A Canonical Correlation Analysis of Occupational Mobility

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The method of canonical correlation between sets of dummy variables is used to assign weights to the categories of occupational mobility tables, in order to test two assumptions: 1. The socioeconomic distance between occupations determines the correlation across individuals in a mobility table. 2. The relative status of occupations has remained constant over time. The weights which yield the maximum correlation are found to correlate very highly with measures of socioeconomic status, thus validating the first assumption. Since the maximum correlation between fathers' and sons' occupations is obtained by assigning similar weights to both sets, the second assumption is also validated.

1. INTRODUCTION

In the study of occupational mobility between and within generations, social scientists have been perennially plagued by the problem of assigning scores or weights to the occupational categories in a mobility table in order to derive a correlation across respondents between the two sets of occupations represented in the table. If one assumes that occupation, insofar as its effects on mobility are concerned, reflects some underlying variable which is conceptually continuous, then there are at least two difficulties inherent in using any set of scores one might choose to represent points along that continuum. The first is that the correlation between, for example, fathers' occupations and the occupations of their sons will vary in magnitude, depending on the scores assigned to occupations. The second difficulty involves the fact that the scores which adequately reflect differences on some underlying dimension among the occupations of sons at the present time may be different from those which accurately reflect differences among fathers' occupations along the same dimension.[1] In other words, one might wish to assign different weights to fathers' occupations than those assigned to sons, even though the set of categories is the same for the two generations.[2]

Solutions to the problem of assigning appropriate scores to occupations for studying mobility and other related problems have taken two major directions. Some have worked toward developing prestige scores for a wide range of occupations by asking people to rank or rate the "social standing" of particular occupations. The most systematic effort in this approach is the well-known National Opinion Research Center study of occupational prestige (described in [16]). The merits and defects of this approach have been dealt with extensively elsewhere and will not be repeated here (see, especially, [16]). Others have worked toward developing a socioeconomic index of occupations. Efforts in this direction have been made by the Bureau of the Census [18, 19], by Blishen [4] for occupations in Canada, and by Bogue [5], among others. However, the most extensive and systematic work in this area has been carried out by Duncan (in [16] and in [3]), who developed a socioeconomic index for all occupations, based on the regression of prestige scores for 45 occupations on measures of the income and education for those occupations, with appropriate adjustments for differences in age distributions.

Using the Duncan socioeconomic index (subsequently referred to as the Duncan SES Index) in studies of occupational mobility, as Blau and Duncan have done [3], entails the assumption that socioeconomic status (SES) is the underlying characteristic of occupations which most heavily determines movement between them, both within and between generations. However, it is possible, though implausible, to imagine an occupational system in which determination of occupational mobility between and within generations was achieved by a different principle. Consider, for example, a system in which each person occupies a position on the occupational ladder as far from the bottom of the ladder as his father is from the top (for example, sons of those at the bottom go all the way to the top; sons of those in the middle category stay in the middle category). Admittedly, this system is somewhat unrealistic, but it is just as conceivable (and just as determinate) as a system (such as ours) in which most people stay at or near the level of the position occupied by their fathers.

In the present article we propose to test two assumptions:

1. That it is the socioeconomic distance between occupations which determines the correlation between two sets of occupations in a mobility table.

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[1] One cannot isolate a definite time span for the period between fathers' and sons' occupations, since the fathers' occupations are reported by sons for their fathers for the time when the son was about 16 years old, a period of time which varies depending on the present age of the son. See Duncan's discussion of this and related problems [3, pp. 24–5].

[2] The problem inherent in assigning the same scale to fathers' and sons' occupations is mentioned in [8, p. 178]. Duncan also discusses the problem [3, pp. 120–1]. Strong evidence already exists to show that the relative status of occupations, as measured by their prestige ratings, has remained remarkably stable over time. See [9].

