MEASURES OF CONCENTRATION

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A VARIETY of indexes of concentration have been used in the description and analysis of industrial structures. We shall review some of these measures, discussing their formal properties, their empirical relations to one another, and some of the significant economic findings that can be obtained with their help.

1. *Main Classes of Indexes*

THE term "economic concentration" has been employed in many different senses, and "indexes of concentration" have been constructed to measure a number of quite distinct characteristics of industrial structure. Our discussion will center on those indexes of concentration that measure the extent to which a small *number* of firms account for a large *proportion* of an industry's output. This definition is somewhat vague since it involves two variables, but it is sufficiently precise to permit a discussion of its economic significance and to distinguish it from other concepts of concentration.

Economic theory suggests that concentration as defined here is an important determinant of market behavior and market results. *Ceteris paribus,* monopolistic practices are more likely where a small number of the leading firms account for the bulk of an industry's output than where even the largest firms are of relatively small importance. Hence, in the explanation of business policy, the characteristics of an industry expressed in the concentration index are likely to play an important part. This relation to the degree of monopoly has motivated most of the empirical studies involving the measurement of concentration.[1]

[1] In some studies, however, concentration has been measured for large sectors of the economy that cannot be regarded as relevant to the problem of *market* behavior. The measurement by Gardiner C. Means of the importance of the largest 200 corporations in relation to the economy as a whole is perhaps the best-known example of an index of this type. A. A. Berle and G. C. Means, *The Modern Corporation and Private Property* (Macmillan, 1932), Bk. I, Chap. III. The significance of this index must be sought in theories that are broader in scope than the conventional economic analysis. The belief that democracy cannot survive where economic power is concentrated was cited by President Roosevelt as one of the bases for the investigations of the Temporary National Economic Committee (*S. Doc.* 173, 75th Cong., 3d Sess.), and probably implies the same concept of concentration as Mean's measure. The belief that the operation of an

It is not difficult for any imaginative investigator to develop a great many indexes to measure concentration in the general sense defined above. Our discussion will, however, be confined to measures that have actually been put to use in analyses of substantial bodies of statistical data.

A basic and very useful device for the description of concentration is the "concentration curve" used in the studies of the Federal Trade Commission.[2] The height of the curve above any point x on the horizontal axis measures the percentage of the industry's total size accounted for by the largest x firms. (Size of firms and industry may be measured in terms of output, employment, assets, or other variables.) The curve is therefore continuously rising from left to right, but rises at a continuously diminishing rate. It reaches its maximum height—100 per cent—at a point on the horizontal axis corresponding to the total number of firms in the industry (or making a product).

Three concentration curves are shown in Chart 1. A short, high curve indicates "high concentration," while a low-lying, long curve indicates "low concentration." When two curves cross, however, the lack of precision in our definition of concentration becomes apparent, and without refining the definition one cannot say which of them represents higher concentration.

The indexes measuring concentration as defined above are easily related to this curve. The most frequently encountered class of indexes can be represented by the height of the concentration curve above a given point on the horizontal axis. Thus, the percentage of output or employment accounted for by the leading four firms or the leading eight firms has been used in the analysis of American data,[3] and the percentage of output accounted for by the leading three firms has been used in Great Britain.[4]

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independent personal business is a generally desirable way of life has been one of the motivations of antitrust legislation and of the special concern of government with "small business," and has prompted the measurement of "over-all concentration" as an indication of the portion of the economy closed to small business. This paper will not be concerned with such "broad" measures of concentration.

[2] See, for example, *The Concentration of Productive Facilities, 1947*, Federal Trade Commission, 1949, and *The Divergence Between Plant and Company Concentration, 1947*, FTC, 1950.

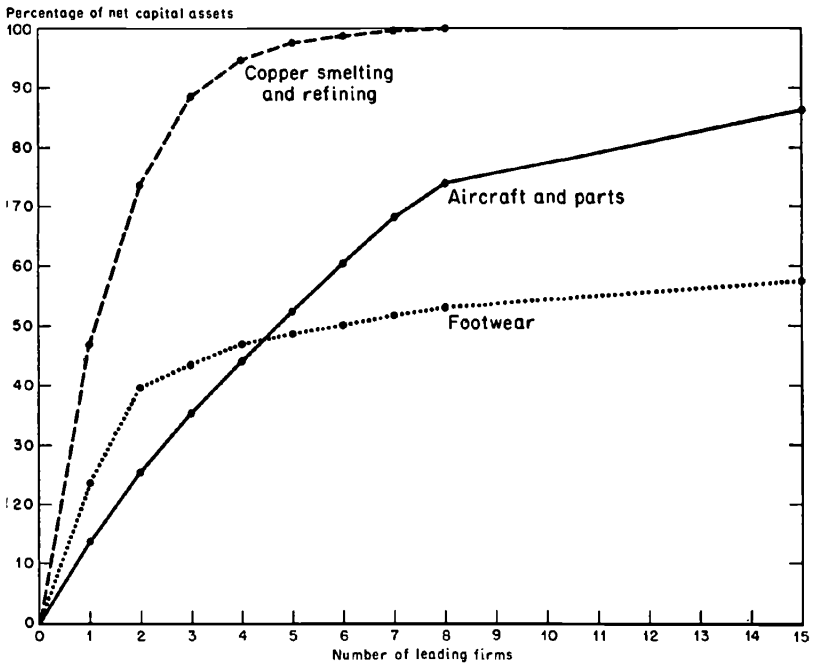
[3] E.g., *The Structure of the American Economy, Part 1*, National Resources Committee, 1939, Appendix 7; *Concentration of Industry Report*, Dept. of Commerce, 1949.

[4] H. Leak and A. Maizels, "The Structure of British Industry," *Journal of the Royal Statistical Society*, Vol. 108 (1945), pp. 142-199.

Instead of measuring the height of the concentration curve at a given horizontal distance from the origin, we can measure the horizontal distance to the curve at a given height. This is an inverse measure of concentration, increasing in numerical value as concen-

Chart 1

Concentration of Net Capital Assets, Three Industries, United States, 1947



Source: *The Concentration of Productive Facilities, 1947*, Federal Trade Commission, 1949, pp. 28, 47, 79.

tration decreases. Thus, the number of plants required to account for 50 per cent of employment has been used by W. L. Thorp in a study for the Temporary National Economic Committee (TNEC)[5] and the writer has used the number of firms required to account for 80 per cent of employment in a study of industrial concentration in Canada.

These two classes of indexes can be criticized on the ground that they depend on only one point on the concentration curve, so that

[5] Willard L. Thorp and Walter F. Crowder, *The Structure of Industry*, TNEC Monograph 27, 1941, Part I.

there are many changes in the position of the curve that leave the index unchanged. The lack of a summary measure utilizing all points on the curve has therefore been lamented[6] and even offered as an argument for using a different concept of concentration.[7] But summary measures can be devised to measure concentration, just as they have been developed for other characteristics of size distributions. An ingenious measure of this type has been employed by O. C. Herfindahl in an investigation of concentration in the steel industry. It consists of the sum of squares of firm sizes, all measured as percentages of total industry size. This index is equal to the reciprocal of the number of firms if all firms are of the same size, and reaches its maximum value of unity when there is only one firm in the industry.[8]

These are the classes of measures that will be investigated in this paper. There is, however, an important class of concentration indexes that do not conform to our concept of concentration. The well-known Lorenz curve measures the cumulative percentages of output accounted for by various *percentages* of the number of firms.[9] Gini's concentration ratio is a function of the area between the Lorenz curve and the diagonal line the curve would follow if all firms were of equal size. It thus measures the extent to which a small *percentage* of all firms account for a large percentage of output, and does not measure concentration in our sense. The characteristic described by Gini's ratio and the Lorenz curve is often called "inequality," and that usage will be followed here, although some writers identify inequality as "relative" concentration and refer to concentration as defined by us as "absolute" concentration.[10]

[6] J. M. Blair, "Statistical Measures of Concentration in Business, Problems of Compiling and Interpretation" (paper presented at the Annual Convention of the American Statistical Association, December 29, 1950).

[7] J. Lintner and J. K. Butters, "Effect of Mergers on Industrial Concentration, 1940-1947," *Review of Economics and Statistics*, February 1950, p. 46.

[8] Orris C. Herfindahl, "Concentration in the Steel Industry" (Ph.D. dissertation, Columbia University, 1950). It should be noted that "summary" is a somewhat ambiguous term, and that in an important sense the measures based on intercepts of the concentration curve are also "summary measures." For example, a change in the size of any one firm will affect all such indexes as well as Herfindahl's index. It is true that many concentration curves and many values of Herfindahl's index are compatible with, say, the concentration of a given percentage of output in the leading four firms. But it is also true that many different values of the percentage concentrated in the leading four firms are compatible with a given value of Herfindahl's index.

[9] M. O. Lorenz, "Methods of Measuring Concentration of Wealth," *Journal of the American Statistical Association*, June 1905, pp. 209-319.

[10] Lintner and Butters, *loc. cit.*

Inequality is also identified with concentration in the work of R. Gibrat, who measures inequality of income-size distributions by the standard deviation of a normal curve fitted to the logarithms of income[11] and defines concentration as inequality of firm size.[12] There are many other measures of inequality, either based on intercepts of the Lorenz curve or summarizing the whole size distribution, and their properties have received more careful study, mainly in connection with the distribution of incomes, than has been devoted to the concentration indexes.[13]

Inequality is of course related to concentration, and an understanding of their relation is important. Given the number of firms, concentration increases with an increase in inequality; and given the degree of inequality, concentration decreases with an increase in the number of firms.[14] This proposition can be demonstrated in various ways. It follows directly from our definition of concentration as the extent to which a small *number* of firms account for a large percentage of output, and of inequality as the extent to which a small *percentage* of the firms account for a large percentage of output. The lack of precision in both definitions does not affect the precise relation between them. A consideration of the relation between the concentration curve and the Lorenz curve demonstrates the same proposition. The only difference between the two curves is that the first measures the cumulative number of firms along the

[11] Or the logarithms of the deviation of income from a given minimum.

[12] R. Gibrat, *Les inégalités économiques* (Librairie du Recueil Sirey, 1931), p. 206: "La concentration se définit et se mésure comme l'inégalité de répartition des entreprises suivant leur importance."

[13] Cf. Dwight B. Yntema, "Measures of Inequality in the Personal Distribution of Wealth and Income," *Journal of the American Statistical Association*, December 1933, p. 423.

[14] This algebraic relation among the three variables also implies, of course, that given the degree of concentration, inequality increases with an increase in the number of firms. It is not surprising, therefore, that some writers in this field have asserted that concentration is not affected by the number of firms but that inequality is so affected, while others have asserted the opposite. Mathematically, either statement can be correct if the right variable is held constant.

