An Analysis of Migration in Oklahoma

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The percentage change in population between 1950 and 1960 ranged from 64.6 percent for Comanche county to —31.5 percent for Haskell country. A large part of this variation is attributable to differences in migration rates. Therefore, in order to understand the factors influencing population changes, it is necessary to understand the factors influencing migration.

There is currently considerable interest in attracting industry to the state and promoting the economic development of the state. One of the expected payoffs from the success of this effort is an increase in total state personal income. An additional result is likely to be a smaller volume of migration from the state and, therefore, a larger population than would otherwise exist. Thus the effect of industrialization programs upon per capita income depends not only on its effect on total income but also on its effect upon population. Any influence which affects either population levels or income may also affect both the demand for public and private services and the institutions which are needed to provide these services. These changes need to be anticipated. Previous studies [5, 6] have been devoted to the estimation of the effects of changes in the economic structure upon income and employment levels. This study is designed to determine the effect of employment levels and other factors upon migration.

Objectives of the Study

The objectives of this study are:

1. To determine the factors most likely to influence migration in Oklahoma,
2. To determine which of the previously existing models of migration seem most useful for analyzing Oklahoma migration,
3. To estimate the parameters of these models using data for various regions of Oklahoma,
4. To determine the effect of adjacent regions upon migration, and
5. To determine the effect of migration inducing stimuli upon the various age groups in the population.

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Previous Studies

Thornthwaite [13] used census data to study internal migration in the United States from 1850 to 1930. One of the statistics used to estimate population movement was the *birth-residence index of population movement.* This statistic was computed for Oklahoma in 1930 (for example) by subtracting the number of persons born in Oklahoma but living outside of Oklahoma in 1930 from the number of persons born outside of Oklahoma but living in Oklahoma in 1930. Aside from errors occurring during the collection and processing of the basic census data, this statistic provides a good measure of the migration component of the population of the state at a particular census. It usually provides a rather poor measure of the total volume of migration that has occurred since migrants who have died or returned to their state where born are not counted. It provides a poor measure of the migration during any time period since for each individual migrant the relevant time period began at the time of his birth. For example, the Oklahoma *index* for native whites in 1900 of 486 (see Table 1) probably resulted primarily from the migration of settlers into Oklahoma during the 1890's, but the index value of 890 in 1910 probably resulted from migration during both the 1890's and the decade after 1910.

Thus a second statistic, *the decennial change in the birth-residence index,* was used to estimate the volume of net migration during each decade. Some of these statistics for Oklahoma from 1890 to 1960 are presented in Table 1. These two statistics are useful for examining past patterns of net migration because they are virtually the only such measures that can be obtained for each state in the nation. Some caution is

Table 1. Oklahoma Birth-Residence Indices of Population Movement, 1890 to 1960.

	Native Whites		Native Negroes		Native Non-Whites	
Year	Index	Change	Index	Change	Index	Change
			(1000's)			
1890	54		3			
1900	486	432	30	27		
1910	890	404	85	55		
1920	852	—37	70	—15		
1930	681	—171	56	—14		
1940	233	—449			—26	
1950	—215	—448			—23	—49
1960	—519	—303			—52	—30

Source: Native white data for 1930 and earlier census years were obtained from Plates I and II of [13]. Data for the change in birth-residence indices for native negroes were obtained from Plate III of [13]. Other data were computed from State of Birth data [20, 35, 37] compiled with decennial censuses.

in order, however, since these statistics are sensitive to the deaths of persons in the migrant streams. For example, by 1950 the persons born outside of Oklahoma but living in Oklahoma were on the average much older than the persons born in Oklahoma but living elsewhere. As a result about one-third of the decrease in the native white birth residence index between 1950 and 1960 can be attributed to deaths of past migrants rather than to out-migration.

Thornthwaite also constructed estimates of the *gross decennial interchange of population* for each state during 1900 to 1910, the volumes and patterns of migration of various racial groups, net rural-to-urban migration for selected areas, net migration estimates for the counties of selected states, and year-to-year changes in population of Oklahoma counties (estimated on the basis of school census data).

Tarver [12] estimated the net migration component of population change from 1940 to 1950 for each of Oklahoma's counties, and state economic areas. The estimates for the state economic areas are presented in Table 2. He and his associates have also made extensive projections of the population of various areas of Oklahoma.

Previous investigators have employed several alternative models to explain the volume and direction of migration. The models used include Markov process models, gravity models, and prospective unemployment models.

Table 2. Estimates of Net In-Migration 1940-1966 for the State Economic Areas in Oklahoma.

State Economic Area[1]	Estimated Net Migration 1940-1950	1950-1960	1960-1966
1	—24,565	—20,838	—600
2	—27,898	—32,309	—5,500
3	—28,465	—12,471	—200
4	—58,627	—20,680	—15,000
5	—56,001	—38,371	—7,100
6	—74,433	—39,086	—6,200
7	—71,173	—30,091	—3,400
8	—55,694	—41,884	—700
9	—73,573	—41,665	—10,200
10	—18,577	—10,081	7,000
A	13,552	38,530	—10,200
B	38,066	41,049	2,100
C	—19,113	—7,241	18,000
D	—4,373	—3,298	4,800
State Total	—460,874	—218,436	—6,000[2]

Source: 1940-1950 data were compiled from [12].
1950-1960 data were compiled from [15].
1960-1966 data were compiled from [16].
[1]Oklahoma's State Economic Areas are shown in Figure 1.
[2]The individual estimates do not sum to the total due to rounding error.

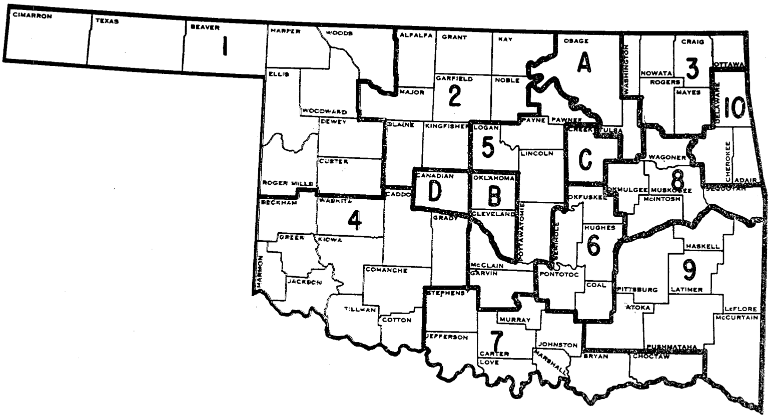

Figure 1. The State Economic Areas of Oklahoma.

