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ABSTRACT

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A FLOW MODEL FOR OCCUPATIONAL STRUCTURES

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Introductory Statement

The Center for Social Organization of Schools has two primary objectives: to develop a scientific knowledge of how schools affect their students, and to use this knowledge to develop better school practices and organization.

The Center works through five programs to achieve its objectives. The Academic Games program has developed simulation games for use in the classroom, and is studying the processes through which games teach and evaluating the effects of games on student learning. The Social Accounts program is examining how a student's education affects his actual occupational attainment, and how education results in different vocational outcomes for blacks and whites. The Talents and Competencies program is studying the effects of educational experience on a wide range of human talents, competencies and personal dispositions, in order to formulate -- and research -- important educational goals other than traditional academic achievement. The School Organization program is currently concerned with the effects of student participation in social and educational decision making, the structure of competition and cooperation, formal reward systems, ability-grouping in schools, effects of school quality, and applications of expectation theory in the schools. The Careers and Curricula program bases its work upon a theory of career development. It has developed a self-administered vocational guidance device to promote vocational development and to foster satisfying curricular decisions for high school, college, and adult populations.

This report, prepared by the Social Accounts program, develops a model for the analysis of occupational history data. The model contributes toward a system of social accounts.

Acknowledgment

This paper is part of a research program in Social Accounting initiated by Peter H. Rossi and James S. Coleman. It was originally presented at the Fifth International Conference on Input-Output Techniques, Palais des Nations, Geneva, January 11-15, 1971.

Abstract

This paper develops a model for the analysis of occupational history data as a contribution toward the development of a system of social accounts. The model is designed to examine the flow of men, throughout their lives, through the occupational structure. Using retrospective life history data collected from a sample of black and white men, the model treats men at age 13 as inputs into different statuses in education and the labor-force, including the military, and examines changes through age 39. In addition, hypothetical experiments are carried out via the model to find the occupational distribution of blacks if their particular educational and occupational experiences were modified to correspond to those of whites. The results of these experiments suggest the general utility of the model both for policy formulation and the scientific study of occupational changes.

Introduction

A key concern at the federal, state and local levels of government is the question of what policies or actions will best increase the socio-economic status of Negroes in the United States. The disadvantaged position of Negro Americans is rarely disputed, but the ways in which socio-economic disadvantage is compounded or alleviated in the course of the life-times of individuals is subject to debate. A major difficulty in the design of effective policies is the lack of a system of social accounts. Such a system can assist in monitoring and measuring changes over the course of careers of various subsets of the population. Optimally, if data were available for different cohorts of the population and across sufficient time periods, the impact of changes in the opportunity structure available to Americans could be assessed.

The present paper discusses intermediate results in a research project designed to contribute to a system of social accounts. The project is the study of the occupational, educational, familial and residential experiences of a cohort of men aged 30-39 in 1968 (Blum, Karweit, Sørensen, 1969).[1] In this paper, a model for the analysis of occupational history data is developed and applied to data from the research project. In effect, this is an examination of occupational flows for a specific cohort. This provides some aid in answering the question of how the occupational and educational structures can be made more effective in increasing the socio-economic status of Negroes in the United States.

In addressing that question, it is possible to conceive of the occupational structure as an extension, in effect, of the educational system: as a system of processes which move a man forward in his career, preparing him for a set of possibilities that was not open to him when he entered the occupation. That conception is utilized here. Two points should be noted in doing this: first, there is a great deal of movement among occupations by individuals in the labor force, and second, this movement declines with age.[2] The first of these observations indicates that occupations do act as a set of processes in the way suggested (as they could not if individuals remained in the same occupations throughout their careers). The second observation indicates that any formal structure designed to describe these processes should be age-specific.

The Theoretical Model

A model that will aid in describing movement from the educational system into the labor force and through different occupations in it is an adaptation of a portion of Stone's (1966) model for the educational system. Stone, adopting a convention introduced in population mathematics, uses a matrix of birth and survival rates, together with a vector that orders the population by ages, to move individuals through those ages in which they may be in school.

If we consider a vector of individuals ordered by age, and within that by status in the educational or occupational system, we have a vector n in which the elements may usefully be double-indexed, $n_{ij}(t)$, the number of individuals in status j at age i in calendar year t. Then a matrix may be introduced which reallocates those in each status into different statuses. If, for example, there are only two educational statuses (one stream which is college preparatory, and the other which is vocational) and two occupational statuses (white-collar occupations and blue-collar occupations), and there are r+1 ages (beginning, say, at age 14, with index 0), one can describe the system by a formulation in which the matrix H is partitioned into a set of r 4x4 submatrices along the diagonal below the main diagonal, plus a row of submatrices in the first row:

$$\begin{bmatrix} n_{0.}(t+1) \\ n_{1.}(t+1) \\ \cdot \\ \cdot \\ n_{r.}(t+1) \end{bmatrix} = \begin{bmatrix} H_{00} & H_{01} & H_{02} & \cdots & H_{0r} \\ H_{10} & 0 & 0 & \cdots & 0 \\ 0 & H_{21} & 0 & \cdots & 0 \\ \cdot & & & & \\ 0 & & & H_{r,r-1} & 0 \end{bmatrix} \begin{bmatrix} n_{0.}(t) \\ n_{1.}(t) \\ \cdot \\ \cdot \\ n_{r.}(t) \end{bmatrix} \qquad (1)$$

where the submatrices in the first row, H_{0j}, represent "birth rates" of men age 14 into each of the four statuses by men of age j. For example, consider men aged 36 (whose age index is 36-14=22). The contribution of these men to 14-year-olds in the educational system and labor force is given by the product $H_{0,22}n_{22,\cdot}(t)$. This product may be expanded for the four-status case to give

$$\begin{bmatrix} h_{01,22,1} & h_{01,22,2} & h_{01,22,3} & h_{01,22,4} \\ h_{02,22,1} & h_{02,22,2} & h_{02,22,3} & h_{02,22,4} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} n_{22,1}(t) \\ n_{22,2}(t) \\ n_{22,3}(t) \\ n_{22,4}(t) \end{bmatrix} \qquad (2)$$

where $n_{22,k}(t)$ is the number of men age 36 (22+14) at time t who are in status k (college preparatory education, vocational education, white-collar job, blue-collar job); and $h_{0j,22,k}$ is the the number of sons of age 14 (0+14) in status j per man of age 36 (22+14) in status k. The value of $h_{0j,22,k}$ will be less than 1.0, since the expected number of boys born to a man's mate during his 22nd year is less than one. Since all sons are in school at age 14, only the first two rows of the matrix are non-zero. The coefficient $h_{0j,22,k}$ is the compound of a number of processes: birth rates to men of age 22 (36-14) who are in status k at age 36 (e.g., white-collar jobs), survival rates from birth to age 14, and selection-and-transfer rates between the two educational streams between the age at which school begins and age 14. Thus the $h_{0j,22,k}$ will vary with k as men of different occupational statuses show different birth rates, and as their sons go differentially into educational stream j. These coefficients will also vary as the third index, 22 here, varies. This index is the age of the man, age 36 at time t, when sons who are now being born into the system were born into the world. Thus the coefficient $h_{0j,.,k}$ will vary widely because of these differing birth rates to men of differing ages.

