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A Simple, Two-Region Simulation of Population, Income, and Employment

By Clark Edwards

As a nation develops, some geographic regions are observed, always, to grow faster than others. Regional analysis of trends in population, income, and employment is needed to help explain regional variations in business activity. Linkages between regions are frequently measured in terms of exchange of final products, capital flows, or migration. Impacts of such exchanges may be assessed on prices, earnings, money supply, and other economic variables. Within the markets of the United States, exchanges of goods and consequent impacts on commodity prices are relatively unhampered; migration of persons and differential earnings constitute what is perhaps a more dramatic aspect of interregional exchange.

This paper presents and discusses a simple simulation model which follows alternative time paths of population, income, and employment in a two-region model for the United States. The connecting link between the two regions is migration. The model contains seven variables, the minimum number that can be used to describe three variables in each of two regions plus one interaction variable. Interpretive results of the model were reported elsewhere.¹ The present paper is concerned more with an explication of the analytic technique than with the economic interpretation of the results, although the general nature of the problem and implications of the model are summarized below. The model was tested by comparing the 10 Great Plains States² with the other 40 States. However, the problem studied is not unique to the Plains.

The Problem

Relative to the rest of the economy of the United States, the Great Plains States exhibit, in some respects, many characteristics of a

depressed area. Income per capita is lower there than in the United States as a whole; and the dollar gap in incomes per capita is widening. People are leaving agriculture there as everywhere; that is a national phenomenon. But residents of the Plains are having more than average difficulty finding nonfarm job opportunities near home. Some seek work in the major cities of the Plains, thus depopulating the small towns and rural places. With a shortage in the Plains of metropolitan development, particularly that related to manufacturing employment, there is considerable migration to cities outside the Plains. Capital flows from savings in the Plains to investments elsewhere. Creation of community investments is slowed for needed schools, roads, recreational facilities, utilities, residential and business areas, and other facilities which flow from local, group action. Depopulation of the hinterlands reduces the demand for the services of central cities and slows the development of social, political, and economic institutions, requiring residents of the Plains to depend in part on institutions outside the region for centralized services. Circularly, the arrested development of the economy in the Plains induces further out-migration.

The 10 States known as the Great Plains contain about 11 percent of the U.S. population but only 10 percent of the jobs and income. Since 1960, the population of the Plains has grown around 1.2 percent per year (see footnote 1). This compares with 1.4 percent for the Nation. The difference appears to reflect net migration influences rather than basic differences in natural increase. A look at county migration patterns makes apparent large areas of population decline in each of the 10 Plains States. The declining counties tend to be in the more sparsely populated, rural areas. Two net migration patterns emerge which are relevant to the present discussion: One a movement from rural to urban places within the Plains leaving vast areas with a sense of depression; the other a net movement from the 10 Plains States into the other 40.

¹Clark Edwards, Creating off-farm employment in the Great Plains. Great Plains Agr. Council Proc., Oklahoma City, Okla., July 30-August 1, 1969.

²North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Colorado, Wyoming, and Montana.

Personal income has been rising in the Plains at a pace of about 6.7 percent per year. With a gain of only 1.2 percent per year in population, this has resulted in rapidly rising incomes per capita, to a level of around \$3,040 in 1968 from \$1,990 at the beginning of the decade. But incomes rose faster in the other States, both in the aggregate and on a per capita basis. Per capita income in 1968 in the other 40 States averaged \$442 higher than in the Plains.

If the objective is to seek more equal incomes among regions, then a benchmark for measuring progress in the Plains is apparent: Incomes per capita in the Plains would have to have gained at a pace of around 6.2 percent per year to have kept the dollar gap at its 1960 size of \$264. Growth was slower than this and allowed the gap to widen during 1960-68; growth faster than this would have been required to close the gap and bring about equal incomes. The reported growth rate for per capita income was only 5.4 percent per year. The trend is evidently toward intensification of the income disparity.

Current trends suggest that over the next few decades, population in the Plains will continue to rise more slowly than in other States and the rate of outmigration will increase (table 1, rows 1 and 2). The gain in per capita incomes in the Plains is likely to be at an annual rate close to that of other States, resulting in a further widening of the dollar gap in incomes. Part of the gain in per capita incomes is likely to come through increased labor force participation and its concomitant reduction of dependent population, but labor force participation is likely to continue below the rate of other States.

