Title

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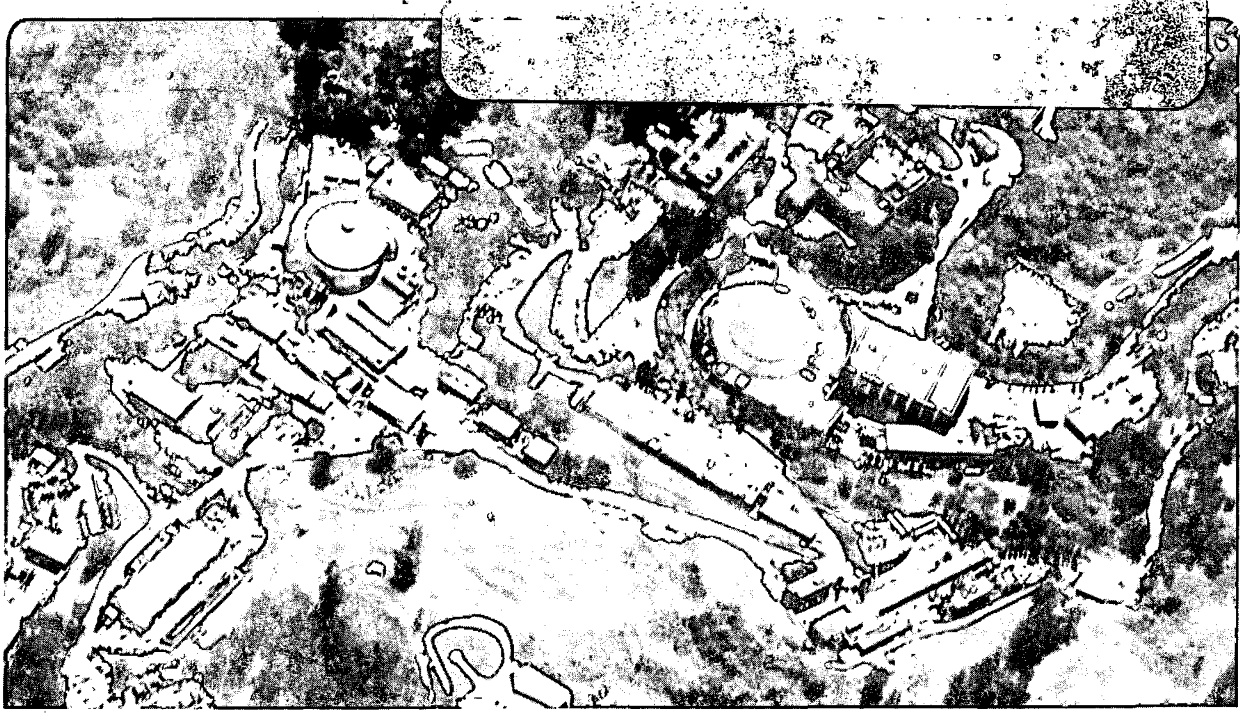

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A Technique for Making More Accurate Projections of Migration Age Detail

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A Technique for Making More Accurate Projections

of Migration Age Detail

Abstract

Population projections are often required for many substate areas, and must be prepared with maximal computer and minimal analytical effort. At the same time, realistic age detail forecasts require a flexible means of treating age-specific net migration. To do this, a simplified version of Pittenger's model is used. Future migration patterns are automatically assigned from characteristics of historical patterns and independent estimates of total net migration. A comparative test of age pattern accuracy at the county level indicates that this technique is superior to the commonly used plus-minus adjustment to historical rates.

1. Introduction

There is no universally superior method of treating migration in population projections. This assertion is made from an *applied* rather than *ideal* standpoint. In reality, demographers must deal with such constraining factors as time, cost, computer storage and data manipulation capabilities.

This paper addresses the situation where age-specific net migration rates must be determined for many geographic areas with a minimum expenditure of analytical effort. The requirement of high production using a small staff is common in the public, private, and academic sectors, and its constraining elements are obvious. Added to this is the desire to treat age-specific migration flexibly; flexible migration rates should yield more accurate age detail than would relatively fixed rates based on historical migration patterns. However, flexibility is usually accompanied by model complexity, whereas high production and few personnel would seem to dictate simplicity.

1.1. Existing Techniques for Treating Migration

The problem indicated above included a requirement for race-sex-age detail in population projection output. This means that we are dealing with techniques used under the "cohort-component" methodological framework. This methodology refers to the case where populations are broken down into race-sex-age groups and moved through time by multiplication by race-sex-age specific rates of fertility, mortality and migration. For details, consult Irwin (1977), Pittenger (1976) or Shryock, Siegel and Associates (1973).

Until recently, most demographers or other technicians preparing subnational projections have relied on the assumption that future race-sex-age-specific net migration rate patterns will be similar to historical patterns for the population in question (Pittenger, 1976, Chapter 8). Irwin's (1977) Census Bureau manual for local planners provides an example of a technique for modifying historical decade migration rates using a "plus-minus adjustment" so that known post-censal trends may be accomodated (Shryock et al., pp 705-6).

The Plus-Minus Technique stretches or compresses net migration rates for individual age groups so that a desired net migration total can be obtained when these rates are applied to the population. A plus factor is applied proportionately to all positive rates that increases them if more in-migration is desired, or decreases them if less in-migration is desired. A minus factor acts in a similar manner on the the negative rates.

This technique is inflexible in that individual migration rates are not allowed to change sign; instead, one scale factor is applied to all positive rates and another scale factor is applied to all negative rates. If the change in migration is so great that it is impossible to obtain the desired net migration total merely by compressing and stretching the individual migration rates, the technique causes one of the adjustment factors to have a minus sign. The larger positive rates could then become the larger negative rates or the larger negative rates could become the larger positive rates. In either case the pattern of the original distribution has been changed considerably, and often unrealistically.

The need for better means of treating age-specific net migration has led to improved models in recent years. The Bureau of the Census (1979) has, since the 1960s, used a model that projects state out-migration by race, age and sex into a pool for reallocation as in-migration. While conceptually attractive, it is operationally of limited flexibility because the flow patterns are fixed in form. Also, the model cannot easily be applied to areas smaller than metropolitan areas and State Economic Areas.

Andrei Rogers (1975) has proposed highly complex multi-regional accounting models that deal with migration in terms of age-specific flows from one region to another. This is attractive as the analyst is dealing with true "at risk" rates, and not pseudo-rates such as rates of in or net migration. Unfortunately, the models designed by Rogers are so complex that data cannot always be found to make them operational. Related to this is an apparent lack of flexibility.

Pittenger (1978) proposed a technique for flexibly modeling age-specific net migration rate patterns. It is based on a simple typology of underlying directional (in and out) age-specific migration rate patterns. Although intermediate cases are possible, directional flow patterns tend to have either early or late age timing of the modal rates. On a five year model, "early" might be age group 20-24 and "late" could be age group 25-29 or 30-34. One class of net patterns ("younger") occurs when in-migration timing is early and out-migration timing is late. Another case ("older") has a late in-migration mode and an early out-migration mode. Shapes of net rate patterns within each type will vary depending upon the magnitude of the rates in each direcion. For example, high age-specific in-migration rates combined with low out-migration rates yield net patterns that are in-migratory. This concept is illustrated in the lower left hand corner of Figure 1.

Pittenger has also observed that the directional flow timing patterns for areas as small as counties normally do not change over time, even though overall net migration can fluctuate between highly out and highly in. This means that, once timing patterns have been established for a given population, realistic age-specific net migration rate patterns can be modeled simply by increasing or decreasing rate magnitudes for directional flows.

1.2. Methodological Strategy

A major problem in adapting Pittenger's model entailed simplifying the computation algorithm. This algorithm is complicated and requires a great deal of analytical effort in assigning parameter values and calibration testing. When projecting a few populations, this creates no special difficulty. But it presents a significant problem if the projections are to be mass-produced, which is the concern of this paper.

Another problem had to do with the assignment of migration pattern types to individual populations. An automated assignment procedure had to be developed to replace an essentially judgmental task.

2. Model Implementation

The implementation of an automated version of Pittenger's model requires essentially two steps - first, defining a set of typical direction flow patterns, and second, developing an algorithm for assigning a particular pattern to each population group.

2.1. Definition of Migration Patterns

The model contains a file of directional flow patterns that, when correctly selected and properly scaled, yield in and out migration rates that can be combined to mimic closely the historical age-specific net patterns. Changes in scale permit flexibility in pattern shape for forecasts. Since the migration of those aged 0-14 will be defined as a function of the migration of their parents, the patterns are not defined for those under 15 years of age. Since retirement migration can vary considerably within migration patterns, it is handled separately. Thus the migration patterns used by the model are defined only for ages 15-64.

The source for analyzing age-specific directional migration flows was data published for State Economic Areas (SEAs) (Census, 1963 and 1972). SEA data are very useful for several reasons: they show migration rates over a five year time period; they are defined for the same geographic areas for two time periods, 1955-1960 and 1965-1970; and they represent a variety of demographic conditions -- central city counties, suburban counties, growing and declining areas, etc.

In defining migration patterns, the age group at which the peak occurs and the height of the peak are two important factors. Also, it appears that the downward slope of the curve after the peak varies with the level of migration.

TABLE 1 - Model Directional Migration Rates
by Age, Slope and Pattern Type

Ages	CS	CT	CX	ES	ET	EX	IS	IT	IX	LS	LT	LX
						Pattern Type						
						Slope 0.09						
(15-19)	.3800	.493	.800	.235	.235	.235	.220	.220	.220	.180	.180	.180
(20-24)	.4000	.400	.750	.400	.500	.620	.330	.475	.580	.280	.280	.280
(25-29)	.3260	.326	.200	.326	.385	.385	.330	.420	.520	.326	.450	.550
(30-34)	.2650	.265	.150	.265	.265	.265	.265	.290	.290	.265	.330	.330
(35-39)	.2150											
(40-44)	.1750											
(45-49)	.1420											
(50-54)	.1160											
(55-59)	.0940											
(60-64)	.0764											
						Slope 0.12						
(15-19)	.3500	.498	.700	.175	.175	.175	.160	.160	.160	.125	.125	.125
(20-24)	.3770	.377	.750	.377	.450	.550	.290	.420	.520	.240	.240	.240
(25-29)	.2860	.286	.200	.286	.330	.330	.290	.370	.470	.286	.390	.480
(30-34)	.2170	.217	.150	.217	.217	.217	.217	.235	.235	.217	.255	.255
(35-39)	.1650											
(40-44)	.1250											
(45-49)	.0948											
(50-54)	.0719											
(55-59)	.0546											
(60-64)	.0414											
						Slope 0.15						
(15-19)	.2200	.337	.450	.090	.090	.090	.080	.080	.080	.060	.060	.080
(20-24)	.2390	.239	.400	.239	.300	.540	.180	.275	.350	.120	.120	.175
(25-29)	.1690	.169	.109	.169	.200	.200	.180	.240	.310	.169	.250	.350
(30-34)	.1200	.120	.100	.120	.120	.120	.120	.130	.130	.120	.150	.200
(35-39)	.0848											
(40-44)	.0600											
(45-49)	.0425											
(50-54)	.0301											
(55-59)	.0213											
(60-64)	.0151											

C = College, E = Early, I = Intermediate, L = Late
S = Short, T = Tall, X = Extreme

Figure 2 shows the exponential slope of the directional migration rate at ages 40-44 for male populations in selected SEAs plotted against the percent directional migration for the same cohort. The upper plot shows out-migration and the lower, in-migration. Both show that at ages 40-44, the slope of the directional migration rate becomes less steep with increasing migration.

