# PROJECTING INCOME DISTRIBUTION IN A REGIONAL ECONOMY

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Presented at the 1978 Meeting of the
Population Association of America

April 15, 1978

# Projecting Income Distribution in a Regional Economy*

Questions of distributional equity are of growing importance at the regional and national levels, yet models of regional economies in particular do not explicitly consider the size distribution of income.[1] In this paper, I report on a simple simulation method which projects manpower demands, supplies, and from these quantities, the distribution of earnings, as part of a large-scale economic-demographic model of the state of Alaska.[2] In the first section of the paper I report briefly on the structure of the basic economic-demographic model. In the following sections, the structure of the manpower-income distribution submodel is presented, and some simulation results are discussed. Research in progress is discussed in a final section, and values of model parameters are appended.

## I. The Alaska Economic-Demographic Model[3]

The Alaska economy is divided into "export" and "residentiary" sectors. Production in the export sectors (mining, federal government, forestry and fisheries) is specified exogenously, which output supply-constrained or subjected to government policy decisions. Outputs in the residentiary industries (trade, transport, services, construction, etc.) are determined by Alaska incomes and prices. Employment in each industry is calculated from a labor requirements function, and wage rates in each industry are functions of national

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*Guidance and helpful criticism from David Kresge are gratefully acknowledged. Remaining errors are the responsibility of the author. This research was supported by the National Science Foundation.

wage rates and local labor market conditions. Employment and wage rates are the primary determinants of Alaska income and aggregate demand, which determines residentiary outputs. The general model structure is similar to the regional model archetype presented by Glickman.[4] The population submodel, however, goes well beyond most regional model specifications and plays a key role in the manpower-income distribution submodel.

In the population submodel,[5] an age-sex-race distribution of the population is linked to the economic model via the determination of net civilian[6] migration to the state. Net civilian migration is a function of employment growth in Alaska and per capita income in Alaska relative to the U.S. as a whole, both of which are outputs of the economic model. This relationship is quite strong over the historical period, and has been reconfirmed during the pipeline construction period 1974-1976. Each year the age-sex-race distribution is combined with a set of exogenous age-sex-race specific fertility and mortality rates, and a standard aging process, to produce the following years' population. Population size influences the relative income term of the migration equation, and also a number of state government expenditure variables, such as education expenditures.[7]

This version of the Alaska model has been used extensively for policy analysis and projections of Alaska's possible future growth paths.[8] Yet, like all other regional models, the Alaska model has been silent on the distributional consequences of growth. In the sections below, I discuss the simple method I have used to extend the model's capabilities to the analysis of the distribution of earnings.

## II. Manpower and Income Distribution

### A. Manpower Demand and Supply[9]

The types of labor employed by each sector of the Alaska economy, by Census occupation groups, is presented in Appendix Table A1. A scanning of this matrix reveals the substantial variation of occupational requirements by sector. If we make the assumption that these "factor proportions" are marginal as well as average, we can then determine the demand for occupational groups given employment levels for each sector:[10]

$$(1) \quad D_i = \sum_j a_{ij} E_j$$

where

$D_i$ = demand for occupation i

$a_{ij}$ = demand per unit employment for occupation i by industry j

$E_j$ = employment in industry j

Measuring manpower supply requires additional assumptions. Using 1970 Census data[11] it is possible to construct a matrix of occupational participation rates specific for age, race, and sex, for Alaska. These rates appear in Appendix Table A2. If we assume that these rates also are marginal as well as average, we can derive first-round supplies of each occupation group:

$$(2) \quad S_i = \sum_j b_{ij} P_j$$

where $S_i$ = supply of occupation i

$b_{ij}$ = supply rate of occupation i by population group j

$P_j$ = population size of group j

j = an age-sex-race category

B. The Occupational Labor Market

Only by chance will $D_i = S_i$ for any i. In order to clear the markets and determine occupational employment, we assume that the market is demand-determined, i.e., a shortage ($D_i > S_i$) will result in an increased supply, and a surplus ($D_i < S_i$) will result in unemployment, withdrawals from the labor force, or occupation switching. All population subgroups are affected proportionately:

$$(3) \quad b^*_{ij} = b_{ij} \cdot (D_i/S_i)$$

where the $b^*_{ij}$ are the market clearing occupational participation rates.[12] This procedure allows new migrants to have a different structure of participation rates, skewed toward those occupations in greatest relative demand. The $b^*_{ij}$ clear the markets and enable us to allocate occupational employment to each of the j population subgroups:

$$(4) \quad S^*_{ij} = b^*_{ij} \cdot P_j$$

(5) $S_i^* = \sum_j S_{ij}^* = D_i$

where $S_{ij}^*$ is the market-clearing supply of occupation i by population group j. The $S_{ij}^*$, when combined with occupational wage distributions, enables us to determine the distribution of earnings.

C. Occupational Wages

Using the same Census data described above, it is possible to calculate mean 1969 earnings for full-time workers in each major occupation group, by age group,[13] and also the variance of earnings for each group. Given that time-series data on occupational earnings are lacking, we assume that growth in occupational wages is a weighted average of growth rates of industry wage rates, with the weights representing the proportion of occupation i's employment accounted for by each industry, so that

(6) $G_{jt} = WR_{jt}/WR_{jt-1}$

(7) $G_{it} = \sum_j w_{ij} \cdot G_{jt}$

(8) $WR_{it} = WR_{it-1} \cdot G_{it}$

where $G_{jt}$ = growth rate of wage rate in industry j in year t

$WR_{jt}$ = wage rate in industry j in year t

$G_{it}$ = growth rate of occupation i wage rate in year t

$w_{ij}$ = importance of industry j to occupation i

$(= \frac{a_{ij}E_j}{S^*_i})$

$WR_{it}$ = mean earnings of occupation i in year t (for each age group)

Given the 1969 starting values for occupational wage rates, and rates of growth of industry wages from the economic model, we can then calculate occupational earnings for all years. To remove the effects of inflation, all growth rates after 1975 are expressed in real terms, so that all earnings distributions are in 1975 dollars. It should be noted that $a_{ij} \neq w_{ij}$, and the $w_{ij}$ will change over time, as the industrial mix of employment changes.