The use of Markov models has usually been justified on the basis of their simplicity, their ability to describe current behavior, and their ability to indicate the consequences of the continuation of present trends rather than on the basis of their causal validity. Their usefulness therefore depends partly upon their ability to predict future population. Their predictive ability depends in turn upon the stability of certain out-migration and in-migration rates. The historical migration data for the state of Oklahoma suggest that these rates are not stable. Thus it seemed more appropriate to use other models which do not require stable migration rates but which attempt to relate migration rates to labor market conditions and to other social and economic variables. The models adopted for this study included gravity models and prospective unemployment models.

Gravity Models

Some of the earliest models employed to analyze migration flows were called gravity models inasmuch as they have the same form as the formula used to represent the force of attraction between two particles. This formula is:

$$f = \frac{Gm_1m_2}{d^2}$$

where

f represents the force of attraction between the two particles,
G is a universal constant,

m_1 and m_2 represent the masses of the particles, and
d represents the distance between the particles.

It has been argued [9] that the probability that any individual would migrate from one region to a second region should be directly proportional to the number of jobs available or to the volume of other opportunities available in the second region and inversely proportional to the difficulty of making the move. Population or the number of employed persons in the second region is usually used as a proxy for the number of opportunities available; some function of the distance between the regions is often used as a proxy for the difficulty of making the move. The expected number of migrants should be equal to the probability of any individual moving times the number of persons or workers in the first region.

The Zipf Model

Thus the Zipf model [41], for example, has the form:

$$M_{ij} = \frac{KP_iP_j}{(D_{ij})^a}$$

where

M_{ij} equals the gross migration between regions i and j,
P_i and P_j equal the populations of regions i and j respectively,
D_{ij} equals the distance between regions i and j, and
a and K are constants.

The Somermeijer Model

The Zipf model has the same major fault as the Markov model, that is, it does not allow migration rates to change in response to economic and other stimuli. However, Somermeijer [11] has shown that Zipf's model can be partitioned in a way which allows the use of economic, social, and other variables to explain the volume of migration from one region to another region. His model has the form:

$$M_{i \rightarrow j} = [K/2 + C(F_j - F_i)] \frac{P_iP_j}{(D_{ij})^a}$$

where

$M_{i \rightarrow j}$ equals the volume of migration from region i to region j,
F_i and F_j are vectors of factors measuring various aspects of the attractiveness of regions i and j, respectively,

C is a vector of parameters associated with $(F_j - F_i)$, and the rest of the symbols have the same meaning as in the Zipf model.

Adding the equations for $M_{i \to j}$ and $M_{i \to j}$ gives the Zipf model. Thus the added variables serve to distribute gross migration between the two migration streams but do not affect the volume of gross migration between any two regions. Of course the incorporation of these factors may change the estimates obtained for a and k when this model is applied to any sample data.

The Lowry Model

The Somermeijer model is somewhat difficult to fit. Therefore, Lowry [7] has formulated an alternative model. The conceptual form of his model is given by:

$$M_{i \to j} = K[\frac{U_i}{U_j} \cdot \frac{W_j}{W_i} \cdot \frac{L_i L_j}{D_{ij}}]$$

where

L_i and L_j equal the number of persons in the non-agricultural labor force in regions i and j,

U_i and U_j equal the unemployment rates existing in regions i and j,

W_i and W_j equal the hourly manufacturing wage rates in regions i and j,

D_{ij} is the airline distance from region i to region j in miles, and

K is a constant.

Actually, Lowry's conceptual form is somewhat misleading. The form that is usually fitted is:

$$\log M_{i \to j} = \log K + a_1 \log U_i + a_2 \log U_j + a_3 \log W_j + a_4 \log W_i + a_5 \log L_i + a_6 \log L_j + a_7 \log D_{ij}$$

where the a_i's $(i = 1, 2, \ldots 7)$ are unknown parameters. All other symbols are defined above.

Data Available

Migration data of the origin and destination type are available for fourteen areas of Oklahoma for the 1955 to 1960 period [36]. For the purpose of fitting various forms of the models described above, data for Creek county (area C) was combined with the data for Tulsa and Osage counties (area A) and data for Canadian county (area D) was combined with the data for Cleveland and Oklahoma counties (area B). These data are presented in Table 3.

Table 3. Migration Between the Twelve Areas of Oklahoma, 1955-1960.

Gaining	Losing Regions											
Regions	1	2	3	4	5	6	7	8	9	10	A+C	B+D
1		1429	213	2626	804	295	615	191	158	43	516	972
2	1501		569	741	1763	318	621	409	138	78	1584	2126
3	160	414		259	824	276	253	963	436	710	4721	762
4	1718	964	307		1641	592	2106	495	725	175	823	3685
5	885	2551	870	2169		1843	2090	1207	971	163	3911	5571
6	52	184	220	419	1549		973	639	690	68	808	1466
7	239	327	254	1965	1810	1205		345	1712	49	833	2338
8	207	517	770	538	574	1050	445		993	956	3800	1297
9	80	140	269	270	417	434	1061	1004		97	615	930
10	129	123	734	113	121	101	141	934	205		1373	346
A+C	264	1854	4873	989	3602	1672	1063	5500	1132	1420		3957
B+D	2211	3953	1192	7442	8651	3953	4385	2436	2831	318	5407	

Source: [36].

Peach, Poole, and Tarver [10] have used school enrollment data to estimate the 1955 population of each of Oklahoma's seventy-seven counties. Their estimates were designed to be consistent with a Bureau of the Census estimate of the state's population in 1955 [18]. For the purpose of this study the Peace, Poole, and Tarver county estimates were used to obtain estimates for each of the twelve areas considered. These estimates were in turn adjusted to conform to a more recent estimate of the state's populaion in 1955 [19]. The resulting estimates are presented in Table 4.

Average wage rates vary among the twelve areas both because of regional differences in the wage paid in particular industries and because of regional differences in the numbers of workers employed in each industry. In order to partially correct for the difference in "industry mix", data from [38] were used to construct a set of 144 wage rates. A set of twelve wage rates were constructed for each of the (twelve) areas. One of these wage rates estimated the non-agricultural wage rate in that region. The other eleven wage rates were designed to estimate the wage that an average worker in that region could have received in each of the other regions.