The misleading notion that measures of concentration are not affected by the number of firms arises in part from the fact that it is possible to calculate, for example, the percentage of output accounted for by the largest x firms without knowing the total number of firms (while this is not in general possible for measures of inequality). This is of great practical importance where complete and accurate statistics are not available. Many industries contain a large number of very small firms, so that total industry output (and hence the percentage accounted for by the leading four) can be estimated with great accuracy from a sample, while the total number of firms could be ascertained only at great cost.

horizontal axis, while the latter measures the cumulative percentage of firms.[15] Hence, if we compare two industries with the same number of firms any difference in their concentration curves must reflect a difference in their Lorenz curves. On the other hand, if we compare two industries with the same Lorenz curves, any difference in their concentration curves must reflect a difference in the number of firms, the industry with more firms having a longer and lower-lying concentration curve.[16]

A third class of concentration measures indicates neither concentration nor inequality as we have defined these concepts, but rather average firm size. In the study entitled *Economic Concentration and World War II*,[17] for example, the plants of an industry are grouped by size classes, size being measured in terms of employment, and the rising percentage of employment in the large-size classes is cited as showing increasing concentration. It is not quite clear whether the authors of this study (and others who have used similar data) have in mind a concept of concentration similar to ours and have made an error in their method of measurement, or whether they have in mind a concept of concentration that identifies it with absolute size. Again, there is, of course, a relation between these concepts. Given the size of the industry, a larger average firm size means fewer firms, and given the degree of inequality of firm size, fewer

[15] The original Lorenz curve measured the cumulative percentage of income on the horizontal axis and the cumulative percentage of the number of incomes on the vertical axis. Moreover, it started with the lowest incomes, while the concentration curve starts with the largest firms. By simply changing the axes and replacing x per cent by $100 - x$ per cent this curve can be transformed into one identical with the concentration curve except for the difference mentioned in the text.

[16] This relation between inequality and concentration can also be shown algebraically in terms of the three types of concentration indexes discussed above.

a. Herfindahl's summary index can be shown, by simple algebraic manipulation, to be equal to $(c^2 + 1) \div n$ where c is the coefficient of variation (standard deviation divided by mean) and n is the number of firms.

b. The index measuring the *number* of firms required to account for x per cent of output is equal to the total number of firms multiplied by the index measuring the percentage of firms required to account for x per cent of output. Here the indexes measure concentration and inequality inversely, so that, again, concentration increases with inequality and decreases with the number of firms.

c. The index measuring the percentage of output accounted for by the leading k firms is equal to $k\ (a/A) \div n$ where a is the average size of the leading k firms, A is the average size of all firms, and (a/A) can be regarded as a measure of inequality of firm size.

[17] *Economic Concentration and World War II*, Report of Smaller War Plants Corporation before Special Committee on Small Business, S. Doc. 206, 79th Cong., 2d Sess., 1946.

firms mean higher concentration. Hence one can say that, *ceteris paribus*, larger firms mean higher concentration. This is in fact frequently said, and the *cetera* are almost as frequently forgotten.

It is reasonable to assume that concentration as we have defined it is more directly relevant than either inequality or average firm size to problems of monopoly and business policy. An index of inequality may tell us that 10 per cent of the firms in an industry control 95 per cent of output, but it does not tell us whether this 10 per cent consists of one firm or perhaps a hundred firms, and surely a competitive pattern of behavior is much more likely in the latter case than in the former. Similarly, the size distribution may tell us that 95 per cent of employment is in firms with over 1,000 employees each, but there may be one such firm or there may be many, depending on the size of the industry, and the likelihood of competition will vary accordingly. In the extreme case in which one firm has a monopoly of the whole output, concentration will reach its maximum value, but inequality will be nil, and firm size may be large or small, as the industry may be large or small.

Concentration is not, of course, the only determinant of the degree of monopoly and perhaps not even the only relevant characteristic of an industry's size structure. Stigler has shown that the number of firms that are larger than a given percentage of the leading firm size *and* account for more than a given percentage of the industry is correlated with price flexibility.[18] Another variable that has been suggested is the height of the point on the concentration curve at which its second difference reaches a minimum. At this point the difference between successive firm sizes is greatest.[19] This measure may have some importance in those industries in which there are a few "giants" separated by a wide gap in size from the remaining firms in the industry, but many concentration curves do not have such a point at all.

2. *Choice of an Index*

WHILE elementary theoretical considerations suggest the relevance of our concept of concentration to the study of monopoly and business policy, they do not enable us to discriminate among the various indexes that have been used. The choice of measure may affect the outcome of an investigation since the different indexes involve dif-

[18] George J. Stigler, "The Kinky Oligopoly Curve and Rigid Prices," *Journal of Political Economy*, October 1947, p. 444.

[19] Cf. Blair, *op. cit.*, p. 8.

ferent scales of measurement, and even the ranking of observations by concentration level may vary with the index used. For example, in 1947 the percentage of fixed assets accounted for by the leading three firms was higher in cigarettes than in motor vehicles, but the percentage accounted for by the largest firm alone was higher in motor vehicles than in cigarettes.[20] In order to select one index as superior to others for a given purpose, careful empirical tests of carefully formulated hypotheses regarding the effects of concentration must be undertaken, and very little such work has been done to date. The research worker using any one of these indexes will therefore want to know how much his results might be altered by the use of another index. We shall examine this problem by comparing the behavior of various indexes when they are applied to the same body of data.

Our first exhibit is a comparison of concentration as measured by the percentage of fixed assets accounted for by the largest firm and the largest two, three, and four firms in a cross section of twenty-six industries for which data were published by the FTC.[21] The rankings of the industries by concentration level are compared in Table 1. It is evident that while many industries change their position in the array as the concentration index is changed, the general pattern remains the same. An industry with a "high" percentage of assets concentrated in the largest firm, in comparison with other industries, does not in general have a "low" percentage of assets concentrated in the largest two, three, or four firms. The similarity of patterns can be summarized by means of rank correlation coefficients. The Spearman correlation coefficients for the various pairs of rankings are as follows:

	CONCENTRATION IN		
	Largest Two Firms	*Largest Three Firms*	*Largest Four Firms*
Concentration in largest firm	.966	.924	.914
Concentration in largest two firms		.961	.939
Concentration in largest three firms			.984

The correlation among indexes of this type based on vertical intercepts of the concentration curve will of course decline as the distance between the two intercepts increases, but the above coefficients are all fairly high. Even when the number of the leading firms on which the index is based is well above four, a high correlation is

[20] *The Concentration of Productive Facilities: 1947*, as cited, Table 3, p. 21.
[21] *Ibid.*

TABLE 1

Ranking of Industries according to the Percentage of Net Capital Assets Controlled by the Largest Firms, United States, 1947

Industry	*Largest Firm* (1)	*Largest Two Firms* (2)	*Largest Three Firms* (3)	*Largest Four Firms* (4)
Linoleum	1	3	3	4
Tin cans, etc.	2	1	2	2
Aluminum	3	2	1	1
Copper smelting and refining	4	4	4	3
Biscuits, etc.	5	8	11	11
Agricultural machinery	6	9	12	8
Office machinery	7	10	9	9½
Motor vehicles	8	7	10	12
Cigarettes	9	6	5	6
Plumbing equipment	10	5	7	9½
Distilled liquors	11	12	6	7
Meat products	12	11	13	13
Primary steel	13	16	16	17
Rubber tires	14	13	8	5
Dairy products	15	15	15	15
Glass and glassware	16	14	14	14
Carpets and rugs	17	18	17	16
Footwear	18	17	19	20
Industrial chemicals	19	19	18	18
Woolen and worsted	20	22½	24	25
Electrical machinery	21	20	20	19
Grain-mill products	22	22½	23	23
Aircraft and parts	23	21	21	21
Bread, etc.	24	25	25	24
Canning	25	24	22	22
Drugs and medicines	26	26	26	26

Source: Derived from *Report on the Concentration of Productive Facilities, 1947*, FTC, 1949, Table 3, p. 21.

obtained. This is shown by the comparison of concentration in the largest four and eight firms in 1935 for a sample of 135 industries for which employment-concentration indexes were published by the National Resources Committee.[22] The ranking of industries by the percentage of employment concentrated in the leading eight firms is very similar to the ranking by the percentage of employment concentrated in the leading four firms, the correlation between the rankings being .989.

[22] *The Structure of the American Economy*, as cited, Appendix 7, Table 1. The sample was selected by taking every second industry in the table with a random start. Three industries for which concentration in the leading four firms was not published and one for which concentration in the leading eight industries was not published were omitted.

Concentration indexes belonging to three different families are compared in Table 2. The table shows, for a group of 96 Canadian manufacturing industries, estimates of (1) the percentage of employment accounted for by the leading three firms; (2) the number of firms required to account for 80 per cent of employment; (3)

TABLE 2

Comparison of Three Concentration Indexes, Selected Canadian Manufacturing Industries, 1948

Group and Industry	*Index 1 Percentage of Employment Accounted for by Leading Three Firms*	*Index 2 Number of Firms Required to Account for 80 Per Cent of Employment*	*Index 3 Herfindahl's Index, Employment*[a]
Foods, beverages, tobacco:			
Cigarettes, cigars, tobacco	84.5	2.1	.1797
Distilleries	84.2	2.5	.2400
Sugar refineries	68.3	4.1	.1805
Malt and malt products	66.2	3.6	.1111
Starch and glucose	64.6	4.0	.1000
Macaroni, etc.	59.9	5.6	.0714
Tobacco processing and packing	58.6	5.6	.1392
Wine	57.5	9.1	.1215
Slaughtering and meat packing	55.3	11.2	.1052
Processed cheese	49.2	7.4	.1053
Breweries	48.6	8.6	.0988
Biscuits and crackers	41.7	11.1	.0723
Condensed milk	35.6	12.0	.0377
Flour mills	34.9	22.0	.0604
Cocoa, confectionery, etc.	33.4	23.4	.0519
Fruit and vegetable preparations	32.4	72.3	.0398
Soft drinks	30.9	149.2	.0345
Bread and other bakery products	20.9	732.5	.0194
Butter and cheese factories	19.2	369.9	.0172
Prepared stock and poultry feeds	15.5	92.4	.0167
Fish curing and packing	14.9	132.5	.0175
Feed mills	3.4	469.8	.0022
Textiles, leather, fur:			
Cotton thread	94.3	1.8	.2975
Cordage, rope and twine	65.9	3.8	.1463
Carpets, mats, rugs	64.0	4.8	.1551
Belting, leather	62.2	6.5	.1435
Cotton yarn and cloth	59.8	5.1	.1317
Narrow fabrics, laces, etc.	53.8	10.3	.1085
Synthetic textiles and silk	48.7	11.3	.0945
Fur dressing and dyeing	41.1	9.1	.0852
Woolen yarne	38.5	14.1	.0659
Corsets and girdles	37.1	13.9	.0654
Cotton and jute bags	36.7	12.8	.0685
Dyeing and finishing of textiles	34.3	12.9	.0635

TABLE 2 (*continued*)

