The Effect of Climate on Migration: United States, 1995-2000

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Abstract

This paper examines the effect of climate on migration. We examine whether climate is an influential factor in internal migration. We assume that most persons tend to avoid exposure to bitter and cold winters, and excessively hot and humid summers, preferring climates between these extremes. When engaging in migration decision-making, therefore, to the extent possible, considerations involving climate are believed to be brought into the calculus. There is a very limited demographic literature on the effects of climate on migration.

In this paper we undertake an aggregate-based analysis of the effect of climate on migration. We examine this relationship among the fifty states of the United States. We focus attention on the varying effects of climate on three migration measures for the 1995-2000 time period, namely, in-migration, out-migration, and net migration. We next evaluate the effect of climate on migration in the context of a broad application of human ecology. Here climate, a manifestation of the physical environment, is measured with three major independent variables; the other ecological predictors pertaining to organization, population, technology, and the social environment are used as controls. This enables us to examine the effects of climate on migration in the context of competing ecological hypotheses.

Key Words: climate, migration, human ecology, temperature, humidity, wind

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Introduction

This paper examines the effect of climate on migration. There is a fair literature, much of it by economists, on the importance of climate as a push or pull factor in internal migration. Much of the literature focuses on the role of climate, versus other economic factors, as a significant predictor of migration (Bass and Alexander, 1972; Graves, 1979; 1980; Schachter and Althaus, 1982; Greenwood and Hunt, 1989; Knapp and Graves, 1989; Greenwood et al., 1991; Clark and Hunter, 1992; Mueser and Graves, 1995; Clark et al., 1996; Cragg and Kahn, 1997). Only a few studies have examined the impacts of climate on migration controlling for both economic and noneconomic factors (Karp and Kelly, 1971; Poston and Mao, 1996; 1998). Also, nearly all prior analyses have used one or more individual indicators of climate and have not considered empirically the basic underlying dimensions of the specific climate variables. This paper is an attempt to address some of these voids.

Ravenstein (1889) was one of the first to suggest that various factors, including "an unattractive climate," tend to push persons from one area to another area. But social scientists have not given much attention to the extent to which attractive and unattractive climates, versus economic and other social and ecological factors, are pulling and pushing persons from certain areas to other areas.

Farley has noted the following in his commentary about internal migration in the U.S. in the 1990s:

> Recent internal migration has overwhelmingly been away from the cold weather states and toward the coasts, especially along the Atlantic from the Chesapeake Bay southward, along the Gulf Coast, and along the Pacific Rim. How much of this massive migration is attributable to favorable meteorological conditions and how much to the economic boom of these places has yet to be determined (Farley, 1996: 276).

Other things equal, it is assumed that most persons tend to avoid exposure to bitter and cold winters, and excessively hot and humid summers, preferring climates between these extremes. When engaging in migration decision-making, therefore, to the extent possible, considerations involving climate are brought into the calculus. At the aggregate level, therefore, areas with favorable climates should be characterized by positive rates of migration more so than areas with less favorable climates.

In this paper we undertake aggregate-based analyses of the effects of climate on migration among the fifty states of the United States. We first describe the dependent variable of migration for the 1995-2000 time period, using three different migration rates. Attention is then directed to the conceptualization of climate, and the varying effects of climate on the migration rates. We set forth eleven different measures of climate, and use factor analysis to produce three different empirical dimensions (factors).The effects of these climate dimensions are then evaluated in the context of a broader application of human ecology. The dimensions of climate per se are entertained as the major independent variables along with other predictors pertaining to organization, population, technology and the social environment serving as controls. This enables us to examine the effects of climate on migration in the context of competing ecological hypotheses.

(One of the reviewers of this paper recommended we restrict our analysis to the 48 coterminous states, thus dropping Alaska and Hawaii. The reviewer stated that these two states "are very different places with an entirely different spatial context and probably quite different migration determinants." We thus estimated regression models with and without Alaska and Hawaii. Since the results are essentially the same with and without these two states in the equations, we retained them in all our analyses.)

The Dependent Variable of Migration

Our dependent variable is migration. We use three migration rates, and each covers the 1995-2000 time period. These are the in-migration rate, the out-migration rate and the net migration rate, and are defined as follows:

1. In-migration Rate, 1995-2000 (IN-MIG) =

$$\left(\frac{\text{In - migrants, 1995 – 2000}}{\text{Population, 1995}}\right) * 1{,}000$$

2. Out-migration Rate, 1995-2000 (OUT-MIG) =

$$\left(\frac{\text{Out - migrants, 1995 – 2000}}{\text{Population, 1995}}\right) * 1{,}000$$

3. Net Migration Rate (NET-MIG) =

$$\left(\frac{(\text{In - migrants, 1995} - 2000) - (\text{Out - migrants, 1995} - 2000)}{\text{Population, 1995}}\right) * 1{,}000$$

Table 1 shows descriptive statistics for the three migration rates. Among the 50 states for the 1995-2000 time period, the average in-migration rate and the average out-migration rate were 108 and 103 migrants per 1,000 persons living in the state in 1995, respectively. On average, there were almost as many persons leaving a state between 1995 and 2000 as entering it. The average net migration rate was therefore positive, but with a low value of 4.8 per 1,000 residents.