The remaining submatrices contain coefficients with a different substantive meaning. They represent the allocation among statuses j=1,2,3,4, at age i+1, of men who were in a particular status k at age i. The submatrices are indexed $H_{i+1,i}$, for the age at the end of the year and the beginning of the year, and the elements of the submatrix $H_{i+1,i}$ are $h_{i+1,j,i,k}$ which is, of all the men who are age i and in status k at the beginning of the year, that fraction which is in status j at the beginning of the next year. This formulation allows not only for the movement from educational statuses into the labor force, and for movement within each of these institutions, but also for movement back into full-time education from full-time occupation. In the present study, this movement occurred with some frequency and could not be ignored. It appears likely that in all countries such shuttling back and forth between education and occupation will increase in frequency to the extent that it should be included in a model like the present one.

This formulation gives a dynamic system in which there is a primary input into the various statuses of age 0, via the sons of men currently in the system, and there is an exit from the system of those men in status k at time t.[3]

For all the intermediate ages between 0 and k, there is an equality such that $\sum_k n_{ik}(t) = \sum_j n_{i+1,j}(t+1)$, or $\sum_j h_{i+1,j,i,k} = 1$ for all statuses k. That is, there are the same number of persons at age i+1 at time t+1 as there are at age i at time t. In the present formulation, there are no deaths until age k at which all men leave the system. However, deaths could be easily incorporated by rescaling $h_{i+1,j,i,k}$ so that $\sum_j h_{i+1,j,i,k} = v_i$, for all statuses k, where v_i is the survival rate for the year for men at age i.

The sum of each column in the matrix H is $1+\theta_{ik}$ (except for the last column, which has a sum θ_{ik}), where θ_{ik} is the birth rate for men of age i and status k. Each of the submatrices $H_{i+1,i}$ in H below the first row has a column sum of 1.0, and each submatrix in the first row, H_{0i}, has column sums equal to the birth rates θ_{ik}.

The model as outlined above can be written

$$n(t+1) = Hn(t) \tag{3}$$

This model describes, for the data from which the coefficients of H are calculated, the allocation and birth process through which men move from one job to another through a career, and give birth to sons at particular ages throughout that career. When applied to different data, that is, a different distribution of individuals among ages and statuses at time t, then it predicts the new status distribution at future times as a function of the age and status distribution at time t, and of the matrix of coefficients, H, which are assumed constant. This would show, for example, the predicted number of persons at time t+τ in different educational streams at each age (assuming the supply of places is not constrained), as a function of birth rates of men at each age and occupational status, distribution of the sons

At each age, a flow matrix can be tabulated from the data, showing the number of men in state j at age i+1 who were in state k at age i, $n_{i+1,j,i,k}$. These numbers divided by the numbers in state k at age i, $n_{..ik}$, give estimates of the elements of the matrix, $h_{i+1,j,i,k}$. In the analysis described below, the following states will be used:

- education (any full-time)
- white-collar job (professional, managerial or proprietary, clerical and sales)
- blue-collar job (craftsman, operative, labor, farm, service)
- military

The black sample and the white sample will be characterized by the proportion of men in each of these states, from age 14 to 39. At age 13, all men in both samples are assumed to be in education.[4]

The data available include only a given cohort which is ten years in span, men born between 1929 and 1938. It will be treated, however, as if it were only a single-year cohort. This means, in terms of the model presented above that data represent a portion of the n vector, $n_{i1}(t)$, $n_{i2}(t)$, $n_{i3}(t)$, $n_{i4}(t)$, for a particular correspondence between i and t. If we measure t according to the calendar, and i with i = 0 at age 14, then the age group that is age 39 in 1968 (the last age of the cohort in this sample) would be denoted by $n_{0j}(1943)$, $n_{1j}(1944)$, and so on with the progression of years to $n_{25j}(1968)$. Thus this is a 4-element portion of the vector which moves progressively down the vector from position i = 0 in 1943 to position i = 25 in 1968.

The functioning of this system of movement into and through the labor force can be seen in Figures 1-4. These figures show the of those men among educational streams, and the movements of men through occupations during their work career. It would show also the predicted size at time $t+\tau$ of each occupational group in the labor force, again assuming that the same coefficients hold. This would be given by $\sum_{i=0}^{r} n_{ij}(t+\tau)$, where $n(t+\tau) = H^{\tau}n(t)$.

Application of the Model

In the research project described earlier, some of the data are available to estimate the elements of H. Data are available to estimate the submatrices along the trailing diagonal, $H_{i+1,i}$, for movement among jobs at each age i, but the data to estimate birth rates into different educational streams must be reconstructed from other sources. Eventually, it will be possible to reconstruct the whole model by use of data from several sources; and the model will be applied separately to the black population and the white population.

However, restricting the application to data from the present project, a portion of the model can be used to examine occupational changes within the same cohort, under existing conditions and under particular hypothetical conditions.

At each age, from 14 onwards, each individual can be characterized as being in one of s "occupational states," including educational activities and military service as occupational states. These states may be divided very finely, or left in broad Census categories. In addition, military service may be divided into officer and enlisted. Education may be treated as a single state or divided into categories, such as high school, college, undergraduate or graduate study.

proportions in each status at each age, for blacks and whites. The values from which Figures 1-4 are plotted have been found by first creating all elements in the H matrix except the top row of submatrices representing birth into the system, estimating $h_{i+1,j,i,k} = n_{i+1,j,i,k}/n_{ik}(t)$. Then the values in Figures 1-4 are a certain portion of the vector n(1943+i), found as:

$$n(1943+i) = H^i n(1943),$$

for i=0,...,25, with calculations made only for the portion of the vector that is $n_{0j}(1943)$, j=1,2,3,4. The figures show the vector of numbers divided by the sample size, so they represent the proportions of the cohort in each of the four statuses.