These results are tabulated in fuller detail in table 2. Tables 3 through 8, summarized in table 1, show details of possible consequences of alternative policies affecting the Great Plains economy with respect to migration, natural population increase, growth in aggregate demand, and increases in productivity per worker. Before discussing the results of these alternatives, let us explain the assumptions and methods underlying the construction of tables 2 through 8.

The Model

Seven variables are used to describe the system in each year of the simulation: population, income, and employment in each of the two regions plus the number of migrants from the Plains to other States.

Six of these variables--population, income, and employment in each of the two regions--were assumed known as initial conditions for the first year of the simulation. The approach was to test the model using 1960 initial conditions. Parameters (discussed below) which led to a close approximation for available estimates for 1967 were assumed to be useful parameters. The model was then initialized to 1967 and run for a 50-year simulation of the seven descriptive variables. Tables 2 through 8 report the results for 5 selected years from the 50-year run. Table 1 facilitates comparisons of alternative runs as of the year 2000 with each other and with an approximation of the current (1970) situation.

Seven equations were required to describe the system:

Employment growth equations.--For each region, employment in a given year was equal to employment in the preceding year plus the number of added workers absorbed from the nonworking population.

$$E_{1,t+1} = E_{1,t} + a_1 (P_{1,t} - E_{1,t})$$

$$E_{2,t+1} = E_{2,t} + a_2 (P_{2,t} - E_{2,t})$$

where E is employment, P is population, a is the demand coefficient, subscripts 1 and 2 refer to regions 1 and 2, and subscripts t and t+1 refer to successive years.

Income growth equations.--For each region, income in a given year was equal to the product of three terms: the growth in income and output per worker, the growth in the number of workers, and the level of income in the preceding year.

$$Y_{1,t+1} = (1 + b_1) (E_{1,t+1}/E_{1,t}) (Y_{1,t})$$

$$Y_{2,t+1} = (1 + b_2) (E_{2,t+1}/E_{2,t}) (Y_{2,t})$$

where Y is aggregate income of the region and b reflects the annual rate of gain in productivity and, by implication, earnings per worker.

Population growth equations.--For each region, population in a given year was equal to population in the preceding year plus natural increase plus (minus) migration to the other region.

$$P_{1,t+1} = (1 + c_1) (P_{1,t}) - M_t$$

$$P_{2,t+1} = (1 + c_2) (P_{2,t}) + M_t$$

where M is the migration to region 2 from region 1 and where c is the annual rate of natural increase.

Table 1.--Summary of projections and simulated alternatives for economic development in the Great Plains with comparisons

Year	Source (table number)	Population growth per year		Net migration per year from the Plains	Income per capita		Workforce participation per 1,000 population	
		Great Plains	Other States		Great Plains	Other States	Great Plains	Other States
		Percent	Percent	Percent	Dollars	Dollars	Persons	Persons
1970..	2	1.163	1.317	0.138	3,146	3,607	348	362
2000..	2	1.071	1.328	.230	10,345	11,672	353	361
2000..	3	1.300	1.300	.000	9,906	11,733	338	363
2000..	4	.858	1.350	.442	10,767	11,620	367	360
2000..	5	.781	1.323	.217	11,116	11,679	379	362
2000..	6	1.761	1.336	.239	8,764	11,656	298	361
2000..	7	1.111	1.323	.191	10,793	11,684	368	362
2000..	8	1.390	1.289	-.091	11,735	11,717	342	363

Source: Tables 2 through 8.

Table 2.--Projection of recent economic trends in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	\$1,000	\$1,000	Thous.
1970	23,223	182,429	8,076	66,048	73,051	657,832	32
1980	26,045	207,960	9,081	75,253	121,588	1,109,450	41
1990	29,140	237,129	10,205	85,750	202,253	1,871,339	55
2000	32,490	270,491	11,457	97,727	336,107	3,156,928	75
2010	36,048	308,707	12,843	111,399	557,725	5,326,817	105

*Based on projections discussed in text.