D. The Distribution of Earnings

With additional assumptions about the shape of the occupational earnings distributions, we can derive earnings distributions for population groups. The coefficients of variation among age groups of the 1969 earnings distributions are assumed to remain constant (see Appendix Table A3):

(9) $SD_{it} / WR_{it} = K_i$

where $SD_{it}$ = standard deviation of earnings

$K_i$ = 1969 occupation i coefficient of variation (for all age groups in an occupation)

Although we assume that full-time workers in an occupation earn the same income regardless of sex or race[14] and that only age affects earnings, we do allow for differences, by age, sex, and race, in the proportions of full and part-time workers. Again, using the Census data described above, we can crosstabulate all employees by hours and weeks worked[15] for each age-sex-race group. Assigning all part-time workers to half-time work, we calculate a reduction in the mean earnings for full-time workers of equation (8):

$$(10) \quad f_j + \tfrac{1}{2}(1 - f_j) = r_j$$

$$(11) \quad WR_{ijt} = WR_{it} \cdot r_j$$

$$(12) \quad SD_{ijt} = K_i \cdot WR_{ijt}$$

where $f_j$ = proportion of group j working full-time

$r_j$ = proportion reduction in mean earnings.

The information obtained from equations 1 through 12 enables us to determine the size distribution of earnings if we make an assumption about the functional form of the earnings distributions. We have assumed normality rather than log-normality or other possibilities, because of computational ease and difficulties in testing for goodness of fit with the underlying data.[16]

Given normality, it is straightforward to map a given number of individuals from a normal distribution with known mean and variance into k earnings size intervals, $Y_1 = < \$5,000$, $Y_2 = \$5,000 - \$9,999, \ldots,$ $Y_k = \$40,000+$. Given the mean $\mu = WR_{ijt}$ and standard deviation $\sigma = K_i^* \cdot WR_{ijt}$, we then know, using the b earnings breakpoints, $y_1$ to $y_b$,

$$(13) \quad p_k = \left| \frac{|y_b - \mu|}{\sigma} - \frac{|y_{b-1} - \mu|}{\sigma} \right|$$

$$(14) \quad N_{ijk} = p_k \cdot S^*_{ij}$$

where $p_k$ = proportion of a group in earnings interval $Y_k$

$N_{ijk}$ = individuals in occupation i in group j in interval k. (t's suppressed)

We can then sum these size distributions into distributions for each race and sex group, for the races as a whole, and for the entire population. We have chosen the time-honored Gini coefficient as a summary statistic of the earnings inequality of these distributions. Some preliminary results are reported in the next section.

## III. Simulation Results

### A. Background

Alaska's economy and population will grow rather rapidly for the next 15 years under almost any plausible set of assumptions about the price of oil (a major source of revenue for the state) and the rate of development of Alaska's petroleum potential, the key driving force behind Alaska's projected economic growth. The distributional effects of three different growth paths are discussed below.[17]

B. Distributional Effects of Alaska's Growth

Figure 1 shows the 1976 and 1990 earnings distribution (in 1975 Alaska dollars) for the Alaska population in $5,000 intervals up to $40,000.[18] The year 1976 was one of rapid growth during the construction of the trans-Alaska oil pipeline. The 1990 distribution is based on economic assumptions which produce a relatively steady growth in economic activity in the 1976-1990 period.[19] Real incomes rise substantially, but the Gini index shows that inequality also is lower in 1990 after considerable real growth. Figures 2 through 5 show the distribution of Figure 1 broken down into sex-race groups (male/female, Native/non-Native, where Natives are Eskimos, Indians, and Aleuts, and non-Natives are mostly whites). The distribution of earnings for Natives tends to be more unequal than that of non-Natives, and also much lower overall, principally as a result of large proportions of Native part-time work. Substantial male-female differentials also exist for the same reason, and also as a result of differing occupational mixes. All groups, however, participate in the real growth to 1990.

The pattern of economic growth 1976-1990 is not completely smooth, and varies with different assumptions about petroleum development. In Figure 6 I have graphed the time path of the Gini index for different growth paths of the economy. The BL case reflects slower growth after 1985 than the Basic case discussed above. The MH case reflects faster growth in earlier years of the projection and almost no growth in the late 1980s. The time paths all conform to the pattern of rapid growth resulting in greater inequality, both across cases and within each case, as 1976 and 1979-81 are rapid growth years for the economy under all sets of assumptions.

IV. Current Research

The discussion of the results in Section III is brief in comparison with Section II by design: the findings are quite tentative given the experimental nature of the model and the stringency of the requisite assumptions. In our current research we are attempting to refine and enrich the model, and also test the sensitivity of various assumptions. Two important areas of current research are discussed below.

The assumption of an unchanging matrix of occupational supply parameters is an obvious candidate for relaxation. Even though the S* change in response to demand, secular changes in relative rates should be incorporated in the model. If the structure of female participation rates trended toward the male structure (certainly a real world phenomenon) or if the Native structure changed in the direction of the non-Native (perhaps as a result of manpower training programs), the effects on inequality could be substantial. A "gap-closing" model of participation rates is under construction now.

The distribution of non-earnings income, although dwarfed by earnings as a proportion of income, is still important and needs to be modeled. Certain types of non-earnings income are clearly skewed to the lower end of the earnings spectrum (transfer payments), while others, such as dividends and interest, are skewed toward the upper end of the distribution. Incorporating these distributions will enrich the model and augment its policy analysis capability.

FOOTNOTES

[1] Glickman provides a good summary of regional econometric models. Metcalf is one of the few U.S. national models to address explicitly the distribution of income. See Robinson for a discussion of income modeling in LDCs.

[2] A full description of the model is contained in Kresge, et al., and recent policy applications are reported in Kresge and Seiver.

[3] This section is based on Kresge and Seiver, loc. cit.

[4] Loc. cit. in footnote 1.

[5] The population model is discussed in detail in Seiver (1975).

[6] The military and military dependent population is treated exogenously.

[7] The fiscal model is described in detail in Goldsmith.

[8] See Kresge et. al. and Kresge and Seiver

[9] This section is based on Seiver (1978a).

[10] Of course, these proportions will probably change for many reasons, among them changing labor market conditions, technological progress, and the distribution of firms by size and type within each sector. This type of fixed proportions matrix has recently been used by Golladay and Haveman in their income distribution work.

[11]A combination of the four state-identified 1 percent Public Use Samples for Alaska, 1970 (12,000 records).

[12]What is missing from this version of the model is an opportunity for relative occupational wages to change in response to changing relative demands. Given sufficient labor queuing (the unemployment rate in Alaska is usually double the national average, but real wages are very high), the omission may not be so serious.

[13]15-19 years, 20-24, 25-34, 45-54, 55-64, and 65+ years.

[14]We could easily allow for direct discrimination or indirect discrimination through occupational mix within each occupation group.

[15]Hours worked are based on the pre-Census week in 1970, while weeks worked is based on 1969 data.