As Figure 1 shows, education is, of course, a state of origin from which evacuation occurs. The evacuation is somewhat more rapid for blacks than for whites. Figure 2 describes how military service is a temporary state beginning in the late teens and ending in the early twenties. For blacks compared to whites, it is skewed slightly to the right, and continues at a slightly higher level in later ages. The major long-term differences occur, of course, in the occupational states where blacks and whites end up, after these transient states are evacuated. Figure 3 shows that a majority of both blacks and whites are in blue-collar jobs at age 39, though about 20% fewer whites than blacks. The kink in the two curves from age 19 to 23 is caused, as Figure 2 shows, by military service.

Over 45% of whites end up in white-collar occupations at age 39, as Figure 4 shows, while only about 20% of the blacks do so, with the remainder in blue-collar occupations (which includes service workers and

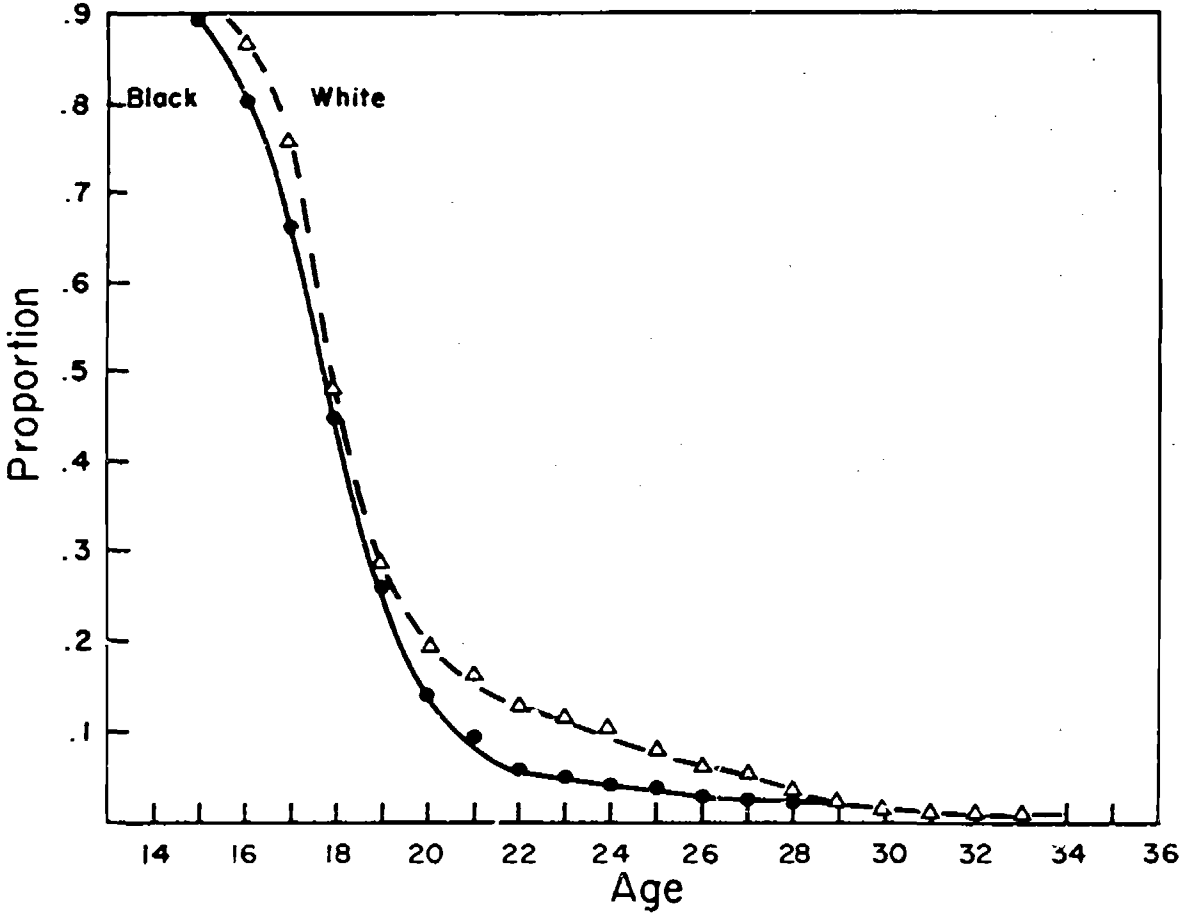


Figure 1. Proportion in Education

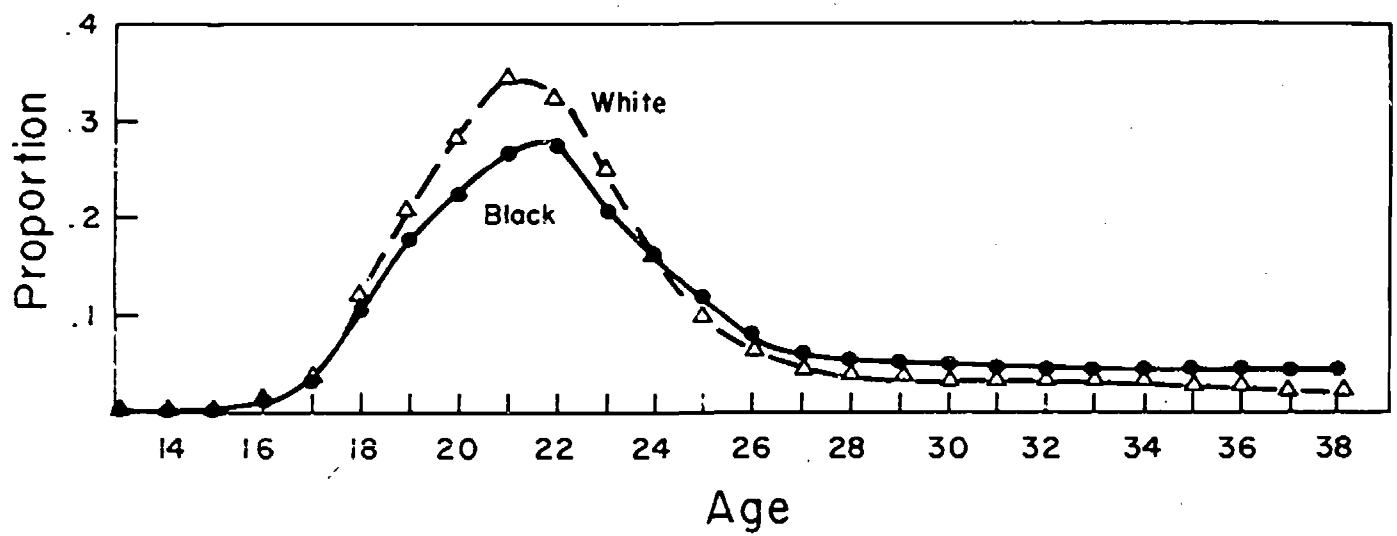
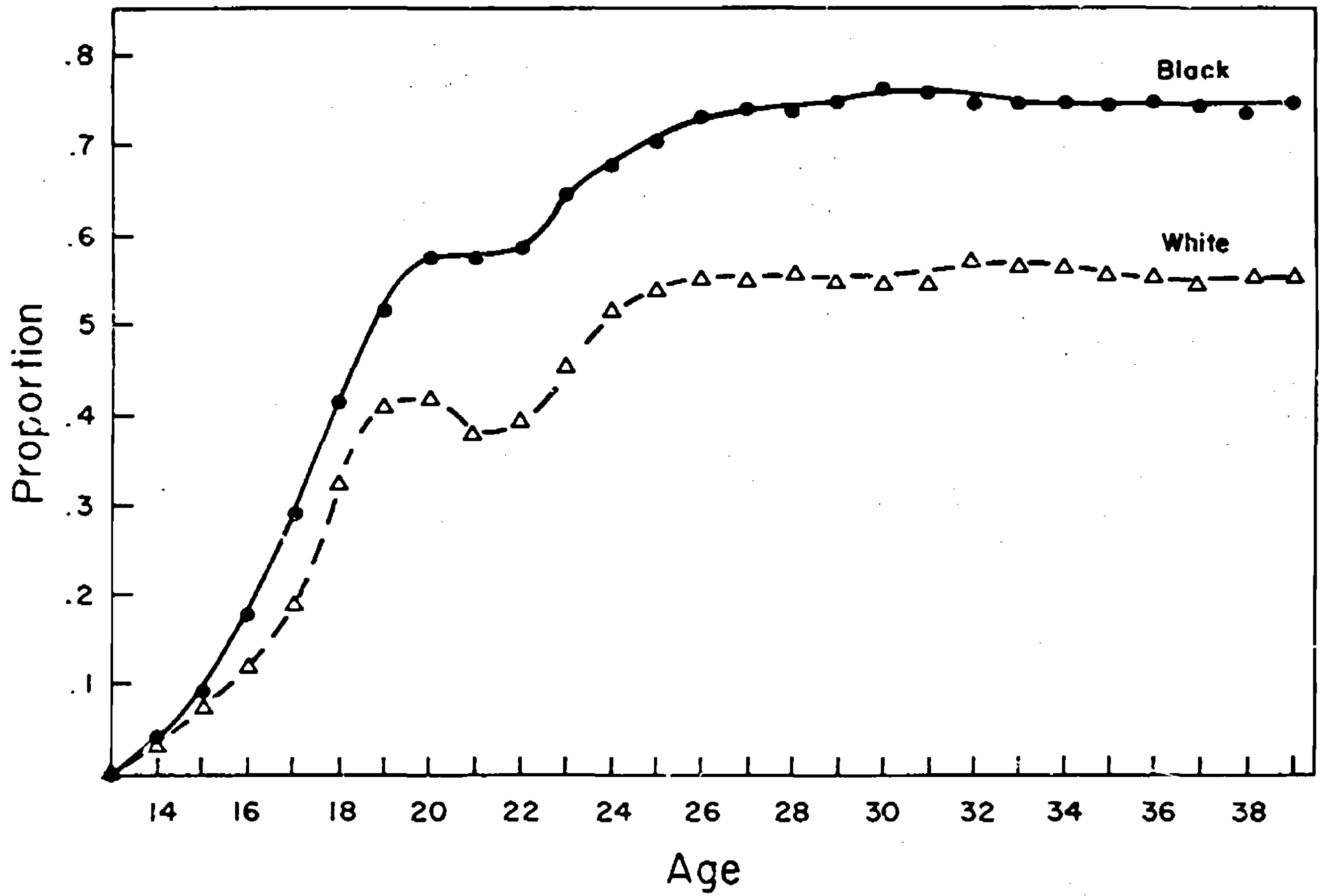


Figure 2. Proportion Military



<u>Figure 3</u>. Proportion Blue Collar

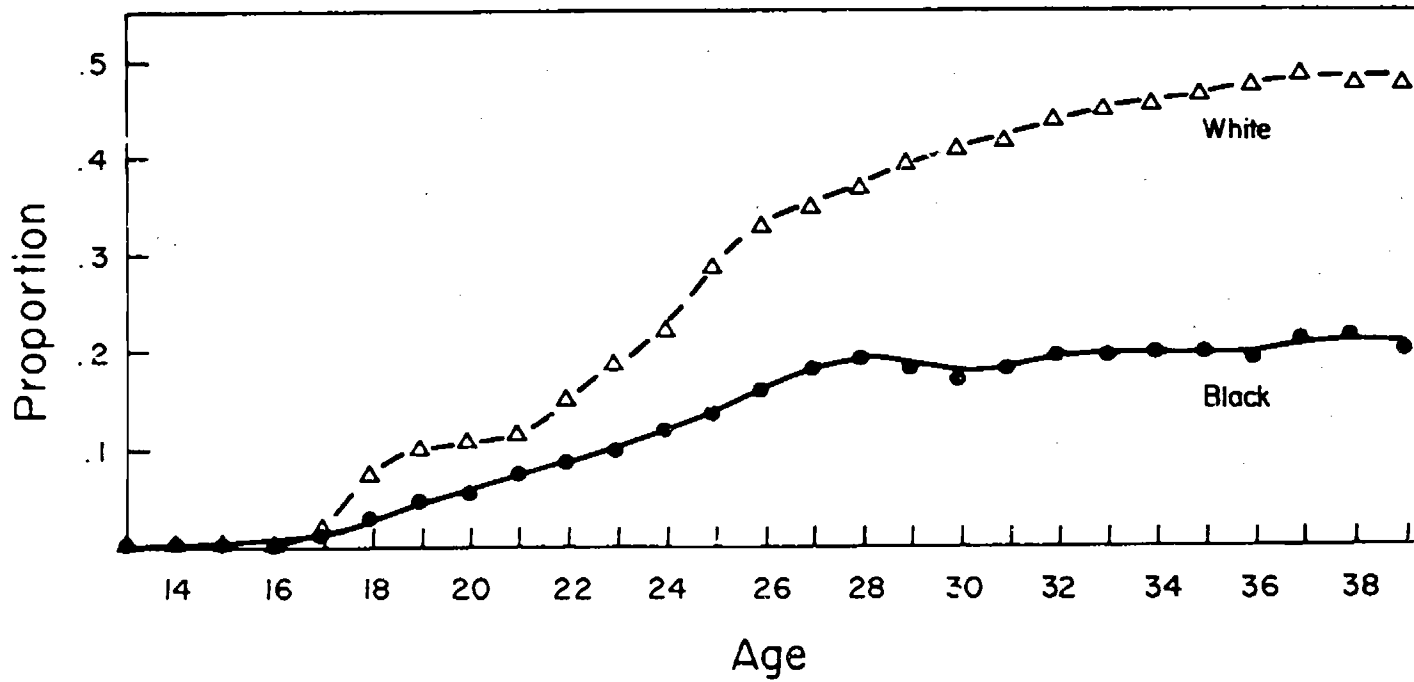


Figure 4. Proportion White Collar

farmers, the latter small in number).

