THE POTENTIAL DEMOGRAPHIC IMPACT OF MIGRATION#

WILLIAM J. SEROW*

I. Introduction

Conventionally derived estimates of net migration begin with a base (enumerated) population, make adjustments for expected (or recorded) mortality and fertility over a specified time interval, and compare the result (expected population) with the enumerated population at the end of the measurement period. Any differences between expected and enumerated population must be the consequence of net migration.

This paper takes this procedure one step further by considering that migration not only brings in or takes out additional persons to/from a region, but also that migrants will bear offspring which will increase or decrease an area's population even more. This latter component is referred to in this paper as the indirect impact of migration—that is, the effect from fertility among migrants on the size and composition of a region's population.

The technique employed here is not new to regional science. A variant of the Leslie matrix technique has been employed by Andrei Rogers.[1] Rogers' analyses use the model outlined below—augmented by variables signifying the probability of a person of given demographic characteristics moving between various regions or between one region and the balance of the country. This approach focuses primarily on *gross* flows of persons between regions. The technique introduced here is somewhat different in conception in that it attempts to determine how the *net* flow of migrants to or from a given region affects the size and composition of the region's population. The basis of the approach begins with an initial population which is assumed to be subject to the forces of fertility and mortality, but not migration. Thus, it may be said that the region's population is closed. By employing the Leslie matrix technique, an estimate of final population can be made. This estimate shows what the population would have been under the influence of prevailing fertility and mortality in the absence of migration. Comparison of this estimate with the enumerated population will show how migration has affected the size and composition of the region's population. Furthermore, by comparing the estimated migration-induced population change with conventionally derived estimates of net migration, it is possible to separate the direct (net migrants) and indirect (locally born offspring of migrants, locally born offspring of offspring, etc.) components of migration-induced population change.

#An earlier version of this paper was presented at the North American meetings of the Regional Science Association in 1973. A note of thanks is due two anonymous referees for many helpful suggestions. As always, all remaining shortcomings are the sole responsibility of the author.

*Research Director, Population Studies Center, Tayloe Murphy Institute, University of Virginia.

This paper is divided into the following sections: a) a review of conventional methods of migration measurement; b) a statement of the theory and components of the Leslie matrix; c) the specification of the matrix model for the period 1950-1970; and d) a summary of the results of application of the model to the population of the State of Virginia.

II. *Conventional Methods of Migration Measurement*

The computation of age-race-sex specific migration data is complicated by the fact that several techniques are available, none of which is demonstrably superior to the others in all situations. If concern is only with the calculation of the overall amount of net migration for a region, then the vital statistics method is most applicable. This method merely defines net migration to be equal to the difference between beginning and ending population, less natural increase. A variant of this technique has been developed by Hamilton (11) to calculate age specific migration data. Although the technique is straightforward, it is tedious to use when results for many regions are sought. To use this technique, it is necessary to apply separation factors because the census day is April 1 while vital statistics of the sort required (births and deaths by age) are usually compiled for the calendar year of occurence.

The life-table survival rate (LTSR) method is often used to calculate age specific migration data. In this technique, the L_x column of the life table is used to calculate a ten year survival probability for each cohort in the population (2, p. 555). These rates are then applied to the region's initial age distribution, resulting in an expected age distribution at the end of the decade. The difference between the expected and enumerated population is attributed to net migration.

In using this technique it is necessary to assume that national rates apply with equal accuracy to all regions (in the absence of state or regional life tables). Unless data are available separately for different racial groups, this assumption is unwarranted. It is also true, as Shryock, Siegel, and associates (24, p. 453) point out, that the application of LTSR tends to understate deaths (thereby overstating natural increase and understating net migration) for a region experiencing net inmigration and to overstate deaths (and overstate net migration) for a region experiencing net outmigration.

A third technique is called the census survival ratio method (CSR). The CSR differs from the LTSR only in that the cohort survival probabilities are calculated from national census data rather than from the life table. Mortality, relative census coverage, and reporting errors are all measured by CSR, making it unnecessary to perform separate adjustments (24, p. 632). This requires only two assumptions: a) that age, race, and sex specific survival rates apply in all regions, and b) that the pattern and incidence of relative changes are uniform across all regions.