Group and Industry	*Index 1 Percentage of Employment Accounted for by Leading Three Firms*	*Index 2 Number of Firms Required to Account for 80 Per Cent of Employment*	*Index 3 Herfindahl's Index, Employment*[a]
Woolen cloth	28.3	25.2	.0412
Tanning	26.5	19.3	.0438
Contractors, women's clothing	23.4	42.4	.0279
Leather gloves	20.9	30.5	.0311
Canvas goods	19.9	39.1	.0257
Hosiery and knitted goods	15.7	55.8	.0205
Miscellaneous leather products	13.8	80.2	.0145
Contractors, men's clothing	10.8	78.2	.0126
Boots and shoes, leather	8.5	109.6	.0087
Clothing, men's factory	8.2	155.4	.0078
Fur goods	5.6	282.1	.0040
Clothing, women's factory	4.0	517.0	.0023
Wood products:			
Excelsior	62.8	4.0	.1000
Coffins and caskets	43.4	14.5	.0759
Plywood and veneer	33.8	13.3	.0526
Flooring	32.0	12.8	.0641
Boats and canoes	17.0	92.7	.0117
Furniture	7.4	277.1	.0047
Sawmills	7.0	1,843.4	.0036
Planing mills, sash and door factories	4.6	377.0	.0035
Paper products:			
Roofing paper	60.5	6.3	.1406
Pulp and paper mills	27.8	22.5	.0448
Paper boxes and bags	16.8	57.6	.0196
Iron and Steel products:			
Pig iron	91.9[b]	2.6[b]	.2955[b]
Automobiles	87.5	1.7	.2181
Railway rolling stock	79.2	3.1	.2159
Aircraft	78.2	3.1	.2012
Steel ingots and castings	76.3[c]	3.4[c]	.2053[c]
Agricultural implements	63.4	4.4	.1377
Bicycles	80.6	2.9	.1546
Shipbuilding	32.3	13.1	.0626
Iron castings	19.8	45.9	.0267
Machine shops	6.2	229.6	.0046
Nonferrous metals:			
Aluminum	100.0 (1 firm)	.8	1.0000
Nickel	100.0 (2 firms)	.9[d]	.8957[d]
Nonmetallic minerals:			
Cement	100.0	1.2	.3333
Gypsum products	91.7	1.6	.2500

TABLE 2 (Continued)

Group and Industry	*Index 1 Percentage of Employment Accounted for by Leading Three Firms*	*Index 2 Number of Firms Required to Account for 80 Per Cent of Employment*	*Index 3 Herfindahl's Index, Employment*[a]
Glass	91.7	1.6	.2500
Artificial abrasives	86.7	2.0	.2000
Abrasive products	81.9	2.7	.1850
Petroleum products	80.1	2.99	.2195
Asbestos products	64.0	4.8	.1591
Coke products	52.7	5.7	.1204
Plate, cut, and ornamental glass	40.4	24.6	.0634
Cement products	11.7	119.2	.0118
Chemicals:			
Hardwood distillation	100.0 (2 firms)	1.0	.5000
Matches	97.9[e]	.9[e]	.8020[e]
Coal-tar distillation	91.7	1.6	.2500
Compressed gases	81.4	2.9	.2272
Soaps	74.6	4.1	.1885
Boiler compounds	66.7	3.7	.1562
Writing inks	66.3	3.8	.1629
Washing compounds	56.3	8.2	.1116
Printing inks	56.7	6.3	.1121
Vegetable oils	53.7	7.0	.1206
Polishes and dressings	36.0	12.1	.0677
Paints and varnishes	31.5	22.2	.0478
Medicinal and pharmaceutical preparations	19.7	49.4	.0238
Miscellaneous:			
Pipes and smokers' supplies	85.3	2.3	.2451
Umbrellas	83.5	2.7	.2416
Fountain pens and pencils	67.3	4.4	.1248
Buttons	48.9	8.8	.0992

[a] See p. 60 and footnote 8. Figures represent *minimum* estimates derived from grouped data on the assumption that firms within each size class are of equal size.

[b] Concentration measured in terms of blast-furnace capacity. Source: *The Primary Iron and Steel Industry, 1948*, Dominion Bureau of Statistics, Ottawa, 1949, p. 8.

[c] Concentration measured in terms of steel-furnace capacity. Source: *The Primary Iron and Steel Industry, 1948*, Dominion Bureau of Statistics, Ottawa, 1949, p. 13.

[d] Concentration measured in terms of value of sales of nickel producers. Source: *Moody's Industrials, 1949*.

[e] Concentration measured in terms of number of matches produced. Source: *Matches*, Report of Commissioner, Combines Investigation Act, Ottawa, Dec. 27, 1949, Ottawa, 1950.

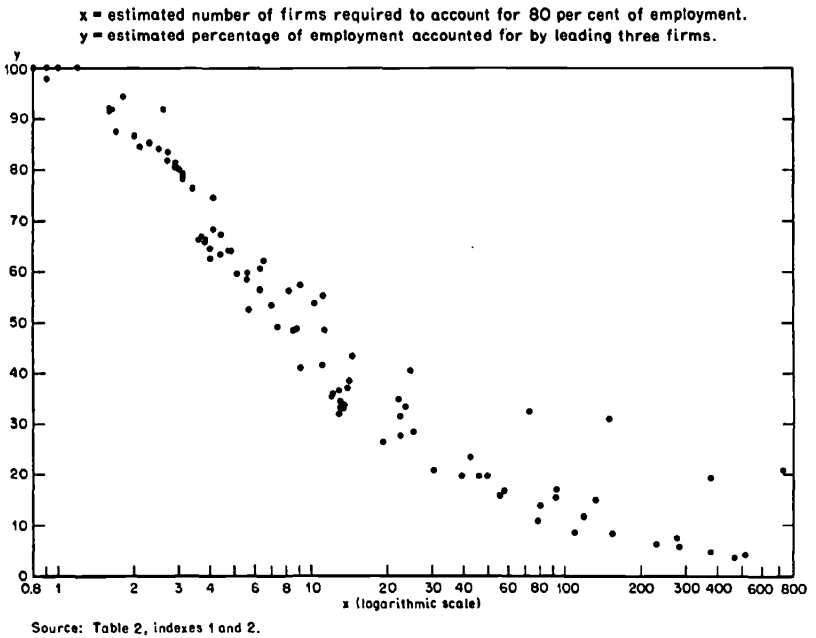
Source: Estimates based on unpublished grouped firm-size distributions obtained from Dominion Bureau of Statistics.

Herfindahl's summary index measuring the sum of squares of firm sizes, expressed as percentages of industry size.

It is again apparent that the ordering of industries by concentration level is largely independent of the particular index employed. The Spearman rank correlation coefficient comparing indexes (1) and (2) is .981, the coefficient comparing indexes (1) and (3) is .980, and the coefficient comparing indexes (2) and (3) is .979.[23] Chart 2 is a scatter diagram of indexes (1) and (2), using a logarithmic scale

Chart 2

Comparison of Two Concentration Indexes, Selected Canadian Manufacturing Industries, 1948



Source: Table 2, indexes 1 and 2.

for index (2). The chart indicates the close but nonlinear relation between the indexes.

These three comparisons suggest that in the analysis of cross-section data, the use of any one of the indexes considered here will result in substantially the same ordering of observations as any of the others. Analytical results that rest on the ordering of observations will not be greatly affected by the index used.

[23] The concentration indexes were estimated from unpublished firm-size distributions which were compiled by the Dominion Bureau of Statistics, Ottawa.

3. *Comparison of Concentration in the United States and the United Kingdom*

As AN example of the use of cross-section data on concentration we have made a comparison of the general level of concentration in the manufacturing industries of the United States and the United Kingdom. It is often said that the British economy is less competitive than that of the United States and it is of interest to see whether there is any basis for such a view in the size structure of business firms.

Reasonably comparable employment-concentration indexes for both countries are available for the year 1935.[24] The main difficulties in making a comparison are that the American indexes measure the concentration of employment in the leading four firms of each industry, while the British data deal with the leading three firms, and that the industrial classifications are not strictly comparable.

It is, of course, vital for a comparison of this sort that industries should be comparable in scope. In general, the more broadly an industry is defined, the greater will be the number of firms and the lower will be the apparent level of concentration. Inspection of the industrial classification of the United States Census of Manufactures and the United Kingdom Census of Production indicates, however, that the scope of the various "industries" is, on the whole, comparable in the two countries, although there are many differences of detail.

An over-all comparison can be made, without reconciling each individual industry classification, by studying the frequency distributions of industries by concentration level in the two countries. For this purpose the two different indexes used must be reconciled. There is of course no completely accurate method for comparing concentration in four firms with concentration in three firms, unless one knows the size of the fourth firm. We have made an estimate by calculating the straight-line regression of concentration in four firms on concentration in three firms for a group of twenty-five industries for which the necessary information was available.[25] Even

[24] *The Structure of the American Economy*, as cited, *loc. cit.*, and Leak and Maizels, *loc. cit.*

[25] *The Concentration of Productive Facilities*, as cited, Table 3, p. 21. One of the twenty-six industries included there is omitted from our calculation since it contains only three firms. The regression equation is $C_4 = 6.784$ per cent $+ .9913\ C_3$ where C_4 is concentration in the leading four firms and C_3 concentration in the leading three firms, both expressed as percentages. The regression line fits the data very well, the correlation coefficient being .984. The 25 observations to which this line has been fitted range from 23.5 per cent to 95.3 per cent (con-

though the data for this regression equation are for 1947 instead of 1935 and measure asset concentration instead of employment concentration it is probably good enough for our purpose.[26] By applying the equation to the class intervals into which the British data were grouped, a comparable grouping of the American statistics could be achieved. The comparison is based on all British industries and a random sample of American industries.[27]

The results are summarized in Table 3 and Chart 3. The percentage of manufacturing industries with concentration ratios above any given level is higher in the United Kingdom than in the United States, and the same relation holds for the percentage of employ-

TABLE 3

Cumulative Frequency Distribution of Manufacturing Industries and Employment by Degree of Concentration, United States and the United Kingdom, 1935

Concentration Index[a]	*Percentage of Industries*		*Percentage of Employment*	
	U.S.	*U.K.*	*U.S.*	*U.K.*
Over 80	3	6	1	2
Over 70	8	13	2	7
Over 60	14	18	5	11
Over 50	22	28	14	19
Over 40	32	38	15	29
Over 30	49	57	28	46
Over 20	63	74	38	64
All industries	100	100	100	100

[a] Percentage of employment accounted for by leading 3 firms.

Source: For the United States, *The Structure of the American Economy, Part I*, National Resources Committee, 1939, Appendix 7, Table 1. (See footnotes 22, 27, above.) For the United Kingdom, H. Leak and A. Maizels, "The Structure of British Industry," *Journal of the Royal Statistical Society*, Vol. 108, 1945, pp. 142-199. Data for nonmanufacturing industries, as shown in Appendix XIII, were subtracted from the frequency distribution shown in Table IX.