One of the most fruitful ways of examining the differential functioning of this system for blacks and whites is to ask what would happen if we were to combine certain portions of the black H matrix with certain portions of the white one. This may be done by combining certain columns from each matrix, to construct a system having the particular properties desired. A first example is to construct a new H matrix with one column for each age from the white matrix, giving the proportions going from white-collar occupations into school, military, and blue collar, and the remaining columns at each age from the black matrix. This newly-constructed H matrix includes proportions characteristic of whites, going <u>from</u> white-collar occupations, and proportions characteristic of blacks going from <u>other</u> statuses <u>into</u> white-collar occupations. A second H matrix may be constructed in exactly the reverse way. With these matrices we can ask the question: what would the proportion white collar among blacks at age 39 be under two possible conditions: first, if the rates of movement from white-collar jobs (to blue collar or education or military) were changed to be like that of whites; and second, if the rates of movement <u>into</u> white-collar jobs from these other states were changed to be like that of whites.

Figure 5 shows, from age 17, the hypothetical condition in which white rates of movement <u>into</u> white collar departs radically from the actual curve for blacks. Under these conditions, the blacks' occupational positions would be about the same as those of whites up to age 26, but would level off after that, due to the greater departure rates

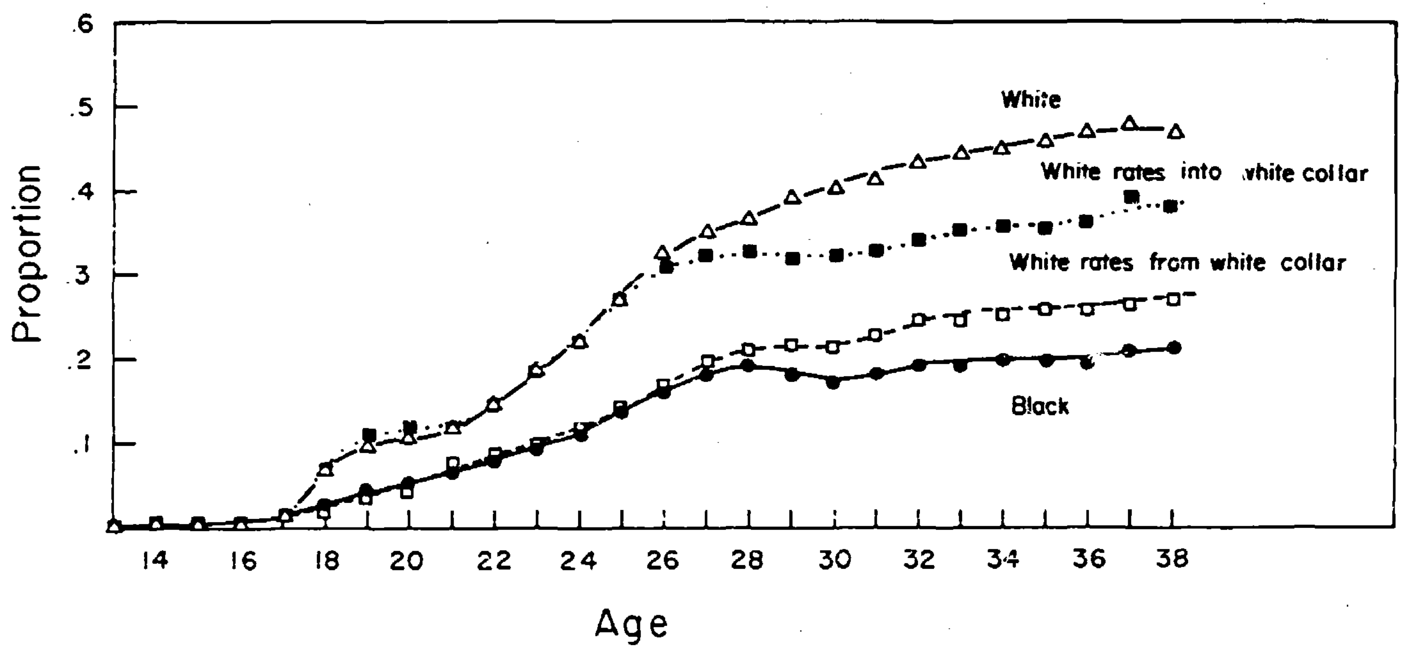


Figure 5. Proportion White Collar

for blacks from white-collar jobs into blue-collar jobs. Still, the blacks' proportion in white-collar occupations under these conditions would hold at about 15-18% above the actual blacks.

In contrast, a hypothetical condition in which the rates of movement from other occupations to white-collar jobs stays like that which blacks already have, while the rates of movement from white-collar jobs are like those of whites, does not deviate from the all-black curve until about age 26. From this age onward, the lower rate for whites of leaving white-collar jobs is apparent, resulting in blacks having about 5% more white-collar jobs by age 32, an increment that maintains itself through age 39.

This comparison shows that the greatest bottleneck for blacks is in the movement into white-collar jobs. Once there, the curve for black rates of movement from white-collar jobs shows that they remain there reasonably well, staying about 15-18% above the actual blacks. However, the curve for blacks with white rates of movement from white-collar jobs shows that unless they somehow get into these jobs, an improvement of their retention rate to equal that of whites will only make about a 5% difference.