III. *Theory and Components of the Leslie Matrix*

The Leslie matrix is a series of simultaneous equations which incorporate the basic processes which determine the natural increase of a population—fertility and mortality. Although matrix techniques have been in use for a variety of problems in population analysis for more than thirty years,[2] it was not until 1964 that results of systematic applications of these techniques to human populations began to appear in the literature. The publication of two papers by Keyfitz (12, 13) in that year has been followed by several other applications of this technique, especially connection with stable population theory.[3] The structure of the Leslie matrix and its characteristics are, by now, quite well known, and a brief summary of its structure should suffice for the present.

The most common use of the matrix is for age-sex specific population projections. The matrix is square, being r x r, with r equal to the number of age groups in the base population. It is customary, but not necessary to use a five year age interval. The matrix is multiplied by an initial population vector (a column vector with r elements) to give a projection for as many years into the future as there are years in the age interval being used. Again, because no account is made of migration, the population is assumed to be closed.

A matrix may be constructed for both the male and the female population. The first row of the matrix consists of age specific fertility variables, ${}_nb_i$. The value of this variable will be non-zero only for females who are, or will be, in the reproductive years at some time during the projection period. This period may be set as being between 10 and 49 years of age. The value of ${}_nb_i$ is equal to:

$$(1) \qquad {}_nb_i = \frac{{}_nL_0}{2\,(l_0)} \left[{}_nF_i + {}_nd_i \quad {}_nF_{i+n}\right]$$

where: ${}_nF_i$ is the age-specific fertility rate for the n – year cohort beginning with age i; and ${}_nd_i$ is the ratio of ${}_nL_{i+n}$ to ${}_nL_i$;

and,

${}_nL_i$ is the life table value referring to the number of person years lived by the cohort beginning at age i for n years;

and,

l_0 is the initial size of the cohort.

These values, computed for each n-year age group comprise the first row of the Leslie matrix. Values will be zero for all males and for those females younger or older than women in the reproductive period. By multiplying this row vector by the female population column vector, the number of persons aged 0 to n who are alive at the end of the projection period will be determined. By using sex- as well as age-specific values of ${}_nF_i$, ${}_nF_{i+n}$, and ${}_nL_0$, it is possible to determine the number of males aged 0 to n and the number of females aged 0 to n who will be alive at the end of the projection period.

Besides the values of ${}_nb_i$, the only other elements of the matrix unequal to zero are along the subdiagonal (that is, the cell in the second row, first column; the cell in the third row, second column; and so on). These cells contain the age- and sex-specific probabilities of surviving to the end of the n-year projection period. Usually, these values, ${}_nd_i$, are defined as follows:

(2) $$ {}_nd_i = \frac{{}_nL_{i+n}}{{}_nL_i} $$

Multiplying every row of the matrix (but the first) by the initial population vector will produce a new population vector showing the number of persons in each successive age group who survive the projection period. For the oldest age group in the population, the probability is set at zero.

To summarize, given an initial population vector p^0 and sets of birth and death probabilities specific to age and sex, ${}_nb_i$ and ${}_nd_i$, is determined by multiplying the initial population vector p^0 by the matrix (M) containing the array of ${}_nb_i$ and ${}_nd_i$:

(3) $$ p' = M \times p^0 $$

or

(4) $$ \begin{bmatrix} p_1' \\ p_2' \\ p_3' \\ \cdot \\ \cdot \\ p_r' \\ \end{bmatrix} = \begin{bmatrix} 0 & b_1 & b_2 \ldots\ldots b_s & 0 \ldots 0 \\ d_1 & 0 & 0 \ldots\ldots & 0 \\ 0 & d_2 & 0 \ldots\ldots & 0 \\ \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & 0 \ldots\ldots d_{r-1} & 0 \end{bmatrix} \times \begin{bmatrix} p_1^o \\ p_2^o \\ p_3^o \\ \cdot \\ \cdot \\ p_r^o \\ \end{bmatrix} $$