[16]Reporting biases in the income data make it very difficult to find any function that fits well consistently. See Seiver (1978b)

[17]Kresge and Seiver and Kresge et. al. provide extensive discussions of projections of Alaska's growth.

[18]The reader is reminded that unemployment in Alaska is very high, and the price level is also much higher than in the rest of the U.S.

[19]Kresge and Seiver, Case 3.

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Table A1

INDUSTRY-OCCUPATION MATRIX FOR AL

| Sector: | Misc. | Mining | Construction | Manufacturing | Transportation |
|---|---|---|---|---|---|
| **Occupation Group** | | | | | |
| Professional, Technical and Kindred | .131 | .214 | .038 | .074 | .136 |
| Managers and Administrators, Excluding Farm | .265 | .106 | .123 | .054 | .116 |
| Sales Workers | .068 | .005 | .007 | .027 | .016 |
| Clerical and Kindred Workers | .072 | .100 | .084 | .088 | .190 |
| Craftsmen and Kindred Workers | .148 | .210 | .524 | .244 | .156 |
| Operatives | .077 | .314 | .112 | .322 | .227 |
| Laborers, Excluding Farm | .114 | .025 | .097 | .152 | .104 |
| Service Workers, Excluding Private Household | .089 | .023 | .019 | .040 | .055 |
| Farm and Private Household | .039 | .000 | .000 | .000 | .000 |
| TOTAL: | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

Source: 1970 Census "Manpower Tallies" tapes. See Seiver (1978a).

Table A2

## OCCUPATIONAL PARTICIPATION RATES FOR ALASKA, 1970

Age Group = 15 - 19 Years

| Occupation | Non-Natives Males | Non-Natives Females | Natives Males | Natives Females |
|---|---|---|---|---|
| Professional, Technical and Kindred | .017 | .008 | ---- | .020 |
| Managers and Administrators, Excluding Farm | .006 | .005 | .021 | .010 |
| Sales Workers | .019 | .050 | ---- | .020 |
| Clerical and Kindred Workers | .034 | .177 | .042 | .157 |
| Craftsmen and Kindred Workers | .063 | .008 | .042 | ---- |
| Operatives | .110 | .045 | .051 | .053 |
| Laborers, Excluding Farm | .181 | .026 | .219 | .098 |
| Service Workers, Excluding Private Household | .123 | .158 | .156 | .147 |
| Farm and Private Household | .019 | .084 | .031 | .039 |
| TOTAL: | .572 | .561 | .562 | .544 |

Source: See Text.

Table A2 (cont'd)

OCCUPATIONAL PARTICIPATION RATES FOR ALASKA, 1970

Age Group = 20 - 24 Years

| Occupation | Non-Natives Males | Non-Natives Females | Natives Males | Natives Females |
|---|---|---|---|---|
| Professional, Technical and Kindred | .043 | .122 | .035 | .014 |
| Managers and Administrators, Excluding Farm | .015 | .019 | .018 | .043 |
| Sales Workers | .008 | .079 | .018 | .014 |
| Clerical and Kindred Workers | .023 | .458 | .018 | .290 |
| Craftsmen and Kindred Workers | .054 | .011 | .105 | ---- |
| Operatives | .115 | .078 | .158 | .203 |
| Laborers, Excluding Farm | .044 | .011 | .263 | .014 |
| Service Workers, Excluding Private Household | .037 | .128 | .211 | .159 |
| Farm and Private Household | .002 | .019 | ---- | .058 |
| TOTAL: | .341 | .925 | .826 | .795 |

Table A2 (cont'd)

OCCUPATIONAL PARTICIPATION RATES FOR ALASKA, 1970

Age Group = 25 - 34 Years

| Occupation | Non-Natives | | Natives | |
|---|---|---|---|---|
| | Males | Females | Males | Females |
| Professional, Technical and Kindred | .215 | .158 | .090 | .017 |
| Managers and Administrators, Excluding Farm | .129 | .014 | .049 | .008 |
| Sales Workers | .043 | .028 | ---- | .025 |
| Clerical and Kindred Workers | .048 | .169 | .041 | .083 |
| Craftsmen and Kindred Workers | .247 | .001 | .123 | ---- |
| Operatives | .101 | .017 | .065 | .033 |
| Laborers, Excluding Farm | .071 | .001 | .131 | .017 |
| Service Workers, Excluding Private Household | .081 | .061 | .139 | .117 |
| Farm and Private Household | .004 | .006 | .008 | .016 |
| TOTAL: | .939 | .455 | .646 | .316 |

Table A2 (cont'd)

## OCCUPATIONAL PARTICIPATION RATES FOR ALASKA, 1970

Age Group = 35 - 44 Years

| Occupation | Non-Natives Males | Non-Natives Females | Natives Males | Natives Females |
|---|---|---|---|---|
| Professional, Technical and Kindred | .188 | .084 | .065 | .023 |
| Managers and Administrators, Excluding Farm | .187 | .030 | .083 | .023 |
| Sales Workers | .040 | .030 | .009 | ---- |
| Clerical and Kindred Workers | .040 | .212 | .019 | .008 |
| Craftsmen and Kindred Workers | .244 | .004 | .120 | ---- |
| Operatives | .135 | .039 | .093 | .045 |
| Laborers, Excluding Farm | .069 | .002 | .213 | ---- |
| Service Workers, Excluding Private Household | .056 | .094 | .102 | .125 |
| Farm and Private Household | .002 | .012 | ---- | .011 |
| TOTAL: | .961 | .507 | .704 | .235 |

Table A2 (cont'd)

OCCUPATIONAL PARTICIPATION RATES FOR ALASKA, 1970

Age Group = 45 - 54 Years

| Occupation | Non-Natives Males | Non-Natives Females | Natives Males | Natives Females |
|---|---|---|---|---|
| Professional, Technical and Kindred | .142 | .107 | ---- | .017 |
| Managers and Administrators, Excluding Farm | .188 | .046 | .029 | .017 |
| Sales Workers | .035 | .056 | .015 | ---- |
| Clerical and Kindred Workers | .042 | .207 | .015 | .138 |
| Craftsmen and Kindred Workers | .285 | .009 | .132 | .017 |
| Operatives | .092 | .036 | .089 | .086 |
| Laborers, Excluding Farm | .080 | .002 | .103 | ---- |
| Service Workers, Excluding Private Household | .058 | .105 | .132 | .052 |
| Farm and Private Household | .004 | .005 | ---- | .052 |
| TOTAL: | .926 | .573 | .515 | .379 |

Table A2 (cont'd)