Table 4. Estimated 1955 Population for Twelve Areas of Oklahoma.

Area	Population	Area	Population
1	94,103	7	165,784
2	169,674	8	160,697
3	134,096	9	126,016
4	250,778	10	44,123
5	182,350	A+C	370,700
6	96,216	B+D	455,457

Table 5. Highway Distances Between the Twelve Areas of Oklahoma.

Areas	Areas											
i, j	1	2	3	4	5	6	7	8	9	10	A+C	B+D
1	---	158	315	184	224	253	304	282	360	334	264	180
2		---	170	143	104	161	211	171	262	193	121	86
3			---	276	119	153	229	94	190	82	61	178
4				---	162	131	141	214	225	261	216	98
5					---	80	148	81	170	120	61	69
6						---	80	92	115	136	108	75
7							---	153	129	189	182	125
8								---	121	51	49	125
9									---	135	164	180
10										---	72	174
A+C											---	118
B+D												---

One to three towns were selected near the center of each region. This resulted in one to nine (highway) distances which could be used for each pair of areas. The distance actually used (see Table 5) was an average of these distances.

Forms of the Gravity Model Actually Used

Three versions of the Lowry model and four versions of the Somermeijer model were fitted to the available data. These seven models can be regarded as specializations of the more general model:

$$M_{i \rightarrow j} = (\beta_0 + \beta_1 W_{ii} + \beta_2 W_{ij}) \frac{P_i^{\beta_3} P_j^{\beta_4}}{d_{ij}^{\beta_5}} \left(\frac{W_{ij}}{W_{ii}}\right)^{\beta_6}$$

where

$M_{i \rightarrow j}$ equals the number of migrants from area i to area j between 1955 and 1960,

W_{ii} equals the 1956 wage rate in area i (in thousands of dollars),

W_{ij} equals the 1956 predicted wage rate in area j for an "average" worker in area i (in thousands of dollars),

P_i and P_j equals the estimated 1955 population (in ten thousands of persons) in areas i and j, respectively,

d_{ij} equals the highway distance (in hundreds of miles) between areas i and j, and the

β_k's (k = 0, 1, ... 6) are parameters.

β_1 and β_2 were assumed to be equal to zero for the first version of the Lowry model:

$$\text{(a.)} \quad M_{ij} = \frac{\beta_0 P_i^{\beta_3} P_j^{\beta_4}}{d_{ij}^{\beta_5}} \left(\frac{W_{ij}}{W_{ii}}\right)^{\beta_6}.$$

The second version incorporated the additional assumption that β_3 equals β_4:

$$\text{(b.)} \quad M_{ij} = \frac{\beta_0 (P_i P_j)^{\beta_3}}{d_{ij}^{\beta_5}} \left(\frac{W_{ij}}{W_{ii}}\right)^{\beta_6}.$$

The third version restricted the model further by assuming that β_6 equals zero:

$$(c.)\quad M_{ij} = \frac{\beta_0 (P_i P_j)^{\beta_3}}{d_{ij}^{\beta_5}}.$$

For all versions of the Somermeijer model β_3 and β_4 were assumed to be equal to one and β_6 was assumed to equal zero. In addition all but the fourth version involved the assumption that β_5 equals one. Thus the first version is:

$$(d.)\quad M_{ij} = (\beta_0 + \beta_1 W_{ii} + \beta_2 W_{ij}) \frac{P_i P_j}{d_{ij}}.$$

The second version also incorporated the assumption that β_1 and β_2 are of equal magnitude but have opposite signs:

$$(e.)\quad M_{ij} = [\beta_0 + \beta_1 (W_{ii} - W_{ij})] \frac{P_i P_j}{d_{ij}}.$$

The third version restricted the model still further by setting β_1 and β_2 equal to zero:

$$(f.)\quad M_{ij} = \frac{\beta_0 P_i P_j}{d_{ij}}.$$

The fourth version involved only the assumptions that β_3 and β_4 equal one and β_6 equals zero:

$$(g.)\quad M_{ij} = (\beta_0 + \beta_1 W_{ii} + \beta_2 W_{ij}) \frac{P_i P_j}{d_{ij}^{\beta_5}}.$$

Estimation Procedures

All seven models were fitted using weighted least squares techniques. Each observation was weighted by a weight equal to the inverse of the square root of the losing region's population (in tens of thousands). Initial parameter estimates were obtained for models a, b, and c by subjecting the logarithms of the relevant variables to (unweighted) multiple regression analysis. The estimates obtained for the seven models fitted are presented in Table 6. Standard errors are presented in parentheses for some of the estimates.

Model a provides no support for the hypothesis that migrants move because of wages differentials. Model b and the Somermeijer models do provide some support for this hypothesis.

Lowry's results [7] tend to imply that economic conditions are more important as attractive forces than as repulsive forces. The results presented here tend to support the opposite view. Beale [1] has claimed that both roles are important. His analysis suggests that economic conditions such as those prevailing in the SMSA's considered by Lowry do act as attractive forces and that the decline in employment in rural areas (ten of the regions considered here are predominately rural) due to technological changes in agriculture and other factors can act as repulsive forces.

Prospective Unemployment Models

Blanco [2, 3] has proposed a model that can be used to analyze net migration. The model suggests that net migration from a region is due to net movements of military personnel from the region or "prospective unemployment" in that region. Blanco's articles do not define "prospective unemployment" very clearly but it seems clear that it is a function of the natural increase in the population of labor force age and the change in employment.

The Basic Prospective Unemployment Model

The basic prospective unemployment model used in this study has the form:

$$M_i^c = \beta_0 P_i + \beta_i \Delta MP_i + \beta_2 \Delta LF_i + \beta_3 \Delta E_i + \beta_4 LF_i + \beta_5 E_i + U_i$$

where

M_i^c equals net civilian migration into county i between 1950 and 1960,

P_i equals the population of county i in 1950,

ΔMP_i equals the net migration of military personnel into county i between 1950 and 1960,

ΔLF_i equals the natural increase in persons aged 15 to 64 in county i between 1950 and 1960,

ΔE_i equals the change in the number of persons employed in county i between 1950 and 1960,

Table 6. Estimates of the Parameters of the Gravity Models.