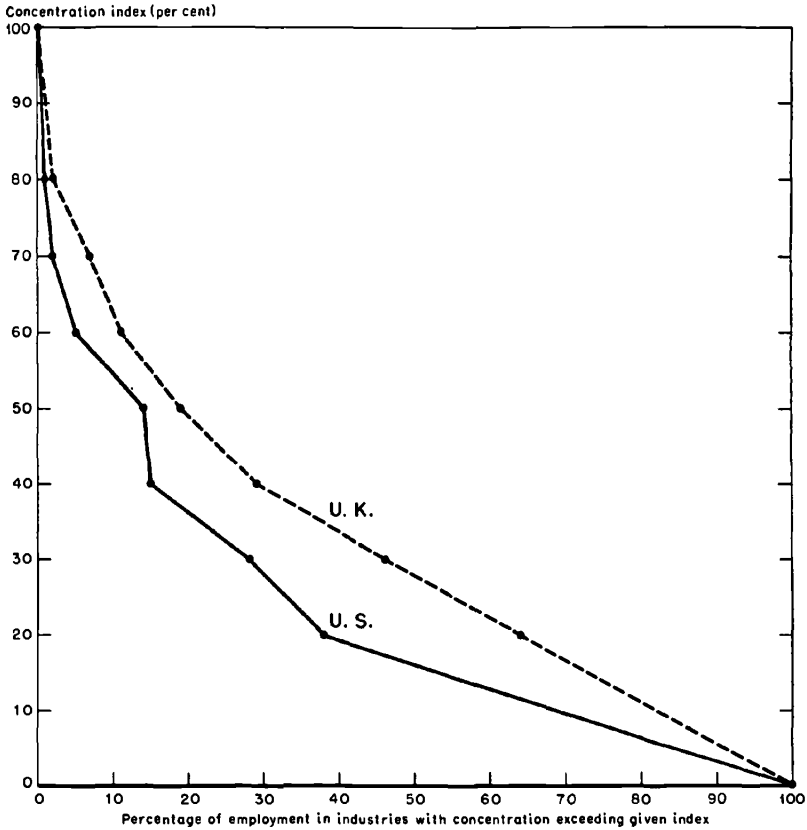
centration in three firms). The equation cannot be expected to fit lower concentration levels, but this is not required since we group together all industries with concentration in three firms below 20 per cent and use the regression equation only to calculate the level of concentration in four firms corresponding to 20 per cent concentration in three firms.

[26] The comparison of concentration in 1935 and 1947, discussed later in this paper, indicates that there has been little change in industry concentration indexes between the two dates. The application of the relation derived from fixed-asset concentration to employment concentration does not involve the assumption that asset and employment concentration are the same but only requires the weaker assumption that the difference between asset and employment concentration in four firms is .9913 times the difference between asset and employment concentration in three firms.

[27] The sample is that used for the comparison of concentration in four and eight firms (note 22 above). One industry, excluded from the above comparison since concentration in eight firms was not available, is included here.

Chart 3

Cumulative Frequency Distribution of Employment in Manufacturing Industries by Degree of Concentration, United States and the United Kingdom, 1935



Source: Table 3.

ment. It is clear, therefore, that the general level of concentration is higher in the British industries.

The extent of the difference can be indicated in various ways. Interpolating between the values shown in Table 3, we find that the median industry has a concentration ratio of about 34 per cent in the United Kingdom and 29 per cent in the United States. Half of all employment is in industries with concentration ratios of over 28 per cent in the United Kingdom and over 16 per cent in the United States. The weighted average concentration indexes (using

employment in each industry as weights) are 33 per cent for the United Kingdom and 19 per cent for the United States.

In both countries the level of concentration when judged by the cumulative distribution of employment appears considerably lower than when judged by the cumulative number of industries. This difference reflects a negative correlation between industry size and concentration level, which is generally found in cross-section data. The relation is shown more clearly in Table 4:

TABLE 4

Average Employment per Industry by Concentration Classes, United States and the United Kingdom

Concentration Index[a]	*Average Number of Employees per Industry*	
	U.S.	*U.K.*
Over 90	[b]	5,450
80–90	10,576	6,367
70–80	3,334	11,406
60–70	18,719	13,970
50–60	32,677	11,704
40–50	5,409	17,077
30–40	23,452	14,673
20–30	22,935	17,430
0–20	51,628	22,842
Average	31,275	16,397

[a] Percentage of employment accounted for by leading three firms.

[b] No industries in the U.S. sample in this class.

Source: For the United States, *The Structure of the American Economy, Part I*, National Resources Committee, 1939, Appendix 7, Table 1. (See footnotes 22, 27, above.) For the United Kingdom, H. Leak and A. Maizels, "The Structure of British Industry," *Journal of the Royal Statistical Society*, Vol. 108, 1945, pp. 142-199.

The negative correlation between industry size and concentration is not strong. It reflects the fact that on the average a large industry is more likely to have a large number of firms, and hence low concentration, than a small one.

An exact reconciliation of American and British classifications was possible for a limited number of industries, and for fifty-seven of these, concentration levels could be compared without resorting to the regression equation.[28] These industries are shown in Table 5.

[28] Since we know that the fourth firm in the United Kingdom cannot be larger than the average size of the largest three, we can be sure that United Kingdom concentration is less than United States concentration if the United Kingdom figure is less than three-fourths of the United States figure. Hence, the only cases in which a conclusive judgment is not possible are those in which the United Kingdom figure is less than the United States figure but greater than three-fourths of the United States figure.

TABLE 5

Comparison of Concentration in the United States and the United Kingdom, 1935, 57 Selected Manufacturing Industries

Industry Group (U.S. Classification, 1935)	*Industry*[a]	*Percentage of Employment Accounted for by Leading Four Firms, U.S.*	*Percentage of Employment Accounted for by Leading Three Firms, U.K.*
A. INDUSTRIES IN WHICH CONCENTRATION IN U.K. EXCEEDS CONCENTRATION IN U.S.			
Food and kindred products	Sugar, beet	62	72
	Liquors, distilled	50	74
	Condensed milk	44	94
	Liquors, rectified	42	57
	Flour and other grain-mill products	20	34
	Butter	19	22
	Feeds prepared for animals and fowls	15	32
	Confectionery	10	15
Textiles and their products	Cordage and twine	29	32
	Rayon manufactures	19	80
	Dyeing and finishing cotton, rayon, and silk	16	24
	Knit goods	5	10
Forest products	Matches	66	89
	Lumber and timber products, n.e.c.	4	7
Paper and allied products	Wallpaper	46	90
Printing and publishing	Printing and publishing, newspapers	14	27
	Bookbinding	12	14
	Printing and publishing, book, music, and job	5	8
Chemical and allied products	Soap	63	70
	Candles	58	77
	Fertilizers	31	34
	Perfumes, cosmetics, and other toilet preparations	18	20
	Drugs and medicines	18	19
Products of petroleum and coal	Petroleum refining	38	82
Stone, clay, and glass products	Cement	31	66
Iron and steel and their products (not including machinery)	Nails, spikes, etc.	51	58
	Wrought pipe	43	71
	Gold and silver refining	49	71
Machinery, not including transportation equipment	Scales and balances	48	70
	Refrigerators and refrigerating apparatus	45	72

TABLE 5 (*continued*)

Industry Group (U.S. Classification, 1935)	*Industry*[a]	*Percentage of Employment Accounted for by Leading Four Firms, U.S.*	*Percentage of Employment Accounted for by Leading Three Firms, U.K.*
	Printers' machinery and equipment	30	38
	Pumps and pumping equipment	21	33
	Machine tools	14	26
	B. INDUSTRIES IN WHICH CONCENTRATION IN U.S. EXCEEDS CONCENTRATION IN U.K.		
Food and kindred products	Vinegar and cider	39	13
Textiles and their products	Lace goods	33	11
	Hats, felt and straw, except millinery	29	9
Forest products	Cooperage	21	14
Chemical and allied products	Paints, pigments, and varnishes	28	16
Products of petroleum and coal	Coke-oven products	42	17
Leather products	Boots and shoes, other than rubber	21	9
Iron and steel and their products (not including machinery)	Files	83	42
	Firearms	79	49
	Saws	69	47
	Blast-furnace products	58	35
	Steel-works and rolling-mill products	46	22
	Wirework, n.e.c.	28	18
Nonferrous metals and their products	Needles, pins, hooks and eyes, and fasteners	65	30
Machinery, not including transportation equipment	Cranes, dredging and excavating machinery, etc.	34	22
Transportation equipment	Cars, electric and steam railroad	64	38
	Motor vehicles, bodies and parts	62	30
	Ship and boat building, steel and wooden, including repair	45	27
	Carriages, wagons, sleighs, and sleds	43	19
Miscellaneous industries	Optical instruments	65	13
	Musical instruments, parts and materials, piano and organ	48	24
	Umbrellas, parasols, and canes	38	18
	Sporting and athletic goods	35	22

[a] Names of industries as used by the *Census of Manufactures: 1935*.

Source: For the United Kingdom, H. Leak and A. Maizels, "The Structure of British Industry," *Journal of the Royal Statistical Society*, Vol. 108, 1945, Appendix III, and *Final Report of the Fifth Census of Production, 1935* (4 volumes and General Summary Tables). For the United States, *The Structure of the American Economy*, Part I, National Resources Committee, 1939, Appendix 7, Table I, pp. 240-248, and *Census of Manufactures: 1935, Industry Classification*, Bureau of the Census.

Of the industries examined, thirty-three have higher concentration in the United Kingdom than in the United States, and twenty-four have higher concentration in this country. The average of concentration indexes (percentage of employment in the leading *three* firms) weighted by employment in each industry is 20 per cent for the United States and 25 per cent for the United Kingdom.[29] These findings confirm the impression gained from the over-all frequency distributions, that the level of concentration is somewhat higher in the United Kingdom.

How much of the difference in average concentration levels is due purely to differences in the relative importance of various industries in the two countries? If each industry in Britain had the concentration index of its counterpart in the United States, the weighted averages would be 20 per cent in the United States and 21 per cent in the United Kingdom. On the other hand, if each industry in the United States had the concentration index of its counterpart in the United Kingdom, the weighted averages would be 26 per cent in the United States and 25 per cent in the United Kingdom. The effect of differences in the relative size of industries on average concentration is therefore slight, and its direction depends on whether measurement is based on United States or United Kingdom concentration ratios. It follows that the difference in average concentration levels between the two countries reflects primarily the difference in concentration ratios for comparable industries.

Further analysis indicates that the sampled industries with lower concentration in the United States are larger in aggregate size, as well as more numerous, than those with lower concentration in Britain. Moreover, the average difference between the concentration indexes of the two countries is greater in the former group than in the latter. These findings are shown in the following tabulation:

	33 Industries with Higher Concentration in U.K. than U.S.	*24 Industries with Higher Concentration in U.S. than U.K.*	*Total*
Percentage of industries	58	42	100
Percentage of employment, U.S.	57	43	100
Percentage of employment, U.K.	56	44	100
Unweighted average concentration index:			
U.S.	25	41	32
U.K.	48	24	38
Difference	23	—17	6

[29] Average for the United States obtained by applying the regression equation shown in footnote 25 to the weighted average percentage concentrated in the leading *four* firms.

The conclusion suggested by the sample of fifty-seven "matched" industries is that the general level of concentration in British manufacturing industries is somewhat higher than in the United States because a majority of industries have higher concentration in the United Kingdom, and because in this majority group the inter-country difference in concentration is greater than in the minority having higher concentration in the United States.

These results can be taken only as suggestions since the sample is of course by no means random. The fifty-seven industries accounted for 32 per cent of manufacturing employment in the United Kingdom and 33 per cent in the United States. The weighted average concentration indexes for the United States and Britain are 20 per cent and 25 per cent respectively in the sample and 19 per cent and 33 per cent respectively for manufacturing as a whole. The sample therefore tends to understate the difference in concentration between the two countries.

4. *Changes over Time*

ARE the different concentration indexes also in substantial agreement when changes in concentration over time are measured? The evidence readily available for the investigation of this problem is more slender and less conclusive than that relating to cross sections.

Herfindahl's study of changes in concentration in the steel industry includes a comparison of his summary index with that measuring concentration in the leading four firms. Table 6 shows time series for concentration of pig-iron and steel-ingot capacity, based on his data.