2. That the relative status of occupations has remained constant over time.

These assumptions will be tested by using a criterion for assigning weights or scale values to occupations which is analytically independent (but not necessarily empirically independent) of socioeconomic status. The criterion proposed here is that of assigning to each of the two sets of occupation categories in a table those weights which, when correlated across respondents, will yield the maximum correlation between the two sets so weighted. The weights obtained by this procedure can then be correlated with measures of SES such as income and education for the occupational categories, to see whether it is true that SES is the single most important variable underlying inter- and intragenerational occupational movement (i.e., the variable which yields the maximum correlation for the table). Furthermore, we can see whether the maximum correlation between fathers' and sons' occupations is obtained by assigning similar weights to the two sets of occupations, a finding which would indicate that the relative status of occupations (so far as the predictability of movement between them is concerned) has remained constant over time.[3]

2. PROCEDURE

The method used to obtain the maximum correlation across respondents from a cross-classification of occupational categories is that of canonical correlation, and the weights or scores assigned to the categories in order to maximize the correlation are the canonical coefficients.[4] Unlike the usual uses of canonical correlations, however, the variables in the present case are "dummy" or binary variables, with values which represent presence or absence of an individual on each occupational category. The canonical correlation is then obtained between the two sets of dummy variables represented in the cross-classification table (e.g., one set for categories of father's occupation and one for son's occupation). Since this technique is mathematically equivalent to a technique for quantitative scaling of attributes developed independently by Guttman and Hayashi and described by Alker [1], there is no need to describe the technique further.[5] Rather, we will turn directly to our results.

3. DATA AND FINDINGS

Before discussing our data and the results from application of the canonical correlation technique, there are two technical points relating to our specific use of canonical correlations which should be mentioned. One is that the dummy variable sets for father's occupation and son's occupation each contain a linear dependency. To eliminate this dependency, we eliminated one category in each set (namely, farm laborers).[6] All the coefficients are thus expressed as deviations from the omitted category, which gets a weight of zero. The second point is that coefficients are all presented in their unstandardized forms. Since the original variables are dummy or binary variables, the variance of each original variable depends on the proportion of cases falling in that category; therefore, we do not express the coefficients relative to their variability (by standardizing). To do so would let the coefficients be determined largely by the marginal frequencies.

The results that follow are based on an analysis of the three basic frequency tables presented by Blau and Duncan [3, pp. 496–8]. These tables are:

1. Son's 1962 occupation cross-classified by father's occupation;
2. Son's first job cross-classified by father's occupation, and
3. Son's 1962 occupation cross-classified by son's first job.

These data represent the national sample of men 20 to 64 years old surveyed by the U. S. Bureau of the Census in order to study "Occupational Changes in a Generation" (see [3, pp. 10–19]).[7]

The maximum correlations for the three mobility tables presented by Blau and Duncan are as follows:

Maximum correlation (first canonical correlation) between:

Father's occupation and son's 1962 occupation	=.447
Father's occupation and son's first job	=.577
Son's first job and son's 1962 occupation	=.574

These correlations are quite similar to those obtained by Blau and Duncan, using Duncan's SES Index [3, pp. 117–28]. Blau and Duncan obtained correlations of .405, .417 and .541 between their measures of the variables

[3] It is important to distinguish between determinateness and immobility. An occupational system might be completely determinate, as is the one described above, in the sense that a prediction equation could be written which would produce a correlation of 1.0 between the occupations of fathers and sons. Although this system is completely predictable, it need not be characterized by lack of mobility. Blau and Duncan [3, p. 141] overlook this possibility in their discussion of the relative magnitude of the correlation.

[4] The solution to the canonical correlation problem with continuous variables was (as far as we know) originally developed by Hotelling [10, 11]. Other solutions have been worked out by Waugh [20], Thomson [17], and Dwyer [7]. The computer program which we used (BMD06M) follows the solution presented by Dwyer. For a description of this program, see [6, pp. 207–14]. Bartlett's article [2] on statistical significance of canonical correlations and Meredith's [15] on the problems associated with the use of canonical correlations on unreliable data may also prove useful to those wishing to make use of canonical correlations.

[5] The authors were unaware of the Guttman-Hayashi method for quantifying attributes until this article was submitted for publication. It may be useful to know, however, that the same technique can be carried out in a canonical correlation format with discrete variables. The authors of the present article have also prepared a technical appendix, which may be of interest to those desiring a more detailed technical description of canonical analysis of discrete variables.