Figure 6 shows the consequences of a different kind of hypothetical change. Only one thing is changed from the black situation: school leaving is changed to correspond to that of whites, both in the overall rates of leaving, and in the various statuses to which school leavers go. The graph shows that the total effect is accomplished in two years at age 18 and 19, resulting in about 4% more white-collar jobs than currently exist among blacks. But that increment does not even maintain

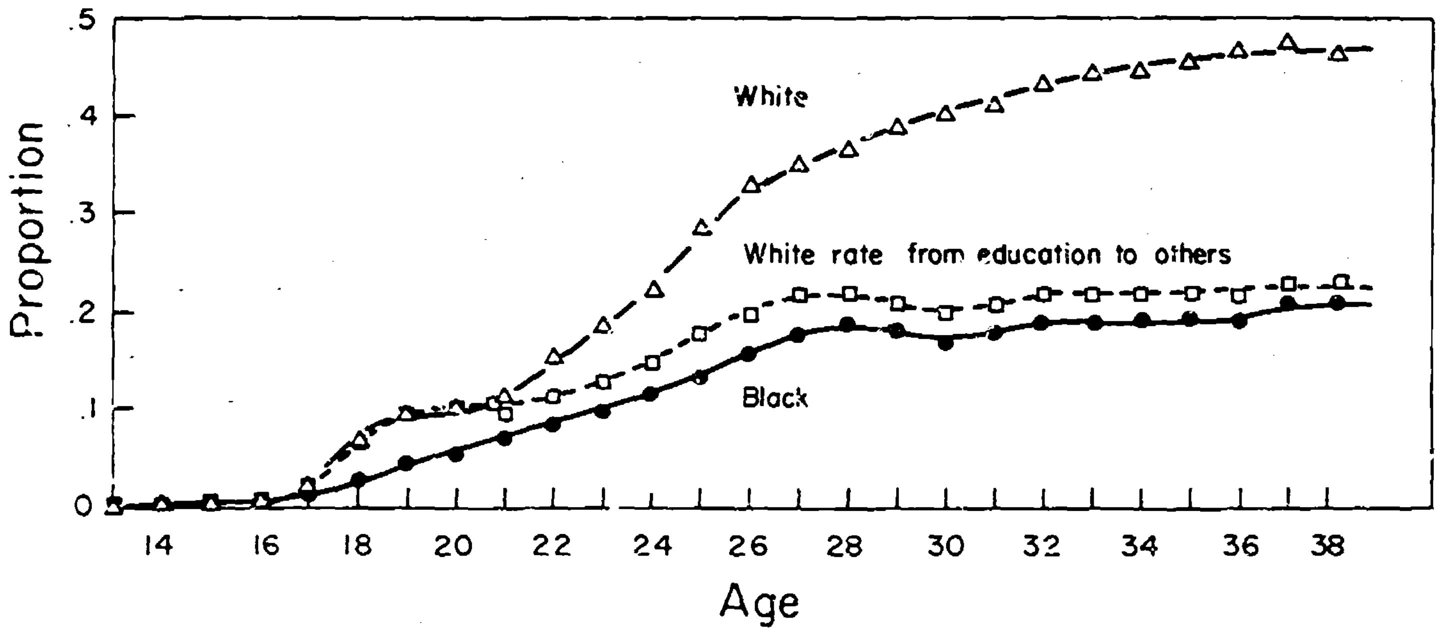


Figure 6. Proportion White Collar

itself; it slowly declines through age 39. Not even the reentry of whites into education, and re-emergence as white-collar workers, has any noticeable impact after age 20.

Figure 7 shows again the consequences of a single change from the blacks' current condition: proportions going from blue-collar jobs to school, military service, or white-collar jobs are changed to be like those of whites. The graph shows that this indeed does make a large difference, reducing the black-white difference in proportion white collar to about half its actual value.

Part of the reason this change shows so much greater effect than the comparable change in rates of leaving white-collar jobs (Figure 5) is that it begins so much earlier. By age 19, the white rates of movement out of blue-collar jobs have begun to feed additional men into white-collar jobs. This effect continues to cumulate, with the gap growing throughout the 20's and 30's. This contrasts sharply to the effect of changes in rates of movement into other statuses from education, shown in Figure 6, for that effect took place only at ages 18 and 19, and was diminished later.

The effect of changes in the destination of blacks who leave the military is shown in Figure 8, comparing it with the effect of education. The scale is doubled here, and only ages 16-26 are shown, since education and military have all their effects in that period. Figure 8 shows the big bulge in white-collar occupations for whites leaving school at ages 18 and 19, but then continuing in a path that is parallel to current blacks. White destinations on leaving military service have their effects on members holding white-collar jobs several