The fluctuations in concentration shown in Table 6 are very small compared with the average difference in concentration among industries shown in Tables 2 and 5. The only large change in the time series is that associated with the formation of the United States Steel Corporation in 1901.

While the increase from 1898 to 1904 is reflected in all three concentration indexes, the subsequent small fluctuations are not so highly correlated as the variation among industries analyzed above. The rank correlation coefficient when Herfindahl's summary index is compared with the index of concentration in the leading four firms is .68 for pig iron and .72 for steel ingot. The rank correlation coefficient when concentration in the leading four firms and the leading eight firms is compared happens to be 1.00 for pig iron, but is only .53 for steel ingot.

The limited evidence of the steel industry suggests that while the

different concentration indexes are in substantial agreement in measuring the relatively large differences among industries, their measurements of the small fluctuations in an industry frequently conflict. The index measuring concentration of capacity in the lead-

TABLE 6

Concentration of Capacity in the Iron and Steel Industry, United States, 1898-1948

	PIG-IRON CAPACITY			STEEL-INGOT CAPACITY		
		Percentage Accounted for by			Percentage Accounted for by	
	Summary Index	Leading Four Firms	Leading Eight Firms	Summary Index	Leading Four Firms	Leading Eight Firms
Year	(1)	(2)	(3)	(4)	(5)	(6)
1898	.03	27.2	35.3			
1904	.16	48.4	56.7	.31	68.4	80.4
1908	.19	53.1	61.6	.25	64.5	77.2
1916	.17	53.9	62.5	.23	65.0	77.0
1920	.14	50.5	60.8	.18	56.7	67.4
1930	.19	65.6	77.3	.15	58.2	74.0
1938	.19	66.2	80.8	.16	63.0	79.2
1940				.16	63.8	80.3
1945	.18	66.6	82.0	.16	64.3	79.6
1948	.18	66.8	83.1	.15	63.9	79.6

Source: O. C. Herfindahl: "Concentration in the Steel Industry" (Ph.D. Dissertation, Columbia University, 1950). Columns 1 and 4 are from footnote 2, p. 44, footnote 2, p. 46, and footnote 1, p. 47, respectively. Columns 2, 3, 5, and 6 are computed from Table 6, p. 57, and Table 7, p. 58.

ing four firms agrees somewhat better with the index measuring concentration in eight firms than with the summary index.

A second source of data on changes in concentration is the *Concentration of Industry Report* published by the Department of Commerce. Here the percentage of value of output concentrated in the leading four and eight firms is given for 1935 and 1947, for 129 manufacturing industries which remained comparable between the two years.[30] Analyzing the direction of change of the two indexes between 1935 and 1947, we obtain the result shown in Table 7.

The two indexes are in substantial agreement with regard to the direction of change in concentration in individual industries between 1935 and 1947. In only 15 of the 129 cases does the evidence presented by the two indexes conflict. A judgment regarding the

[30] The report gives these data for 131 industries, but reference to the National Resources Committee's study indicates that in one of them (rubber, boots and shoes) the index listed for "eight firms" actually refers to a larger number of firms. Another industry was omitted by mistake.

change in concentration based on one index is therefore not likely to be contradicted by the other.

This conclusion differs from that based on the iron and steel industry, but we are dealing here with a large number of industries,

TABLE 7

Distribution of Industries by Direction of Change in Concentration Indexes, United States, 1935-1947

		CONCENTRATION IN FOUR FIRMS[a]			
		Increase	*Decrease*	*No Change*	*Total*
Concentration in Eight Firms[b]	Increase	49	8	0	57
	Decrease	7	64	0	71
	No change	0	0	1	1
	Total	56	72	1	129

[a] Percentage of value of output accounted for by leading 4 firms.
[b] Percentage of value of output accounted for by leading 8 firms.
Source: Compiled from *Concentration of Industry Report*, Dept. of Commerce, 1949.

only two years, and only two of the three indexes compared for the iron and steel industry. The average change in concentration from 1935 to 1947 is, however, not large, as will be shown below, and seems to be of the same order of magnitude as the fluctuations in iron and steel. It appears that in the great majority of industries, fluctuations in the index measuring concentration in the leading eight firms will generally agree with the movements of the index measuring concentration in the leading four firms, although some industries, such as steel ingot, will show very imperfect agreement.

5. *Change between 1935 and 1947*

THE fact that the average change in concentration between 1935 and 1947 was small is indicated in a rough way in the Department of Commerce's tabulation of changes in the concentration index, of which Table 8 is a summary.

It is possible, however, to obtain a more accurate idea of the general change in concentration between 1935 and 1947. This is a matter of considerable interest since there has been much speculation regarding the trend in concentration and the effect of the war. The above analysis suggests that if we can describe the general change in concentration by one index, such as the percentage accounted for by the leading four firms, our conclusions are probably also applicable, in broad terms, to the change in a number of other indexes,

TABLE 8

Number of Industries Showing Specified Changes in Concentration Index,[a] United States, 1935-1947

	Increase	*Decrease*
Less than 5 per cent	32	35
5-9.9 per cent	17	10
10-19.9 per cent	5	22
20 per cent and over	4	5
Total	58	72

[a] Percentage of output accounted for by leading 4 firms.

Source: *Concentration of Industry Report*, Dept. of Commerce, 1949, Table v, p. 26.

such as the percentage accounted for by the leading eight firms.

On the basis of the percentage of output accounted for by the four leading firms, the general level of concentration in a given year can be described by a weighted average of industry-concentration indexes, the relative output of the industries being used as weights. For the group of industries for which the industrial classification of 1935 matches that of 1947 the weighted average of concentration indexes was 44.0 per cent for 1935 and 41.4 per cent for 1947. There has thus been a drop of 6 per cent in the average level of concentration as measured by this index.

This decline in concentration is the result of changes both in concentration within industries and in the relative importance of different industries. What has been the relative influence of these two factors?

The average change in concentration within industries can be measured by considering how the two weighted averages would compare if there had been no change in the relative size (value of output) of different industries. The relative sizes of industries were held constant at both their 1935 level and their 1947 level, and both systems of weights gave about the same result, as shown below:

	1935 Weights	*1947 Weights*
1935	44.0%	41.2%
1947	44.4	41.4

With both systems of weights there is a very slight average *increase* in concentration within industries between 1935 and 1947, amounting to less than 1 per cent. The drop in concentration between the two dates must therefore be ascribed entirely to the shift in the relative importance of different industries. The effect of this shift can be seen by reading along the *rows* of the above tabulation.

If all industry-concentration indexes had remained constant at their 1935 level, the shift in the relative importance of industries would have lowered the average from 44.0 per cent to 41.2 per cent. If concentration indexes had remained constant at their 1947 level, the shift in the relative importance of industries would have lowered the average from 44.4 per cent to 41.4 per cent.

We conclude that while there have been many changes in concentration in particular industries between 1935 and 1947, these changes have been small in most cases, and they show no unity of direction, the average change being close to zero. There has, however, been some increase in the relative size of industries with low concentration.[31]

These conclusions are again based on a nonrandom sample. The weighted average index of output concentration for 1935, as derived from this sample, is 44 per cent, while the corresponding index derived from the random sample of 136 industries used for the comparison with the United Kingdom is 35 per cent.[32] Industries with relatively high concentration are therefore overrepresented in the present sample, and our conclusions are misleading if there is a correlation between the level of concentration in 1935 and the change from 1935 to 1947. This possibility is investigated in Table 9, which indicates some association between high concentration (1935) and large decrease in concentration from 1935 to 1947, so that it appears that our sample, by overweighting the industries with high concentration, overstates the decrease in concentration.[33]

The bias in the *change* in concentration arising from the bias in the percentage distribution of the sample between concentration classes, as shown in columns 4 to 6 of Table 9, can be calculated by adding the products of columns 3 and 6. This procedure yields a bias of .90 index points, and adding this to the sample difference of

[31] The ten largest of the industries in the sample with lower-than-average concentration and greater-than-average increase in output are: soft drinks, malt liquors, poultry dressing, prepared animal feeds, pulp mills, paperboard boxes, lithography, sheet metal work, wire drawing, structural and ornamental products.

The ten largest of the industries with higher-than-average concentration and a smaller increase in value of output between 1935 and 1947 than the averages are: cereal preparations, malt, chocolate and cocoa products, cane-sugar refining, beet sugar, cigarettes, chewing and smoking tobacco, tires and inner tubes, tin cans and other tinware, welded pipe.

[32] These figures refer to concentration of output, while the comparison with the United Kingdom was based on concentration of employment.

[33] The observed association may reflect the well-known regression effect, and a grouping by 1947 index classes may show the opposite association.

−2.64 shown at the foot of column 3, we obtain a corrected difference of −1.74 index points between the average concentration indexes of 1947 and 1935. Using this corrected figure in conjunction

TABLE 9

Change in Concentration, 1935-1947, by Concentration Class, 1935, Manufacturing Industries, United States

CONCENTRATION INDEX CLASS,[a] 1935	WEIGHTED AVERAGE CONCENTRATION INDEX			PERCENTAGE OF OUTPUT, 1935		
	1935	1947	Difference	1935-1947 Sample	Random Sample	Difference
	(1)	(2)	(3)	(4)	(5)	(6)
Under 10	6.38	7.43	1.05	2.9	17.8	14.9
10–20	13.80	17.87	4.07	11.4	21.1	9.7
20–30	25.63	24.13	—1.50	22.2	15.4	—6.8
30–40	36.79	37.11	.32	24.2	10.9	—13.3
40–50	44.58	44.83	.25	4.7	10.6	5.9
50–60	53.69	60.15	6.46	4.2	1.9	—2.3
60–70	67.56	63.59	—3.97	12.3	13.6	1.3
70–80	75.29	75.05	—.24	4.2	3.9	—.3
80–90	85.32	80.88	—4.44	13.5	4.7	—8.8
90 and over	92.00	70.10	—21.90	.4	0	—.4
Total or average	44.04	41.39	—2.64	100.0	100.0	.0

[a] Percentage of value of output accounted for by leading 4 firms.

Source: Computed from *Concentration of Industry Report*, Dept. of Commerce, 1949, Table 1, pp. 4ff.; *The Structure of the American Economy, Part I*, National Resources Committee, 1939, Appendix 7, Table 1; and *Census of Manufactures: 1935*, Bureau of the Census, Table 4, pp. 22ff.

with the average concentration index given by the random sample for 1935, we conclude that the average level of output concentration was about 34.8 per cent in 1935 and 32.9 per cent in 1947.[34]

[34] This procedure is based on the following considerations. The difference shown at the bottom of column 3 can be expressed algebraically as (1) $\Sigma\, c_{47}\, v_{47} - \Sigma\, c_{35}\, v_{35} = \Sigma\, (c_{47} - c_{35})\, v_{35} + \Sigma\, (v_{47} - v_{35})\, c_{47}$ where c is the weighted average concentration index in a given concentration class—columns 1 and 2—v is the proportion of output in a given class shown by the biased sample—column 4 for 1935—the subscripts refer to the two years, and the summation is over all concentration classes. An industry's concentration class is determined throughout by its *1935* concentration index.