Model migration patterns were designed with reference to three factors - the height of the peak age-specific rate, the age at which this peak occurs, and the general slope of the curve as defined by the rate for age group 40-44. Thirty-six patterns were created for the present application. To preserve the relationship of slope to migration rate level, migration rate patterns were developed for three different slope values, 0.09, 0.12 and 0.15. For each of three slope categories, there are three amplitudes at the peak (short, tall and extreme), and four timings of the peak ("college", "early", "intermediate" and "late"). These are presented in Table 1.

Since most of the migration occurs in the ages 15-34, the migration model is most concerned with estimating the migration flows for those ages. At present, it does not seem necessary to distinguish different migration patterns within each slope value for the remaining age groups. Thus, in Table 1, the numbers printed under CS for these other age groups are to be applied across all patterns within the slope category. Further study may indicate that this procedure should be modified.

2.2. Procedure Used

Since migration flows in a particular area are apt to be considerably different for each race-sex group, the procedure is used once for each group. In summary, the following steps are involved -

1) Slope assignments are made on the basis of independent net migration estimates or forecasts -- not on historical rates.

2) The in- and out-migration patterns are chosen for the ages 15-64 on the basis of historical migration rates.

3) The in- and out-migration patterns for ages 0-14 are defined as a function of those for ages 25-39.

4) The in- and out-migration patterns for ages 65 and over are defined from external sources.

5) Various adjustment factors are calculated to account for retirement related migration, the military and the student population.

6) The in- and out-migration patterns with the necessary adjustment factors are scaled to yield the desired net migration for each race-sex group.

2.2.1. Slope Estimation

The model depends upon an exogenous estimate of total population to determine the total net migration for each race-sex group for each projection or estimation interval. The volume of net migration is calculated as a residual after comparing this independent estimate of population with the initial population survived over one time period. The ratio of this total net migration to the survived population is the total net migration rate.

By using the linear relationships implied by Figure 2, a slope can be assigned once the directional rates at ages 40-44 have been determined. Thus, from the independently estimated total net migration, it is necessary to obtain an estimate of in- and out-migration rates at ages 40-44.

Figure 3 shows a plot of net migration rates for age group 40-44 vs. the total net migration rate for the race-sex group. From this plot, it appears that the net migration rate at the age group 40-44 can be approximated by that of the total race-sex group.

It is now necessary to go from the percent net migration at age 40-44 to directional migration for this age group. Figure 4 shows plots of the in-migration rate at age 40-44 vs. net migration at age 40-44. The upper graph is for males and the lower is for females. Although there is some scatter, it appears that it is possible to use the net migration rate for the race-sex group to estimate the in-migration rate for age cohort 40-44. The out-migration rate is then obtained using the identity Out = In-Net. By using the linear relationships implied by Figure 2, a slope can be assigned to both the in- and out-migration curves. It should be noted that the slope assignments may vary as the estimates of total net migration vary.

2.2.2. Chosing the Directional Migration Patterns

Once the slope has been determined for a race-sex group in a particular area, a decision must still be made as to which of the twelve patterns within the slope grouping best describe the character of this area. The applicable pattern is identified by examining the historical inter-censal net migration rates for the age groups 15-19 through 35-39. Since these are the age groups where the majority of the migration occurs and where changes in inflection of net rate patterns are usually found, the differences between migration patterns are most evident here. Let the net migration ratio be defined as one plus the net migration rate. Then we can calculate the net migration ratio for age cohorts 15-19 through 35-39, i.e., for age groups with indices 4 through 8.

TABLE 2 - White Males in West Virginia
1960-1970

Age Index	Age Group	Migration Rate	Migration Ratio	Rank
4	15-19	-.140	.860	
5	20-24	-.393	.607	Low
6	25-29	-.346	.654	
7	30-34	-.096	.904	
8	35-39	-.083	.917	High

As an example, Table 2 shows data for white males in West Virginia for the decade 1960-1970 (Bowles et al., Part 3, page 64). Of the five age groups of interest, the eighth group, ages 35-39, has the highest ratio and the fifth group, ages 20-24, has the lowest ratio. By convention, denote this rank pattern as 85, i.e., the index of the highest ratio is first and the index of the lowest ratio is second. Furthermore, let the amplitude, A, be defined as the high ratio minus the low ratio, or, in this example, A = .917-.607 = .310.

TABLE 3 - Migration Pattern Assignments

Rank Pattern	Assignment
45, 46, 47, 48 (1)	CS - ET if A < .30 CT - ET if .30 < A < 1.00 CX - IX if 1.00 < A
56, 57, 58	ES - LS if A < .20 ET - LT if .20 < A < .60 EX - LT if .60 < A
64, 65, 54	IT - ES if A < .35 IX - ES if A > .35
67, 68, 78	IT - LS if A < .35 IX - LS if A > .35
74, 75, 76, 84	LS - ES if A < .30 LT - ET if .30 < A < .60 LX - ET if .60 < A
85, 86, 87	LS - IS if A < .20 LS - IT if .20 < A < .30 LS - IX if A > .30

where A = Amplitude

(1) If, for rank patterns 45, 46 or 47, the ratio of the net migration ratio for age group 4 to that for age group 8 is <0.950, then the assignment should be that for rank pattern 86. This is to distinguish "true" college patterns from patterns more symmetrical in their outflow of young adults.

Table 3 was established to assign in- and out-migration patterns according to the rank pattern and the amplitude A. The pattern assignments were defined after studying plots of past migration rates for many areas. The rank pattern locates the position of the peak for both the in- and out-migration flows --

whether college (C), early (E), intermediate (I), or late (L). The amplitude (A) is used to estimate the height of the peak -- short (S), tall (T), or extreme (E).

2.3. Youth Migration

Children do not migrate on their own but follow their parents. Since the migration patterns vary considerably for the ages 15-34, the migration of the children should vary correspondingly. For each of the three youngest cohorts (0-4, 5-9, and 10-14), the in- and out-migration rates were defined as those of the age group 25 years older. Since the youngest age group 0-4 is only at risk half as long, its in- and out-migration rates were defined as half that of the age group 25-29.

As was stressed earlier, each race/sex group has its own migration pattern. Within each race group, the migration pattern for males can be different from that of females. Thus the procedure outlined in the above paragraph could lead to very different migration rates for young males and young females in the same racial group. Empirical data suggest this is unlikely. To avoid this problem, the migration pattern for young females is as indicated above, whereas the migration pattern for young males is an average of that of the initial calculations for young males and young females.

2.4. Retirement Migration

Retirement migration is handled separately for two important reasons --

1) The migration patterns for the retirement age population can vary considerably within migration patterns exhibited by the population less than 65. The factors that cause the retirement age population to in-migrate or out-migrate are often independent of those affecting the population less than 65.

2) Fairly good estimates of retirement age migration can be obtained by using Medicare data on the population over 65, if the model is to be

used for making inter-censal or post-censal age estimates rather than for forecasting.

2.4.1. Migration of the Population over 65

Overall retirement age net migration is forecast exogenously and distributed by age. From post-censal estimates, this migration might be treated as in the following example. By comparing the 1970 population that survived to 1975 with the 1975 Medicare based estimates (Census, 1980a), estimates of net migration can be obtained for those cohorts over 65. For each cohort, the net migration rate is calculated as the net migration divided by the 1970 population survived to 1975. These net migration rates are used for the age groups 65-69, 70-74, and 75+.

2.4.2. Retirement Related Migration

Retirement related migration does not necessarily begin at age 65. Some people, for reasons of health or finance, retire well before they reach the age of 65. Since wives are apt to be younger than their husbands, there appears to be considerable retirement related migration for females less than age 65.

Figure 5 illustrates this for areas that are well known for their in- or out-migration of the retirement age population. The upper plots show net migration rates in Arizona and Florida for males and females. The lower plots show net migration rates in New York and Illinois for males and females. In all cases, the bulge due to retirement migration starts well before the age group 65-69. Thus, in areas experiencing large retirement migration, the migration rates of the age groups just below age 65 should be modified to account for this. Furthermore, it should be noted that the change in migration rates due to retirement for females preceeds that for males.

An area is considered to have "retirement" migration for a given race-sex group if the net migration rates for all age groups 65 and over of that race-sex have the same sign. Since this retirement migration is also having some impact on the age groups just under age 65, the migration rates of these age groups must be modified accordingly.

TABLE 4 - Retirement Related Migration
as a percent of Migration of the Population over 65

Age	Males	Females
45-49	0	2.5
50-54	2.5	7.0
55-59	7.5	17.0
60-64	22.5	32.5

The following modification is made for those areas that are experiencing retirement migration, whether in or out. The net migration of the population 65 and over for each race-sex group is calculated by summing over the age groups 65-69, 70-74, and 75+. Using Table 4, a retirement related migration is calculated for each age group 45-49 through 60-64 by multiplying the total retirement migration by the percentage corresponding to that age group. This retirement related migration is converted to a rate by dividing by the corresponding survived population. These adjustments are added to the estimated net migration rates defined by the model. These percentages were estimated from 1965-1970 Census data for selected states.

2.5. Adjustments for Special Populations

As is common with most cohort component population projection models, the special populations are handled separately (Schroeder, 1980). Since the population projections in the project that funded this research are only concerned with the civilian population, once the military population has been subtracted out of the base population, they are left out for the rest of the projection process. The college population is also subtracted out of the base population and is then added back in after the projection process to obtain the population at the end of the period.

Both net migration rates and directional migration rates based on census data are usually calculated for the total resident population. Census data limitations make it difficult to delete the migration of college students or the military. Thus, the 1960-1970 patterns from which the model is calibrated in this example, also include the military and student migration. Other researchers may be able to correct for this if data on college and military populations in both censuses are available in convenient form.

2.5.1. Correcting for Military Population

The observed migration rates on which the pattern selection depends, in this illustration, are the net migration rates from 1960 to 1970. In that period, there were relatively few females in the military. In an area with a considerable military population, male migration rates would be more affected by the presence of the military than would female migration rates. It was felt that the civilian male migration rates could be better approximated by the female migration rates of the same race rather than by the observed male migration rate of that race. Thus, in these areas, the observed male migration rates are replaced by the observed female migration rates.

2.5.2. Student Population

In those areas with a sizable student population, the college students are subtracted from the 1970 civilian population. The 1970 civilian non-institutional population is then projected to 1975. Just before forcing the individual race-age-sex cohorts to sum to an independent population control total, the student population is added back in. Due to the lack of more current nationwide data comparable to the 1970 Census data on students, it is assumed that the student population in a given area does not vary after 1970, i.e., the student population is held fixed. Users of the model may choose to incorporate data based on an alternative assumption.

By handling the student population separately rather than with the cohort component procedure, a net migration is implicitly assumed. To avoid a double counting of student migrants (by the student model and by the migration model), the net migration estimated by the migration model is adjusted by subtracting out the net migration implied by the student model.

2.6. Calibration

This section covers the steps involved in calibrating the patterns and applying the various adjustments to yield the desired net migration total.

First, the in- and out-migration patterns are each scaled so that the rates for age group 40-44 are the percent in- and out-migration, respectively, that were estimated as described above. A trial net migration rate vector is formed by subtracting the scaled out-migration pattern from the scaled in-migration pattern and adding the various adjustments for retirement and the special populations. This trial net migration rate vector is applied to the survived population plus births in that period, to obtain an estimated net migration. The sum over this estimated net migration is compared with the desired net migration to obtain an error term. The scaled in-migration rates are then multiplied by another scalar to correct for this error. (In-migration is assumed to be more volatile than out-migration and therefore is the vector that is altered.) Each final net migration rate is the rescaled in-migration rate minus the scaled out-migration rate plus the various adjustments for retirement and the special populations.