OCCUPATIONAL PARTICIPATION RATES FOR ALASKA, 1970

Age Group = 55 - 64 Years

| Occupation | Non-Natives Males | Non-Natives Females | Natives Males | Natives Females |
|---|---|---|---|---|
| Professional, Technical and Kindred | .103 | .164 | .024 | ---- |
| Managers and Administrators, Excluding Farm | .140 | .044 | ---- | ---- |
| Sales Workers | .033 | .082 | ---- | ---- |
| Clerical and Kindred Workers | .033 | .104 | ---- | .071 |
| Craftsmen and Kindred Workers | .310 | .011 | .143 | ---- |
| Operatives | .078 | .020 | .071 | .048 |
| Laborers, Excluding Farm | .058 | .011 | .071 | ---- |
| Service Workers, Excluding Private Household | .107 | .120 | .143 | .071 |
| Farm and Private Household | .012 | .010 | ---- | .048 |
| TOTAL: | .874 | .566 | .452 | .238 |

Table A2 (cont'd)

## OCCUPATIONAL PARTICIPATION RATES FOR ALASKA, 1970

Age Group = 65 + Years

| Occupation | Non-Natives Males | Non-Natives Females | Natives Males | Natives Females |
|---|---|---|---|---|
| Professional, Technical and Kindred | .064 | .087 | ---- | ---- |
| Managers and Administrators, Excluding Farm | .064 | ---- | ---- | ---- |
| Sales Workers | .027 | .033 | ---- | ---- |
| Clerical and Kindred Workers | .036 | .011 | ---- | .037 |
| Craftsmen and Kindred Workers | .100 | .011 | .091 | ---- |
| Operatives | .045 | .033 | ---- | ---- |
| Laborers, Excluding Farm | .055 | ---- | .045 | ---- |
| Service Workers, Excluding Private Household | .073 | .054 | ---- | ---- |
| Farm and Private Household | ---- | .011 | ---- | ---- |
| TOTAL: | .464 | .240 | .136 | .037 |

Table A3

COEFFICIENTS OF VARIATION FOR OCCUPATIONS,

1970

| Occupation | $\sigma / \mu$ |
|---|---|
| Professional, Technical and Kindred | .611 |
| Managers and Administrators, Excluding Farm | .564 |
| Sales Workers | .748 |
| Clerical and Kindred Workers | .533 |
| Craftsmen and Kindred Workers | .399 |
| Operatives | .490 |
| Laborers, Excluding Farm | .715 |
| Service Workers, Excluding Private Household | .507 |
| Farm and Private Household | .776 |

Source: See Text

Table A4

ADJUSTMENTS FOR PART-TIME WORK,

1970

| Ages (yrs.) | Non-Natives Males | Non-Natives Females | Natives Males and Females |
|---|---|---|---|
| 15 - 19 | .515 | .595 | .532 |
| 20 - 24 | .753 | .695 | .607 |
| 25 - 34 | .887 | .728 | .717 |
| 35 - 44 | .904 | .707 | .753 |
| 45 - 54 | .894 | .786 | .718 |
| 55 - 64 | .847 | .797 | .727 |
| 65 + | .750 | .650 | .700 |

Source: See Text

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A reprint from Growth and Change, Vol. 12, No. 4, October 1981

# Projecting the Income Distribution in a Regional Economy

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QUESTIONS of distributional equity are of growing importance at the regional and national levels, yet models of regional economies do not explicitly consider the size distribution of income.[1] In this paper, I report on a simple simulation method which projects manpower demand and supply and, from these quantities, the distribution of earnings and income as part of a large-scale economic-demographic model of the state of Alaska.[2] In the first section of the paper, I report briefly on the structure of the basic economic-demographic model. The second section contains a brief discussion of theories of income distribution and their relation to my model. In the following sections, the structure of the manpower-income distribution submodel is presented, and some simulation results are discussed. Conclusions are presented in a final section.

## The Alaska Economic-Demographic Model

The Alaska economy is divided into export and residentiary sectors.[3] Production in the export sectors (mining, federal government, forestry, and fisheries) is specified exogenously, with output supply-constrained or subject to government policy decisions. Outputs in the residentiary industries (trade, transport, services, construction, and so on) are determined by Alaska incomes and prices. Employment in each industry is calculated from a labor requirements function, and wage rates in each industry are functions of national wage rates and local labor market conditions. Employment and wage rates are the primary determinants of Alaska income and aggregate demand, which determine residentiary outputs. The model is structured similarly to the regional model archetype presented by Glickman.[4] The population submodel, however, is specified in much greater detail than many regional models, and that submodel plays a key role in the manpower-income distribution submodel.

In the population submodel,[5] an age-sex-race distribution of the population is linked to the economic model via the determination of net civilian[6] migration to the state. Net civilian migration is a function of both employment growth in Alaska and per capita income in Alaska relative to per capita income in the United States, both of which are outputs of the economic model. This net migration relationship is quite strong over the historical period and has been reconfirmed during the Alaskan oil pipeline construction period, 1974-76. For each year, the age-sex-race distribution is combined with a set of exogenous age-sex-race specific fertility and mortality rates, as well as with a standard aging algorithm, to produce the following year's population. Population size influences the relative per capita income term of the migration equation and also a number of state government expenditure variables, such as education expenditures.[7]

This version of the Alaska model has been used extensively for policy analysis and projections of Alaska's possible future growth paths.[8] Yet, like all other regional models, the Alaska model has been silent on the distributional consequences of growth. In the sections below, I will discuss a simple method that I have used to extend the model's capabilities to the analysis of the distribution of income.

## Explaining Income Differences

In recent years, the study of income distribution has shifted from theoretical and empirical analysis of the factor distribution of income (dividing output among suppliers of land, labor, and capital)[9] to the size distribution of personal income, primarily with respect to the dispersion of labor earnings and secondarily with respect to the dispersion of wealth and thus nonlabor income. In this paper I attempt to simulate the dispersion of personal incomes within a region and to measure the degree of inequality, the latter a task which both has a long history[10] and is the subject of renewed interest.[11]

Several competing theories of the personal distribution of incomes have been advanced in this century, and this massive and growing literature has been surveyed elsewhere.[12] My simulation methodology is eclectic in approach and draws on several of the following theories.

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Labor incomes differ for many reasons. Many are related to worker characteristics such as innate abilities and human capital endowments (both formal training and on-the-job training). These labor supply factors interact with luck, custom, and various demand factors, such as the job characteristics required by the output mix of the economy, to yield employment-unemployment outcomes and, with wage rates, to yield labor incomes.