The "correct" difference we seek is

(2) $\Sigma\, c_{47}\, v'_{47} - \Sigma\, c_{35}\, v'_{35} = \Sigma\, (c_{47} - c_{35})\, v'_{35} + \Sigma\, (v'_{47} - v'_{35})\, c_{47}$ where v' is the correct proportion of output in a given class—column 5 for 1935.

Since we do not know v'_{47} we assume that $v'_{47} - v_{47} = v'_{35} - v_{35} = e$—column 6.

It follows that $v'_{47} - v'_{35} = v_{47} - v_{35}$, and hence the second term on the right-hand side of equation 2 is equal to the corresponding term in equation 1.

Therefore, the difference between equations 2 and 1 is $\Sigma\, (c_{47} - c_{35})\, v'_{35} - \Sigma\, (c_{47} - c_{35})\, v_{35} = \Sigma\, (c_{47} - c_{35})\, (v'_{35} - v_{35}) = \Sigma\, (c_{47} - c_{35})\, e =$ the sum of products of columns 3 and 6.

This model involves a number of special assumptions (e.g., the assumption

The stability of concentration patterns shown by our sample has characterized a twelve-year period in which average plant size (in terms of employment) has increased by 21 per cent and total employment in manufacturing has increased by 73 per cent. This impressive increase in activity, the great technological advances of the period, the uneven wartime increase in plant capacity, the increased participation of government in economic activity, and all the other changes associated with the New Deal, war, and postwar readjustment have had remarkably little effect on the average level of industry concentration. The great expansion of industry size has been matched by increases in average firm size and/or in the degree of inequality of firm size within industries.

6. *The Dimensions of Measurement*

THE problems of measurement discussed in the preceding sections have been concerned with the *form* of the concentration index and with techniques for summarizing a large number of concentration readings.

Equally important, however, are problems concerning what might be called the "dimensions" of concentration. First, what is the appropriate business unit for the measurement of concentration? The plant? The firm? What degree of corporate control should define the firm? What about firms that operate in several industries? Secondly, what is the appropriate "scope" of an index? An industry (that is, group of plants or firms)? A product? A regional sector of an industry? How are industries or products to be classified? Thirdly, how should size be measured? In the preceding sections employment,

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that the 1935-1947 sample correctly represents the average concentration index in each class, or that $v'_{47} - v'_{35} = v_{47} - v_{35}$) but it is nevertheless a fairly reliable and fast method of calculating the bias due to the association of high initial concentration and decreasing concentration.

This correction has not, of course, taken account of bias arising from other sources. Both new and rapidly growing industries and industries that are old and declining are likely to be in the group for which 1935 and 1947 classifications are not comparable, and hence omitted from the sample. The former are often divided and redivided by the statistician as they grow, while the latter, when they become small enough, are merged into the "other" or "miscellaneous" groups.

We may hazard the guess that the rapidly growing industries are characterized by decreasing concentration, and the decaying industries by increasing concentration (cf. TNEC Monograph No. 27, Part 1, Chap. IV, especially pp. 58-59, 61-62). Over the period 1935-1947 the former undoubtedly predominated so that it seems likely that the over-all decline in concentration is greater than the corrected figure shown by the sample.

output, and fixed assets have all been used, and other measures, such as income, are possible. Finally, what is the best time period for the measurement of concentration; for example, output in a month? A year? A two-year period? These problems are, of course, to some extent interdependent. For example, if the index is based on products it would be difficult to use employment as the measure of size.

We shall not undertake an exhaustive discussion of these questions here. The most appropriate set of dimensions must depend on the particular problem in hand, and the set of dimensions actually used will depend only partly on what is most appropriate and very largely on the statistics that are available. In every empirical study of concentration the investigator will have to substitute what he can get for what he would like.

Instead of discussing the "optimum" set of dimensions we shall therefore comment on the empirical relation between some of the alternatives. Such comparisons must be of interest to any investigator forced to use "substitutes," and will also reveal important features of the industrial structure.

PLANTS AND FIRMS

THE statistics published by the National Resources Committee, *The Concentration of Industry Report* for 1947, and the firm-size data compiled by the Canadian Bureau of Statistics for 1948, all use "industries" that are defined as groups of *plants* with a common major product. The "firms" in these statistics consist of groups of plants under common ownership within such an industry. A firm that has plants in two industries as defined by the Census of Manufactures appears in the statistics as two firms.

If the industry classification is reasonably suitable for the study of monopoly, this definition of the firm and the industry is probably more appropriate for the measurement of concentration in particular markets than one which would throw all activities of the firm into the same industry. An incidental advantage for our present purpose is that this classification enables us to compare plant- and firm-concentration indexes having exactly comparable scope.

Firm concentration in an industry cannot be lower than plant concentration, but it may be higher if there are multiplant firms. Each firm has at least one plant, so that the collective size of the

largest x firms cannot be less, but may be greater, than the size of the x largest plants.[35]

Two important questions can be answered by a comparison of plant and firm concentration for a cross section of industries. First, are plant and firm concentration correlated? If we have data concerning one, can we draw conclusions concerning the other? Secondly, how great is the difference between plant and firm concentration? If all multiplant firms were split up, and their plants made independent, how much lower would the level of concentration be?

Analysis of the Canadian statistics for 1948, for the sample of industries listed in Table 2, shows that the ranking of industries by firm-concentration index is very similar to the ranking by plant-concentration index. The Spearman correlation coefficient for the two rankings is .947. This analysis is based on employment concentration.[36]

The *difference* between plant and firm concentration is measured in Table 10 by the comparison of cumulative frequency distributions similar to those used in our comparison of concentration in

TABLE 10

Comparison of Plant and Firm Concentration in 58 Selected Canadian Manufacturing Industries, 1948

CONCENTRATION INDEX (*Number of Firms or Plants Required to Account for 80% of Industry's Employment*)[a] (1)	PERCENTAGE OF EMPLOYMENT IN INDUSTRIES WITH HIGHER CONCENTRATION THAN THE SPECIFIED INDEX		*Difference* (2)—(3) (4)	*Relative Difference* (4)÷(2)×100 (5)
	Concentration by Firms (2)	*Concentration by Plants* (3)		
3	12	8	4	31
6	25	13	11	46
12	34	19	15	45
24	41	37	4	10
100	63	58	4	7

[a] High concentration indicated by low numerical value of index.

Source: Estimates made in unpublished study, "Concentration in Canadian Manufacturing Industries," from data supplied by Dominion Bureau of Statistics. Figures are rounded to nearest percentage point.

[35] Stigler has pointed out possible exceptions, such as the case where several firms jointly operate one plant, or successively operate one plant within the period on which the concentration measure is based.

[36] The index used is the number of the largest plants or firms required to account for 80 per cent of an industry's employment.

the United States and the United Kingdom. The table is based on a group of 58 industries in which concentration measured on a "national" basis can reasonably be expected to be related to price policy. Industries with a very heterogeneous product structure or products that are largely produced in other industries are excluded, as are industries with substantially separate regional markets and those in which imports or exports play a large role.

A comparison of plant and firm concentration that is to be relevant to problems of social policy must provide the answer to this question: If one takes a given concentration level as representing the maximum compatible with adequate competition, how large is the industrial sector with "excessive" firm concentration, and how much would it be reduced if all plants were independent? Table 10 answers this question for the concentration levels shown.

The table shows, for example, that 25 per cent of all employment is in industries in which fewer than six *firms* account for 80 per cent, but only 13 per cent of all employment is in industries in which fewer than six *plants* account for 80 per cent. Hence, if all plants were made independent, the total employment represented by "excessively" concentrated industries would be reduced by 40 per cent, as shown in column 5. If any concentration index between 3 and 12 is taken as representing the highest level that should be tolerated, a drastic "trust-busting" policy would reduce the area of "excessive concentration" by between one-third and one-half.

How far are these findings for Canada applicable to the United States? A comparison of plant and firm concentration in this country has recently been published by the Federal Trade Commission, but unfortunately it does not answer either of the questions we have asked above.[37]

A rough idea of the degree to which the Canadian results are applicable to the United States can, however, be obtained by comparing the number of plants per firm in the manufacturing industries of the two countries. The decile values of the number of plants per firm in the 96 Canadian industries on which our correlation of

[37] *The Divergence Between Plant and Company Concentration, 1947*, as cited. In this study the divergence between plant and company concentration is measured by the area between the plant and company concentration curves for the first fifty plants and firms, and is presented as an index, based on the median area as 100. It is impossible to tell from these statistics how closely plant and firm concentration are correlated, or how much the area of "excessive concentration" (on any given definition) differs when plant and firm concentration are compared.

plant and firm concentration is based are compared below with those for 452 United States manufacturing industries for 1947.[38]

	Number of Plants per Firm	
	96 Canadian Industries	*452 U.S. Industries*
Decile	*1948*	*1947*
1	1.00	1.00
2	1.00	1.01
3	1.01	1.02
4	1.02–1.03	1.04
5	1.05	1.06
6	1.09	1.10
7	1.17–1.18	1.15
8	1.31–1.32	1.24
9	1.75–1.81	1.52–1.56

The arrays are very similar, but the dispersion is somewhat greater in the Canadian sample than in the United States. It is reasonable to expect that great variation in the number of plants per firm will tend to reduce the correlation between plant and firm concentration, so that one may hazard the guess that the correlation is not likely to be worse in the United States than in Canada. One cannot, however, be so confident about the applicability to the United States of the divergence pattern shown in Table 10. In any case, there is no good reason for guessing, since the materials are available and the problem should be studied directly.

INDUSTRY AND PRODUCT CONCENTRATION

THE problems of industry and product classification and their suitability for the study of monopoly are discussed in other papers presented to this conference. It is obvious that since many firms produce more than one product, a difference between industry concentration and product concentration may arise. Without entering into the discussion of their respective merits for the study of monopoly, we may say a word about the mathematical relation between these two concepts.

Some writers have asserted that product concentration typically exceeds industry concentration. This is true if industries and products are defined in such a way as to make it true. If the product classification is more detailed than the industry classification, so that there are more products than industries, it is extremely likely, though not mathematically necessary, that product concentration

[38] Data for United States from J. I. Mills, *A Proposed System for Classifying Manufacturing Concerns by Size*, Dept. of Commerce and National Production Authority, 1951, Table III, pp. 75-84.

will be higher than industry concentration. The average product market will be smaller than the average industry, and if there is any degree of specialization among firms, the average number of firms producing a given product will be less than the average number of firms in an industry, so that concentration will tend to be higher. It is therefore not surprising that the general level of concentration in 1,807 manufactured products analyzed by W. F. Crowder in his study for the TNEC is considerably higher than the average level of concentration in manufacturing *industries* analyzed by Means for the National Resources Committee.[39] The product classification used by Crowder was much finer than the Census of Manufactures industry classification.

Suppose, however, that product and industry classifications are used that are strictly comparable; there is an industry corresponding to each product, the industry consisting of those firms that produce more of the given product than of any other product, by value. In this case there is no reason to expect a priori any bias toward higher or lower product concentration, and it is theoretically possible for all product-concentration indexes to be either higher or lower than the corresponding industry-concentration indexes.[40] An appreciable

[39] Thorp and Crowder, *op. cit.*, Part v, Table 1, p. 275, and *The Structure of the American Economy*, as cited, p. 115 and Appendix 7. About one-third of the *industries* analyzed in the latter study for 1935 had concentration indexes above 50 per cent, but over three-quarters of the *products* analyzed in the former study for 1937 were in this high-concentration class.