Migration patterns are essentially held constant from one forecast interval to the next. Small details such as slope class may be permitted to change when the exogenously determined overall net migration values differ considerably from historical data.

3. Validation

A thorough testing of this model can not be done until Summary Tape File 4 (STF4) of the 1980 Census is available. Population data from STF1 and STF2 (Census, 1982) represent the entire resident population, whereas the model being tested projects just the civilian population. Furthermore, STF1 contains population by race by sex only. (STF2 contains population by race, sex and age but the authors do not have access to it.) Thus although the projections are done by race, sex and age, they must be added across races for comparison with the presently accessible 1980 Census data. Nonetheless, some tests have been run comparing the migration model and the plus-minus technique with the early 1980 Census data.

3.1. Substate Comparisons

Some measure of the model's performance can be obtained by comparing 1980 state and county population projections by sex by age with the available 1980 figures. Population projections were run twice for each area -- once using the migration model just described and once using the plus-minus technique. The plus-minus technique was applied to the observed 1960-1970 age-specific net migration rates (Bowles et al., 1975), after these rates had been divided by two to obtain half decade rates.

The comparisons were made using data for counties in the states of California, New York and Washington. This selection was based on three factors:

1) the need to have a variety of growth patterns, economic profiles, population densities, special population types and so forth,

2) the authors' familiarity with the areas in question: knowledge of the counties permitted us to hypothesize why the techniques performed well or poorly in individual cases, and

3) the limited number of counties in the data base on which the

population projections are calculated.

A more rigorous test would require comparisons for all counties or at least a random selection of them. However, since the selection of counties in this test was made without known systematic bias, the authors are fairly confident that the findings are not misleading.

Data presented in Figures 6-8 and Table 5 are for the three states, all 39 counties in Washington, all counties in New York save Broome and the five New York City boroughs, and about half of the counties in California. The data base on which the projections are run includes mostly multi-county areas rather than single counties. Except for Arizona, Ohio, New York and Washington, only the largest counties in each state are included.

The figures are presented in four parts -- *a*, *b*, *c*, and *d*. Part *a* indicates the mean absolute percent error for each technique and each sex. Part *b* has the same format, but the percent error for the worst-fitted age group is the error indicator. Parts *c* and *d* deal respectively with the data in *a* and *b*, and were derived by subtracting the error for the new model from that of the plus-minus technique. Table 5 summarizes the data from parts *c* and *d* of Figures 6-8.

Table 5 shows that the migration model performed better in 86 percent of the cases where mean error was the yardstick and in 82 percent of the cases where the worst-fitted cohort was used. The state-specific range was 81 to 93 percent in the former group and 79 to 86 percent in the latter. There were no overall accuracy differences by sex although the new model did better for males in Washington and for females in New York; California was mixed.

The Census Bureau has not released its traditional postcensal estimates of intercensal components of population change for counties, so performance can not yet be tested rigorously in cases where historical migration trends were broken.

TABLE 5 - Summary of Results
Tally of Cases in which each technique was better

A. Number of Cases

Area		Mean Error Model	Mean Error Plus-Minus	Worst Cohort Model	Worst Cohort Plus-Minus
California	Males	23	5	22	6
	Females	25	3	24	4
New York	Males	49	8	46	11
	Females	46	11	48	9
Washington	Males	37	3	34	6
	Females	36	4	32	8
Total		216	34	206	44

B. Percent of Cases

Area		Mean Error Model	Mean Error Plus-Minus	Worst Cohort Model	Worst Cohort Plus-Minus
California	Males	82	18	79	21
	Females	89	11	86	14
New York	Males	86	14	81	19
	Females	81	19	84	16
Washington	Males	93	7	85	15
	Females	90	10	80	20
Total		86	14	82	18

Examination of the counties where the older technique did better yields no identifiable patern with respect to such factors as metropolitan, suburban, or rural character, and presence of college, military , or institutional populations. These results suggest that the proposed model does improve projection of age detail at the county level. This improvement seems to be general; cases of non-improvement appear to be random occurrences.

3.2. Conclusion

The model described in this report seems to be both a theoretical and empirical improvement over existing methods for making accurate large-scale forecasts of age-specific migration and, by extension, population age detail.

Although projection models based on Pittenger's migration pattern typology have been operational since 1977, they have not been widely used. This is because they were difficult to calibrate. The value of the present technique is that it provides a rough, yet workable version of Pittenger's concepts to users with neither the time nor expertise to program and operate a model based on his 1978 paper. Indeed, the most important practical contribution is the automated pattern selection scheme which opens the technique to a wide range of users including planners and marketing researchers.

However, the reader should be cautioned that, while the present technique yields an overall accuracy improvement when applied to many areas, it can give poor results in individual cases. Thus, for "customized" forecasts of a limited number of areas, the forecaster should feel free to experiment with alternative pattern assignments or even redesign the patterns.

This model represents only a first attempt at implementing an automated, flexible migration model for use in large scale population projections. As more data from the 1980 Census become available, more comparisons will be made. Research will continue on improving the shapes of the patterns and on the assignment procedure.

4. References

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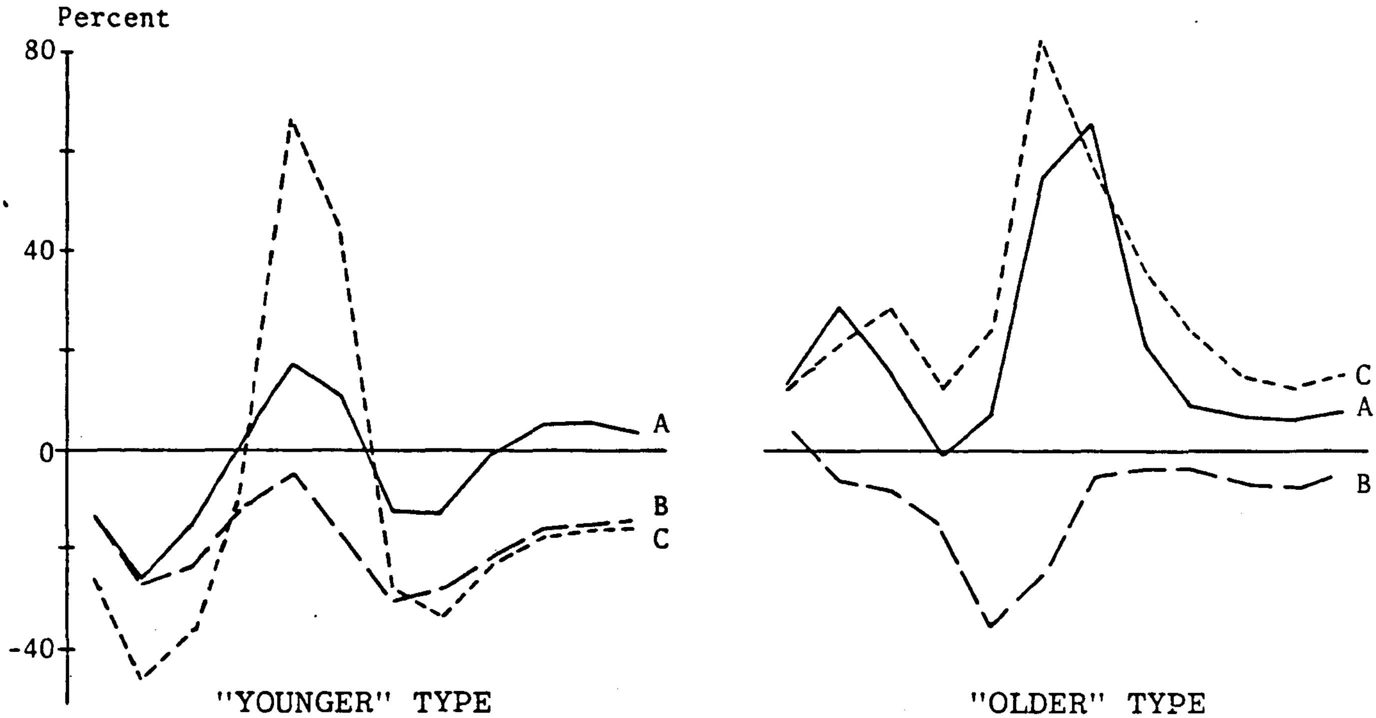
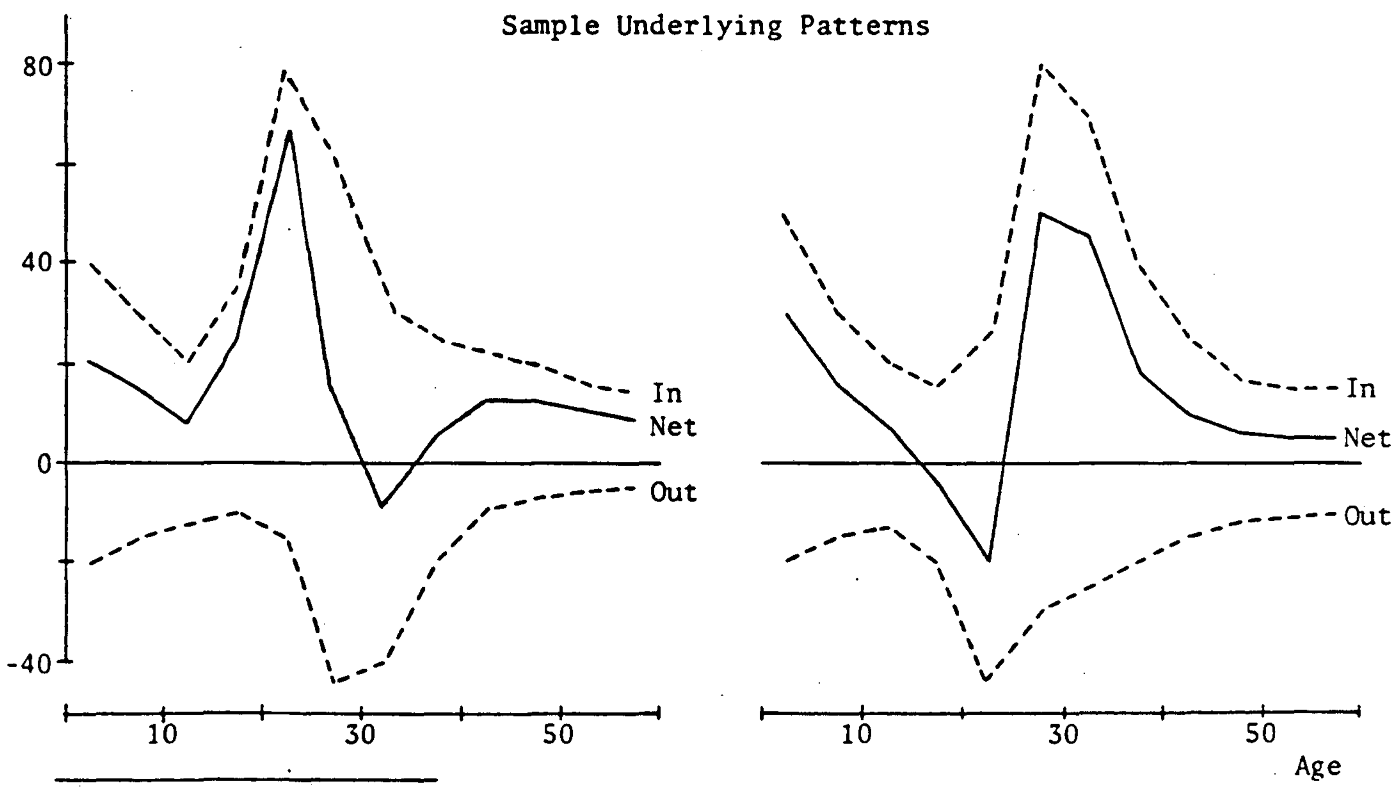
Figure 1.--Illustration of Age-Specific Net Migration Rate Typology Based on Underlying Directional Patterns.