Becker and Chiswick[13] and Mincer[14] have emphasized the human capital explanation of earnings dispersion, which we can incorporate in our aggregate model in only an indirect fashion. Scholars of human capital theory have long noted that incomes tend to rise with age, a fact which they attribute to on-the-job training experience. Different occupations have different age-income profiles, however, and these differences reflect in part the returns to formal training; this training is important for professionals, for example, and unimportant for laborers. I have incorporated the 1970 census age-income profiles for Alaska occupations in the model discussed in the next section.

Subgroups of the population (males, females, whites, nonwhites) may differentially acquire the skills necessary for various occupations. Rates of time preference, innate abilities, and opportunities may differ among subgroups; overt discrimination can also play a part in determining which subgroups enter given occupations. To capture these elements of earnings dispersion, my model attributed to each demographic subgroup the array of skills (occupations) documented by the 1970 census for the employed and the unemployed.

Another supply side factor causing earnings differences is the individual's hours-of-work decision. A complete model of this leisure decision is described by Blinder.[15] In my model, each demographic subgroup supplies full- and part-time workers based on 1970 patterns.

The importance of the demand side of the labor market has been stressed by manpower and educational planners[16] and income distribution theorists such as Tinbergen.[17] Which jobs the economy will require to be filled depends heavily on the sectoral output mix and the labor requirements of each sector. I have taken the simplest skills-planning approach in modeling the demand for labor: each sector has a fixed set of occupational (skill) requirements, following Golladay and Haveman.[18]

Using these occupational demands and supplies, I assume that workers compete for jobs, rather than wages, to clear labor markets. This "job competition" approach is similar to one developed by Lester Thurow.[19] Essentially, workers queue for jobs at given wage rates rather than offer themselves at lower wages until the markets clear. Employment is thus demand determined, and scarce jobs in some occupations are rationed proportionally among demographic subgroups. The wage rates are determined outside the labor market model, à la Thurow. The persistence of customary wage differentials has been well documented, as reported by Thurow, and wage stratification is also consistent with theories of internal labor markets of Doeringer and Piore.[20]

The remaining variation in labor earnings within age-race-sex-occupation groups this model leaves to stochastic processes, in the tradition of Gibrat and others.[21] It is true that homogeneous groups have more symmetrical earnings distributions than heterogeneous groups, and thus I employ the normal distribution. The homogeneous subgroups of workers used here are distributed around the mean wage for the group in accordance with the variance of the normal distribution. Although chance certainly plays some role in determining the earnings distribution and randomly distributed but unmeasurable innate abilities also play a role, it is true that stochastic theories of earnings distribution have not held up well under a theoretical and empirical onslaught.[22]

My modeling of nonlabor income (the return on wealth) takes an agnostic approach to theories of wealth accumulation and transmission. I simply use the empirical pattern of variation in the earnings-income ratio for different age-race-sex groups of the population to generate income distributions from earnings distributions.

Having described the numerous forebears of this simulation methodology, I will in the next section spell out in detail the model undertaken and the assumptions made.

## Manpower and Earnings Distributions

*Manpower demand and supply.*[23] Examples of the types of labor employed by each sector of the Alaska economy, by census occupation group, are presented in Table 1. Scanning just these two columns[24] reveals the substantial variation of occupation requirements by sector. If one assumes that these factor proportions are marginal as well as average, one can then determine the demand for occupational groups based on the full-time equivalent employment levels for each sector.[25]

(1) $D_i = \Sigma_j a_{ij} E_j$,

where $D_i$ is the demand for occupation $i$, $a_{ij}$ is the demand per unit of employment for occupation $i$ by industry $j$, and $E_j$ is total employment in industry $j$.

Measuring manpower supply requires additional assumptions. Using 1970 census data[26] makes it possible to construct a matrix of occupational participation rates

TABLE 1. A PORTION OF THE INDUSTRY-OCCUPATION MATRIX FOR ALASKA, 1970

| Occupation Group | Manufacturing | Trade |
|---|---|---|
| Professional, technical, and kindred workers | 0.074 | 0.026 |
| Managers and administrators, excluding farm | 0.054 | 0.129 |
| Sales workers | 0.027 | 0.222 |
| Clerical and kindred workers | 0.088 | 0.174 |
| Craftsmen and kindred workers | 0.244 | 0.095 |
| Operatives | 0.322 | 0.083 |
| Laborers, excluding farm | 0.152 | 0.067 |
| Service workers, excluding private household | 0.040 | 0.199 |
| Total | 1.000 | 1.000 |

Source: Daniel A. Seiver, "Projections of Manpower Requirements and Supplies Using Public Use Sample Data," *Review of Public Data Use*, vol. 6, no. 1 (January 1978), pp. 3-11.

specific to age, race, and sex for Alaska. A sample of these rates appears in Table 2.[27] If we assume that these rates too are marginal as well as average, we can derive first-round labor supply for each occupation:

(2) $S_i = \Sigma_j b_{ij} P_j$,

TABLE 2. A PORTION OF THE OCCUPATIONAL PARTICIPATION RATES FOR ALASKA, 1970

| Occupation | 25- to 34-Year-Old Nonnatives | |
|---|---|---|
| | Males | Females |
| Professional, technical, and kindred workers | .215 | .158 |
| Managers and administrators, excluding farm | .129 | .014 |
| Sales workers | .043 | .028 |
| Clerical and kindred workers | .048 | .169 |
| Craftsmen and kindred workers | .247 | .001 |
| Operatives | .101 | .017 |
| Laborers, excluding farm | .071 | .001 |
| Service workers, excluding private household | .081 | .061 |
| Farm and private household | .004 | .006 |
| Total | .939 | .455 |

Source: Same as Table 1.

where $S_i$ is the supply of workers in occupation $i$, $b_{ij}$ is the supply rate of workers to occupation $i$ by the population in group $j$, $P_j$ is the population size of group $j$, and $j$ represents an age-sex-race category.

*The occupational labor market.* Only by chance will $D_i$ equal $S_i$ for any $i$. In order that the markets will clear and so that one can determine occupational employment, the market is assumed to be demand determined; that is, a shortage ($D_i > S_i$) will result in an increased labor supply, and a surplus ($D_i < S_i$) will result in unemployment, withdrawals from the labor force, or occupation switching. All population subgroups are affected proportionately:

(3) $b^*_{ij} = b_{ij} \cdot (D_i/S_i)$,

where the $b^*_{ij}$ are the market-clearing occupational participation rates.[28] Proportionate effects allow new migrants to have a different structure of participation rates, one skewed toward those occupations in greatest relative demand. The $b^*_{ij}$ clear the markets and enable us to allocate occupational employment to each of the $j$ population subgroups:

(4) $S^*_{ij} = b^*_{ij} \cdot P_j$

(5) $S^*_i = \Sigma_j S^*_{ij} = D_i$,

where $S^*_{ij}$ is the market-clearing supply of workers in occupation $i$ by population group $j$. The $S^*_{ij}$, when combined with occupational wage distributions, enable one to determine the distribution of earnings.