or

(5) $$ p_1' = \sum_{i=1}^{s} b_i p_i^o $$

(6) $$ p_q' = d_{q-1} p_{q-1}^o \qquad (q=2, \ldots, r) $$

IV. Specification of the Matrix for Virginia, 1950-1970

The base population used in this example is that of Virginia in 1950, broken down by age, race, and sex. This population was assumed to be closed through 1970 and five-year projections were made employing recorded rates of fertility by age (in Virginia) as well as race-sex specific values of $\frac{{}_nL_0}{2(l_0)}$ from United States life tables. Life table values for Virginia are not available for each point in time. Therefore, to insure consistency, rates for the entire United States were used. This procedure will introduce a small amount of bias into the results to the extent that mortality in Virginia differed from that of the entire country.[4]

The values of ${}_5b_i$ were adjusted to account for differences in recorded age specific fertility over the course of each five year period. Similar adjustments were made for the values of $\frac{{}_5L_0}{2\,(l_0)}$.

For the period from t to t + 1, the value of ${}_5b_i$ would be:

(7) $${}_5b_i = \frac{\frac{{}_5L_0}{2\,(l_0)_t} + \frac{{}_5L_0}{2\,(l_0)_{t+1}}}{2} \left[{}_5F_{i,t} + \frac{({}_5d_{i,t} + {}_5d_{i,t+1})}{2}\, {}_5F_{i+5,t+1}\right]$$

Because studies by Hamilton and others (9, 25) have generally shown the superiority of census survival rates to life table survival rates for the estimation of migration, the value of ${}_5d_i$ was computed using these national rates rather than life tables rates (as shown in equation 2). The value of ${}_5d_i$ is taken to be:

(8) $${}_5d_i = \sqrt{{}_5R_i}$$

since the census survival rates for each five-year age group ${}_5R_i$ are calculated for an entire decade.[5] Additionally, use of census survival rates in the matrix facilitates comparison of the results in the next section with estimates of net migration prepared by use of these same rates.

Age specific fertility rates for Virginia were obtainable for the years 1950, 1960, and 1970.[6] For 1955 and 1965, it was assumed that measurements in the age specific fertility schedule of the state would follow the same pattern as the schedule for the United States as a whole. An example of the final matrix is presented in Table 1. This pertains to white females aged 0-49 for the period 1950-1955. Matrices for other groups and all time periods are included in Appendix 1.

In brief, then, the 1950 population of Virginia, segmented by race and sex, was successively multiplied by four Leslie matrices constructed in the manner outlined above. This procedure generated a hypothetical population representing what the population of Virginia would have been in 1970, assuming: a) no movement to or from the state and, b) that observed vital rates would have prevailed in the absence of migration. This population was contrasted to the 1970 Census results in order to determine the demographic impact of migration over the twenty year period. One weakness of this result that is immediately evident is the failure to correct for census errors. At present, it is perhaps too early to evaluate possible enumeration errors of the 1970 Census, although studies have shown significant errors in earlier censuses.[7]

TABLE 1. ELEMENTS OF THE LESLIE MATRIX, VIRGINIA, WHITE FEMALES, 1950-1955

Age in 1950	Fertility Probability $_5b_i$	Mortality Probability $_5d_i$
0-4	0	1.00977
5-9	.00145	.99912
10-14	.19121	.99355
15-19	.62908	1.00220
20-24	.80693	1.00277
25-29	.60439	.99894
30-34	.36503	.99428
35-39	.16751	.99761
40-44	.04320	.97019
45-49	.00391	.97054

V. Results

The results of successive application of the Leslie matrices to the 1950 population are summarized below in Table 2, which shows the enumerated 1970 population of Virginia and the hypothetical 1970 population. Briefly, it can be seen that migration directly and indirectly added some 216,000 persons to Virginia's population over the period. The direct increase consists of the sum of net increases for all cohorts 20-24 and over (that is, those persons who were alive at the time of the 1950 Census), plus that share of the increase in the four youngest cohorts representing those who migrated into the state, as opposed to those who represent births occurring to persons moving into the state (net) sometime during the period. This latter group constitutes the indirect impact of migration. In common with other migration estimation techniques, no account is made here of those who moved into the state (or who were born to those who moved into the state) during the period, but either died or moved out prior to April 1, 1970.