1960-1970 Empirical Examples*

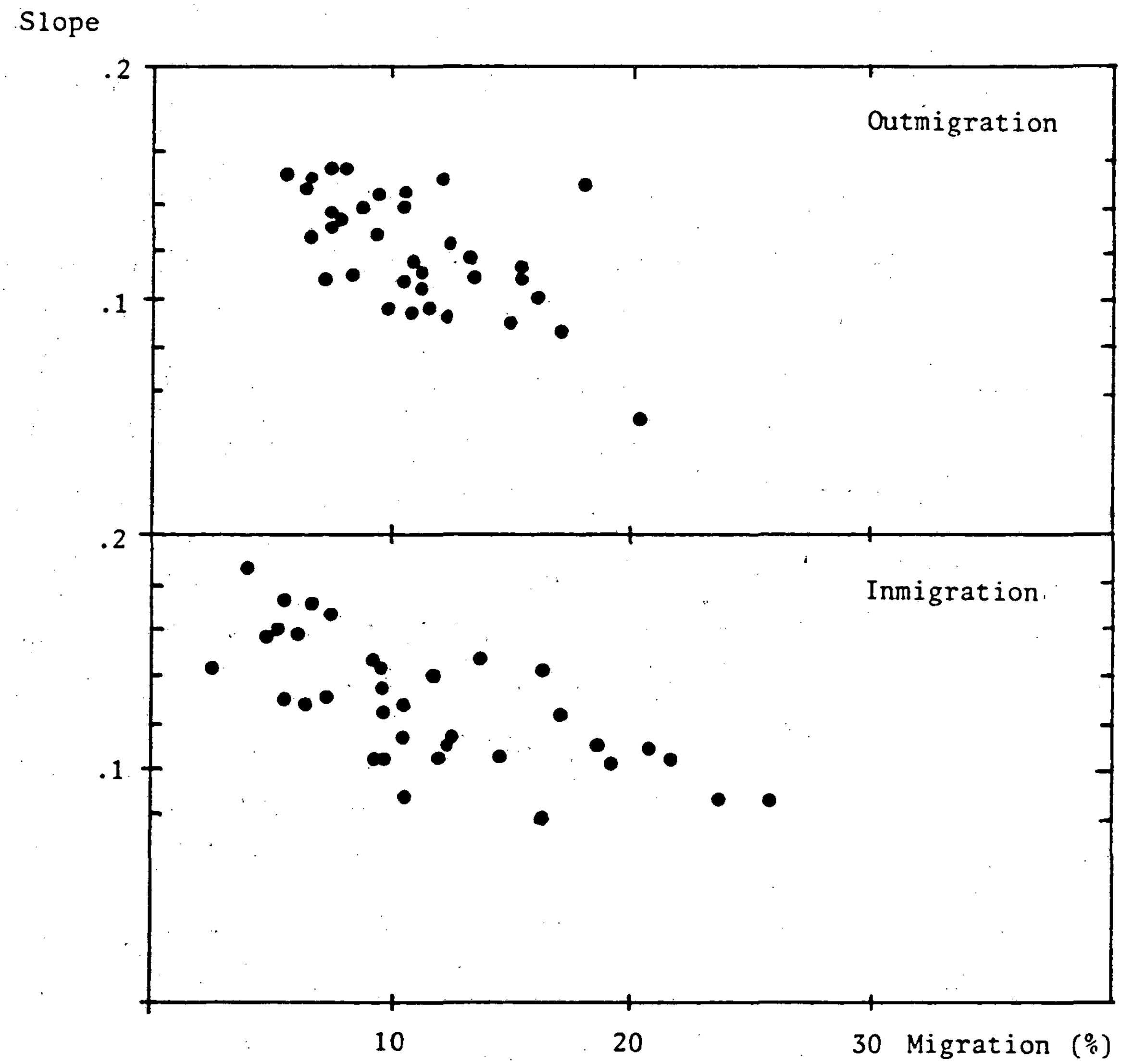
A. Queens Co., N.Y. White Females
B. Kings Co., N.Y. White Females
C. San Francisco Co., Cal. White Females

A. Bucks Co., Pa. White Females
B. Franklin Co., N.Y. Females
C. Burlington Co., N.J. White Females



* Source: Bowles, et. al., 1975.

Figure 2.--Relationship of Migration Slope to Migration Level at Ages 40-44: Selected State Economic Areas, 1965-70; Males.



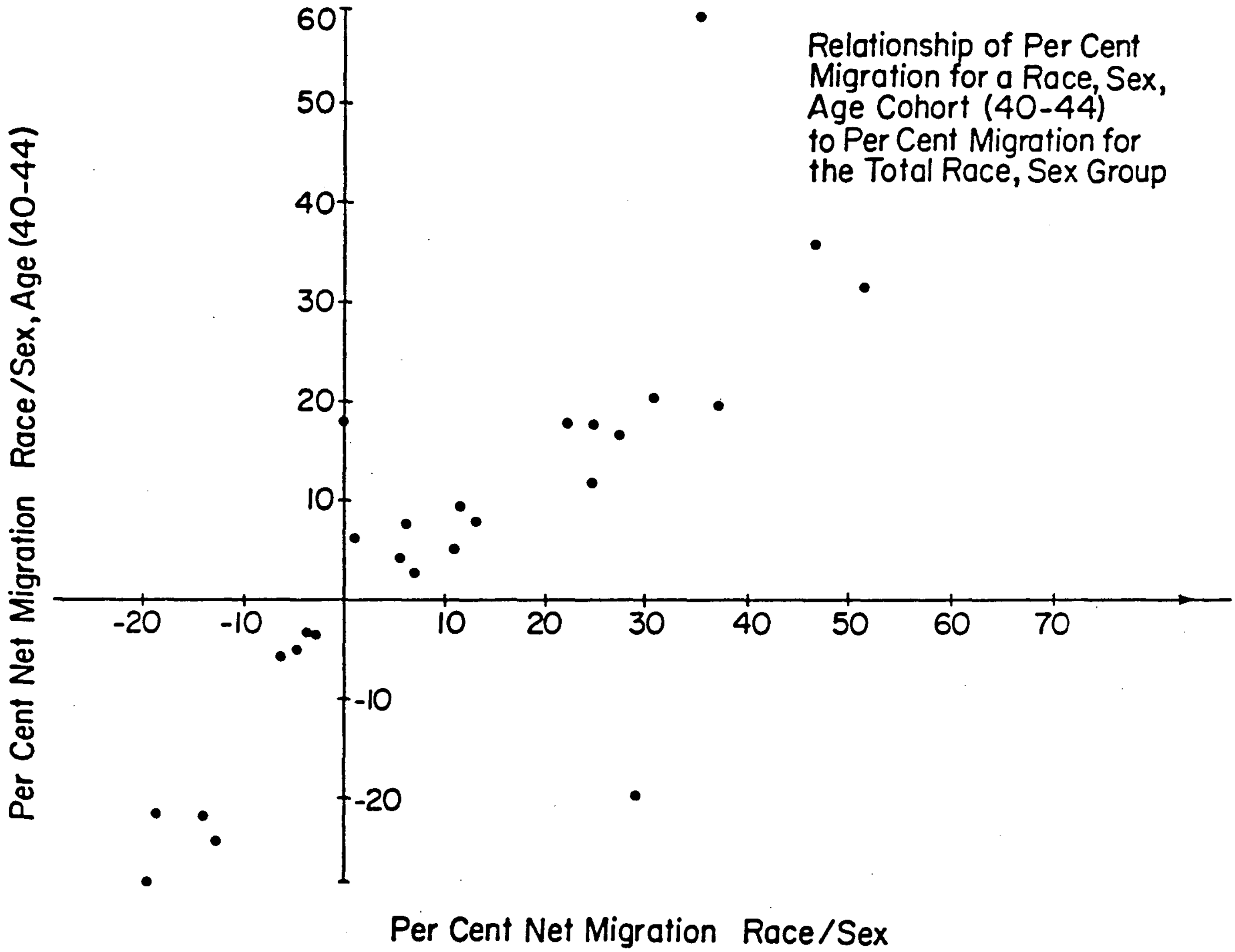
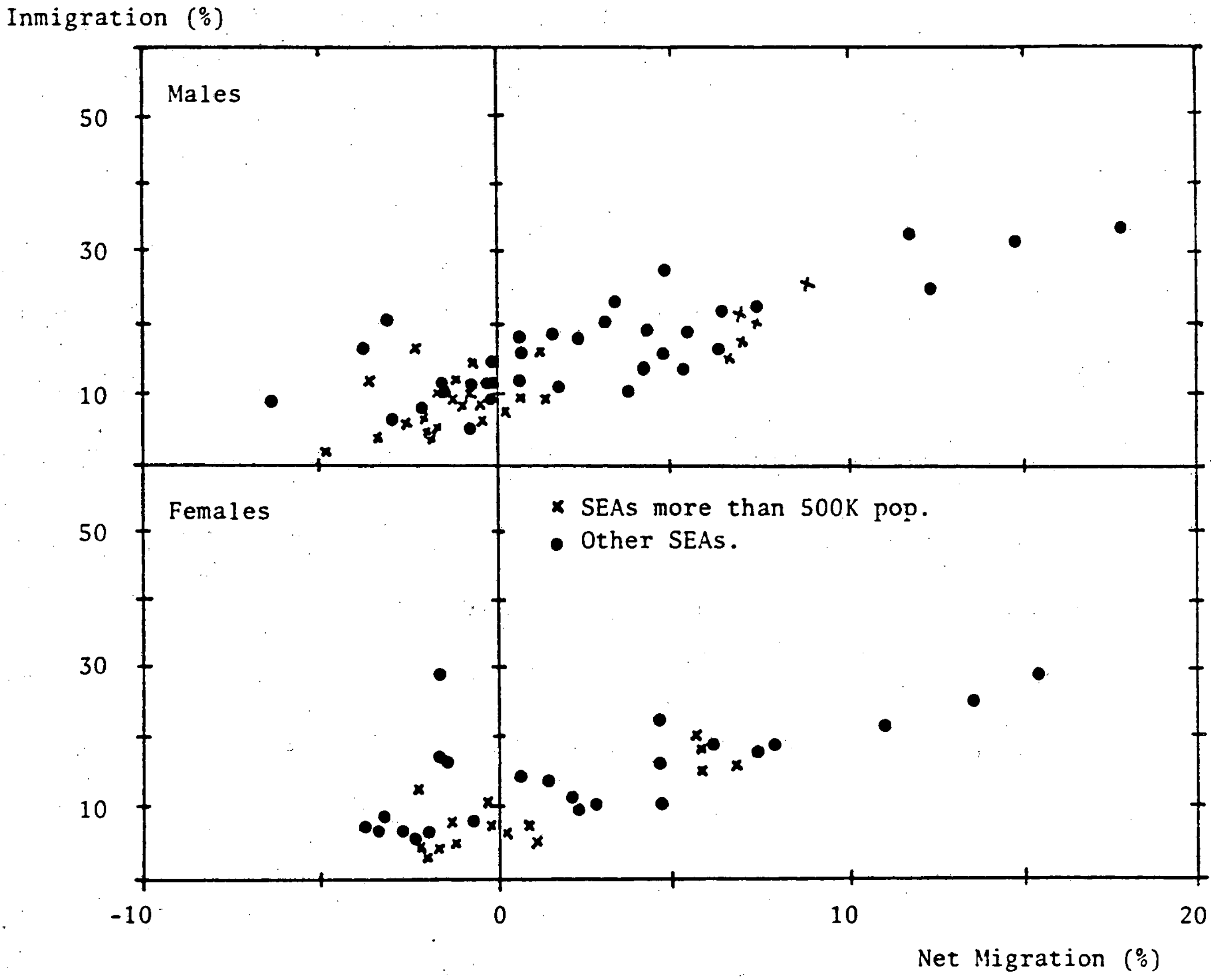
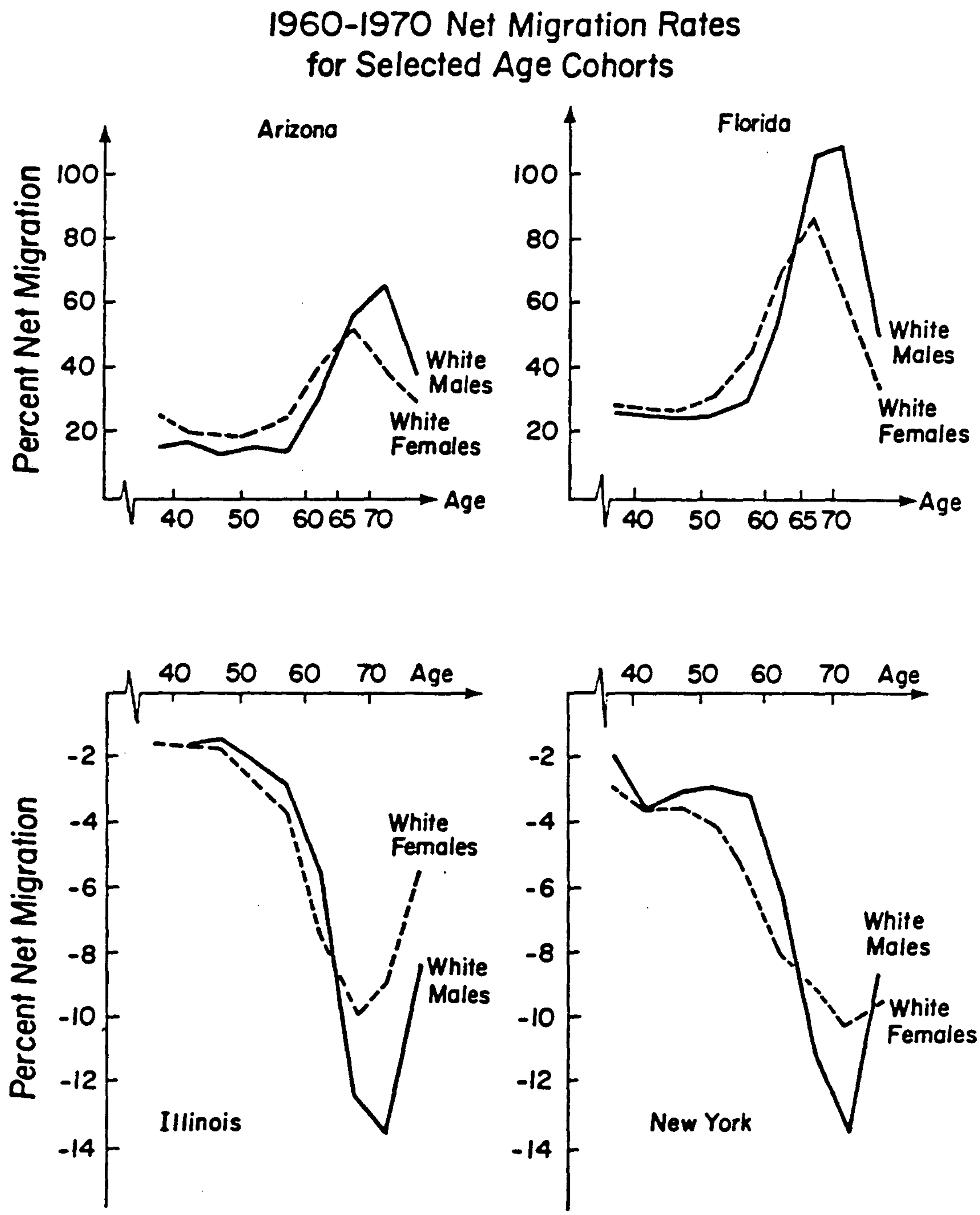