Model	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\beta}_5$	$\hat{\beta}_6$	Residual Sum of Squares (1,100's)
a (initial estimates)	7.645			.740	1.067	1.246	—.280	3.315
				(.119)	(.110)	(.104)	(.248)	
a	8.326			.635	1.161	1.032	—.232	2,885
b (initial estimates)	7.288			.912	.912	1.247	.068	3,746
				(.061)	(.061)	(.105)	(.138)	
b	7.734			.917	.917	1.026	.402	3,217
c (initial estimates)	7.356			.910	.910	1.247		3,847
				(.061)	(.061)	(.105)		
c	11.832			.856	.856	1.047		3,484
d	9.141	—1.459	.056	1.000	1.000	1.000		2,999
	(1.517)	(.272)	(.349)					
e	4.523	—.916	.916	1.000	1.000	1.000		3,217
	(.163)	(.213)	(.213)					
f	4.737			1.000	1.000	1.000		3,676
	(1.6546)							
g	9.562	—1.477	.067	1.000	1.000	1.082		2,973

LF_i equals the number of persons aged 15 to 64 in county i in 1950,
E_i equals the number of persons employed in county i in 1950,
and the β_k's ($k = 0, 1, 2, \ldots 5$) are paramenters, and
U_i is the error term associated with this model for the ith county.

This model treats the change in employment during the decade as a predetermined variable. Some persons (see [4], for example) have criticized this assumption and claim that there is a "feedback" from migration to employment. Presumably this "feedback" could take one of two forms. On the one hand, if migration changes the supply of local labor and thereby changes the wage rate then employment could be affected. On the other hand, in-migration could increase the demand for local services and thereby increase employment. There is undoubtedly some "feedback" effect. However, the existence of low average returns to labor in agriculture, low wage rates, minimum wage laws, and the small size of most of Oklahoma's counties suggests that the "feedback" is probably rather small in Oklahoma.

Blanco's version and most other versions of this model do not include variables such as LF_i and E_i. Presumably this is due to the fact that they assume migration during a period tends to achieve a sort of balance between the labor force and employment at the end of the period. However, it seems reasonable to believe that migration which occurred in the first part of the decade may be more easily attributed to conditions existing at the beginning of the decade than to those expected at the end.

Blanco and others have typically formulated their versions of this model using variables expressed at rates per 1,000 population for each county rather than using the absolute volumes for each county. The economic model itself is unaffected by this difference. The estimates obtained for the parameters would also be unaffected by this difference if the assumptions made about the error terms are also changed in a consistent manner.

Data Available

Survival ratios from [17] and 1950 populations of each of the various age groups from [31, Table 41] were used to estimate the number of persons in the 15 to 64 age group in 1950 and to estimate the natural increase in this age group between 1950 and 1960. Employment data from the 1950 and 1960 censuses [31, Table 43; 32, Table 85] were used to estimate the change in employment for the same period and the number of persons employed in 1950. The difference between estimated net total migration and net civilian migration between 1950 and 1960 provided an estimate of the military component of net migration during this period.

Estimation Procedure

For the purpose of estimating the parameters of this model it was assumed that the variance of the error term for each county is proportional to the 1950 population for that county. Thus the estimates of the parameters were obtained using weighted regression. Each county's observation was weighted by the inverse of the square root of the population of that county. The estimates obtained are presented in Table 7.

An Alternative Labor Force Definition

The choice of the age group 15 to 64 to represent the working force age group was somewhat arbitrary. Therefore an alternative model was fitted which used the age group 20 to 64 to represent the working force age group. The estimates obtained for this model are also presented in Table 7.

An Attempt to Use Additional Information

Tweeten [14] has suggested that the attitudes held by persons living in depressed regions are different from those held by persons living in developing regions. It seems reasonable to assume that these attitudes could also influence migration. Of course it is not possible to directly include these attitudes in the model. However, if these attitudes and their effects are rather persistent then their effect upon migration dur-

Table 7. Estimates Obtained for the Parameters of the Prospective Unemployment Model.

	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\beta}_5$	Residual Sum of Squares
Basic Model	.454 (.184)	.769 (.103)	—1.162 (.307)	2.188 (.090)	—1.088 (.262)	.521 (.134)	1965
Model with alt. definition of labor force age	.157 (.127)	.760 (.104)	—1.179 (.304)	2.124 (.092)	—.683 (.228)	.448 (.168)	1985
Zellner's method 1950-1960 period	.414 (.181)	.712 (.102)	—1.147 (.305)	2.147 (.089)	—1.062 (.258)	.591 (.133)	
Zellner's method 1940-1950 period	—.707 (.271)		—.779 (.413)	1.578 (.149)	.193 (.429)	1.405 (.275)	
Adjacent county effects model	.453 (.185)	.766 (.105)	—1.171 (.313)	2.164 (.095)	—1.084 (.264)	.516 (.137)	1964 ($\hat{\lambda}$=.0057)
Adjacent county effects model	.408 (.187)	.769 (.104)	—1.114 (.302)	2.207 (.089)	—1.037 (.264)	.537 (.135)	1944 ($\hat{\lambda}$=.0092)

ing the 1940 to 1950 period should be similar to, and thus probably correlated with, their effect upon imgration during the 1950 to 1960 period.

If the effects of these attitudes are substantially independent of the variables already incorporated in the model, the residuals from the two periods should be correlated. Finally, if all of the above conditions are met and, in addition, the explanatory variables for the two periods are reasonably uncorrelated then one would expect some gain in the efficiency of estimation of the 1950-1960 period parameters as a result of fitting the models for the two periods simultaneously.

A migration model for the 1940 to 1950 periods was constructed. It is analogous to the 1950 to 1960 model except that military migration was excluded. This variable was excluded only because it was not possible to obtain estimates of net military migration for the 1940 to 1950 period.

Zellner's method [40] was used to estimate the parameters of these two models simultaneously. The estimates for the two periods are presented in Table 7. They are very similar to the estimates obtained independently for that period. This is, of course, consistent with the fact that the calculated correlation between the residuals for the two periods was only about .17.

The Effect of Adjoining Counties

Up to this point it has been assumed that net migration into any given county is influenced only by labor market conditions and other conditions in the same county. However, a county is usually too small to be a complete economic system or even to include the entire labor market area relevant to its population or employers. Some people, therefore, live in one county and work in another county. Thus labor market conditions in one county could influence net migration in adjoining counties. An excess of jobs in one county could serve either to encourage migration to that county from adjoining counties or to discourage migration to more distant locations.