*Occupational wages.* Using the same census data described above, one can calculate the mean and variance of 1969 earnings for full-time workers in each major occupation and age group.[29] Because time-series data on occupational earnings are lacking, I use a weighted average of growth rates of industry wages to represent growth in occupational wages. The weights represent the proportion of occupation $i$'s employment accounted for by each industry, so that

(6) $G_{jt} = WR_{jt}/WR_{jt-1}$

(7) $G_{it} = \Sigma_j w_{ij} \cdot G_{jt}$

(8) $WR_{it} = WR_{it-1} \cdot G_{it}$,

where $G_{jt}$ is the growth rate of wages in industry $j$ in year $t$, $WR_{jt}$ is the wage rate in industry $j$ in year $t$, $G_{it}$ is the growth rate of occupation $i$'s wage rate in year $t$, $w_{ij}$ represents the importance of industry $j$ to occupation $i$ ($= a_{ij}E_j/S^*_i$), and $WR_{it}$ equals the mean earnings of occupation $i$ in year $t$ (for each age group).

Given the 1969 starting values (in 1967 U.S. dollars) for occupational wage rates and the rates of growth of industry wages from the economic model, one can calculate occupational earnings for all years. To remove the effects of inflation, all growth rates are expressed in real terms, so that all earnings distributions are in 1967 U.S. dollars. It should be noted that

$a_{ij} \neq w_{ij}$

and that the $w_{ij}$ will change over time as the industrial mix of employment changes.

*The distribution of earnings.* With additional assumptions about the shape of the occupational earnings distributions, one can derive earnings distributions for population groups. The coefficients of variation among age groups of the 1969 earnings distributions are assumed to remain constant.[30] Thus,

$$(9)\ SD_{it}/WR_{it} = K_i,$$

where $SD_{it}$ is the standard deviation of earnings and $K_i$ is the 1969 occupation $i$ coefficient of variation (for all age groups).

Although I assume that full-time workers in an occupation earn the same income regardless of sex or race[31] and that only age affects earnings, I do allow for differences, by age, sex, and race, in the proportions of full- and part-time workers. Again using the census data described above, one can cross-tabulate all employees by hours and weeks worked for each age-sex-race group. Assigning all part-time workers to half-time work,[32] one can calculate a reduction in the mean earnings for the full-time workers of equation 8:

$$(10)\ f_j + 1/2\ (1 - f_j) = r_j$$

$$(11)\ WR_{ijt} = WR_{it} \cdot r_j$$

$$(12)\ SD_{ijt} = K_i \cdot WR_{ijt},$$

where $f_j$ represents the proportion of group $j$ working full time and $r_j$ represents the proportional reduction in mean earnings. Although the markets clear on a full-time equivalent basis, each population subgroup has a unique mix of full- and part-time employees based on the census data.

The information obtained from equations 1 through 12 enables one to determine the size distribution of earnings if an assumption about the functional form of the earnings distributions is made. I assume normality rather than log-normality or other possibilities, in part because of computational ease and difficulties in testing for goodness of fit with the underlying data.[33]

If the distribution is assumed normal, mapping is straightforward. A given number of individuals from a normal distribution with known means and variances form $k$ earnings size intervals ($Y_1 <$ \$5,000), ($Y_2 =$ \$5,000-\$9,999), . . ., ($Y_k =$ \$40,000+). If the mean, $\mu$, is $WR_{ijt}$ and the standard deviation, $\sigma$, equals $(K_i \cdot WR_{ijt})$, we then know, by using the $b$ earnings breakpoints, $y_1$ to $y_b$, that

$$(13)\ P_k = \left|[((y_b - \mu))/\sigma] - [((y_{b-1} - \mu))/\sigma]\right|$$

$$(14)\ N_{ijk} = P_k \cdot S^*_{ij},$$

where $P_k$ is the proportion of a group in earnings interval $y_k$ and the $N_{ijk}$ are the individuals in occupation $i$ in group $j$ in interval $k$ ($t$ subscripts are suppressed). One can then sum these size distributions into distributions for each race and sex group, for the races as a whole, and for the entire population.

## Extension to Income Distribution

A complete model of the income distribution requires inclusion of (1) nonearnings income of labor force participants and (2) income of the population not in the labor force. Even though these elements are dwarfed in size by labor income, especially in Alaska, we have made an attempt to include them in the model.

We can calculate for each age-occupation group the ratio, $R$, of the total income of labor force participants to their labor income. From 1969 census data, $R_{ij}$ is estimated to be in the range of 1.00 to 1.09. These ratios applied to each $WR_{ijt}$ calculated above generate mean total income:

$$(15)\ TI_{ijt} = R_{ij} \cdot WR_{ijt}.$$

If we again assume normality, we can set the $\mu$ equal to $TI_{ijt}$ in equations 13 and 14 and generate size distributions of income for the labor force.

This approach cannot be used for income receivers not in the labor force. One can calculate, however, the mean income of those receiving income and the proportion of income receivers in the population by race, sex, and age. Because the numbers involved are small and the distribution is not normal, I use mean values only, and thus these recipients appear only in a summary measure of income per capita for race-sex groups. Thus the extensions enable me to calculate the size distributions of total income for labor force participants by race and sex group and also to calculate mean incomes for nonlabor income recipients.

I have chosen the Gini index as a summary measure of inequality of the size distributions discussed below. It is probably the most commonly used measure of inequality, in spite of its shortcomings.[34] Another popular measure, Atkinson's index, gives similar results, but only the Gini is reported here.