Relationship of Per Cent
Migration for a Race, Sex,
Age Cohort (40-44)
to Per Cent Migration for
the Total Race, Sex Group
60
50
40
30
20
10
-10
-20
-20
-10
10
20
30
40
50
60
70
Per Cent Net Migration Race/Sex, Age (40-44)
Per Cent Net Migration Race/Sex

Figure 3

Figure 4.--Relationship of Inmigration to Net Migration, Ages 40-44: Selected State Economic Areas, 1965-70.





1960-1970 Net Migration Rates
for Selected Age Cohorts
Arizona
Percent Net Migration
100
80
60
40
20
40
50
60 65 70
Age
White Males
White Females
Florida
100
80
60
40
20
40
50
60 65 70
Age
White Males
White Females
Illinois
40
50
60
70
Age
-2
-4
-6
-8
-10
-12
-14
White Females
White Males
New York
40
50
60
70
Age
-2
-4
-6
-8
-10
-12
-14
White Males
White Females

Figure 5

FIGURE 6a

Comparisons of 1980 Population Projections with 1980 Census data

	Males Mean Absolute Percent Error Migration Model	 Plus-Minus Technique	Females Mean Absolute Percent Error Migration Model	 Plus-Minus Technique
State of California	6.7	8.8	5.0	6.3
Alameda County	4.9	8.1	5.3	7.6
Butte County	16.2	17.9	12.8	15.5
Contra Costa	8.0	7.7	9.0	9.1
Fresno County	5.9	10.3	4.4	9.7
Humboldt County	5.0	13.8	4.0	13.6
Imperial County	9.8	13.8	7.3	12.5
Kern County	7.2	6.4	9.2	9.7
Los Angeles County	8.8	11.0	8.5	8.6
Marin County	15.1	17.7	13.8	14.6
Merced County	10.5	13.2	5.7	6.8
Orange County	11.2	9.5	7.5	7.1
Placer County	11.5	17.6	8.2	20.5
Sacramento County	6.3	9.9	4.6	7.2
San Diego County	16.6	16.9	4.9	6.1
San Francisco County	12.9	11.4	11.2	7.7
San Joaquin County	7.1	13.3	6.6	12.9
San Mateo County	12.0	9.9	10.5	9.5
Santa Barbara County	7.6	13.2	5.9	10.4
Santa Clara County	9.4	11.8	7.7	10.4
Santa Cruz County	10.3	14.7	9.3	14.8
Shasta County	8.7	19.2	5.1	16.9
Solano County	15.1	15.4	6.6	8.8
Sonoma County	8.3	14.3	6.5	13.8
Stanislaus County	6.3	14.6	5.7	13.9
Tulare County	7.8	10.2	6.1	10.1
Ventura County	10.3	12.8	5.1	11.8
Yolo County	6.0	12.2	5.8	10.9

FIGURE 6b
Comparisons of 1980 Population Projections with 1980 Census data

	Males: Percent Error in Worst Fitted Cohort — Migration Model	Males: Plus-Minus Technique	Females: Percent Error in Worst Fitted Cohort — Migration Model	Females: Plus-Minus Technique
State of California	18.3	25.2	13.5	16.1
Alameda County	15.1	28.2	16.2	21.3
Butte County	33.4	55.6	33.1	47.4
Contra Costa	24.6	28.9	22.2	24.4
Fresno County	13.2	40.6	10.5	38.0
Humboldt County	16.1	37.3	8.4	30.7
Imperial County	18.9	37.4	22.6	31.8
Kern County	15.8	17.0	21.5	26.7
Los Angeles County	19.0	23.8	20.3	21.5
Marin County	33.7	48.9	31.8	36.6
Merced County	29.7	35.8	12.8	20.8
Orange County	27.9	24.4	17.1	11.9
Placer County	51.6	36.1	24.7	35.4
Sacramento County	17.2	25.9	12.2	19.6
San Diego County	33.0	32.0	10.9	21.2
San Francisco County	35.1	25.2	39.1	25.1
San Joaquin County	16.6	39.8	18.6	30.6
San Mateo County	37.1	26.4	31.4	23.3
Santa Barbara County	18.4	27.4	13.6	20.6
Santa Clara County	23.5	30.4	18.3	22.4
Santa Cruz County	26.4	35.6	26.4	25.5
Shasta County	18.1	35.6	13.4	32.7
Solano County	41.9	39.2	14.7	22.5
Sonoma County	20.2	39.0	22.2	31.1
Stanislaus County	13.4	28.2	12.6	26.8
Tulare County	13.1	30.2	15.3	27.6
Ventura County	31.3	40.7	14.0	19.5
Yolo County	12.0	26.7	12.7	23.4

FIGURE 6c

Advantage of Migration Model Versus Plus-Minus Technique
(Plus-Minus Technique Error Minus Model Error)

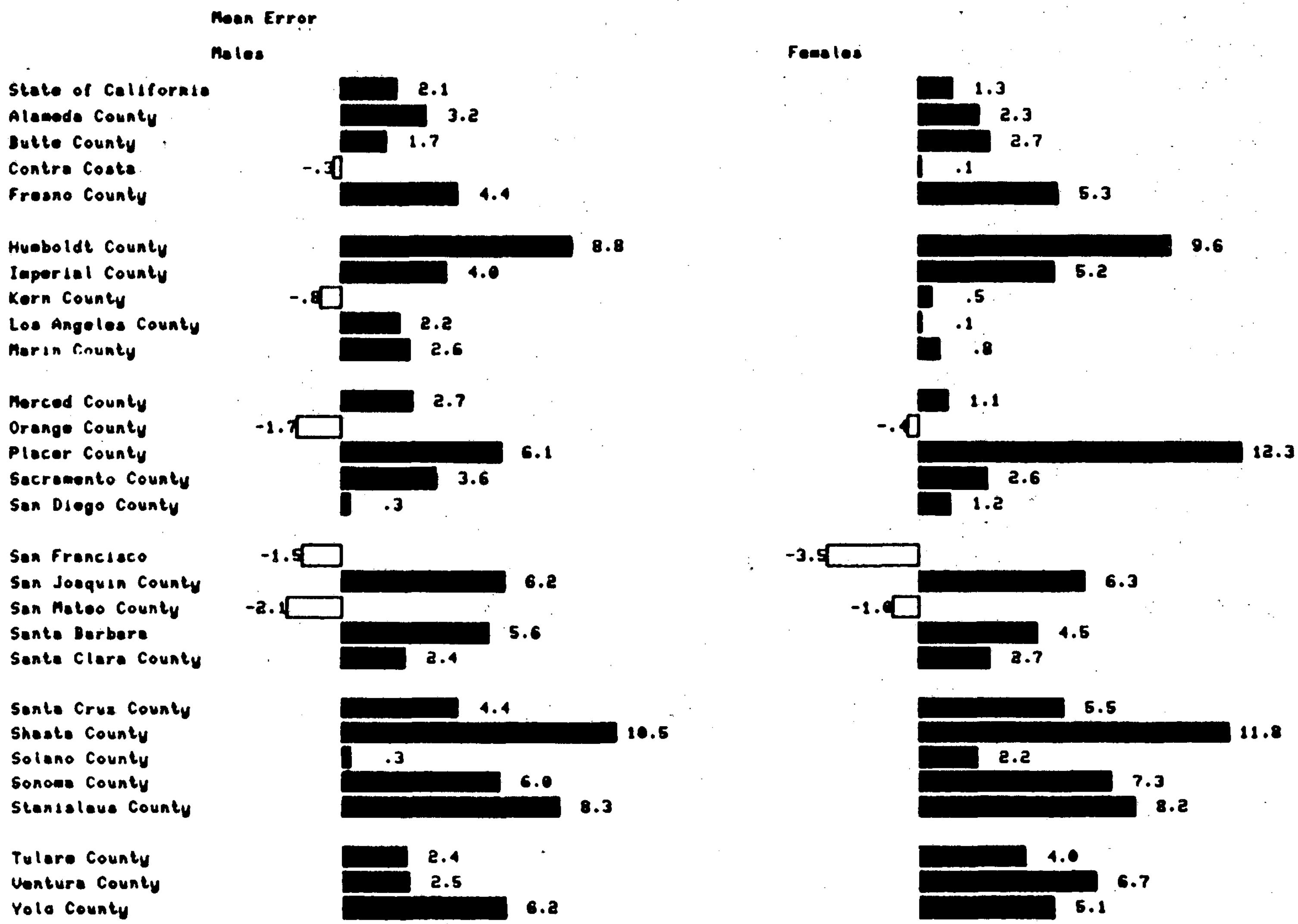


FIGURE 6d

Advantage of Migration Model Versus Plus-Minus Technique
(Plus-Minus Technique Error Minus Model Error)