Conventionally derived estimates of migration for the 1950-1970 period[8] show total *net* inmigration to Virginia to be 164,346 (162,069 from 1960 to 1970 and 2,177 from 1950 to 1960). This may be considered to be the *direct* impact of migration. However, as can be seen from Table 2, the total impact of migration was 215,836. Hence, the *indirect* impact of migration was an additional increase of 51,490 persons, all of whom must have been aged 0-19 in 1970.

Of equal significance, however, is the impact of migration on the age and racial composition of the state. By examination of the data in Table 2 it is evident that there were net increases through migration for all five- year age cohorts, save 40-44, 55-59, 60-64, and 70-74. Almost all of these gains occurred among cohorts 30-34 and younger. While 60.7 percent of Virginia's population in 1970 was under age 35, 96.0 percent of the net increase through migration occurred in these cohorts. While this outcome is in part a function of the increase in births due to the presence of migrants, the data do suggest that the age composition of Virginia has been altered through migration. Although younger persons tend to be more mobile, in the aggregate, than their elders, Virginia would seem to have received a disproportionate increase in younger persons, particularly in the 20-24 age group.

TABLE 2. POPULATION OF VIRGINIA, BY AGE: ENUMERATED 1970 AND HYPOTHETICAL 1970

Age	1970 Enumerated	1970 Hypothetical	Net Increase Through Migration
0-4	392,093	382,276	9,817
5-9	456,958	424,882	32,076
10-14	474,282	446,277	28,005
15-19	440,872	407,362	33,510
20-24	439,818	386,064	53,754
25-29	335,045	307,537	27,508
30-34	280,402	257,890	22,512
35-39	269,296	260,444	8,852
40-44	280,666	285,578	-4,912
45-49	282,485	278,404	4,081
50-54	247,903	247,713	190
55-59	210,620	210,927	- 307
60-64	172,033	172,494	- 461
65-69	134,140	133,602	538
70-74	99,014	99,176	- 162
75+	132,867	132,032	835
Total	4,648,494	4,432,658	215,836

This is probably due in no small measure to the rather large number of military installations in the state.

A convenient way of considering age composition and one that points to the significance of the age composition in various spheres of public policy is the total dependency ratio (TDR) which may be defined as:

$$(9)\qquad TDR = \frac{P_{0\text{-}14} + P_{65+}}{P_{15\text{-}64}} \times 100$$

or, simply the ratio of the dependent (not of working age) population to the population of working age.

The TDR may be further broken down into the Youth Dependency Ratio (YDR) and the Aged Dependency Ratio (ADR), as follows:

$$(10)\quad YDR = \frac{P_{0\text{-}14}}{P_{15\text{-}64}} \times 100$$

$$(11)\quad ADR = \frac{P_{65+}}{P_{15\text{-}64}} \times 100$$

Dependency ratios are useful in cross sectional or intertemporal comparisons of populations to indicate, in a general fashion, whether the age composition of the region is favorable in terms of prospects for economic advancement, *ceteris* paribus. Because of the arbitrariness involved in setting upper and lower limits to working age, some caution should be exercised in drawing conclusions from differences in dependency ratios, especially where cultural differences are present.

This problem does not exist in evaluating the population of Virginia as enumerated by the 1970 Census and the population of Virginia as it would have been in 1970 in the absence of migration since 1950. The TDR for the enumerated population was 57.1 "dependents" for every 100 persons of working age. Of the 57.1 dependents 44.7 were between 0 and 14, the remaining 12.4 being aged 65 and over. In the hypothetical population, the TDR would be slightly higher at 57.5. However, the YDR would have been slightly lower, 44.5, while the ADR would have been slightly higher at 13.0. In other words, because of the direct and indirect impact of migration, the age distribution of the population of Virginia could be termed slightly more favorable than it would have been in the absence of this migration. This change is attributable to the small number of aged "dependents" added by migration relative to persons of working age. The latter is sufficiently large, on balance, to outweigh the relative increases in young "dependents" added by migration.