Table 3.--Simulated impact of stopping outmigration in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	\$1,000	\$1,000	Thous.
1970	23,316	182,336	8,077	66,048	73,056	657,825	0
1980	26,530	207,475	9,098	75,233	121,808	1,109,165	0
1990	30,188	236,081	10,265	85,680	203,438	1,869,806	0
2000	34,351	268,630	11,598	97,561	340,257	3,151,579	0
2010	39,087	305,668	13,121	111,076	569,770	5,311,333	0

*Differs from table 2 in that the propensity to migrate is set equal to zero.

Table 4.--Simulated impact of doubling the rate of outmigration in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	\$1,000	\$1,000	Thous.
1970	23,132	182,520	8,076	66,049	73,046	657,839	63
1980	25,595	208,411	9,066	75,271	121,379	1,109,722	77
1990	28,204	238,065	10,150	85,814	201,163	1,872,747	101
2000	30,871	272,110	11,330	97,875	332,388	3,161,720	137
2010	33,446	311,308	12,600	111,684	547,143	5,340,416	191

*Differs from table 2 in that responses to inducements to migrate are multiplied by a factor of two.

Table 5.--Simulated impact of slowing down the rate of natural increase in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	\$1,000	\$1,000	Thous.
1970	23,018	182,427	8,075	66,048	73,040	657,832	31
1980	25,082	207,928	9,047	75,252	121,129	1,109,437	36
1990	27,283	237,024	10,090	85,745	199,968	1,871,223	47
2000	29,576	270,274	11,206	97,711	328,757	3,156,414	64
2010	31,884	308,333	12,396	111,364	538,295	5,325,130	91

*Differs from table 2 in that the natural rate of increase is reduced to 1.0 percent per year in the Plains while held at 1.3 in other States.

Table 6.--Simulated impact of expanding the rate of natural increase in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	\$1,000	\$1,000	Thous.
1970	23,706	182,431	8,079	66,048	73,078	657,832	35
1980	28,435	208,033	9,164	75,255	122,700	1,109,480	52
1990	34,001	237,357	10,495	85,762	207,999	1,871,595	72
2000	40,547	270,956	12,112	97,761	355,317	3,158,048	97
2010	48,213	309,492	14,061	111,475	610,596	5,330,437	131

*Differs from table 2 in that the natural rate of increase is increased to 2.0 percent per year in the Plains while held at 1.3 in other States.

Table 7.--Simulated impact of expanding aggregate demand in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	\$1,000	\$1,000	Thous.
1970	23,242	182,410	8,127	66,048	73,511	657,831	25
1980	26,149	207,856	9,310	75,249	124,649	1,109,390	32
1990	29,362	236,907	10,627	85,735	210,614	1,871,012	44
2000	32,863	270,118	12,090	97,692	354,687	3,155,809	63
2010	36,606	308,148	13,709	111,335	626,821	5,323,713	95

*Differs from table 2 in that the growth in aggregate demand for workers is set equal to the rate in other States. In table 2, demand in the Plains absorbed only 83 percent as much of the available labor as would have been absorbed in other States.

Table 8.--Simulated impact of increasing the productivity per worker in the Great Plains*

Year	Population		Employment		Personal income		Migration per year from Great Plains to other States
	Great Plains	Other States	Great Plains	Other States	Great Plains	Other States	
	Thous.	Thous.	Thous.	Thous.	\$1,000	\$1,000	Thous.
1970	23,226	182,426	8,076	66,048	74,110	657,832	29
1980	26,142	207,864	9,083	75,250	129,438	1,109,416	23
1990	29,569	236,700	10,220	85,732	226,180	1,870,944	6
2000	33,730	269,251	11,517	97,656	395,807	3,154,652	-30
2010	39,004	305,751	13,017	111,196	694,753	5,317,067	-103

*Differs from table 2 in that the annual gain in productivity per worker and in earnings was set at 4.5 percent per year in the Plains while that in other States was held at 4.0 percent per year.

Migration equation.--Migration to region 2 from region 1 was the sum of three inducements to migrate: regional disparities in aggregate demand, regional disparities in income per worker, and regional disparities in employment opportunities per capita.

$$M_t = d(a_2 - a_1) + e(Y_{2,t}/E_{2,t} - Y_{1,t}/E_{1,t}) + f(E_{2,t}/P_{2,t} - E_{1,t}/P_{1,t})$$

where d is the propensity to respond to a differential in capacity for demand to absorb idle workers, e is the propensity to respond to a differential in earnings per worker, and f is the propensity to respond to a differential in participation of the population in the work force.