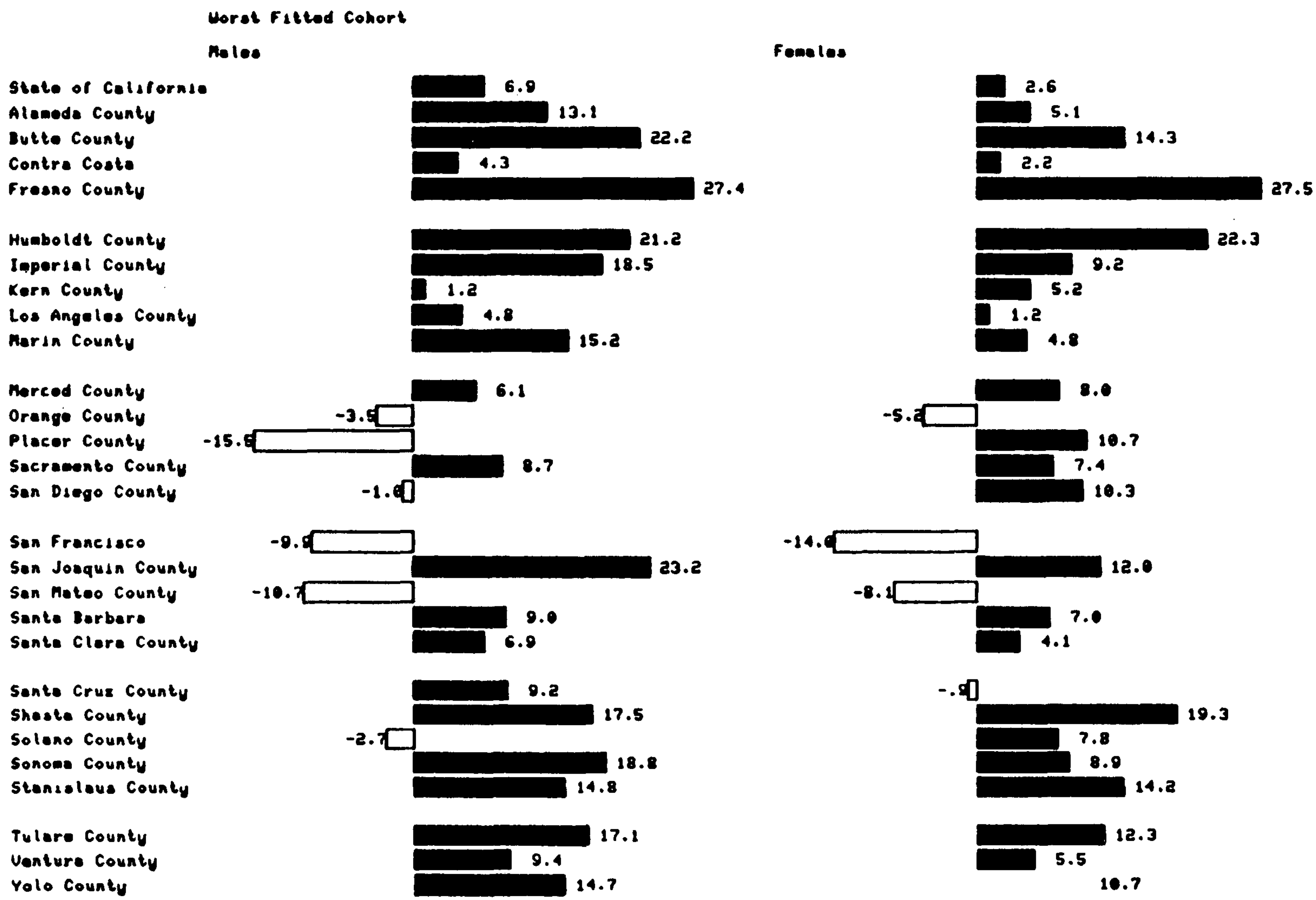


FIGURE 7a
Comparisons of 1980 Population Projections with 1980 Census data

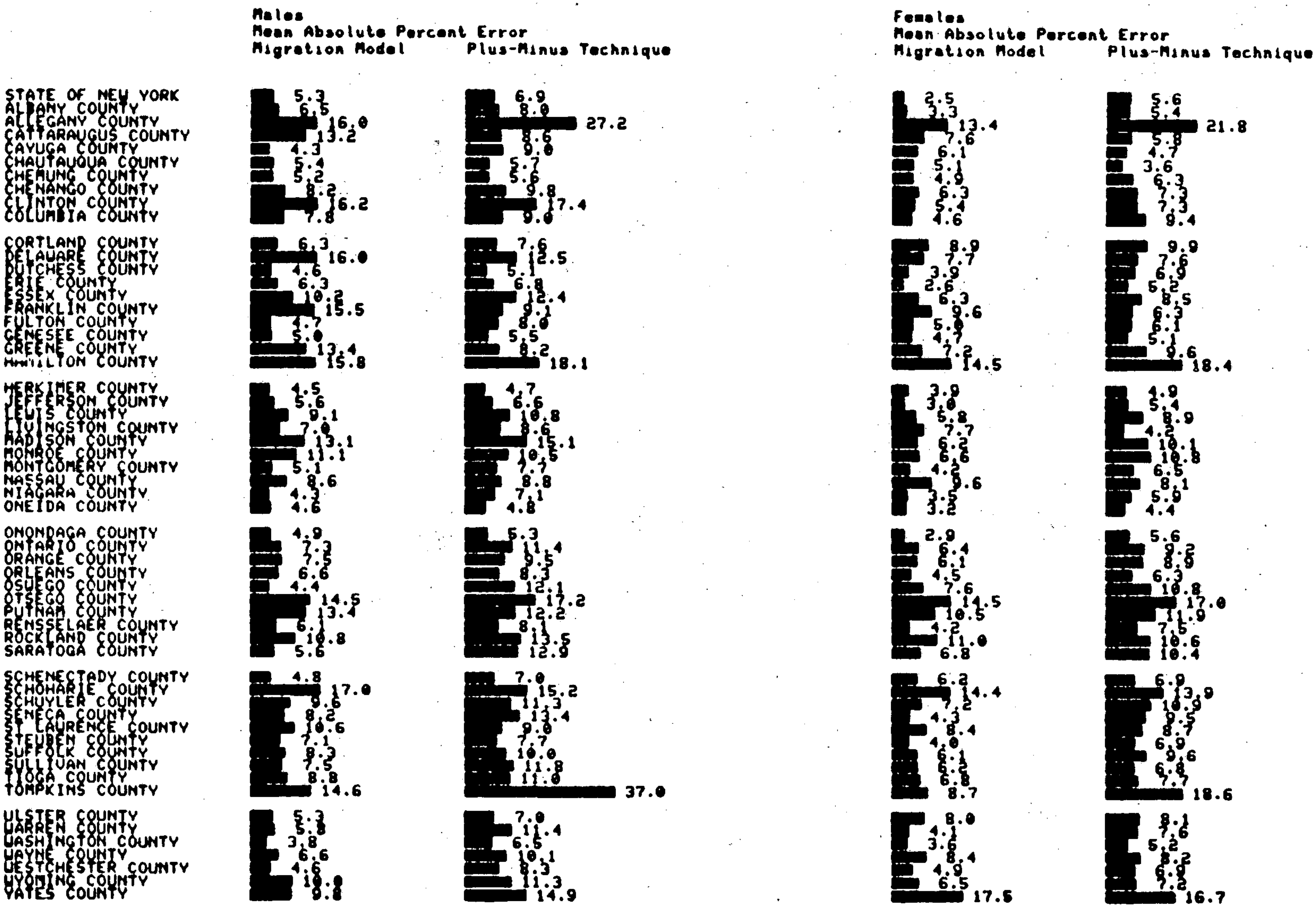


FIGURE 7b
Comparisons of 1980 Population Projections with 1980 Census data

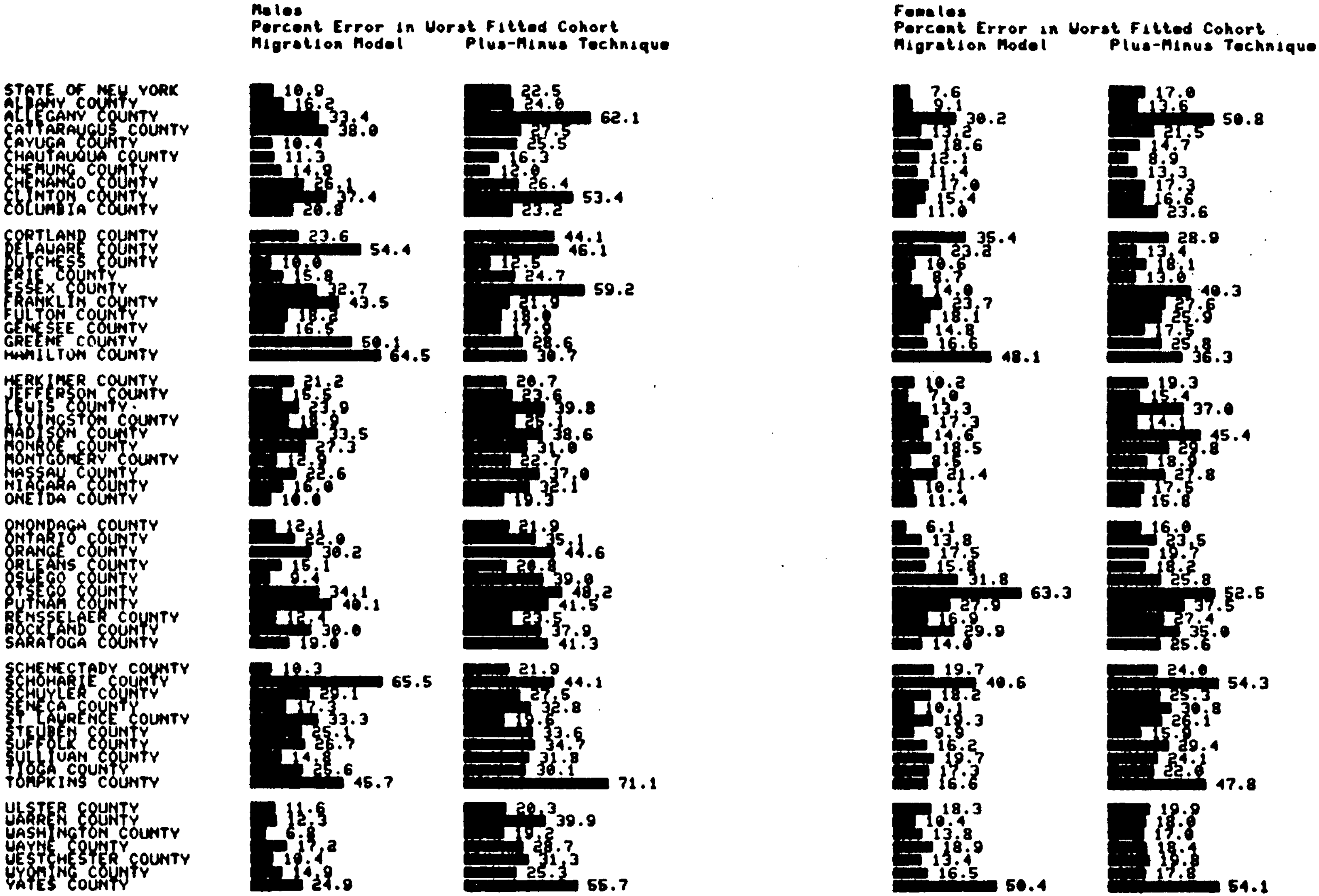


FIGURE 7c

Advantage of Migration Model Versus Plus-Minus Technique
(Plus-Minus Technique Error Minus Model Error)

