of industry's output accounted for by these firms	18%
Over-all capital coefficient	$0.1793[a]
Median of firm over-all coefficients	$0.1822
Range of firm over-all coefficients	$0.0944–0.2931

[a]The over-all capital coefficients are ratios of undepreciated plant and equipment values to estimated capacity net sales. All plant and equipment values are uncorrected for price changes. The capital-to-sales ratio for the same firms is 0.3080; twenty firms, including the twelve here covered, had an average weighted capital-to-sales ratio of 0.3216. For 1952, the twenty firms had a capital-to-sales ratio of 0.2179. Twelve firms, for which capital-to-sales ratios could be computed for the years 1951, 1952, and the first quarter of 1953, had capital-to-sales ratios of 0.3187, 0.2188, and 0.1954, respectively.

Source: Moody's or published statements of individual firms.

No comparison of these coefficients with the over-all capital coefficient developed from tax amortization certificates is possible until an adjustment for price change is made. The over-all coefficient from accounting data was clearly based on capacity net sales valued in 1951 prices. The plant and equipment values were historic ones, however, and required price adjustment to obtain the ratio of capital facilities to net capacity sales, both valued in 1951 prices. The procedure used for this adjustment was as follows:

(1) The balance sheet data for fifteen firms available for each of the years 1942-1951 was used for an estimate of the amounts of their 1951 property which was purchased in various years since 1942.[8]

2. It was assumed that all purchases prior to 1947 were, on the average, purchased at 1942 prices and that the purchases each

[8]The estimates are based on the assumption that the change in the plant and equipment account, as shown at the beginning and end of each year, *plus* any write-offs of plant and equipment items during the year, measure the value of facilities acquired during the year. In most cases write-offs during the year are not shown on the balance sheets. They may be estimated, however, if it is assumed that any write-offs of property are also taken in identical amounts from the accumulated depreciation account. The write-offs from accumulated depreciation must be the annual depreciation less the difference between the beginning-of-year and end-of-year accumulated depreciation. While the assumptions that the plant account and the accumulated depreciation are always adjusted in the same amount can be shown to have exceptions, it seems to hold for the major adjustments. Use of the above method in this case produced the following dis-

year beginning with 1947 were recorded on the books in prices of the year in which purchased.[9]

3. A price index was constructed from 1942 to 1951 based on a building materials price index to represent construction costs and a machine tool price index to represent equipment costs, each of these indexes being weighted in terms of the relative proportions which appeared appropriate from the analysis of the certificate of necessity data.

4. This index was then used to obtain the value of the plant and equipment appearing on the books in 1951, all in 1951 prices and this was expressed as a ratio to the undepreciated book value.

5. The capital assets numerator of the coefficients was expressed in the same price terms as its capacity sales denominator, using the ratio as an index.

6. Finally, the coefficient expressed in 1951 prices was converted to 1950 prices for direct comparison with the over-all coefficient obtained from certificate of necessity data.

The over-all capital coefficient thus obtained was $0.296. This may be compared with the balanced over-all capital coefficient

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tribution of yearly purchases of the items in the 1951 plant account for the fifteen firms whose balance sheets were available:

Year	*Book Value*	*Year*	*Book Value*
Property account total:			
End 1951	$105,019		
Beginning 1951	92,899		
Average 1951	98,959		
		Prior to 1947	$69,774
Purchased in 1951 (half-year)	6,060	1946	11,591
		1945	2
1950	6,750	1944	1,249
1949	3,103	1943	4,242
1948	8,169	1942	8,229
1947	5,103	Prior to 1942	44,461

The distribution appears quite in line with general knowledge. The 1946 purchases are not strictly comparable since this was the year when plants were purchasing equipment leased to them by the government during the war years. The purchase prices for this equipment were probably significantly below original prices.

[9]The blocking-in of the purchases in the years 1942–1946 inclusive, along with years prior to 1942, was decided on because (1) price changes between 1942 and 1945 were negligible, (2) the estimated purchases in 1946, being in terms of unknown price levels, gave no basis for any specific price adjustment, and (3) balance sheet data were not readily available for the years prior to 1942.

selected from the certificate data of $0.435. It is difficult to know how to appraise such a comparative finding. The various adjustments made in deriving either coefficient are so numerous that the margin of error possible could be quite large. Certainly no probabilistic test of significant difference between them seems appropriate. The amount of confidence which can be placed in these values is quite problematical.