[6] Eliminating a different category would yield a different set of coefficients, but the difference between any two coefficients would remain the same. The coefficients themselves are not unique, since multiplication of each coefficient by a common scalar would produce the same correlation, as would adding the same constant to each coefficient, or adding together any two or more solutions to the set of simultaneous equations from which the coefficients are derived.

[7] To keep the number of cases within the limits required by the canonical correlation program, we divided each of the cells in the table by 10, a reduction which resulted in N's of 3408, 3531 and 3601 for the three tables. (The N's differ because of different rates of non-response on the tables. The no-answer category was omitted from our calculations.) There is a problem with this technique in that the extreme categories of a mobility table are likely to have very small frequencies. If the frequency in each cell is divided by 10, one runs the risk of biasing the results by omitting a disproportionate number of the cells in the extreme categories. To avoid this problem, we pooled and summed the frequencies of all cells with 1–5 members to determine how many cases should have been allocated to all of these cells taken together. If, for example, the total frequency in these cells was 70, then there were 7 cases to be allocated among these cells. Cases were allocated among these cells on the basis of a random sampling procedure, with the probability of choosing each cell being weighted by the frequency in that cell. That is, a cell with a frequency of 4 had 4 times as great a chance of being allocated a case as did a cell with a frequency of 1. Aside from this sampling problem, our results would be identical with those obtained from using the complete Blau-Duncan tables.

listed above.[8] The largest difference occurs between their correlation and ours for father's occupation and son's first job. The fact that the scores assigned to occupations by Duncan's SES index produce a correlation between father's occupation and son's first job which is considerably less than the maximum correlation, which could be obtained using different scores, indicates:

1. Part of that maximum correlation is due to factors other than the SES of the occupations, and (by implication),
2. The scores which maximize this correlation are produced by a variate slightly different from those which maximize the other two correlations listed earlier[9]

The unstandardized canonical coefficients or first canonical variate for each of the three mobility tables are presented in Table 1. In each set the coefficients have been divided by a common constant, so that the largest coefficient equals 1.0. It is unnecessary to examine the scores themselves in any detail. With only a few exceptions they show a steady monotonic decline as one reads down any column of the table, from professional to farm labor occupations. When these coefficients are correlated with the median income, median education, and Duncan's SES index for the relevant occupational categories, as done in Table 2, we find that the underlying variate in all cases appears to be predominantly socioeconomic status. The lowest correlation between any set of coefficients and any of the SES variables is .646, and the highest is .952. However, the pattern of correlations in general supports the inference that SES (as measured by these variables) is not as adequate in determining the coefficients for son's first job as predicted from father's occupation and vice versa as it is for the other sets of coefficients. Compared with the other correlations, the correlations involving these sets of coefficients are considerably weaker. They are, however, strong enough to indicate that any variables which might more adequately represent the underlying factor would have to be quite highly related to SES (race, perhaps?). In summary, then, we can say that our findings provide empirical confirmation of the assumption that the single most important dimension of occupations which determines mobility between them is their differences in socioeconomic status.

On the basis of the canonical coefficients we can also answer the question: To what extent have the factors which determine the distance between occupations (insofar as that distance is determined by the scores which would maximize the correlation between the occupational statuses of fathers and sons) remained constant over time? Differences between the sets of weights would indicate that the factor underlying the scores for father's occupation was different from that underlying those for the occupations of sons, i.e., that the pattern of occupational status had changed between generations. As the following correlations show, this is not the case.

Correlation between canonical coefficients
(first canonical variates) for:

Father's occupation predicted from son's 1962 occupation and Son's 1962 occupation predicted from father's occupation	=.982
Father's occupation predicted from son's first job and Son's first job predicted from father's occupation	=.988
Son's first job predicted from son's 1962 occupation and Son's 1962 occupation predicted from son's first job	=.995

Of course the correlations are symmetric, so the direction of prediction can be reversed. The magnitude of these correlations shows dramatically that positions on the underlying continuum of occupational status have not changed, either inter- or intragenerationally. The variate which underlies the scores for father's occupation is virtually identical with that which underlies the scores for son's 1962 occupation, thus confirming by another method the conclusion of Hodge, Siegel and Rossi [9] that the occupational prestige structure has remained remarkably constant over time.