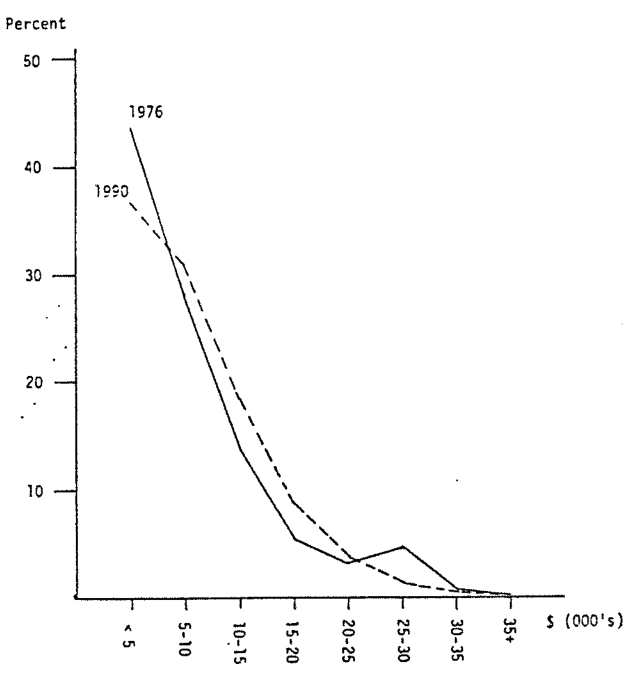
## Simulation Results

*Background.* Alaska's economy and population will grow rather rapidly for the next 10 years under almost any plausible set of assumptions about the price of oil (a major source of revenue for the state) and the rate of development of Alaska's petroleum reserves. The development potential of these reserves is the driving force behind Alaska's projected economic growth.[35] The distributional effects of two different growth paths and of one policy experiment are discussed below.

*Distributional effects of Alaska's growth.* Figure 1 shows the 1976 and 1990 income distributions for labor force members in 1967 U.S. dollars. The 1976 distribution reflects the high-wage pipeline construction work that was in progress at the time. The 1990 distribution is the result of more than a decade of relatively steady growth in economic activity.[36] The 1976 Gini index is abnormally high because of the presence of the pipeline workers, and after the completion of the pipeline it drops rapidly, as shown by the base-run case in Figure 2.

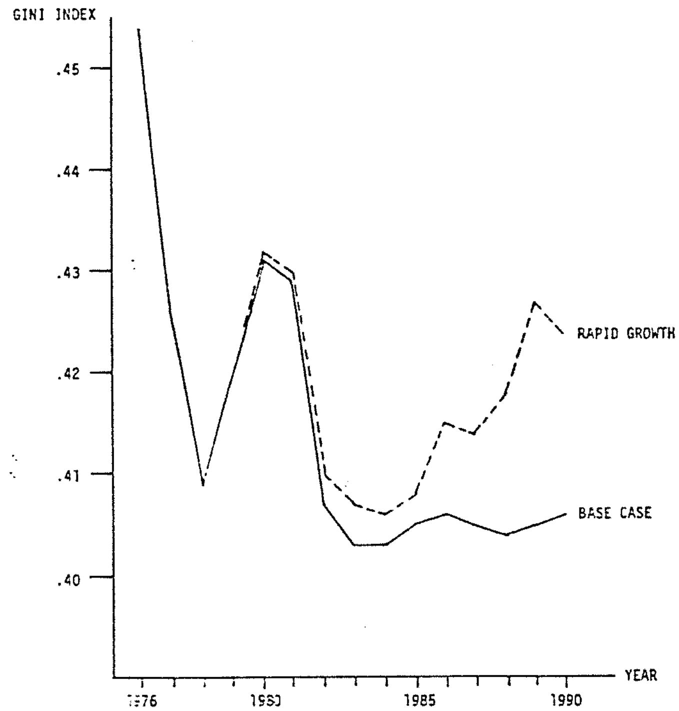
The shape of the distribution in 1990 is of interest in itself. The standard skew to the right is evident, even with the assumption of normal subdistributions. Although the calculations of total income and the lower income levels of females and Alaskan natives add additional skewness, the earnings distribution of nonnative males (not shown) is also quite skewed.[37] The major reason is the different mean levels of occupational earnings by age group, and the minor reason, the inclusion of part-time workers who are bunched at the low end of the distribution. The base run assumes unchanging labor force participation rates, so most of the high-paying jobs go to nonnative males. In an experiment discussed below, this assumption is relaxed.

FIGURE 1. INCOME DISTRIBUTION FOR TOTAL POPULATION




Source: See text.

FIGURE 2. GINI INDEXES FOR BASE CASE AND RAPID GROWTH CASE




Source: See Text.

More rapid growth of the Alaska economy tends to increase inequality, as shown in Figure 2. The overall Gini index for the rapid-growth case exceeds the index in the base case in all years. The peak in 1980 reflects the assumption of construction of a natural gas pipeline and the abnormally high wages it entails. Alaska's support sector grows more rapidly in the faster-growth case, creating new relatively low-wage jobs which tend to raise the Gini index.

One can relax the assumption of an unchanging participation rate structure by allowing the rates for native Alaskans to move toward the nonnative male rates. In this simulation, it is assumed that 2 percent of the gap is closed each year. This progress could be the result of an extensive manpower training program. Such a program, as simulated here, would result in both increasing participation by natives and a changing occupational mix.

The results of this simulation are presented in Table 3, where we compare the base case with the case in which the gap is closed as suggested above. Native participation rates are higher, as are earnings per worker; both reflect occupational shifting. The Gini index for native females is also higher, however, as a new native middle class begins to coexist with the former low-wage groups. The classic growth-versus-equality trade-off is quite evident in this example. The Gini index for native males falls in 1990, however, a fact which suggests that the trade-off may not be inevitable in all cases.[38]

TABLE 3. PARTICIPATION RATE EXPERIMENT, 1990

| | Base Case | Gap-Closed Case |
|---|---|---|
| Native males | | |
| Participation rate | .459 | .498 |
| Earnings per worker | 9,555 | 10,035 |
| Income per capita | 3,498 | 3,958 |
| Gini index | .400 | .397 |
| Native females | | |
| Participation rate | .311 | .393 |
| Earnings per worker | 7,293 | 8,883 |
| Income per capita | 2,017 | 2,920 |
| Gini index | .403 | .414 |

## Usefulness of the Model

I have presented above a relatively simple method of projecting a regional income distribution based on a regional econometric model. A number of restrictive assumptions are required. In particular, I have been forced to simulate the labor market in the form of a job-competition, rather than a neoclassical wage-competition, model. Thus, labor markets with excess supplies and shortfalls are equilibrated by occupation shifting among workers, with the demand for occupations and relative wages remaining unchanged.

Time-invariant matrices of occupational demand by industry and of occupational supply by demographic subgroup are lesser assumptions which greatly simplify the simulation process and lead to experiments such as the extension of the simulation process to an income distribution, as reported above. Many other minor assumptions must also be made, such as having a constant set of $K_i$s, which would have a relatively small impact if relaxed. A cautionary note: To eliminate the necessity for all of these assumptions would require additional data which might be expensive and difficult to obtain.

The simulations demonstrate, however, that this model can be used to examine important distributional issues in a regional context. Work in progress is centering on increasing the degree of distributional detail and on relaxing some of the assumptions.