The seven equations contain nine parameters, as follows:

The demand coefficient for the Plains was found to be $a_1 = .00630$, that for other States $a_2 = .00745$ on the basis of 1960-67 gains in population and employment. For table 7, $a_1 = a_2 = .00745$.

The productivity coefficient in each region was initially set near the recent national average: $b_1 = b_2 = .04$. This may be a little higher than might be expected to obtain over the next 50 years. In reproducing 1960-67 changes, it picks up part of the recent upturn in general price levels. Observed differences in gains in productivity and income appeared to favor the other States slightly relative to the Plains. The differences were small enough to suggest an advantage to assuming the same rate initially. For table 8, $a_1 = .045$ for the Plains; $a_2 = .04$ for other States.

The population growth coefficient in each region was initially set near current rates: $c_1 = c_2 = .013$. For table 5, $c_1 = .01$ for the Plains. For table 6, $c_1 = .02$ for the Plains.

The three migration coefficients were initially set: $d = 5,200$, $e = .022$, and $f = 414$. These settings attribute about half the total propensity to migrate to the differential in earnings. The other half is about equally divided between the differentials in demand and in labor force participation. For table 3 these three coefficients were set equal to zero. For table 4 these three coefficients were doubled in value.

Application of the Model

Current trends suggest that overt policies with respect to changes in the Plains in income,

population, and employment might avert a further divergence in the level of development relative to the other 40 States. Broad policies (reviewed below) focus on migration, natural increase, aggregate demand, and income and productivity per worker.

For example, we hear it said that one way to make the Plains grow is to stop outmigration. Table 3 shows the consequences of doing that. It can add close to 2 million people to the Plains by the year 2000. But fewer than 10 percent of the additions will find employment, given the current job market structure. Work force participation rates may fall to 34 percent of the population from the current level of around 35 percent. Per capita income, as a result, could run more than \$400 below what can be expected under current trends. Incomes in the other 40 States, on the other hand, might rise \$50 or so above trend in consequence of reduced competition there for jobs, and less unemployment. Stopping outmigration brings about increases in aggregate population, income, and employment, but unless accompanied by other programs will lead to less real income per capita in the Plains than can be expected with current trends.

If stopping outmigration makes things worse, will doubling the rate make things better? Table 4 shows the consequences of doubling the response to inducements to migrate. This cuts the rate of population growth in the Plains to less than 1 percent per year. In a matter of 25 years or so, the problems of unemployment may be taken care of in the Plains under such a policy and workforce participation rates of the population will about equal the average of the other 40 States. And by the year 2000, per capita incomes in the Plains may run as much as \$800 above trend although continuing below the average in the other 40 States. These apparent benefits are slow in coming; they are at the expense of slowing down the rate of aggregate growth in general business activity in the Plains and of exporting some unemployment problems to the other States; and they are not sufficient to close the development gap.

The conclusion with respect to migration policies is this: It may be that reduced outmigration is a meaningful target for regional income and employment policy, but manipulating migration rates is not the way to reach income and employment targets. Migration plays the role of an end, not a means.

The population explosion is often blamed for holding progress toward development goals down to a snail's pace. Table 5 shows the consequences of lowering the rate of natural

population increase to 1.0 percent per year in the Plains from the 1.3 percent rate used in preparing table 2. This cuts the rate of population increase sharply in the Plains, and with reduced outmigration, cuts the rate of increase in the other 40 States slightly, as well. With less unemployment, income per capita rises in the area as the family planners suggest. At the end of the 50-year simulation income per capita in the area was running only \$100 below that in other States. The per capita gains are realized at the expense of reduced total business activity, down about 2 percent below trend by the year 2000.

Were the natural rate of population increase in the Plains to rise instead of fall, a rise in total business activity would be gained at the expense of a deterioration in the rate of improvement in income per capita. Table 6 shows the consequences of stepping up the rate of natural increase in the Plains to 2 percent per year without simultaneously expanding the local economies' ability to absorb workers. A 5 percent larger total economy in the year 2000 is accompanied by a level of income per capita some \$1,600 below trend.