State and national variables undoubtedly affect Oklahoma migration but there is very little that can be done with cross section data about estimating these effects since these effects are presumably the same for each county. Thus, it is simply necessary, when applying the results to different time periods, to make a priori adjustments in the coefficients to account for changes in state and national variables. It should be possible to determine the effect of conditions in adjoining counties. Therefore, the model was extended by adding an additional set of six additional explanatory variables. Each of the additional variables was analogous to one of the original variables and was constructed by summing the values taken by the analogous "in-county" variable in each of the adjoining counties. The needed data for counties of bordering states was obtained from Tables 41 and 43 of [21, 23, 25, 27, 29, 33] and Table 85 of [22, 24, 26, 28, 30, 34]. In order to compensate for the fact that not all counties share borders with the same number of counties this sum was then divided by the number of adjoining counties. It seemed reasonable to assume that the parameters associated with included "adjoining county" variables are proportional to the parameters associated with the corresponding "same county" variables.

Thus this model has the form

$$M_i^c = \beta_0 P_i + \beta_1 \Delta MP_i + \beta_2 \Delta LF_i + \beta_3 \Delta E_i + \beta_4 LF_i + \beta_5 E_i + \frac{\lambda}{n_i} \left[\sum_{j \varepsilon A_i} (\beta_0 P_j + \beta_1 \Delta MP_j + \beta_2 \Delta LF_j + \beta_3 \Delta E_j + \beta_4 LF_j + \beta_5 E_j) \right] + U_i$$

where: λ is the proportionality parameter,

A_i is the set of indices of counties surrounding county i, and

n_i is the number of counties surrounding county i. (All other parameters have been defined previously.)

Two versions of this extended model were fitted. The first version has been discussed above. The second version is the same as the first except that the average population of adjoining counties and the average military migration into adjoining counties were deleted from the model.

Estimates of the seven parameters (β_k, k = 1, 2, . . . 6 and λ the proportionality parameter) of these models are presented in Table 7. Surprisingly, these estimates provide very little support for the inclusion of variables from adjoining counties. The "same county" variables dominated the "adjoining county" variables and thus the estimated effect of adjoining counties variables as reflected by the estimate of proportionality coefficient λ is less than one percent of the "effect" of the "same county" variables in both cases. The estimated values of the other parameters are virtually identical with those obtained using the original model.

The method employed above is probably lacking in intuitive appeal. A more appealing but virtually powerless test was also employed. The "predicted" migration for the state of Oklahoma during 1950-60 was compared with the actual migration. This sort of test is intuitively appealing but its nature is such that it is virtually useless. The "state" equation is equal to the sum of the equations for the seventy-seven counties. If unweighted regression had been applied to the data for the counties and if an intercept term had been included in the model, this procedure would only test the accuracy of the data construction and the computational accuracy. The intercept was excluded on *a priori* grounds since it did not seem reasonable to assume that every county, regardless of size and population, would, all other things being equal, lose or gain the same number of persons simply because it is a county. The effects of weighting and omission are hard to assess but probably are small.

As might be expected, the "predicted" migration is very close to the "actual" migration. "Actual" migration was -220,729; the prediction was -220,698. If this prediction had been independent of the data used to estimate the parameters, the expected standard error would have been about 11,000.

Analysis of the Migration of the Various Age Groups

Since the various age groups would be expected to react differently to various migration stimuli, two approaches to the estimation of the impact of these stimuli were employed in this study.

Decomposition of the Prospective Unemployment Model by Age Groups—

One approach involved the division of the total effect of each of several stimuli among the various age groups in the population. This is the simplest of the two approaches and is guaranteed to produce estimates which are consistent with (i.e. could be aggregated to get) the initial model adopted. The model used was

$$M_{ij} = P_i\hat{\beta}_0\gamma_{0j} + \Delta MP_i(\hat{\beta}_1 + 1)\gamma_{1j} + (\Delta LF_i\hat{\beta}_2 + \Delta E_i\hat{\beta}_e)\gamma_{2j}$$
$$+ (LF_i\hat{\beta}_4 + E_i\hat{\beta}_5)\gamma_{3j} + U_{ij}$$

where: M_{ij} is the volume of total net migration of the jth population group into the ith county between 1950 and 1960 (this data was obtained from [39]),

the γ_{ij}'s ($i = 1, \ldots 4$) are parameters (percentages) to be estimated, and

U_{ij} is the error term for the jth age group in the ith county. (All other variables have been defined previously.)

The coefficient of ΔMP_i involves $\hat{\beta}_1 + 1$ rather than $\hat{\beta}_1$ since the migration variable in this model is a measure of net total migration whereas the migration variable in the initial model was a measure of net civilian migration. Essentially this model groups the effects of the six variables used in the inital model into four effects: (a) the initial population "effect", (b) the military migration "effect", (c) the "effect" of a change in the volume of "prospective unemployment", and (d) the "effect of the volume of initial "unemployment".

The estimates of the γ's are presented in Table 8. The estimated standard errors are presented (in parenthesis) for the first age group. The estimated standard errors for any other groups can easily be inferred from this information and the residual sums of squares. The printed standard errors for all of the parameters and especially for the γ_2's and γ_3's would be expected to be too small due to the method of constructing the regressions associated with these parameters.

The persons in the first three age groups (those under 15 in 1960) presumably migrated because their parents did. The next two age groups are transitional groups. They were too young in 1950 to independently move in response to labor market conditions existing in 1950. However, by the end of the decade many of these persons had or would soon become old enough to enter the labor force. Thus they tended to move away from places with high employment rates in 1950 to places with high "prospective" employment rates in 1960.

As expected the migration of military personnel affected those of service age during the decade (those who were between the ages of 18 and 35 at sometime during the decade) and those young enough to be dependent (younger than 35 at sometime during the decade). Older age groups were essentially not affected at all by military migration.