Migration has made significant change in the racial composition of the state as well. As can be seen in Appendix 2, total population change through migration was 430,685 for whites and –214,849 for nonwhites. Conventionally derived migration estimates show net inmigration for whites to be 296,096 from 1950 to 1970 (73,650 from 1950 to 1960, and 222,446 from 1960 to 1970). Hence, migration indirectly added 134,589 white persons to the population of Virginia. On the other hand, conventionally derived migration estimates for nonwhites from 1950 to 1970 total –131,750 (–71,473 from 1950 to 1960 and –60,377 from 1960 to 1970). Consequently, the indirect impact of migration caused Virginia to have 83,099 fewer nonwhites than there would have been in the absence of migration. In the absence of migration, the population of Virginia in 1970 would have been comprised of 3,330,829 whites (75.1 percent) and 1,101,829 nonwhites (24.9 percent). The census enumeration showed these data to be 3,716,514 (or 80.9 percent) and 886,980 (or 19.1 percent), respectively.

VI. *Summary and Conclusions*

Perhaps the most important finding is the degree of impact that migration may have on the size and composition of the population of an area. This is due not only to the net volume of inmigration, but also to the contributions that migrants make to the natural increase of the area. In those instances where the age composition of inmigrants is heavily skewed toward those who might be classified as "young adults" this contribution can be of considerable magnitude. Furthermore, although the direct impact of migration is a single occurrence, the indirect impact extends indefinitely due to reproduction among migrants, among their children, among their children's children, and so on. In other words, in analyzing the social and economic costs and benefits of migration to a region, it is important to take into account the medium and long range demographic changes that may be induced by migration.[9]

Actually, the present paper does little more than touch upon the surface of demographic change as induced by migration. A possibly serious omission is the failure to consider the possibility that migration will affect age specific fertility (and perhaps mortality rates). These rates have been treated as though they were not influenced by migration—that is, that age specific rates were equal for both the indigenous and migrant populations. There is some evidence to suggest that this is not the case.[10]

Although the results presented here are specific to Virginia, similar results are likely to occur in states which have received a large volume of inmigration among persons in the peak reproductive years. In those states which receive a large number of older inmigrants, the indirect effect of this migration would presumably be lessened considerably. Finally, a similar procedure could be employed for states which have experienced net outmigration to demonstrate direct and indirect effects of this type population movement.

APPENDIX 1. VALUES FOR LESLIE MATRICES, BY RACE AND SEX: VIRGINIA 1950-1955 TO 1965-1970

White Females	First Row 1950-1955	First Row 1955-1960	First Row 1960-1965	First Row 1965-1970
0-4	0	0	0	0
5-9	.00145	.00122	.00095	.00091
10-14	.19121	.21558	.18796	.15382
15-19	.62908	.75964	.66900	.53600
20-24	.80693	.96390	.86987	.72344
25-29	.60439	.64487	.58957	.50832
30-34	.36503	.34110	.29725	.23758
35-39	.16754	.15193	.12064	.08646
40-44	.04320	.03954	.02630	.01752
45-49	.00391	.00245	.00122	.00068
50 +	0	0	0	0

Subdiagonal, 1950-55 and 1955-60				Subdiagonal, 1960-65 and 1965-70			
0-4	1.00977	40-44	.97019	0-4	.99753	40-44	.98120
5-9	.99912	45-49	.97054	5-9	1.00243	45-49	.96848
10-14	.99355	50-54	.94789	10-14	.99781	50-54	.96644
15-19	1.00220	55-59	.95326	15-19	.99319	55-59	.94275
20-24	1.00277	60-64	.91413	20-24	.99719	60-64	.91271
25-29	.99894	65-69	.81648	25-29	.99569	65-69	.82815
30-34	.99428	70-74	.71776	30-34	.99331	70-74	.72802
35-39	.97761	75 +	0	35-39	.98284	75 +	0