The conclusion with respect to population growth policies is this: If one were forced to a choice between either stepping up outmigration or reducing the rate of natural increase as a means of improving per capita income in the Plains, the latter appears preferable to the former. But neither seems to be a very efficient or very satisfactory approach. Each might prove useful as a minor adjunct to other income and employment policies, but neither alone will be likely to carry the burden of solving development problems.

Expanding aggregate demand is the solution to income and employment problems in vogue with economists over the last 30 years. Table 7 shows the impacts of raising to the level of the other 40 States the capacity of the Plains economy to absorb potential workers annually. During 1960-67, the other 40 States were absorbing about 745 workers into the work force each year per million persons not at work. The Great Plains economy was able to absorb 630 workers per year per million persons not at work. Those not at work include persons able to work, such as recent graduates of high schools and colleges, working-age people who have dropped out of the labor force, unemployed, and adults who have never been in the labor force. Those not at work also include, in this method of calculation, persons unable to work such as children, old people, the sick, and other unemployables.

Stepping up the demand for nonfarm employment shows promising potential for closing some of the economic development gap between the Plains and the other 40 States. Even so, this policy followed alone is not likely to be sufficient. While it will work well in the short run, it is not likely to prove a sustainable, long-run means. According to table 7, income per capita rises to a level some \$400 above trend by the year 2000 although continuing well below incomes in the other 40 States. With more jobs and more income per capita, outmigration is reduced and the rate of population growth in the Plains increases slightly. And total business activity in the region is indicated around 5 percent above trend by the year 2000.

Pursuing a policy of matching the capacity of the Plains economy to that of the other 40 States to absorb idle workers may be pressing against the limits of feasibility in the long run. Work-force participation rates rise from the current level of 35 percent of the population to the average of other States (36 percent) in 25 years, according to the simulation. It is beyond that point that difficulties of sustaining this policy would become acute. Yet at that point the gap between the level of economic development in the Plains and the other 40 States is not yet closed.

Increasing productivity per worker and reducing the high rate of underemployment in the Plains is an effort to solve the development problem from the point of view of the quality of the supply of labor and its utilization. This is in contrast to the appraisals discussed above which work on the quantity of workers supplied or on the quantity demanded without any changes in the way they do things. Table 8 shows the impacts of raising the level of income and output per worker at a pace of 4.5 percent per year while that in the other 40 States continues to rise at 4.0 percent.

The first striking result of pursuing this policy in the simulations is that it stopped outmigration from the Plains in 25 years. As the run continued through its 50-year period, migrants flowed into the Plains to join its productive work force and share in its economic rewards.

The second striking result is that the gap in per capita incomes between the Plains and other States was closed by the year 2000.

Thirdly, aggregate population, income, and employment rose above the trend line under this policy, due to a substantial rise in total business activity as well as to improved incomes per worker.

Efforts to raise income and output per worker in the Plains make greater demands on policy implementers than the other approaches discussed so far. They also offer greater returns, and appear to be worth the effort. They require significant improvements in programs dealing with health, education, job training, family location, commuting patterns, central city services, and other factors. They require reducing the high rate of underemployment in the labor force of the Plains as well as increasing the capacity of each worker to produce. Both the job and the worker need upgrading. They require changing attitudes of leaders and followers as well as finding new ways of doing things in the Plains.

In summary, the discussion of tables 2 through 8 suggests the following: The level of income and output per worker in the Plains is lower than the average for other States and the gap has been widening. One of the most promising policies for economic development

in the Plains appears to focus on stepping up the rate of improvement in quality of the labor force, and the rate of its utilization. Secondly, efforts to expand aggregate demand in the Plains more nearly in line with the rate of expansion in other States will be a useful companion policy to one that improves the productivity of workers. Thirdly, policy makers need not look askance at some moderate reduction in the natural rate of increase of population in the Plains, but overt efforts to make this the objective of development policies do not appear warranted. Stopping outmigration as a natural consequence of following the development policies above might be considered desirable; but using overt migration policies to achieve development ends does not appear warranted. Finally, while there were side effects in the other 40 States, some good and some not, the general level of activity was only moderately affected outside the Plains by development policies within the Plains.