### FOOTNOTES

1. Guidance and helpful criticism from David Kresge are gratefully acknowledged. Remaining errors are the responsibility of the author. This research was supported by the National Science Foundation. An earlier version of this paper was presented at the 1978 meeting of the Population Association of America.
Norman J. Glickman's "Son of 'The Specification of Regional Econometric Models' " [*Papers of the Regional Science Association*, vol. 32 (1974), pp. 155-77] provides a good summary of regional economic models. Charles E. Metcalf's *An Econometric Model of the Income Distribution* (Chicago: Markham Publishing, 1972) is one of the few U.S. national models to address explicitly the distribution of income. See Sherman Robinson, "Toward an Adequate Long-Run Model of Income Distribution and Economic Development," *American Economic Review*, vol. 66, no. 2 (May 1976), pp. 122-27, for a discussion of income modeling in less developed countries.
2. A full description of the model is contained in David T. Kresge et al., *Issues in Alaska Development* (Seattle: U. of Washington Press, 1978), and policy applications are reported in David T. Kresge and Daniel A. Seiver, "Planning for a Resource-Rich Region: The Case of Alaska," *American Economic Review, Papers and Proceedings*, vol. 68, no. 2 (May 1978), pp. 99-104.
3. This section is based on Kresge and Seiver, op. cit.
4. See footnote 1.
5. The population model is discussed in detail in Daniel A. Seiver, "Alaskan Economic Growth: A Regional Model with Induced Migration," mimeographed (Paper presented at the Annual Meeting of the Regional Science Association, Cambridge, Mass., November 1975).
6. The military and military-dependent population is treated exogenously.
7. The fiscal model is described in detail in Oliver S. Goldsmith, "A Fiscal Model for Alaska: Structure and Policy Applications," mimeographed (Paper presented at the Annual Meeting of the Western Economic Association, Anaheim, Cal., June 1977).
8. See Kresge et al., op. cit., and Kresge and Seiver, op. cit.
9. See Harry G. Johnson, *The Theory of Income Distribution* (London: Gray-Mills, 1973).
10. Gini first published his index in 1912.
11. Daniel A. Seiver, "The Measurement of Income Inequality with Interval Data," *Review of Income and Wealth*, vol. 25, no. 2 (June 1979), pp. 229-34.
12. Gian Sahota, "Theories of Personal Income Distribution: A Survey," *Journal of Economic Literature*, vol. 16, no. 1 (March 1978), pp. 1-56.
13. Gary Becker and Barry Chiswick, "Education and the Distribution of Earnings," *American Economic Review*, vol. 56, no. 2 (May 1966), pp. 358-69.
14. Jacob Mincer, *Schooling, Experience and Earnings* (New York: National Bureau of Economic Research, 1974).
15. Alan S. Blinder, *Toward an Economic Theory of Income Distribution* (Cambridge, Mass.: M.I.T. Press, 1974).
16. See Robin G. Hollister, "The Economics of Manpower Forecasting," *International Labor Review*, vol. 89, no. 4 (April 1964), pp. 371-97.
17. Jan Tinbergen, *Income Distribution: Analysis and Policies* (Amsterdam: North-Holland, 1975).
18. Frederick L. Golladay and R. H. Haveman, *The Economic Impacts of Tax-Transfer Policy* (New York: Academic Press, 1977).

19. Lester C. Thurow, *Generating Inequality: Mechanisms of Distribution in the U.S. Economy* (New York: Basic Books, 1975).
20. In Britain between 1412 and 1914 (500 years), the wage rate for masons remained 50 percent above that for laborers. Ibid., p. 58. Wage stratification is documented in Peter B. Doeringer and Michael J. Piore, *Internal Labor Markets and Manpower Analysis* (Lexington, Mass.: D. C. Heath, 1971).
21. A good review of stochastic theories is contained in Blinder, op. cit., chap. 1.
22. See Paul Taubman, *Sources of Inequality in Earnings* (Amsterdam: North Holland, 1975). Even in Taubman's equations, however, there is still much unexplained variation.
23. This section is based on Daniel A. Seiver, "Projections of Manpower Requirements and Supplies Using Public Use Sample Data," *Review of Public Data Use*, vol. 6, no. 1 (January 1978), pp. 3-11.
24. The full table is available from the author.
25. Of course, these proportions will probably change for many reasons, including changing labor market conditions, technological progress, and the distribution of firms by size and type within each sector. This type of fixed proportions matrix has recently been used by Golladay and Haveman, op. cit., in their income distribution work.
26. The data used are a combination of the four state-identified 1 percent Public Use Samples for Alaska, 1970 (12,000 records).
27. The full table is available from the author.
28. What is missing from this version of the model is an opportunity for relative occupational wages to change in response to changing relative demands. With sufficient labor queueing (the unemployment rate in Alaska is usually double the national average, but real wages are very high), if we use the method of Thurow and others, the omission may not be so serious. In future research, I will attempt to simulate neoclassical labor market adjustment.
29. Age groups are 15-19 years, 20-24, 25-34, 45-54, 55-64, and over 65 years.
30. The coefficients are available from the author.
31. We could easily allow for direct or indirect discrimination through the occupational mix within each occupation group.
32. Hours worked are based on those reported for the week immediately preceding the 1970 census, while weeks worked is based on 1969 data. Part-time workers in representative groups in the Alaska population tend to work between 0.4 and 0.6 of full-time hours.
33. Reporting biases in the income data make it very difficult to find any function that fits well consistently. See Seiver, "The Measurement of Income Inequality." Metcalf, op. cit., among others, has pointed out that earnings distributions are not normal in shape. His displaced log-normal form is too complicated to be used here, however. Some representative plots of earnings distributions are available from the author.
34. The Gini index can be misleading when the underlying Lorenz curves intersect. A. B. Atkinson, "On The Measurement of Inequality," *Journal of Economic Theory*, vol. 2, no. 3 (September 1970), pp. 244-63, provides an excellent discussion of alternative measures of inequality, including his own.
35. Kresge and Seiver, op. cit., and Kresge et al., op. cit., provide extensive discussions of projections of Alaska's growth.
36. Steady growth in real per capita state expenditures, funded principally by oil revenues, produces fairly steady growth. See Kresge and Seiver, op. cit. Total income in the income distribution model is forced to be consistent with total income in the economic model; the required adjustment is less than 10 percent.
37. This suggests that educational "screening" for the high-paying occupations and on-the-job experience differentials are sufficient to produce the familiar skewed earnings distribution.
38. There is no method to measure the envy and frustration that may be felt by the native males and females left behind as the native middle class emerges. The problem bears striking resemblance to the U.S. black poverty problem.