Table 8. Estimates Obtained for the Parameters of the Decomposed Prospective Unemployment Model.

i	Age of Group in 1960	$\hat{\gamma}_{0j}$	$\hat{\gamma}_{1j}$	$\hat{\gamma}_{2j}$	$\hat{\gamma}_{3j}$	Sums of Squares: Total	Sums of Squares: Residual
1	0-4	.151	.056	.021	.137	176	123
		(.046)	(.013)	(.006)	(.041)		
2	5-9	.293	.131	.086	.265	797	175
3	10-14	.266	.042	.106	.251	1029	79
4	15-19	—.652	.080	.058	—.568	1874	151
5	20-24	—1.082	.286	.109	—.948	6471	382
6	25-29	.250	.128	.188	.243	3477	150
7	30-34	1.096	.172	.155	.992	2106	298
8	35-39	.446	.082	.085	.410	657	71
9	40-44	.132	.031	.054	.125	290	35
10	45-49	.014	.001	.041	.017	187	19
11	50-54	.010	.002	.031	.013	109	15
12	55-59	.015	.000	.022	.016	55	10
13	60-64	.035	.000	.014	.031	24	12
14	65-69	.022	—.003	.010	.018	23	17
15	70-74	.010	—.003	.008	.007	13	7
16	75+	—.005	—.005	.013	—.006	25	10

An Alternative Age Group Model —

The alternative approch is embodied in the following model:

$$M_{ij} = P_{ij} \left[\alpha_{oj} + \alpha_{1j} \frac{\Delta MP_i}{MAG_i} + \alpha_{2j} \frac{E_i + \Delta E_i}{LF_i + \Delta \hat{LF}_i} + \alpha_{3j} \frac{E_i}{LF_i}\right] + U_{ij}$$

where: P_{ij} is the intial population (population in 1950 or births in the decade) in the jth age group in the ith county,

MAG_i is the initial population aged 10 to 34 in 1950,

α_{ij} (i = 1, . . . 4) are parameters of the model for the jth age group. (All other variables have been defined above.)

This model involves the assumption that the percentage rather than the total number of an age group that migrates is dependent upon the various factors represented in the migration model.

All of the explanatory variables in this model except perhaps for the third one were defined in a fairly natural way. The third variable represents the "prospective" employment ratio for 1960. Since E_i and LF_i are already present in the fourth variable, the third one could reasonably have been:

$$P_{ij} \frac{\Delta E_i}{\Delta \hat{LF}_i}.$$

The estimates obtained with the model used are undoubtedly different than those that would have been obtained with alternative specifications of the third explanatory variable. Note that this sensitivity to specification was also present in the preceeding model, but since the preceeding model was linear in the variables ΔE_i, E_i, LF_i, and ΔLF_i the effect upon the estimates of an analogous change in the third variable can be determined from the estimates already obtained.

The results (see Table 9) obtained with the model are fairly consistent with those obtained from the other approach. Again the migration of persons in the first three age groups was probably due to the migration of their parents and thus the estimates for these age groups are not directly meaningful. The next few groups are transitional groups and once again appear to react differently to labor market conditions in 1950 than did older age groups. Again those under 35 at some time during the decade were most strongly affected by the migration of military personnel, whereas older groups were less affected and tended to offset to a small degree the effect of military migration.

Table 9. Estimates Obtained for the Parameters of the Alternative Age Group Model.

i	Age of Group in 1960	Mean Migration Rate	$\hat{\alpha}_{0j}$	$\hat{\alpha}_{1j}$	$\hat{\alpha}_{2j}$	$\hat{\alpha}_{3j}$	Residual Sum of Squares
1	0.4	—.011 (.008)	—.352 (.099)	.388 (.089)	—.011 (.079)	.631 (.241)	121
2	5-9	—.002 (.018)	—.409 (.126)	.543 (.091)	.820 (.109)	—.174 (.308)	228
3	10-14	—.102 (.020)	—.418 (.104)	.236 (.097)	1.054 (.084)	—.410 (.250)	127
4	15-19	—.143 (.031)	.769 (.192)	.688 (.186)	2.051 (.158)	—3.563 (.463)	335
5	20-24	—.271 (.065)	1.309 (.401)	2.905 (.411)	3.982 (.338)	—6.449 (.962)	1197
6	25-29	—.271 (.047)	—1.157 (.119)	1.195 (.115)	2.730 (.104)	—.771 (.282)	120
7	30-34	—.186 (.040)	—2.313 (.185)	1.699 (.203)	.867 (.177)	3.132 (.439)	371
8	35-39	—.096 (.023)	—1.083 (.136)	.822 (.128)	.780 (.113)	1.005 (.325)	123
9	40-44	—.068 (.017)	—.348 (.097)	.292 (.084)	.940 (.075)	—.427 (.229)	41
10	45-49	—.056 (.014)	.023 (.062)	—.033 (.056)	.932 (.047)	—1.046 (.146)	17
11	50-54	—.047 (.011)	.047 (.057)	—.026 (.054)	.740 (.044)	—.881 (.135)	13
12	55-59	—.031 (.009)	.080 (.054)	—.057 (.054)	.608 (.041)	—.784 (.127)	9
13	60-64	—.004 (.007)	.082 (.070)	—.077 (.073)	.394 (.054)	—.532 (.165)	12
14	65-69	.007 (.008)	.167 (.089)	—.166 (.089)	.362 (.071)	—.632 (.210)	16
15	70-74	.022 (.007)	.121 (.067)	—.114 (.071)	.366 (.055)	—.515 (.159)	7
16	75+	.000 (.004)	.031 (.035)	—.058 (.038)	.280 (.030)	—.304 (.082)	10

Comparison With the Results of Migration Studies of Metropolitan Areas

Mazek [8] conducted an analysis of the 1955-1960 migration of laborers in the nation's SMSA's. His variables were defined in terms of rates per person. The population base (or numerator) for these rates was the population that would have existed in 1960 if there had been no migration. The prospective unemployment rate was the primary explanatory variable.

His findings indicated that a prospective unemployment rate (for 1960) of about 12.7 percent would have been needed to discourage net white in-migration into the SMSA's considered. For non-whites a rate of 4.3 percent would have been required. In 1960 the actual (national) urban unemployment rate was about 11.7 percent.

The variables used in this study were defined somewhat differently. If the results of this study are adjusted to conform to Mazek's definitions they would indicate that a prospective unemployment rate (for 1960) of about 3.6 percent would have been required to prevent net out-migration of labor force age persons from Oklahoma. A prospective unemployment rate of about 4.7 percent would have been required to prevent net out-migration of the non-military population during the decade. Oklahoma's actual unemployment rate in 1960 was 4.4 percent.