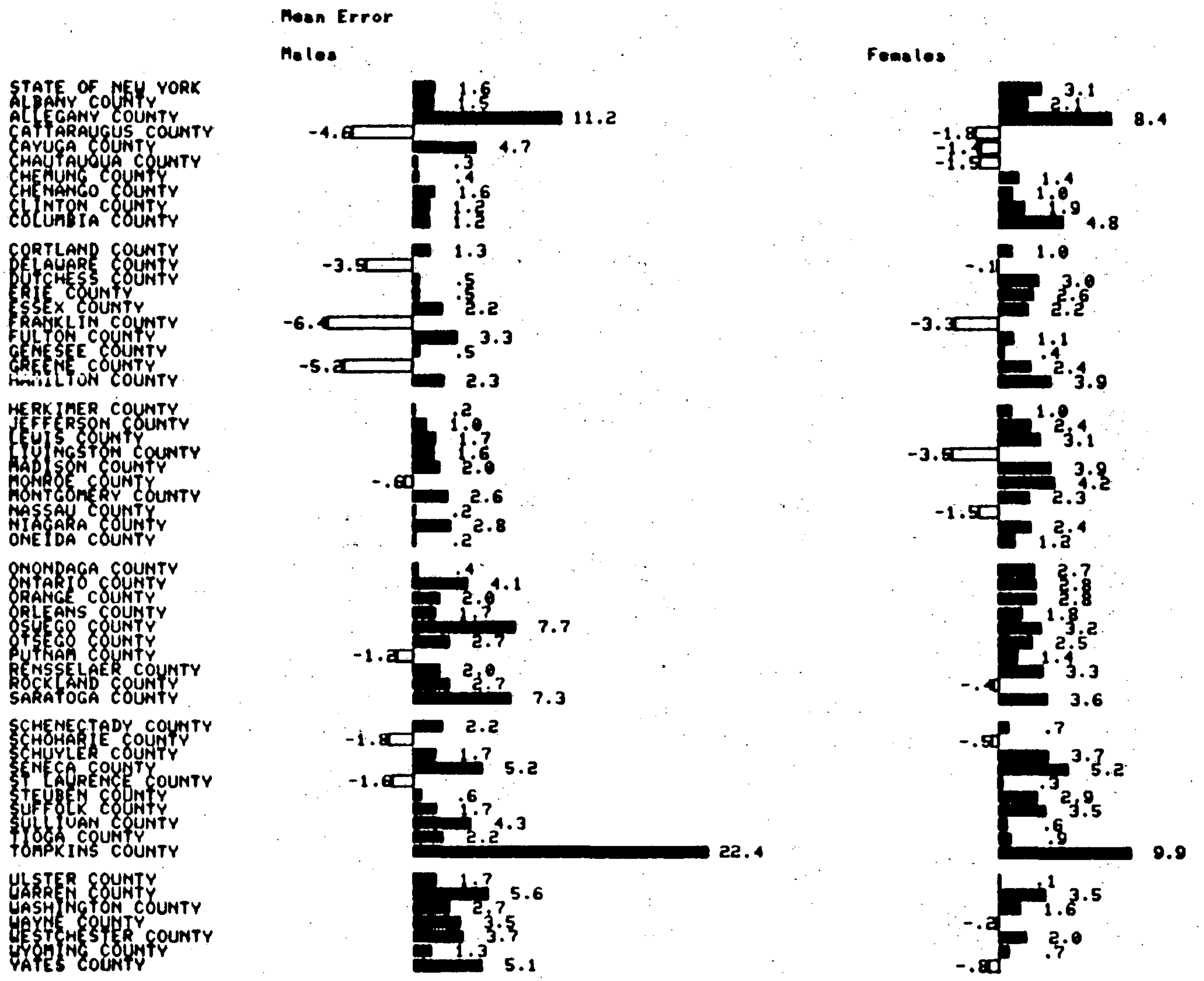


FIGURE 7d

Advantage of Migration Model Versus Plus-Minus Technique
(Plus-Minus Technique Error Minus Model Error)

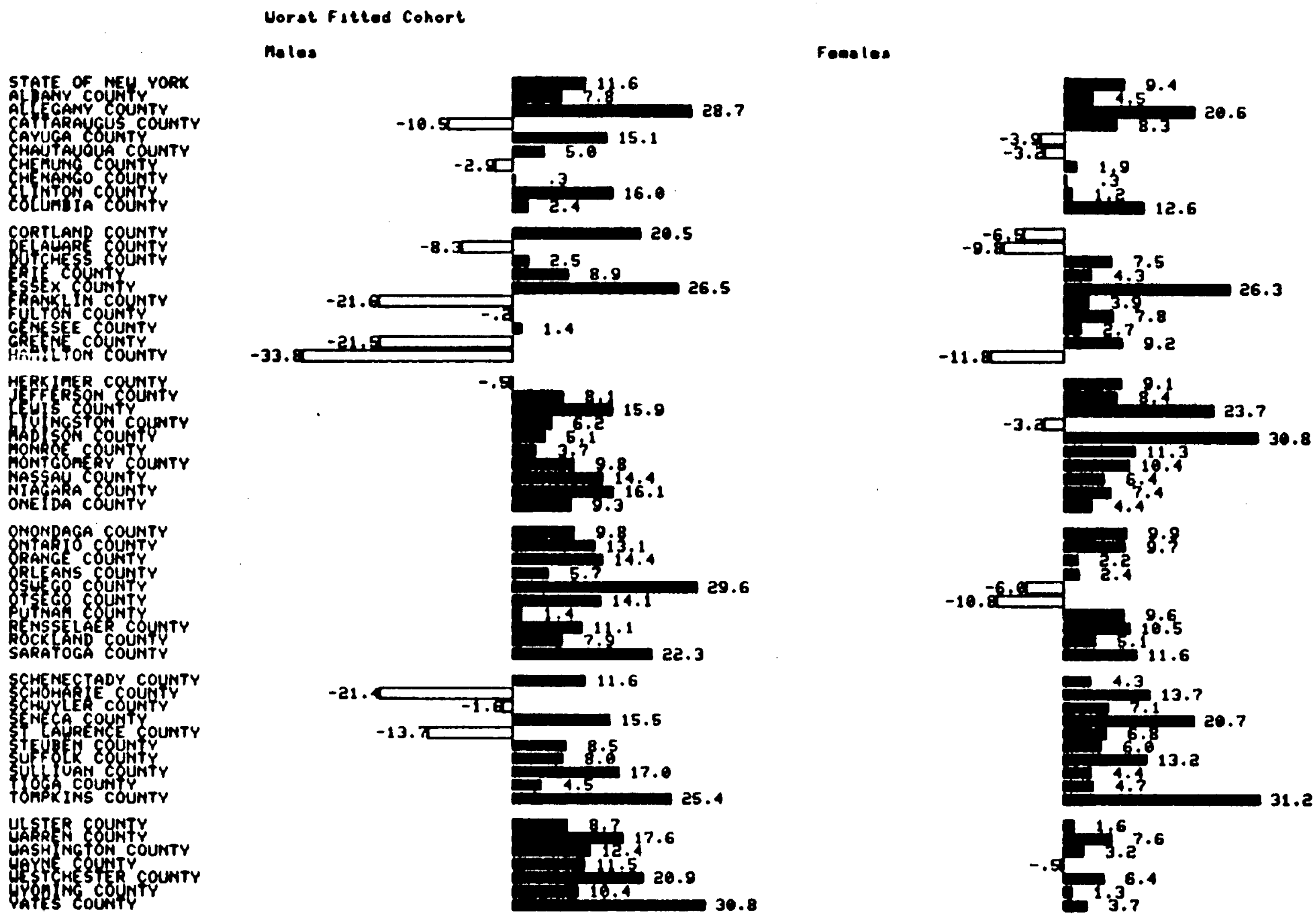


FIGURE 8a
Comparisons of 1980 Population Projections with 1980 Census data

	Males: Mean Absolute Percent Error		Females: Mean Absolute Percent Error	
	Migration Model	Plus-Minus Technique	Migration Model	Plus-Minus Technique
STATE OF WASHINGTON	4.6	10.3	5.7	8.7
ADAMS COUNTY	12.6	19.5	13.8	15.9
ASOTIN COUNTY	7.1	13.8	7.0	12.6
BENTON COUNTY	10.9	19.8	6.4	16.9
CHELAN COUNTY	5.1	10.7	4.5	6.8
CLALLAM COUNTY	9.4	21.0	6.9	18.4
CLARK COUNTY	4.8	15.2	5.9	13.0
COLUMBIA COUNTY	17.6	22.7	15.9	18.3
COWLITZ COUNTY	5.3	12.3	5.9	9.4
DOUGLAS COUNTY	10.2	20.4	6.8	13.9
FERRY COUNTY	18.5	32.2	14.7	24.1
FRANKLIN COUNTY	11.6	15.6	14.1	16.2
GARFIELD COUNTY	30.0	33.7	26.9	30.5
GRANT COUNTY	17.1	11.7	8.6	10.4
GRAYS HARBOR COUNTY	6.1	12.3	6.8	10.2
ISLAND COUNTY	30.4	32.0	11.4	23.1
JEFFERSON COUNTY	18.6	21.9	14.0	20.3
KING COUNTY	6.8	9.7	5.9	8.4
KITSAP COUNTY	13.2	19.1	5.9	20.0
KITTITAS COUNTY	20.7	28.7	23.3	27.5
KLICKITAT COUNTY	11.1	21.8	14.5	21.3
LEWIS COUNTY	9.6	14.7	4.5	10.5
LINCOLN COUNTY	12.7	16.5	12.3	16.8
MASON COUNTY	16.4	14.5	14.4	14.1
OKANOGAN COUNTY	15.6	16.7	12.1	10.7
PACIFIC COUNTY	12.4	11.7	14.6	10.6
PEND OREILLE COUNTY	13.8	29.0	12.8	28.8
PIERCE COUNTY	12.2	12.4	5.6	7.5
SAN JUAN COUNTY	25.0	30.6	32.0	33.6
SKAGIT COUNTY	6.3	13.8	5.8	11.0
SKAMANIA COUNTY	13.2	18.3	14.3	16.7
SNOHOMISH COUNTY	7.7	11.4	7.3	10.2
SPOKANE COUNTY	6.0	10.2	5.6	9.1
STEVENS COUNTY	21.7	33.2	11.1	20.5
THURSTON COUNTY	8.3	18.5	7.5	18.2
WAHKIAKUM COUNTY	17.2	21.7	14.6	15.8
WALLA WALLA COUNTY	7.5	12.2	8.4	7.5
WHATCOM COUNTY	9.5	19.9	9.2	20.4
WHITMAN COUNTY	28.7	29.4	21.4	28.8
YAKIMA COUNTY	5.6	16.7	11.5	13.1