[40] Suppose there are two products, A and B, and two corresponding industries, each consisting of two firms. We measure concentration by the percentage of the industry or product accounted for by the leading firm. In model 1, output is distributed by firms, industries, and products as follows:

	INDUSTRY A				INDUSTRY B		
	Product A	*Product B*	*Total*		*Product A*	*Product B*	*Total*
Firm 1	90	10	100	Firm 3	10	90	100
Firm 2	*80*	*20*	*100*	Firm 4	*20*	*80*	*100*
Total	170	30	200	Total	30	170	200

Industry concentration is 50 per cent in both industries. Product concentration, however, is $90 \div 200 = 45$ per cent for both products. Product concentration is, therefore, lower than industry concentration for all products and industries.

In model 2, output is distributed as follows:

	INDUSTRY A				INDUSTRY B		
	Product A	*Product B*	*Total*		*Product A*	*Product B*	*Total*
Firm 1	100	0	100	Firm 3	1	9	10
Firm 2	*80*	*20*	*100*	Firm 4	*1*	*9*	*10*
Total	180	20	200	Total	2	18	20

Industry concentration is again 50 per cent in both cases. But concentration in the production of product A is $100 \div 182 = 55$ per cent, and concentration in

divergence of product concentration from industry concentration is of course not likely in those industries where the product accounts for the bulk of the industry's output and no large portion of the product originates outside the industry. Since industry-concentration data are often used as a substitute for product concentration, the percentage of the industry's output accounted for by the product and the percentage of the total product output produced outside the industry should be studied in interpreting such data.

OUTPUT, EMPLOYMENT, AND ASSETS

THE concentration statistics used in the preceding sections have employed value of output, employment, and fixed assets as measures of size. If we wish to know whether results obtained by the use of one of these variables are applicable to another, two questions must be answered. First, are there systematic differences in the level of concentration as measured by these three variables, and secondly, does an industry having high or low concentration (in relation to other industries) in terms of one of the measures also have high or low concentration in terms of another.

Output and assets concentration can be compared for a very limited number of industries by using the Department of Commerce *Concentration of Industry Report* and the FTC *Report on the Concentration of Productive Facilities, 1947*. For eleven industries the classifications appear to be comparable so that a comparison of concentration indexes can be made. Even for this limited group of industries the scope of the indexes is not strictly comparable, since in the FTC's study the "industry" consists of a group of firms, while the "industry" as defined by the Census of Manufactures and used in the Department of Commerce study consists of a group of plants and a "firm" consists of those plants *within an industry* that are under common ownership.

The comparison of assets and output concentration in eleven industries is shown in Table 11.

In this sample assets concentration exceeds output concentration. There are only two industries in which this relation is reversed—cigarettes and biscuits—and in the latter the concentration indexes differ by a negligible amount. The higher level of assets concentra-

product B is 20 ÷ 38 = 53 per cent. In this example, therefore, product concentration exceeds industry concentration for all products and industries.

The Census of Manufactures contains many examples of industry-product relations such as those used in these models.

TABLE 11

Assets and Output Concentration, United States, 1947

INDUSTRY	CONCENTRATION IN THE LEADING FOUR FIRMS	
	Net Capital Assets	*Value of Shipments*
Primary aluminum[a]	100.0	100.0
Tin cans and other tinware	96.4	77.8
Linoleum	93.6	80.3
Rubber tires and tubes	88.3	76.6
Cigarettes	87.8	90.4
Distilled liquors	84.6	74.6
Plumbers' supplies	74.3	34.7
Biscuits, crackers, pretzels	71.4	71.5
Footwear (except rubber)	46.8	27.3[b]
Bread and other bakery products	30.6	16.4
Woolen and worsted goods	30.3	28.1

[a] The industry consists of three firms.

[b] Includes "house slippers." Output concentration index is estimated from the indexes for "footwear" (27.9) and "house slippers" (26.9) published separately by the Department of Commerce.

Sources: *Concentration of Industry Report*, Dept. of Commerce, 1949; *Report on the Concentration of Productive Facilities*, FTC, 1949.

tion reflects a positive correlation between firm size (in terms of fixed assets) and the ratio of assets to sales, within industries.

While assets concentration exceeds output concentration, the two are highly correlated, the (Pearsonian) correlation coefficient being .910.[41] The sample is of course very small, and the correlation for manufacturing as a whole may be appreciably higher or lower. The 95 per cent confidence limits for the correlation coefficient are about 0.65 and 0.97.[42]

The relation between output and employment concentration can be investigated with considerably greater confidence, for the National Resources Committee study for 1935 includes both output-

[41] In the primary aluminum industry, output and assets concentration are of necessity equal since there are only three firms. This is an extreme illustration of the general proposition that the correlation between assets and output concentration is in large part due to the influence on both variables of variation in the number of firms.

The correlation coefficient for the ten industries other than primary aluminum is .898.

[42] See F. N. David, *Tables of the Correlation Coefficient* (Cambridge, 1932) Chart II.

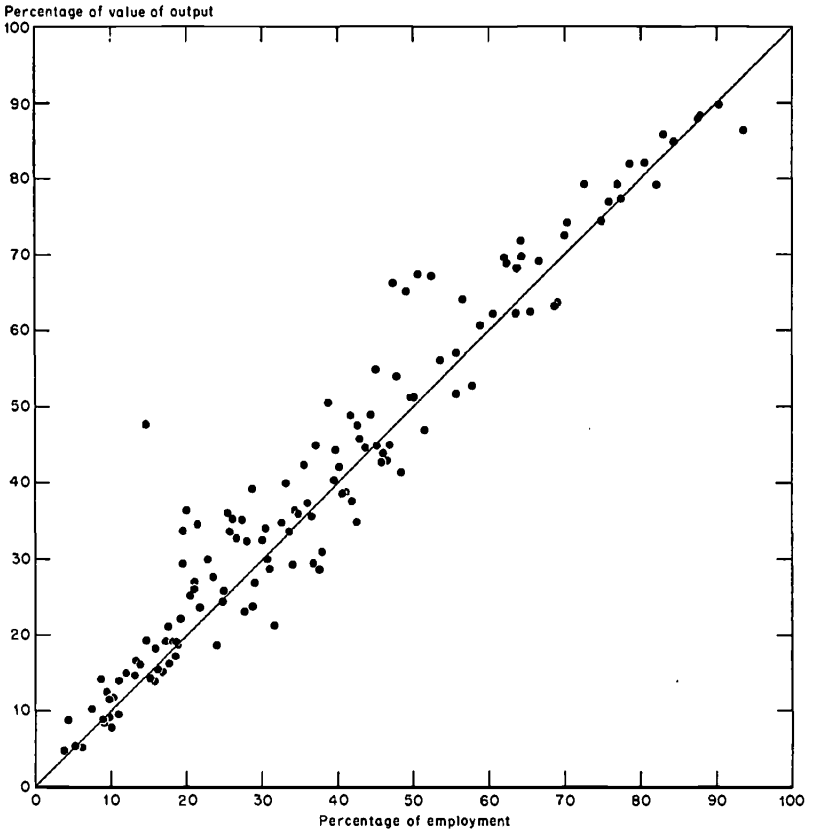
The confidence interval indicates that in samples of size 11 from a bivariate normal population with correlation coefficient less than .65 the probability of obtaining a sample correlation coefficient as high as .91 is less than 2.5 per cent, while if the population correlation coefficient is greater than .97, the probability of obtaining a sample coefficient as low as .91 is less than 2.5 per cent.

and employment-concentration indexes. The number of industries for which data are available is much greater, and the industries and firms are strictly comparable. A comparison of output and employment concentration was therefore made for the sample of 136 industries that were used for our comparison of concentration in the United States and the United Kingdom. This sample, it will be recalled, contains every second industry listed in the National Resources Committee tabulation of concentration data.

A graphic comparison of output and employment concentration is shown in Chart 4. The diagonal line drawn across the scatter

Chart 4

Concentration of Employment and Output in Leading Four Firms, 136 Manufacturing Industries, United States, 1935



Source: *The Structure of the American Economy*, National Resources Committee, 1939, Part I, Appendix 7, Tables I and II.

diagram is not a regression line fitted to the points, but is intended to show where the points would lie if output concentration were exactly equal to employment concentration in all industries. The diagram shows that the majority of points lie above this line, indicating that in most of the industries output concentration exceeds employment concentration. This tendency is, however, not overwhelming. In 48 of the 136 industries examined—over one-third of the total—output concentration is less than employment concentration, and in two industries they are equal. Nevertheless, there is a considerable difference between the weighted average indexes of output and employment concentration. The former (using value-of-output weights) is 35 per cent, while the latter (using employment weights) is 26 per cent.

The diagram also shows that output and employment concentration are highly correlated, so that the value of one can be used with great confidence for estimating the other. The rank correlation coefficient relating output and employment concentration is .958.

These two investigations suggest that while, in general, concentration in terms of fixed assets exceeds output concentration, which in turn exceeds employment concentration, the ordering of industries by concentration level is much the same, no matter which standard of size is used, so that the results of cross-section analyses based on one measure will also be applicable to the others. With respect to asset concentration, this conclusion is based on a very small sample and must be regarded as tentative.

THE TIME PERIOD

THE concentration statistics we have examined are all based on periods of one year, but it is not obvious that this particular period is the most suitable for the study of the structural factors that govern business policy. Stigler has suggested that the period is too short, since there is a random element in the year-to-year changes in a firm's output, so that a concentration index based on annual data may not adequately reflect the normal long-run size structure that is relevant to considerations of price policy. He has also suggested that an index based on a longer period would show lower values than one based on a year, since the averaging of fluctuations in individual firm sizes tends to lower their inequality.

Given a constant group of firms, an index based on a period of several years may be lower than the average of indexes for the component years if the ranking of firms changes during the period, and

it would be of interest to investigate the actual importance of such changes for different industries and periods. Some evidence on this point is provided by Crowder's study of product concentration for the TNEC. Comparing the four leading companies in 1935 and 1937 for 262 products, he tabulated the extent to which the leaders coincided in the two years, as shown in the following summary:[43]

Number of Firms among the Leading Four in Both 1935 and 1937	*Percentage of Cases (Products)*
4	19
3	41
2	27
1	11
0	2
	100

Over the three-year period covered by this comparison, two or more of the leading firms were replaced by others in 40 per cent of the cases. This result certainly suggests that concentration indexes computed on a three-year basis would tend to be lower than the corresponding average of annual concentration indexes. Crowder suggests that the identity of the leading firms is more stable in old, well-established industries and in industries not subject to style or model changes than in others.

Granted that random year-to-year fluctuations in output are important and should not be reflected in the concentration index, the averaging or summing of output figures for individual firms may not be the best solution. The structural characteristics that a concentration index is intended to measure are not fixed; they may change over time, and one of the purposes of our indexes is to measure this change. In averaging firm sizes for several years one may average out not only random fluctuations but also real, long-term changes in industrial structure. This problem could perhaps be handled by the use of moving averages; an alternative solution would be to measure concentration for short periods, but in terms of a variable less subject to random fluctuations than output and employment. It would be reasonable to treat changes in *capacity* as representing structural changes that should be reflected in the index, and to measure con-

[43] We compiled this summary from the detailed data in Thorp and Crowder, *op. cit.*, Part v, Table 2C, pp. 495-505. In the text (p. 342) Crowder gives the number of products as 256 instead of 262 and the percentage of cases in which two of the leaders repeat as 7 instead of 27. The figure 256 is probably an error, and the figure 7 per cent certainly is, since his other percentages agree with ours.

centration in terms of plant capacity owned by each firm, thus eliminating the effect of fluctuations in the use of capacity.