The differences in these two results undoubtedly stem, in part, from differences in methodology and formulation. However, some of the differences can also be attributed to differences in the nature of the regions studied and to differences in the structure of labor markets and wage rates, and so forth prevailing in the regions considered. It would seem to be irrational to leave a region with a 4 to 5 percent unemployment rate to go to a region with a 10 to 12 percent unemployment rate except for the fact that wage rates are also higher.

Implications of the Findings

Two different types of models have been used to study migration. Of the two, the prospective unemployment model seems more useful. This judgment is based upon several considerations. First, the prospective unemployment model is linear. This means that it is much easier to formulate, estimate, and use. Second, the data needed for this model are available on a county basis. This means that greater flexibility was available (even though it was not used) in establishing regions to use in estimating the parameters of the model. It also means that more flexibility is available (even though it may not be used) in establishing regions to use when applying the results. This second consideration is made more important by the fact that the basic migration data needed for gravity models is usually collected for regions which are relatively homogeneous internally. Many of the regions to which the results might be applied have been constructed on the basis of criteria other than internal homogenity. More attention must thus be paid to the formulation of the gravity model if the results are to be transferable. Third, the data needed for the prospective unemployment model are probably more accurately and uniformly collected since they come from the same agency. For these reasons most of the implications of this study will be based upon results from the prospective unemployment model.

Conditional Predictions of Net Migration and Population

One potential use for the prospective unemployment model presented in this section would be for the computation of conditional predictions of net migration and total population. The predictions would be conditional predictions since the population figures are usually released by the census prior to the release of the census employment figures needed to predict migration and therefore population. The result is that if one is merely interested in an estimate of total population, then other procedures which use school census data, periodic reports of the State Employment Security Commission, or other proxies for population may be more appealing.

On the other hand, there are some situations for which conditional predictions or simulations can be useful. If one is interested in programs which are aimed directly at increasing employment levels or which produce changes in employment as side effects, then conditional predictions may be useful.

In this section the conditions prevailing in 1960 are combined with alternative estimates or guesses about 1970 to produce conditional predictions of migration and employment. This period was chosen for several reasons. First, the 1960 census is the last census for which population and employment figures are completely available. Second, the initial population and its distribution by age groups is probably more important than is sometimes thought. Thus it seemed appropriate to use a period whose initial conditions are more familiar. Lastly, the use of this period will facilitate the evaluation of this model. The final census results for 1970 will be available in a few years. If the implications of this model for alternative 1970 employment levels are set forth explicitly here, then any deficiencies of the model will be more obvious when the final census results are obtained.

Since the 1970 census figures for the state of Oklahoma have not yet been published in final form, it was necessary to make some assumptions about the level of employment and about the volume of net military migration during the period. Net military migration is not likely to have a very great total impact. Therefore, a figure of 2,500 was assumed for Oklahoma. The crucial variable is the change in the level of employment. It was assumed that employment has increased by 120 to 140 thousand. The second column of Table 10 gives the conditional net migration predictions for increases in employment ranging from 100,000 to 150,000 under the assumption that the structural coefficients have not changed.

The assumption of unchanged structural coefficients is undoubtedly unrealistic. It seems more reasonable to assume that changes in labor market conditions outside of the state may influence certain of these coefficients. An alternative form of the model which allows changes in the coefficients is given by:

$$\frac{M_i^c}{P_i} = \alpha + \beta_1\left[\frac{\Delta MP_i}{P_i} - \frac{\Delta MP_{us}}{P_{us}}\right] + \beta_2\left[\frac{\Delta LF_i}{P_i} - \frac{\Delta LF_{us}}{P_{us}}\right] + \beta_3\left[\frac{\Delta E_i}{P_i} - \frac{\Delta E_{us}}{P_{us}}\right] + \beta_4\left[\frac{LF_i}{P_i} - \frac{LF_{us}}{P_{us}}\right] + \beta_5\left[\frac{E_i}{P_i} - \frac{E_{us}}{P_{us}}\right] + \frac{U_i}{P_i}$$

where: α is the intercept parameter,

ΔMP_{us} equals the gain in U. S. population attributable to movement and deaths of armed forces personnel between 1950 and 1960,

ΔLF_{us} equals the natural increase in persons aged 15 to 64 in the U. S. between 1950 and 1960,

ΔE_{us} equals the change in the number of persons employed in the U. S. between 1950 and 1960,

LF_{us} equals the number of persons aged 15 to 64 in the U. S. in 1950,

E_{us} equals the number of persons employed in the U. S. in 1950, and

P_{us} equals the U. S. population in 1950. (All other variables have been defined above.)

This version differs from the original version in two ways. One trivial difference is that the variables included are expressed as rates per 1,000 of initial population. The second difference is that the explanatory variables are expressed as differences between the rate in Oklahoma and the national rate. If this model had been fitted using the same assumptions about the distribution of the error terms as before the estimates of all of the parameters except α would be the same as reported above since the national rates are constants for any time period. The estimate of α would have been .00954.

Table 10. Net Civilian Migration Predictions for Alternative Assumptions About the 1960-1970 Increase in State and National Employment.

Increase in State Employment (1,000's)	Predicted Migration for Unchanged Parameters	Increase in National Employment (Millions)				
		11.5	12.0	12.5	13.0	13.5
100	—31,300	—78,600	—92,800	—107,100	—121,300	—135,000
110	—9,400	—56,800	—71,000	—85,200	—99,400	—113,600
120	12,400	—34,900	—49,100	—63,300	—77,500	—91,700
130	34,300	—13,000	—27,200	—41,400	—55,600	—69,900
140	56,200	8,900	—5,300	—19,500	—33,700	—47,900
150	78,100	30,800	16,600	2,400	—11,900	—26,100

Since the national variables are different for the 1960-1970 decade than for the 1950-1960 decade accounting for the changes in these variables would produce different estimates of migration. The national increase in employment is also not yet accurately known but should be about 11.5 to 12.5 million. The last five columns of Table 10 give the predictions for various combinations of increases in national and state employment. These predictions are point predictions. The standard error relevant for forming confidence intervals around these predictions ranges from about 20,000 to 25,000 persons. The large size of this standard error is principally due to the fact that the expected increase in employment is nearly 100,000 larger than for the 1950-1960 decade.

As indicated by the table, the predicted in-migration increases by about 21,900 for each 10,000 increase in state employment and decreases about 14,200 for each 500 thousand increase in national employment.