It is instructive to compare the weights obtained by the method of canonical correlations to the scores assigned by another method which also makes no use of preassigned scores for occupations. Blau and Duncan carried out a Guttman-Lingoes Smallest Space Analysis-I on the distances between occupational destinations with respect to origins and vice versa, as measured by the index of dissimilarity (the sum of the positive percentage differences between any two categories of occupational origin with respect to occupational destination, and between any two categories of destination with respect to origin).[10] In the Guttman-Lingoes technique, the criterion for a solution is the minimization of the distances between a set of points, the points in this case being the triangular matrix of pairwise distances between occupations, measured by the index of dissimilarity. Solutions can be obtained in as many dimensions as desired, depending on the goodness of fit desired between the solution and the original data matrix. However, Blau and Duncan settled for a two-dimensional solution (analagous to using the first two factors in a factor analysis or the first two sets of canonical variates). They concluded by inspection of the results that the first dimension appeared to represent SES. Duncan has generously provided us with the occupational scores or values on the two-dimensional solution for the indexes of dissimilarity computed on the three tables discussed in this article. The correlations between the first dimension and our first canonical variates are shown in Table 3. As Table 3 shows, the first dimension obtained in the two-dimensional Guttman-Lingoes Least Space Analysis solution is remarkably similar to our first

[8] It should be pointed out that the Blau-Duncan correlations are obtained from more detailed occupational categories, whereas those for the canonical correlations have been aggregated. Presumably, the Blau-Duncan correlations would be increased by aggregation. However, if the canonical correlation were computed on the detailed categories, the disparity observed here could only be increased.

[9] It is important to note that the first canonical correlation does not explain all the variance shared by the two sets of variables involved. The first canonical correlation is merely the correlation between the linear combinations of two sets of variables which give the best prediction of any two linear combinations of the sets. This point is well made in [14].

[10] See Blau and Duncan's description of this analysis [3, pp. 67–75]. Also, see their description of the index of dissimilarity [3, p. 43]. An abstract of the computer program for the Guttman-Lingoes Smallest Space Analysis-I has also been published [13,]. A more extensive description is given in [12, pp. 171–2].

Table 1. UNSTANDARDIZED CANONICAL COEFFICIENTS FOR 17 OCCUPATIONAL CATEGORIES (*first canonical variates*), SCALED SO THAT LARGEST COEFFICIENT IN EACH SET EQUALS 1.0

Occupational category	Coefficients predicting to: Father's occup. from 1962 occup.	1962 occup. from father's occup.	Father's occup. from first job	First job from father's occup.	First job from 1962 occup.	1962 occup. from first job
Professionals, self-employed	1.000	1.000	1.000	1.000	1.000	1.000
Professionals, salaried	0.794	0.829	0.936	0.901	0.694	0.700
Managers	0.803	0.792	0.925	0.941	0.486	0.490
Salesmen, other	0.821	0.844	0.973	0.993	0.380	0.462
Proprietors	0.711	0.580	0.928	0.956	0.352	0.332
Clerical	0.698	0.575	0.903	0.856	0.369	0.397
Salesmen, retail	0.602	0.652	0.865	0.835	0.336	0.326
Craftsmen, manufacturing	0.500	0.479	0.835	0.770	0.225	0.252
Craftsmen, other	0.480	0.457	0.787	0.767	0.216	0.238
Craftsmen, construction	0.382	0.369	0.743	0.654	0.142	0.191
Operatives, manufacturing	0.363	0.373	0.785	0.712	0.173	0.209
Operatives, other	0.381	0.361	0.773	0.680	0.168	0.209
Service	0.392	0.399	0.779	0.725	0.174	0.223
Laborers, manufacturing	0.217	0.293	0.679	0.633	0.138	0.166
Laborers, other	0.246	0.249	0.701	0.605	0.153	0.179
Farmers	0.021	-0.049	0.132	-0.036	-0.029	0.012
Farm laborers[a]	0.000	0.000	0.000	0.000	0.000	0.000

[a] Omitted from computation. Coefficients assumed equal to zero.