At present we have no comprehensive data for either the measurement of concentration for longer periods than a year or its measurement in terms of capacity, and we can only speculate about the time period and measure of size most closely related to business policy. This is just one illustration of the need for better data and tests of carefully framed hypotheses, to be discussed in the next section.

7. *Empirical Tests*

WE DO not, as yet, know enough about the behavior of the various concentration indexes to be able to choose between them in investigating any given problem. Such knowledge can, however, be gained by using the indexes in empirical tests of hypotheses regarding the influence of concentration on business policy. Some, but very little, systematic work in this direction has been done to date.

Tests of this sort are not likely to discriminate effectively among the various indexes unless the concentration measures are used in conjunction with other determining variables, and the effects of the different variables are segregated as far as possible.

The danger involved in neglecting other variables is illustrated by an experiment we performed on a recent study by J. S. Bain. Bain finds a weak but significant association between profit rate and concentration index in a cross section of 42 industries, using the percentage of employment in the leading eight firms (taken from the National Resources Committee study) as measure of concentration. We found a very slightly better (inverse) association between his profit-rates data and the number of *plants* in each industry.[44] It

[44] Joe S. Bain, "Relation of Profit Rate to Industry Concentration, American Manufacturing, 1936-1940," *Quarterly Journal of Economics*, August, 1951, pp. 293-324, esp. Table 1, p. 312 and pp. 311-17.

For this comparison we used Kendall's rank correlation coefficient, which is based on a comparison of all possible pairs of observations. We say that two variables—profit rate and concentration—"agree" in a pair of observations (industries) if their ranks are in the same order, e.g., if higher profit rate in industry A than in industry B is associated with higher concentration in industry A than in industry B. Supplementing Bain's data by the number of plants in each of the industries (from the 1935 Census of Manufactures), we can classify the pairs of industries by type of agreement as follows:

would be rash to conclude that the number of plants is as important a variable in the determination of profit rates as the concentration index used by Bain, but it is correct to conclude that very little can be said about the significant determinants of profit rates by testing one causal variable at a time. In this case a possible explanation might be that the number of firms has a certain independent influence (that is, that profit rates are higher if a given concentration index is due to a small number of firms rather than to a large number of firms and high inequality) and that the number of plants is highly correlated with the number of firms.

The conclusion is that we can learn what is a useful concentration index only in the process of learning more about the determinants of business policy and market results. In this field, as in many others, we require more tests of carefully formulated hypotheses regarding the joint effects of a number of variables.

COMMENT

ORRIS C. HERFINDAHL, Committee for Economic Development

THESE comments are directed at the finding that substantially the same ranking of industries is given by the three types of concentra-

DISTRIBUTION OF PAIRS OF INDUSTRIES[a]

		Concentration Index		
		Agreement with Profit Rate	*Disagreement with Profit Rate*	*Total*
Number of plants[b]	Agreement with profit rate	443	93	536.5
	Disagreement with profit rate	79.5	245	324.5
	Total	522.5	338.5	861

[a] The total number of pairs that can be obtained from 42 industries is 42 x 41 ÷ 2 = 861. Nine pairs having "ties" in one of the rankings are classified by assuming that each of the two possible orderings of the pair applies to "half" the pair.

[b] Agreement denotes association between fewer plants and higher profit rate.

Kendall's coefficient of rank correlation for concentration and profit rates is (522.5-338.5) ÷ 861 = .21, while the coefficient measuring the correlation between fewness of plants and profit rates is (536.5-324.5) ÷ 861 = .25. The tabulation shows that the slight difference between the values reflects the fact that there are 93 pairs of industries in which the number of plants agrees with profit rate but concentration does not, and only 78 pairs in which concentration agrees with profit rates while number of plants does not.

tion measures compared by Rosenbluth.[1] My remarks do not represent disagreement with his findings and evaluation of their significance, but serve to emphasize some points that were perhaps inadequately stressed in his paper.

Agreement among the ranks resulting from the use of these three measures of concentration does not, of course, permit the conclusion that the measures are good indicators of monopoly power or business policy. They may be equally poor indicators, suggesting differences among industries where none exist or even suggesting differences in the wrong direction. Lack of knowledge on this point should lead to caution in evaluations of Rosenbluth's study of concentration changes over time in the United States and his comparison of manufacturing industries in the United States and the United Kingdom. We cannot be sure whether limited differences in these concentration measures over time or between countries are important or not. This is not to say that such investigations, using measures whose significance for business behavior is not well understood, are not useful. After all, these measures came to be used because observation indicates, at the least, that some differences in the sizes of the coefficients are strongly associated with differences in the behavior of the industries' firms. Similarly, a showing of substantial change in concentration over a period of time is important because a part of the changes within industries will likely be indicative of changes in competition even though some of the changes in concentration are not.

In measuring concentration, the goal need not be, however, a measure whose every level corresponds to a different degree of competition. If we think of the measurement problem in terms of the concentration, numbers, and inequality framework used by Rosenbluth in his paper, the various combinations of number and inequality produce a concentration surface for a given measure. It is not necessary that the levels of this surface be in a one-to-one correspondence with the competitive behavior of the industry, for a significant improvement in the measurement of concentration would be represented by a partitioning of this surface into several sectors, each corresponding to a different degree of competitiveness.

We can be quite sure that the three types of measure under consideration in the paper do correspond with the competitiveness of

[1] The three types of measures are (1) the percentage of the industry's output accounted for by a given number of leading firms, (2) the number of leading firms required to account for a given percentage of the industry's output, and (3) a "summary" measure equal to the reciprocal of the number of firms in the industry times one plus the square of the coefficient of variation of the firm's outputs.

industry behavior for rather extreme values of the measures, but the area of uncertainty is sizable. So long as studies of the relationship between the values taken on by these measures and the behavior of the industries are lacking, the possibility is open that the measures do not take account of some significant aspects of the size distributions. In the case of the first two types of measures, there is some doubt that they give proper weight to the number of firms in the industry. The definitions of these measures do not include the number of firms, and the association between the measures and the number of firms is weak enough for the same level of concentration to be assigned to industries with possibly important differences in the number of firms.

From Rosenbluth's reformulations of types one and two measures, in order to show the relations among concentration, number, and inequality that are desirable in a measure of concentration, it may appear that the two measures do adequately reflect the number of firms. His purpose, however, was a demonstration of the desirable relationships and not that number is actually taken into account. Following Rosenbluth's suggestion, the type one measure—e.g. the percentage controlled by the top four firms—can be regarded as

$$\frac{4}{\text{Total no. of firms}} \qquad \frac{\text{(average size of 4 largest)}}{\text{(average size of all firms)}},$$

with the right factor viewed as a measure of inequality and the left factor reflecting the number of firms. But this measure can also be viewed as

$$\frac{\text{average size of 4 largest}}{\text{average size if 4 firms accounted for all output.}}$$

The number of firms is not essential to calculation of the measure.

The type two measure can be viewed as $N(n/N)$, where n is the number of firms required to account for a given percentage of industry output and N is the total number of firms in the industry. But the total number of firms cancels out in this formulation so that again it is not essential to calculation of the measure.

The fact that these two measures reflect only one point in the distribution rather than the whole distribution also makes it possible for inequality to change, with number of firms constant, without affecting the measure of concentration, contrary to the relationships desired if we choose to measure concentration in terms of number

and inequality. Suppose there are two industries with the firms' outputs distributed as follows:

INDUSTRY A		INDUSTRY B	
Firm Outputs	*Cumulated Outputs*	*Firm Outputs*	*Cumulated Outputs*
40	40	55	55
35	75	20	75
15	90	20	95
10	100	5	100
100		100	

Concentration is the same in both industries if it is measured by the percentage of output accounted for by the two largest firms or by the number of firms required to account for 75 per cent of the industry's output. Yet inequality is greater in industry B, unless special significance is attributed to the cumulated values for two firms.[2]

The fact that a measure can permit inequality to increase without showing an increase in concentration, number of firms remaining the same, is not necessarily a serious defect. Nor does a showing that the number of firms is not essential to the calculation of a concentration measure permit the conclusion that the measure is inadequate. It may be highly correlated with the number of firms or if it is not, the size distributions that it fails to distinguish may actually not differ in any respect significant for industry behavior.

The second possibility is not dealt with here, but the 1947 data from the Department of Commerce study of concentration in manufacturing can throw some light on the question of correlation between types one and two measures and the number of firms. It will be recalled that the rank correlations between type one measures for one, two, three, and four firms, based on the twenty-six industry FTC data, were all over .90. The lowest was .91, between one and four firms. The 1935 National Resources Committee data gave a correlation of .99 for measures based on four and eight firms, and the Canadian data gave a correlation of .98 between types one and two measures, using measurement axes of three firms and 80 per cent of employment, and a coefficient of .98 between type three and each of the first two types.

The 1947 Commerce data suggest that these measures would not be so highly correlated with measures that give more weight to the

[2] The "summary" measure used by Rosenbluth, the sum of the squares of the percentage/100 outputs of the firms, does differentiate between the two industries because it depends on the outputs of all the firms. By this measure, concentration is .315 for industry A and .385 for industry B.

number of firms in the industry. These data give a rank correlation of .49 between the percentage of output accounted for by the four leading firms and the number of firms in the industry.[3] Perhaps more to the point is the range in number of firms at approximately the same level of concentration as measured by the percentage accounted for by the four leading firms.

The differences in number of firms for industries with approximately the same level of concentration are so great as to suggest that the type one measure fails to differentiate industries whose behavior may be distinctly different. Table 1 invites investigation of such

TABLE 1

Variation in Number of Firms in Industries at Various Levels of Concentration

Per Cent of Industry Output Accounted for by Top Four Firms	*Number of Industries in Class Interval*	*Number of Industries with Firms Less than Stated Number*	*Number of Industries with Firms Greater than Stated Number*	*Range in Number of Firms*
90–100	11	3 under 13	3 over 33	3 to 50
80–89	20	6 under 16	6 over 33	9 to 93
70–79	28	8 under 24	8 over 68	13 to 249
60–69	35	9 under 31	9 over 80	14 to 346

Based on the 1947 Dept. of Commerce study of concentration in manufacturing.

questions as the following: What difference to the behavior of an industry does the presence of a fringe of smaller firms make? What is the significance of an increase in the number of firms for industries with various initial number of firms? Or, as Rosenbluth suggests at the end of his paper, does the number of firms have an "independent" influence on the behavior of an industry? And, of course, the number of firms is not the only aspect of the size distribution that calls for attention.

These remarks emphasize the importance of Rosenbluth's final conclusion that the way to find out how to measure concentration is to investigate empirically the relations between business policy and concentration indexes or their constituents. Knowledge of this sort is indispensable to the formulation of a satisfactory concentration index.

[3] This calculation is based on industries with 50 per cent or more of the output accounted for by the four leading firms.