If the estimated model is combined with some guess about the birth rate structure prevailing between 1960 and 1970, conditional predictions of the 1970 population could be obtained. In order to demonstrate the effect of birth rates and changes in employment levels upon population nine estimates of 1970 population were made by combining three alternative birth rate assumptions with three alternative levels of employment in 1970. The national change in employment was assumed to be 12.5 million. The results are presented in Table 11. This table provides the basis for making at least three observations. First, one can observe that the population would be expected to increase by about 26,200 for each 10,000 increase in employment and by about 54,200 for each 10 percent increase in the birth rate. Second, by comparing Tables 10 and 11, one can also note that during the 1960-1970 period the migration component of population change was probably less important than during the 1950-1960 period. Third, it appears that the model has overestimated the

Table 11. Oklahoma Population Predictions for 1970.

Change in State Employment (1,000's)	Birth Rate Structure (As a Percentage of the 1960 Birth Rate Structure		
	90%	100%	110%
120	2515	2568	2622
130	2540	2595	2649
140	2566	2621	2676

1970 population. As noted above the employment data needed are not yet available from the 1970 census. However, data from other sources tend to indicate an increase in Oklahoma employment of about 120 thousand during the 1960-1970 period. If the 1960 birth rates are assumed relevant, then a estimated popultion of 2,568 thousand results. This is about 70 thousand persons greater than the preliminary census figure.

The previous sections have outlined some of the implications of changes in employment upon migration and changes in population. For this purpose the starting point was assumed to be the 1960 state population. Combining different initial populations with the assumed employment changes would have produced different findings. In fact, one could turn the problem around a bit and ask whether there is some population distribution that would remain unchanged if faced with a given initial employment and a given change in employment. It would be tempting to think of such a population as a long run equilibrium population, but it would be more appropriate to think of this as a temporary equilibrium.

Estimates of this temporary equilibrium were obtained for several hypothetical employment situations. They are presented in Table 12.

Several observations can be made about these results. First, they must be interpreted with a great deal of caution. They are rather sensitive to birth rates and to migration parameters for the younger age groups. The estimates of these rates and parameters are less reliable than the parameters for older age gorups. As a result the actual equilibrium for the employment levels hypothesized could be quite different from the estimates obtained here. Secondly, even if the estimates of equilibrium population are reasonably accurate this equilibrium may not be a stable one. That is, if the initial population distribution differs from the equilibrium distribution, then the population distribution at the end of the decade may be even further from the equilibrium than the initial distribution. Thirdly, even if the population at the end of the decade is closer to the equilibrium population, the amount of the adjustment may be small relative to the adjustment that would be required to reach the equilibrium population.

Table 12. Equilibrium Population and Migration Per 1,000 of Initial Employment

Age Group	Large Increase in National Employment				Small Increase in National Employment			
	No Increase in State Employment		5% Increase in State Employment		No Increase in State Employment		5% Increase in State Employment	
	Migration	Population	Migration	Population	Migration	Population	Migration	Population
0-4	20	243	—21	512	—40	632	—112	1098
5-9	32	254	—60	390	—101	451	—262	686
10-14	14	254	—86	421	—131	496	—304	786
15-19	—135	118	—12	374	42	490	255	936
20-24	—220	33	—15	402	77	568	433	1209
25-29	—9	107	—132	238	—187	298	—400	527
30-34	147	179	—154	243	—290	272	—814	383
35-39	50	155	—84	152	—144	150	—377	144
40-44	6	181	—44	194	—66	200	—153	223
45-49	—9	140	—26	120	—35	110	—65	74
50-54	—6	164	—20	164	—26	163	—49	163
55-59	—2	126	—13	97	—18	84	—37	33
60-64	4	149	—6	138	—11	134	—30	115
65-69	4	108	—2	78	—5	65	—15	13
70-74	3	116	1	106	1	102	—3	85
75+	—1	165	—1	134	—1	119	—2	64
Total	—102	2493	—675	3763	—935	4333	—1935	6539

Implications for Industrialization Programs

Population is one of the variables in the per capita income identity. Therefore, it is appropriate to examine the implications of this study for industrialization programs and other programs which are designed to increase employment in Oklahoma.

The length of period upon which this study was based in ten years. Thus the study provides no information about the short run effect of increases in employment upon population. The results of this study do suggest that in the intermediate run (five to ten years) an increase in employment by 1,000 jobs would tend to cause an increase in the population of about 2,620 persons. This suggests that in the intermediate run increasing the level of employment may tend to decrease the population/employment ratio slightly as compared to the 1960 ratio of 2.96.

The long run ratio has been estimated at 2.49 if national employment continues to increase rapidly and at 4.33 if it increases less rapidly. If 2.49 is the relevant long run ratio then increasing employment in Oklahoma would have favorable effects but only as long as the actual population to employment ratio exceeds 2.62. On the other hand, if 4.33 is the relevant long run ratio then it would appear that increasing employment can lower the ratio only temporarily. It is tempting to qualify these conclusions by noting that the accuracy of the long run estimates is probably low and that even if they were very accurate one can not be sure which ratio is applicable. However, a more relevant qualification is in order.

The accuracy of these estimates is made less relevant by the fact that the adjustment to either of these ratios would be very slow even if they are correct. For example, if there had been no increase in Oklahoma employment and a rapid increase in national employment during the 1960 to 1970 period the population to employment ratio would have made an adjustment equal to about 20 percent of the difference between 1960 ratio of 2.96 and the estimated ratio of 2.49. Adjustment in the opposite direction would have been much slower. If there had been no increase in Oklahoma employment and a more moderate increase in national employment then the ratio would have made an adjustment equal to only about 2 percent of the difference between the 1960 ratio and 4.33. This suggests that there is very little need to be unduly concerned about the endpoints of the range in long run ratio estimates. Instead one could expect that the relevant range for the foreseeable future is from about 2.7 to 3.05 for the state of Oklahoma.

The preceding discussion suggests that industrialization programs and other such programs can have relatively little influence upon population to employment ratios. It also sugegsts that indiscriminately pursuing these programs will lead to little or no improvement in per capita incomes. These conclusions are based, at least implicitly, on the assumption that total personal income is a linear homogeneous function of employment. Fortunately, this need not always be the case. Thus it may be possible to increase per capita income by increasing employment in Oklahoma, but it appears that this increase, if it occurs, must result primarily from an increase in the personal income per employee.

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