Nonwhite Females	First Row 1950-1955	First Row 1955-1960	First Row 1960-1965	First Row 1965-1970
0-4	0	0	0	0
5-9	.01181	.01047	.01046	.01140
10-14	.37469	.37929	.35945	.32272
15-19	.89203	1.02276	.95610	.80233
20-24	.90943	1.12017	1.02849	.83471
25-29	.62073	.74808	.67542	.54076
30-34	.37216	.42683	.38434	.29958
35-39	.17977	.19214	.17183	.13268
40-44	.05285	.05157	.04524	.03283
45-49	.00480	.00441	.00372	.00268
50 +	0	0	0	0

Subdiagonal, 1950-55 to 1955-60

0-4	1.02076	40-44	.93689
5-9	.98618	44-49	.93383
10-14	.97230	50-54	.90454
15-19	.99640	55-59	1.01047
20-24	.99252	60-64	.94181
25-29	.98938	65-69	.72355
30-34	.98570	70-74	.67771
35-39	.93778	75 +	0

Subdiagonal, 1960-65 to 1965-70

0-4	1.01506	40-44	.96582
5-9	1.01352	45-49	.94432
10-14	1.00700	50-54	.95888
15-19	1.02125	55-59	.96135
20-24	1.03211	60-64	.90966
25-29	1.01278	65-69	.75895
30-34	.99459	70-74	.66725
35-39	.96762	75 +	0

White Male	Subdiagonal 1950-55 and 1955-60	Subdiagonal 1960-65 and 1965-70
0-4	1.00713	.99995
5-9	.99176	1.00121
10-14	.97876	.99182
15-19	.99089	.98500
20-24	.99907	.99083
25-29	.99543	.98857
30-34	.99257	.98446
35-39	.97697	.97258
40-44	.96024	.96467
45-49	.95014	.93990
50-54	.90729	.91845
55-59	.89282	.86473
60-64	.84255	.81925
65-69	.75072	.72925
70-74	.63904	.62076
75 +	0	0

Nonwhite Male		
0-4	1.01772	1.01773
5-9	.98198	1.01194
10-14	.93081	.98265
15-19	.96514	.97765
20-24	.98917	1.00945
25-29	.98757	.99474
30-34	.99344	.98336
35-39	.95295	.95789
40-44	.93481	.95224
45-49	.92976	.92105
50-54	.86699	.91524
55-59	.92937	.88350
60-64	.87800	.84522
65-69	.71236	.70013
70-74	.62270	.60028
75 +	0	0

APPENDIX 2. ADDITIONS TO POPULATION THROUGH MIGRATION, BY AGE, RACE, AND SEX: VIRGINIA, 1950-1970

Age in 1970	White Male			White Female		
	Hypothetical	Actual	Net	Hypothetical	Actual	Net
0-4	136,440	155,862	19,422	128,491	149,212	20,721
5-9	151,335	181,110	29,775	142,175	172,978	30,803
10-14	164,404	186,494	22,090	154,078	178,490	24,412
15-19	152,317	175,779	23,462	144,172	167,228	23,056
20-24	148,499	195,166	46,667	144,812	172,356	27,544
25-29	116,679	141,752	25,073	114,768	140,113	25,345
30-34	96,597	117,076	20,479	94,938	116,221	21,283
35-39	102,565	111,332	8,767	95,476	111,324	15,848
40-44	119,334	115,094	–4,240	105,854	117,767	11,913
45-49	109,590	113,937	4,347	112,190	120,924	8,734
50-54	99,024	100,889	1,865	99,470	104,164	4,694
55-59	83,746	83,542	– 204	86,378	89,600	3,222
60-64	65,868	66,282	414	73,252	76,295	3,043
65-69	46,766	47,599	833	58,378	61,251	2,873
70-74	32,821	33,143	322	45,374	48,293	2,919
75-79	20,941	21,229	288	31,612	34,188	2,576
80 +	18,552	18,430	– 122	33,933	36,394	2,461
Total	1,665,478	1,864,716	199,238	1,665,351	1,896,798	231,447