Galle and his colleagues have noted that the so-called "attractive" forces, or "pull" factors, that attract migrants to a community are "reflected by the rate of migration into the community" (1993: 160) that is, the in-migration rate. Conversely, the "strength of the 'unattractive' factors in the community which 'push' persons out of the community is reflected in the rate of out-migration" (Galle et al., 1993: 160). The net migration rate thus represents the "differences between these two sets of attractive and repelling forces" (1993: 160).

However, in-migration rates are not usually related negatively with out-migration rates. This seems to go against common sense reasoning because, presumably, if "a variable … has an effect on the in-migration rate in one direction, (it) ought to have an effect on the out-migration rate in the opposite direction" (Galle et al., 1993: 160). If a climate variable is negatively related with in-migration, and positively related with out-migration, the in-migration and out-migration rates should themselves be negatively related with each other.

However, research has shown fairly consistently that in-migration rates and out-migration rates are related in a positive direction. This anomaly is the result of a series of factors such as "compositional effects, counterstream processes, boundary location, vacancy chain migration, and dynamic population adjustment" (Galle et al., 1993: 160: see also Mueser and White, 1989).

Figure 1 is a scatterplot illustrating the relationship between the in-migration and out-migration rates among the fifty states of the U.S. in 1995-2000. (We have used the actual state name abbreviations as symbols to represent the locations of the states on the plot.) The diagonal line in the figure is not the regression line, but, instead, is the true diagonal connecting equal values on the in-migration and out-migration axes. Therefore, states above the diagonal line have higher in-migration than out-migration rates, and the opposite for states below the line. The plot shows a positive and fairly strong association between the two rates. The zero-order correlation between the rates for the 1985-90 period among the fifty states is r = 0.64. For the most part, states with high values on one rate have high values on the other (e.g., Alaska, Nevada, Arizona, and Wyoming). States that are low on one tend to be low on the other (e.g., Michigan, Wisconsin, Ohio, and California).

The third measure of migration is the net migration rate. As already mentioned, the states of the U.S. had a mean net migration rate between 1995 and 2000 of almost 5 per 1,000. Hawaii had the lowest net migration rate, -65.4 per 1,000; for every 1,000 persons living in Hawaii in 1995, there was a net loss of more than 65 persons in the 1995-2000 period. In contrast, Nevada had the highest rate, 301.8 per 1,000; for every 1,000 persons living in Nevada in 1995, the state gained an additional 302 inhabitants via net migration in the five years between 1995 and 2000. The net migration rate is strongly and positively associated with the in-migration rate (r = 0.71) but has no statistically significant relationship with the out-migration rate (r = -0.09). We turn next to the conceptualization and operationalization of climate, whose effect on migration is the major focus of this paper.

Conceptualization and Operationalization of Climate

One of the more thoughtful statements about climate as a characteristic or attribute of geographic areas is that of Graves (1980) and his suggestion that areas are characterized by different kinds of "climate bundles"; some areas "will have more attractive bundles than others" (1980: 228). With regard to the effect of climate on migration, other things equal, climate should operate as a "push" or as a "pull" factor, either attracting or repelling migrants (Lee, 1966). But it is one thing to hypothesize about the positive and negative impacts of climate on migration, and it is quite another thing to specify what is meant by climate.

Before considering the meaning of climate, we note that climate is not the same as weather. Climate typically refers to average weather conditions, so it takes into consideration the variability in weather.

Empirical research in the social sciences using climate as an independent variable often includes temperature as one consideration of climate, and sometimes as the only consideration; if more than one climate indicator is employed, their underlying dimensions are seldom considered, let alone measured (see, for example, Bass and Alexander, 1972; Knapp and Graves, 1989; Clark and Hunter, 1992; Mueser and Graves, 1995; Clark et al., 1996; Cragg and Kahn, 1997). A temperature measure usually, but not always, involves the measurement of average daily temperature for the months of January and July; some indexes have used the two temperatures as separate indicators of climate (Cushing, 1987).

Investigators have also used other variables to measure climate. One of the more extensive analyses of climate and migration is by Graves (1980) who used five different measures of climate, namely, average temperature variance, wind velocity, average humidity, degree of warm weather, and degree of cold weather. A later analysis by Cushing (1987) added several topographical criteria, such as proximity to mountains and coastlines; it also used a variant of Graves' measure of warmth by introducing a measure of sunshine. Few analyses of climate and migration, however, have examined the empirical relationships between such dimensions of climate as temperature, humidity and wind velocity. We turn to such a concern.