Table 2. CORRELATIONS OF CANONICAL COEFFICIENTS (*first canonical variates*) WITH THREE SOCIOECONOMIC VARIABLES FOR 17 OCCUPATIONAL CATEGORIES

Canonical coefficients predicted for:	*Median income*	*Median education*	*Duncan SES index*
Fa. Occ. from Son's 1962 Occ.	.868	.921	.936
Son's 1962 Occ. from Fa. Occ.	.848	.921	.922
Fa. Occ. from Son's First Job.	.703	.693	.646
Son's First Job from Fa. Occ.	.716	.721	.694
Son's First Job from Son's 1962 Occ.	.891	.952	.908
Son's 1962 Occ. from Son's First Job	.905	.952	.912

set of canonical variates, confirming once again the similarity of findings arrived at by very different methods.

4. THE SECOND CANONICAL VARIATE

We have not analyzed at all any of the canonical variates other than the first set. This does not mean, however, that these sets are unimportant. Since each of the sets of weights for a particular mobility table is orthogonal to the others for that table when correlated across individuals, these other sets of weights can explain more of the variance shared by the two sets of variables than that represented by the first canonical correlation alone. This residual common variance is not negligible, considering that the second canonical correlations for the three mobility tables in this study are .280 for 1962 occupation predicted from father's occupation, .343 for son's first job predicted from father's occupation, and .413 for 1962 occupation predicted from son's first job. The second set of canonical variates (Table 4) could be analyzed in a manner similar to the first, to see what additional factors determine the predictability of mobility in the occupational system. It is not obvious from looking at the weights themselves what these factors might be.[11]

5. SUMMARY AND CONCLUSIONS

The results of the foregoing canonical analysis of occupational mobility have not been particularly surprising, in that they confirm the assumptions of previous research that SES is the most important single dimension underlying occupational mobility in the United States. Indeed, it would have been disconcerting to have found out otherwise. The importance of the present analysis is that it provides an independent validation of this assumption and also validates the assumption that the distance between occupations along a continuum defined by the factor which maximizes the correlation between fathers and son's occupational status (a factor which turns out to be distance along a socioeconomic continuum) is the same for two different generations and for initial and later career stages within a generation.

The preceding analysis has also demonstrated that socioeconomic factors including median income, median education, and the Duncan SES Index more accurately represent the variate underlying the relationship between fathers' occupations and sons' present occupations and that between sons' first jobs and sons' present occupations than they do the relationship between fathers' occupations and sons' first jobs. It was suggested that other factors related to SES but imperfectly represented by it play a part in determining entry into the occupational system, although they do not affect ultimate destinations within that system.

Finally, the present research has, it is hoped, provided a basis for widening the use of the technique of canonical correlations by sociologists and other social scientists. Several ways of expanding such usage come readily to mind. One is the application of canonical correlation to more detailed occupational mobility tables, so that factors other than SES would become more apparent as determinants of mobility. A second and related use would be to determine the factor underlying the second canonical variates presented here, as mentioned above. Third, canonical correlations could be used to study phenomena such as ethnic and religious intermarriage or intercity and intercountry migration, with ethnic groups, religious

Table 3. CORRELATIONS BETWEEN FIRST CANONICAL VARIATES AND GUTTMAN-LINGOES VALUES

Correlation between Canonical Coefficients for:	
Fa. Occ. predicted from 1962 Occ. and Guttman-Lingoes First Dimension Values Computed from Corresponding Outflow IOD Matrix:	= .989
1962 Occ. predicted from Fa. Occ. and Guttman-Lingoes First Dimension Values Computed from Corresponding Inflow IOD Matrix:	= .982
Fa. Occ. predicted from Son's First Job and Guttman-Lingoes First Dimension Values Computed from Corresponding Outflow IOD Matrix:	= .906
Son's First Job as predicted from Fa. Occ. and Guttman-Lingoes First Dimension Values Computed from Corresponding Inflow IOD Matrix:	= .986
Son's First Job as predicted from 1962 Occ. and Guttman-Lingoes First Dimension Values Computed from Corresponding Outflow IOD Matrix:	= .987
1962 Occ. as predicted from Son's First Job and Guttman-Lingoes First Dimension Values Computed from Corresponding Inflow IOD Matrix:	= .969