FIGURE 8b

Comparisons of 1980 Population Projections with 1980 Census data

	Males: Percent Error in Worst Fitted Cohort — Migration Model	Males: Percent Error in Worst Fitted Cohort — Plus-Minus Technique	Females: Percent Error in Worst Fitted Cohort — Migration Model	Females: Percent Error in Worst Fitted Cohort — Plus-Minus Technique
STATE OF WASHINGTON	8.9	29.4	11.2	18.6
ADAMS COUNTY	37.4	67.3	58.0	45.8
ASOTIN COUNTY	14.8	27.1	14.0	24.7
BENTON COUNTY	31.5	52.0	21.2	57.4
CHELAN COUNTY	12.1	30.0	9.3	20.0
CLALLAM COUNTY	29.2	64.0	18.5	49.9
CLARK COUNTY	12.6	35.6	11.5	29.4
COLUMBIA COUNTY	48.9	52.0	91.0	72.7
COWLITZ COUNTY	13.4	31.3	14.0	23.5
DOUGLAS COUNTY	31.6	36.4	14.4	39.1
FERRY COUNTY	61.4	113.3	46.7	74.4
FRANKLIN COUNTY	28.4	39.7	31.3	65.7
GARFIELD COUNTY	74.6	65.8	78.4	76.1
GRANT COUNTY	66.2	41.6	18.6	30.7
GRAYS HARBOR COUNTY	14.0	31.0	15.7	20.6
ISLAND COUNTY	56.5	62.7	30.2	72.2
JEFFERSON COUNTY	43.3	50.4	32.5	41.4
KING COUNTY	20.9	22.4	18.4	18.7
KITSAP COUNTY	33.1	51.5	13.5	44.9
KITTITAS COUNTY	67.3	70.2	81.0	70.7
KLICKITAT COUNTY	24.5	74.6	44.1	96.4
LEWIS COUNTY	44.0	29.9	19.6	30.9
LINCOLN COUNTY	38.8	63.9	61.6	98.0
MASON COUNTY	39.7	39.6	27.0	46.5
OKANOGAN COUNTY	53.6	61.7	38.9	36.3
PACIFIC COUNTY	41.2	47.1	31.0	26.2
PEND OREILLE COUNTY	91.1	187.4	47.4	117.0
PIERCE COUNTY	33.8	38.8	10.2	16.2
SAN JUAN COUNTY	112.3	67.1	85.4	89.4
SKAGIT COUNTY	13.6	48.6	16.4	47.4
SKAMANIA COUNTY	40.2	44.4	33.7	25.7
SNOHOMISH COUNTY	15.3	26.3	19.1	22.9
SPOKANE COUNTY	16.4	29.0	13.7	19.7
STEVENS COUNTY	80.2	115.0	32.4	79.6
THURSTON COUNTY	24.0	39.4	14.3	35.8
WAHKIAKUM COUNTY	115.4	75.2	30.9	34.3
WALLA WALLA COUNTY	22.9	33.0	15.8	18.3
WHATCOM COUNTY	19.8	45.6	26.8	47.0
WHITMAN COUNTY	117.2	73.2	96.6	78.0
YAKIMA COUNTY	22.1	50.7	25.7	52.7

FIGURE 8c

Advantage of Migration Model Versus Plus-Minus Technique
(Plus-Minus Technique Error Minus Model Error)

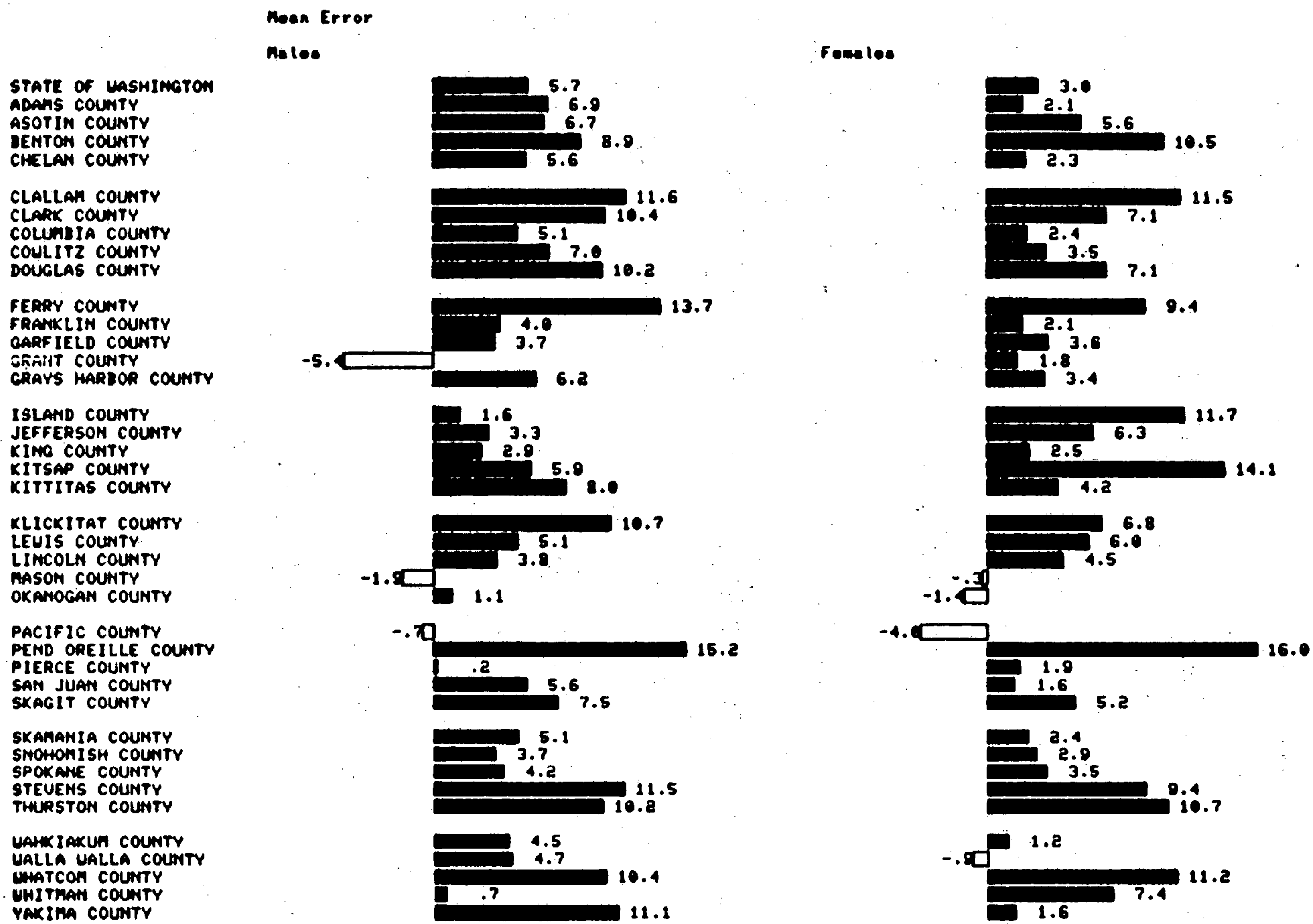
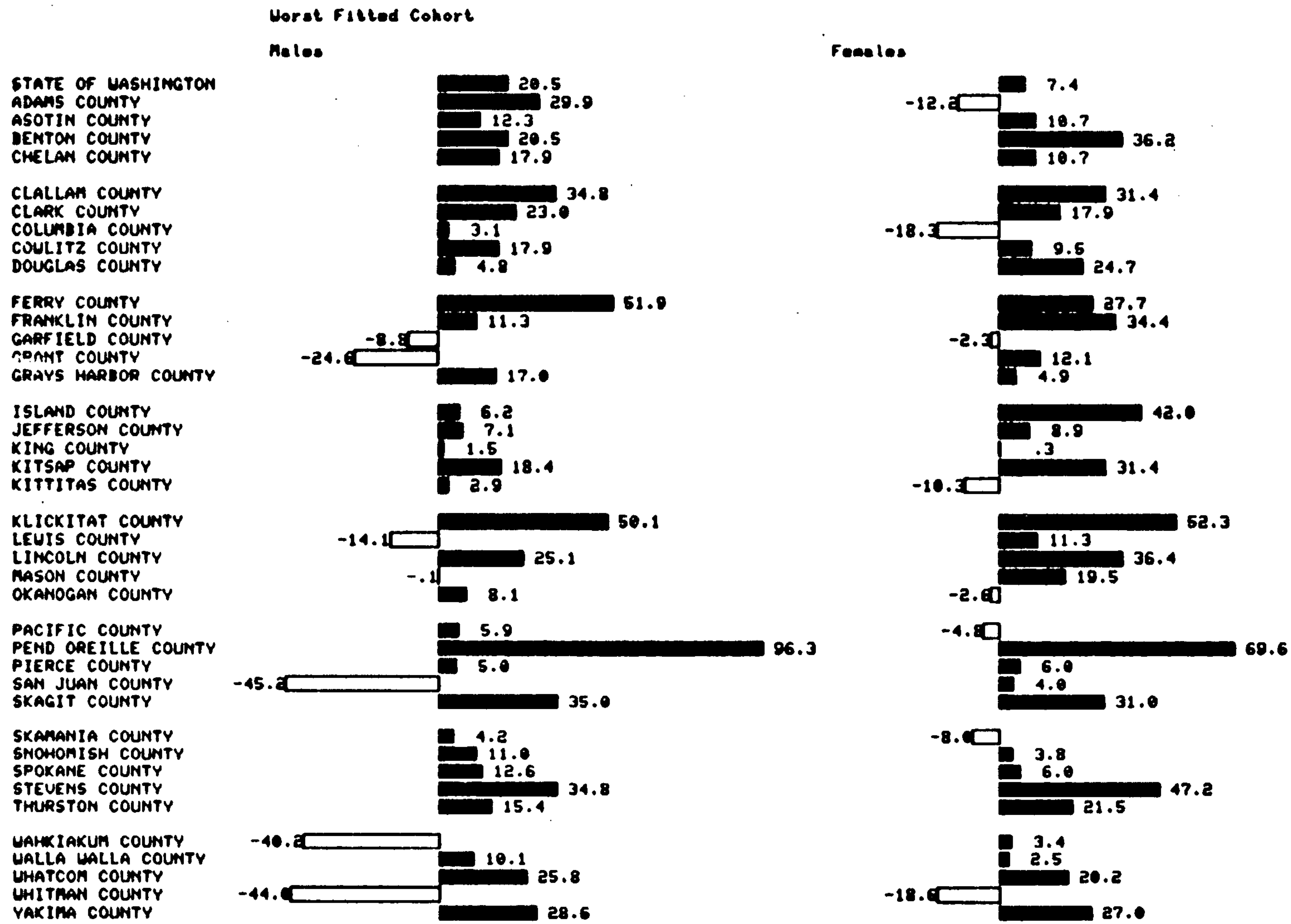


FIGURE 8d

Advantage of Migration Model Versus Plus-Minus Technique
(Plus-Minus Technique Error Minus Model Error)



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