	Nonwhite Male			Nonwhite Female		
0-4	59,259	43,723	– 15,536	58,086	43,296	– 14,790
5-9	66,429	51,398	– 15,031	64,943	51,472	– 13,471
10-14	64,704	54,708	– 9,996	63,091	54,590	– 8,501
15-19	55,822	49,255	– 6,567	55,051	48,610	– 6,441
20-24	45,266	36,344	– 8,922	47,487	35,952	– 11,535
25-29	36,291	25,886	– 10,405	39,799	27,294	– 12,505
30-34	31,044	22,289	– 8,755	35,311	24,816	– 10,495
35-39	29,264	21,554	– 7,710	33,139	25,086	– 8,053
40-44	29,287	22,223	– 7,064	31,103	25,582	– 5,521
45-49	28,118	22,940	– 5,178	28,506	24,684	– 3,822
50-54	24,537	20,925	– 3,612	24,682	21,925	– 2,757
55-59	20,065	18,353	– 1,712	20,738	19,125	– 1,613
60-64	15,870	14,084	– 1,786	17,504	15,372	– 2,132
65-69	12,516	11,315	– 1,201	15,942	13,975	– 1,967
70-74	9,085	7,797	– 1,288	11,896	9,781	– 2,115
75-79	5,510	4,909	– 601	6,960	6,361	– 599
80 +	6,044	4,702	– 1,342	8,480	6,654	– 1,826
Total	539,111	432,405	–106,706	562,718	454,575	–108,143

FOOTNOTES

1. Rogers' numerous articles on the subject are contained, for the most part, in (22). See also Stone's slight elaboration of Rogers' findings (26).
2. Some of the earlier references are Bernadelli (1), Leslie (14), and Lopez (16).
3. For example, Murphy (17) and Goodman (7).
4. The extent of these differences may be realized by considering the values of life expectancy at birth for Virginia and for the United States for the periods 1949-51 and 1959-61:

	1949-51	1959-61
United States:		
White male	66.31	67.55
White female	72.03	74.19
Nonwhite male	58.91	61.48
Nonwhite female	62.70	66.47
Virginia:		
White male	65.95	67.20
White female	72.40	74.37
Nonwhite male	56.89	60.17
Nonwhite female	61.23	65.14

Source: (8, pp. 309-313).

5. For 1950 to 1960, these rates are found in (18); for 1960 to 1970, in (19).
6. For 1950 and 1960, the data are from Grove and Hetzel (8). For 1970, the rates were computed by dividing registered births by the appropriate age cohort adjusted for the April 1- July 1 time differential (rates should be computed on a mid-year basis).
7. See, for example, Coale (5), Zelnik (27), Bogue et al. (3), and Coale and Rives (6).
8. Data for 1950-1960 are contained in Bowles and Tarver (4), while 1960-1970 data are from Serow and Spar (23). The methodology employed in both volumes is identical. Although estimates from these sources are added together in the text, it is not, strictly speaking, valid to do so because the 1960-1970 estimates used the 1960 Census enumeration as a base which includes both the direct and indirect impact of migration during the 1950-1960 decade.
9. For an extensive review of the costs and benefits of migration not only in the realm of public services but also in areas such as private housing and social overhead capital see Riew (20). He points out "... the possibility that significant divergence exists between individual and social calculations of the net economic benefit of migration." (p. 74). There have been many studies attempting to measure the direct and indirect impact of international migration although none have employed precisely the methodology used here. Several recent examples are cited in Shryock and Siegal (24, pp. 608-611).
10. According to Long (15), past fertility affects current mobility adversely. However, differences in the fertility performance of migrants and nonmigrants are not clear cut. Ritchey and Stokes (21) have found from the 1967 Survey of Economic

Opportunity that: "Migrants displayed equal or higher fertility than nonmigrants (Author's note: contrary to expectations), although limitations of the data require caution in generalizing these results." (p. 229). In general, fertility of migrants may be expected to be lower than that of nonmigrants. A more precise measure of differential fertility between the migrant and nonmigrant portions of an areas' population could be determined by use of the Public Use Sample. With this data source, it might be possible to adjust age specific fertility rates so they are specific to mobility patterns.