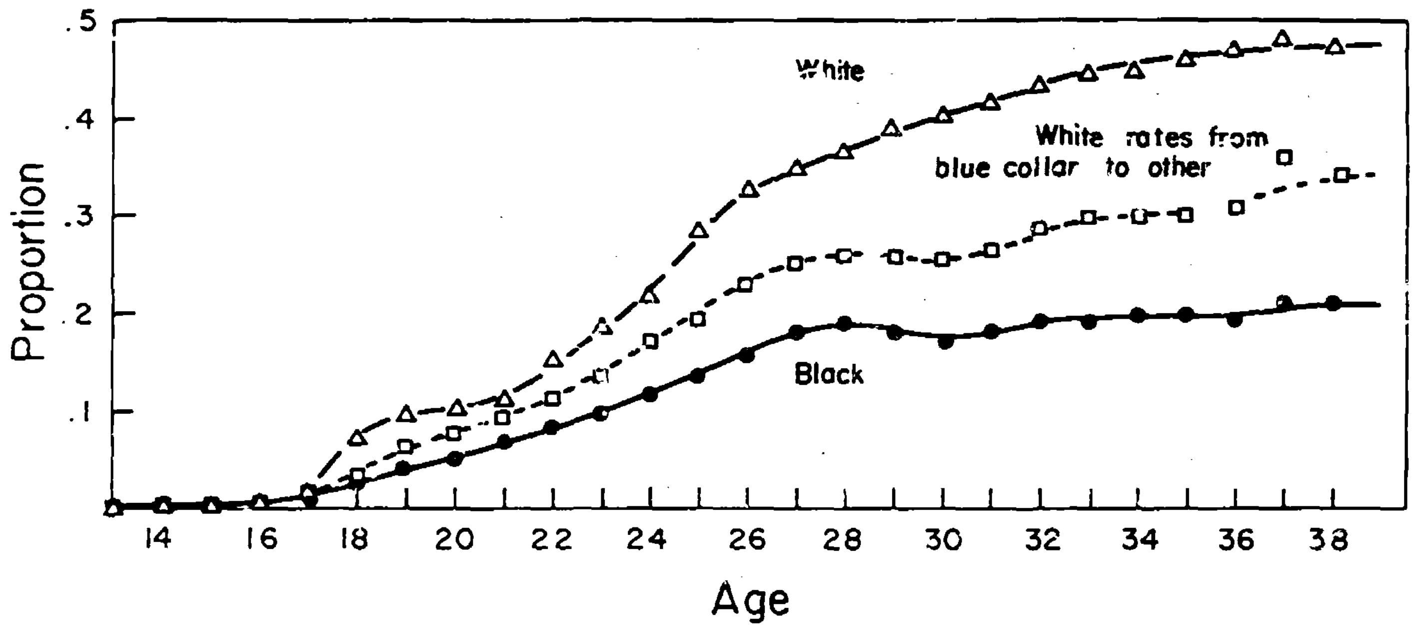


Figure 7. Proportion White Collar

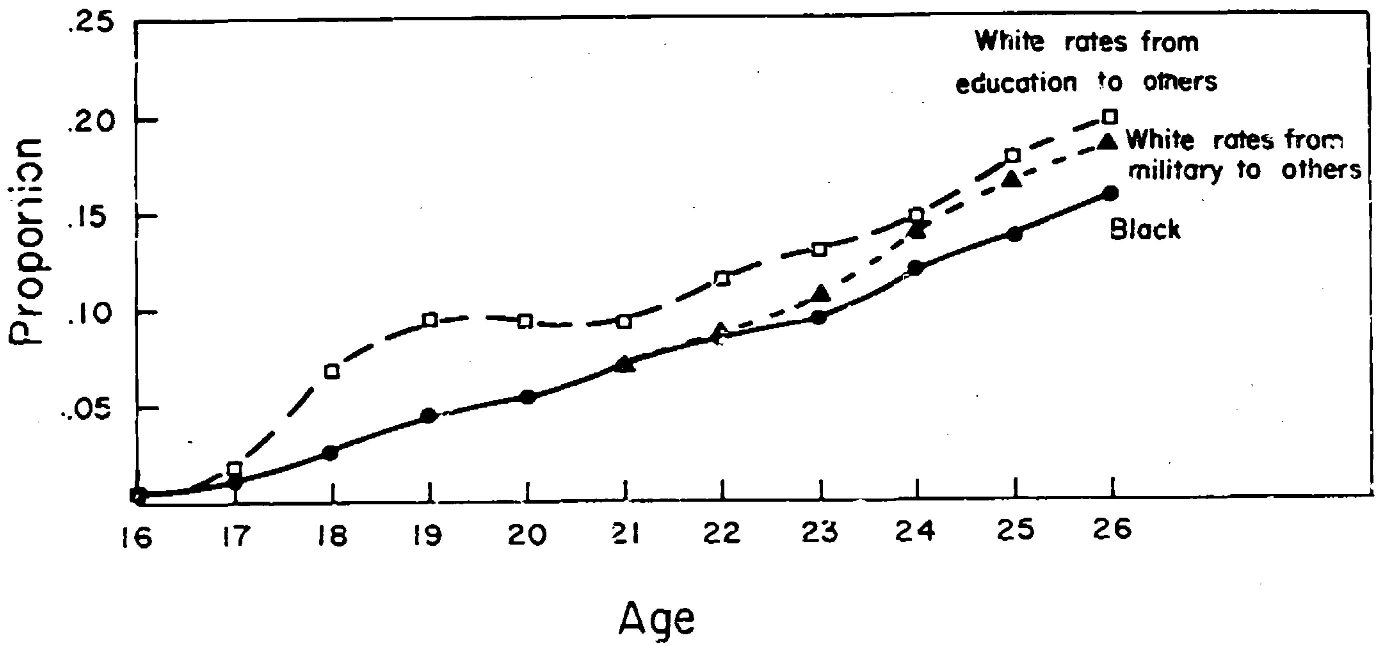


Figure 8. Proportion White Collar

years later, in ages 23-25. Perhaps the most interesting point is that the long-term effect is nearly the same. The curve for white movement out of military service (not shown here) is parallel and very close to the curve for white movement out of education, all the way to age 39.

This similar but delayed effect of changing blacks' destinations after military service to correspond to whites can be seen by a reverse experiment, giving whites exit rates from military service into other statuses that correspond to those of the blacks. This is shown in Figure 9, which also includes a curve showing whites with black movement from education to other statuses. Again the difference shows up at ages 18 and 19 for education, but not until ages 23 and 24 for military service, yet with the same result. The curves are almost identical from age 26 on.

It is important to be clear about the interpretation of this result. It does not mean that military service is as "effective" for obtaining white-collar jobs as is education, but in fact almost the opposite of that. It means that the occupational differences between blacks and whites that show up before military service still remain at the end of military service. The difference in profiles of jobs obtained by whites and blacks after military service is enough like the difference in profiles of jobs obtained after education that the long-range effect of changing the movement from military service is nearly identical to that of changing the movement from education.