[11] It should be noted that although the second canonical correlation is orthogonal to the first, as mentioned above, this does not mean that the sets of coefficients or weights are orthogonal to one another. That is, the correlation across individuals should not be confused with the correlation across occupational categories. In fact, the correlations between the first and second sets of canonical coefficients are (in the order presented in Table 3) .661, .075, .325, .358, .465, and .199. This lack of orthogonality reflects the fact that both sets of coefficients contain elements related to some aspects of SES, although the correlations of the second set with the socioeconomic indicators used in Table 3 are much lower than those of the first set (they range from .093 to .864).

It is interesting, although puzzling, to find that our second set of canonical variates is not particularly similar to the second dimension of the Guttman-Lingoes two-dimensional solution mentioned above. The correlation between this second dimension and the second canonical variates (in the order used in Table 3) are .698, .284, .826, −.169, and −.890.

Table 4. UNSTANDARDIZED CANONICAL COEFFICIENTS FOR 17 OCCUPATIONAL CATEGORIES (*second canonical variates*), SCALED SO THAT LARGEST COEFFICIENT IN EACH SET EQUALS 1.0

	Coefficients predicting to:					
Occupational category	Father's occup. from 1962 occup.	1962 occup. from father's occup.	Father's occup. from first job	First job from father's occup.	First job from 1962 occup.	1962 occup. from first job
Professionals, self-employed	1.000	0.682	1.000	0.871	1.000	1.000
Professionals, salaried	0.402	-0.681	0.463	0.422	-0.077	-1.138
Managers	0.443	-0.468	0.358	0.403	-0.523	-2.011
Salesmen, other	0.667	-0.408	0.682	0.762	-0.676	-2.171
Proprietors	0.496	-0.551	0.465	1.000	-0.447	-1.907
Clerical	0.258	-1.319	0.185	-0.088	-0.561	-2.095
Salesmen, retail	0.316	-0.811	0.161	0.024	-0.568	-2.022
Craftsmen, manufacturing	-0.180	-1.892	-0.343	-0.354	-0.546	-1.954
Craftsmen, other	-0.056	-1.343	-0.164	-0.216	-0.572	-1.886
Craftsmen, construction	-0.117	-1.181	-0.241	-0.331	-0.515	-1.740
Operatives, manufacturing	-0.316	-1.636	-0.486	-0.524	-0.548	-1.827
Operatives, other	-0.157	-1.366	-0.188	-0.256	-0.538	-1.755
Service	-0.195	-1.644	-0.283	-0.459	-0.522	-1.755
Laborers, manufacturing	-0.470	-1.839	-0.538	-0.560	-0.503	-1.688
Laborers, other	-0.331	-1.286	-0.311	-0.304	-0.501	-1.513
Farm	0.497	1.000	0.087	0.119	0.336	0.435
Farm laborers[a]	0.000	0.000	0.000	0.000	0.000	0.000

[a] Omitted from computation. Coefficients assumed equal to zero.

groups, cities, and countries as the respective analogies to occupational categories.

Canonical correlations could also be used in more traditional fashion to develop indexes based on continuous variables, whenever one is faced with two sets of items which must be appropriately weighted to measure two underlying constructs, between which one wants to obtain a single correlation. An example is reflected in the proposition that increased structural differentiation in organizations requires the increased use of formal coordinating mechanisms. One might wish to develop indexes of both of these concepts, since neither can be adequately represented by a single indicator. These are but a few of the potential uses for canonical correlations. However, they serve to indicate the variety of social phenomena for which this technique might be utilized.

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