REFERENCES

(1) Bernadelli, H. "Population Waves," *Journal of the Burma Research Society,* 31 (1941), 1-18.
(2) Bogue, D. J. *Principles of Demography.* New York: John Wiley and Sons, Inc., 1969.
(3) ——— et al. "A New Estimate of the Negro Population and Negro Vital Rates in the United States," *Demography,* 1 (1964), 339-358.
(4) Bowles, G. K. and J. D. Tarver. *Net Migration of the Population, 1950-60 by Age, Sex, and Color* (vol. I, no. 3). Washington: U.S. Department of Agriculture, 1965.
(5) Coale, A. J. "The Population of the United States in 1950 Classified by Age, Sex, and Color—A Revision of Census Figures," *Journal of the American Statistical Association,* 50 (1955), 16-54.
(6) ———and N. W. Rives. "A Statistical Reconstruction of the Black Population of the United States: Estimated True Numbers by Age and Sex, Birth Rates, and Total Fertility," *Population Index,* 39 (1973), 3-36.
(7) Goodman, L. A. "An Elementary Approach to the Population Projection Matrix, to the Population Reproductive Value, and to Related Topics in the Mathematical Theory of Population Growth," *Demography,* 5 (1968), 382-409.
(8) Grove, R. D. and A. M. Hetzel. *Vital Statistics Rates in the United States, 1940-1960.* Washington: National Center for Health Statistics, 1968.
(9) Hamilton, C. H. "On the Difference Between the Vital Statistics and CSR Methods of Estimating Net Migration Among Subclasses of the Nation's Population," *Papers of the World Population Conference* (Belgrade), 3 (1965), 262-263 (abstract).
(10) ———. "Practical and Mathematical Considerations in the Formulation and Selection of Migration Rates," *Demography,* 2 (1965), 429-443.
(11) ———. "The Vital Statistics Method of Estimating Net Migration by Age Cohorts," *Demography,* 4 (1967), 464-478.
(12) Keyfitz, N. "Matrix Multiplication as a Technique of Population Analysis," *Milbank Memorial Fund Quarterly,* 42 (1964), 68-84.
(13) ———. "The Population Projection as a Matrix Operator," *Demography,* 1 (1964), 56-73.
(14) Leslie, P.H. "On the Use of Matrices in Certain Population Mathematics," *Biometrika,* 33 (1945), 183-212.
(15) Long, L. H. "The Influence of Number and Ages of Children on Residential Mobility," *Demography,* 9 (1972), 371-382.
(16) Lopez, A. *Problems in Stable Population Theory.* Princeton: Office of Population Research, 1962.
(17) Murphy, E. M. "The Latent Roots of the Population Projection Matrix," *Demography,* 3 (1966), 259-275.
(18) "National Census Survival Rates, by Color and Sex, for 1950 to 1960," *Current Population Reports,* Series P-23, no. 15 (July 12, 1965).
(19) "Preliminary National Census Survival Rates, by Race and Sex, for 1960 to 1970," *Current Population Reports,* Series P-23, no. 41 (April 1972).
(20) Riew, J. "Migration and Public Policy," *Journal of Regional Science,* 13 (1973), 65-76.
(21) Ritchey, P. N. and C. S. Stokes. "Residence Background, Migration, and Fertility," *Demography,* 9 (1972), 217-230.
(22) Rogers, A. *Matrix Analysis of Interregional Population Growth and Distribution.* Berkeley: University of California Press, 1968.
(23) Serow, W. J. and M. A. Spar. *Virginia's Population: A Decade of Change. II. Net Migration for State Planning Districts.* Charlottesville: Tayloe Murphy Institute, 1972.
(24) Shryock, H. S., J. S. Siegal, and associates. *The Methods and Materials of Demography,* (vol. II). Washington: U. S. Bureau of the Census, 1971.
(25) Stone, L. O. "Evaluating the Relative Accuracy and Significance of Net Migration Estimates," *Demography,* 4 (1967), 310-330.
(26 ———. "Stable Migration Rates from the Multiregional Growth Matrix Operator," *Demography,* 5 (1968), 439-442.
(27) Zelnik, M. "Errors in the 1960 Enumeration of Native Whites," *Journal of the American Statistical Association,* 59 (1964), 437-459.