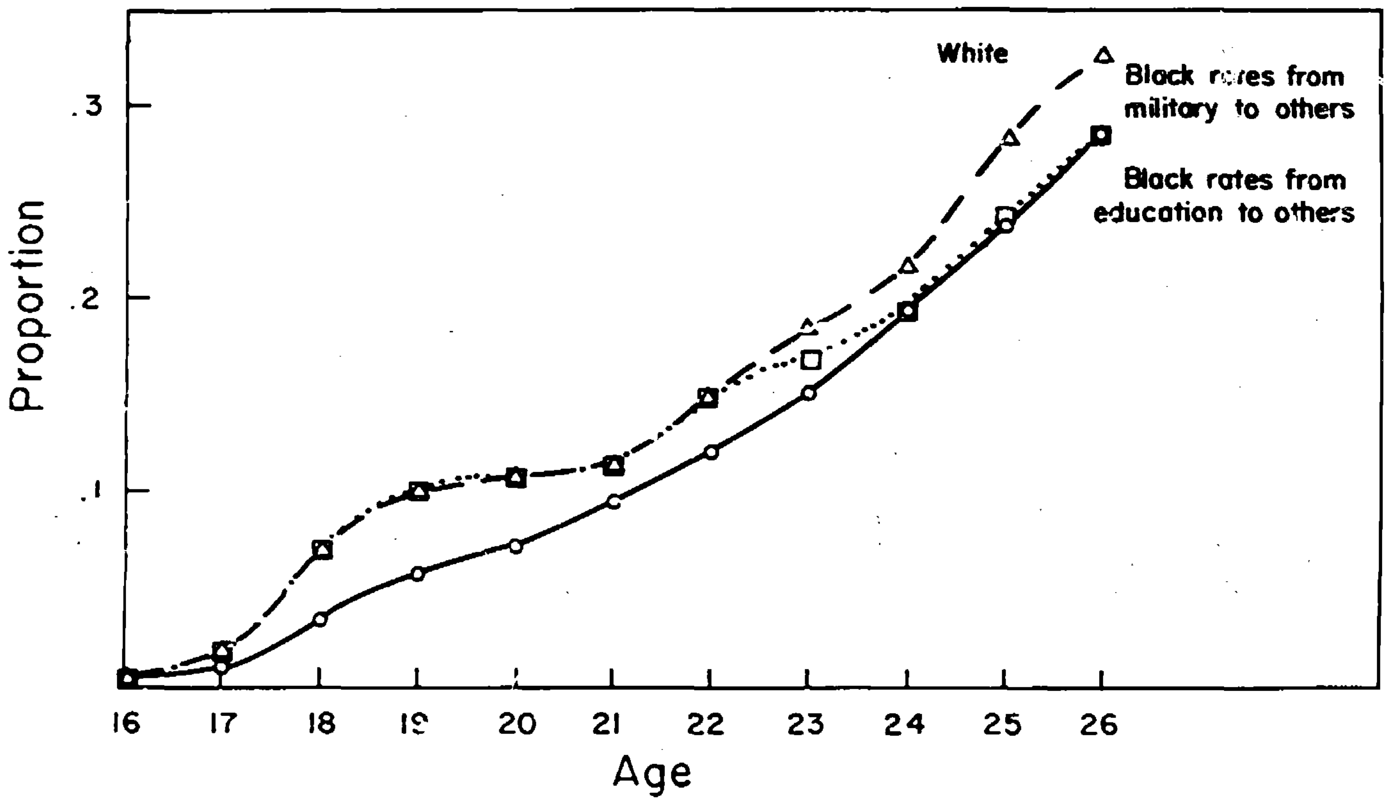


Figure 9. Proportion White Collar

Summary and Conclusions

This paper develops a model for the analysis of occupational history data. The model is designed to examine the flow of men, throughout their lives, through the occupational structure. In the formulation, the occupational structure is viewed as an extension of the educational system; as a system of processes which move men forward in their careers, preparing them for a set of possibilities that was not open to them when they first entered occupations.

As a first application, examples are given from life history data collected from a cohort of white men and a cohort of black men. Starting with age 13, at which time all the men are in education, the men are treated as inputs into different statuses, and the changes they experience through age 39 are examined. The statuses used are education, military service and full-time occupations (blue-collar and white-collar jobs). In addition, hypothetical experiments are carried out via the model to find the occupational distribution of blacks if certain rates of movement were modified to correspond to those of whites.

This investigation is only a portion of that which is possible with a model of the sort developed and data of the type used here, i.e. data which give a continuous record of changes in jobs, education, and other major statuses. The model contributes toward a system of social accounts, and the possibilities that the social accounts approach holds both for policy formulation and for the scientific study of occupational changes (within and between generations) appear great indeed.

Footnotes

[1]The universe of the two samples of this study are the total populations of black and nonblack males 30-39 years of age, in 1968, residing in households in the United States. Individuals in the sample were selected by standard multi-state area probability methods. The execution of the sample design consisted of two parts: (A) A national sample, designed to yield the required number of nonblack eligibles plus a number of eligible blacks proportional to their representation in the population as a whole; and (B) A supplementary selection of black households only, designed to supply the additional eligible blacks required to satisfy the design. The black sample consists of blacks interviewed in the National sample and the blacks interviewed in the supplementary sample. Only individuals normally classified by the Census as Negroes are included in what we are calling the black sample. In each sample, selection was made so that each person in the universe had an equal probability of being interviewed. The analysis is based on 1589 cases: 738 blacks and 851 nonblacks. The overall completion rate for the study was 76.1% for Sample A and 78.2% for Sample B.

[2]For the cohorts studied, the mean number of jobs for whites is 9.4 (s.d. = 5.1) and 7.2 for blacks (s.d. = 4.2).

[3]For a comparison of the present model with an input-output formulation, see Appendix A.

[4]The information collected in the study begins with the respondent's age 14. While a few men may have already been out of full-time education by age 13, the present analysis assumes that the observed movement to other states occurred between age 13 and age 14.

Appendix A

The model presented here is not an input-output formulation, although the model has some similarities to an open-ended dynamic Leontief system. There are, as in an input-output system, primary inputs, in the form of new men at age 0, and there are final outputs comparable to final consumption, in the form of men who leave the system at age k. However, the matrix of coefficients, H, is different from the matrix of technological coefficients in input-output analysis. Its dimensions are men in state j at age i+1 per men in state k at age i, that is units output per unit input, while the technological coefficients in input-output analysis have a dimension exactly the inverse of this. Empirically, the difference is this: if the number of persons in state k at age i and j at age i+1 is $n_{i+1,j,i,k}$, if the number in state k at age i (at time t) is $n_{ik}(t)$, and if the number in state j at age i+1 (at time t+1) is $n_{i+1,j}(t+1)$, then the coefficient $h_{i+1,j,i,k}$ is equal to $n_{i+1,j,i,k}/n_{ik}(t)$. Coefficients comparable to input-output coefficients, however, would be $a_{i+1,j,i,k} = n_{i+1,j,i,k}/n_{i+1,j}(t+1)$.

It would be quite possible to make the present model into an input-output model by merely creating a matrix of a's as indicated, rather than a matrix of h's. But the two models have different implicit empirical assumptions about what remains constant when the input vector changes. The model used here assumes that of the men who are in a given state, k, the fraction going to each state j is constant. The input-output formulation assumes that of the men who arrive at state j, the fraction coming from each state k is constant, independent of the number of men in each state of origin. The present formulation assumes that the allocation rates are not affected by the number of "places" or "positions" in each state of destination, and that the system is thus directed by the demands of men in origin state k for positions in each destination state j. The input-output formulation assumes that the allocation is not affected by the number of men in each state of origin, and that the system is directed by the supply of places in destination state j, with the same fraction of them going to men from a given origin state k, independent of the number in that origin state. The present model is a forward-generating process, which can calculate the output, given the input, while an input-output model is a backward-generating process, which calculates the input necessary to arrive at a given output.

Obviously, the input-output formulation is incompatible with the idea of a "birth rate" from men in given states into given states, because a "birth rate" is a rate per man in the state of origin, a forward-generation process, rather than a backward one. In an input-output model, the numbers of men born into each state of the system at age 0 by a given set of birth rates would be incompatible with the relative numbers required by different destination states at age 1, except for one particular configuration of requirements.

Apart from the birth rate problem, a system of either sort could be constructed. However, neither assumption appears strictly true in reality: the fraction of men in occupational state k going into occupational state j depends on the number of positions in that state and other states, and the fraction of jobs in occupational state j that go to men from occupational state k depends on the number of men in that state, as well as the number of men in other origin states. A formulation that would probably come closer to empirical reality than either of the previous formulations is the assumption that except for births into the system, the quantity $n_{i+1,j,i,k}/(n_{i+1,j}(t+1) \times n_{ik}(t))$ is constant. Such coefficients would have the dimension, number of persons in destination occupation per person in origin state and job in destination state. That formulation is not examined here (see Coleman, 1968).

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