In our analysis of climate and migration among the 50 U.S. states, we use eleven different climate variables. These climate variables are based on population weighted climate data for the major cities in each state. The major cities are the locations of the "major weather observing stations" of the National Climatic Data Center, the federal agency providing the climate data that are used here. Table 2 shows for each of the 50 states the major cities used to calculate the climate measures. For example, when calculating the eleven different measures of climate for the state of Alabama, we first obtained the values for each of the eleven variables for the cities of Birmingham, Huntsville, Mobile and Montgomery. We then weighted the values on each of the city-specific climate measures by the population of the city in 1990, and summed the population weighted city-specific climate scores for each of the eleven measures.

The eleven climate variables are:

1. January temperature (JAN-TEMP) is the average daily temperature for the month of January for the thirty year period of 1931-1960 (U.S. Bureau of the Census, 1972).

2. July temperature (JULY-TEMP) is the average daily temperature for the month of July for the thirty year period of 1931-1960 (U.S. Bureau of the Census, 1972).

3. The temperature index (TEMP-INDEX) is the average daily maximum temperature in January divided by the average daily minimum temperature in July; the averages cover the thirty year period of 1955-1985 (U.S. Bureau of the Census, 1989).

4. The warm days index (WARM-DAYS) is the average number of days in a year when the temperature is 90 degrees Fahrenheit or higher (National Climatic Data Center Webpage, 2008).

5. The cold days index (COLD-DAYS) is the average number of days in a year when the temperature is 32 degrees Fahrenheit or lower (National Climatic Data Center Webpage, 2008).

6. The morning humidity index (AM-HUMIDITY) is an index of relative humidity based on an average for each day in the year of morning measurements of "the amount of moisture in the air compared to the maximum amount of moisture the air can hold at the same temperature and pressure" (National Climatic Data Center Webpage, 2008).[1]

7. The afternoon humidity index (PM-HUMIDITY) is an index of relative humidity based on an average for each day in the year of afternoon measurements of "the amount of moisture in the air compared to the maximum amount of moisture the air can hold at the same temperature and pressure" (National Climatic Data Center Webpage, 2008).[2]

8. The rain index (RAIN) is the average number of inches of precipitation per year for the thirty year period of 1931 to 1960 (U.S. Bureau of the Census, 1972).

9. The cloudy days index (CLOUDY) is the mean number of days when the average sky cover during daylight hours is between 80 and 100 percent (National Climatic Data Center Webpage, 2008).[3]

10. The sunshine index (SUN) is the "total time that sunshine reaches the surface of the earth … expressed as the percentage of the maximum amount possible from sunrise to sunset with clear sky conditions" (U.S. Bureau of the Census, 1972: lvi). Data for this measure were gathered for cities in the fifty states "from stations having automatic sunshine recorders for a considerable period of time and for which sunshine records have been summarized" (U.S. Bureau of the Census, 1972: lvi).

11. The wind index (WIND) is the average speed of the wind each day irrespective of the direction in which the wind is blowing (National Climatic Data Center Webpage, 2008).[4]

Table 3 shows descriptive statistics for the eleven climate variables for the fifty states. The measure of mean January temperature (JAN-TEMP) has an average value among the 50 states of almost 31 degrees, with a low of 7.6 degrees in North Dakota and a high of almost 72 degrees in Hawaii. Mean July temperature (JULY-TEMP) has an average value of 75 degrees with a low of 58.9 degrees in New Hampshire and a high of 85.3 in Arizona.

The third climate variable, the temperature index (TEMP-INDEX) has an average value among the states of 0.62; the lowest value is in North Dakota with an index score of 0.31; Hawaii has the highest score of 1.1. These values mean that in North Dakota the average maximum January temperature in the state is almost one-third of the average minimum July temperature in the state. Conversely, in Hawaii, the average maximum January temperature is about 1.1 times the average minimum July temperature (Poston and Mao, 1996: 320). Under the assumption that most persons prefer to avoid exposure to bitter and cold winters and to excessively hot and humid summers, the higher the value of this index, the more favorable the climate. This is because the index value is lowered if it is cold during the day in winter or hot during the night in summer (Karp and Kelly, 1971: 25).

The next measure, WARM-DAYS, is similar to the JULY-TEMP variables. Arizona is the state with the greatest number of warm days, over 122, and the highest average temperature in July. Regarding the COLD-DAYS variable, New Hampshire has the greatest number of days in a year when the temperature is 32 degrees or lower, and Hawaii has no such cold days.

The morning and afternoon humidity measures (AM-HUMIDITY and PM-HUMIDITY) are similar. On average, across the 50 states, it tends to be more humid in the morning (78%) than in the afternoon (56%). Of all the states, Nevada has the lowest humidity score in the morning and Arizona has the lowest score in the afternoon.

Mississippi has the highest humidity score in the morning and New Hampshire has the highest afternoon humidity.

Among the fifty states, the average amount of precipitation (RAIN) per year is 35.9 inches. Nevada has the least amount of rain, 5.8 inches per year, and Maryland the most, almost 71 inches per year. The next two measures capture the amount of cloudiness (CLOUDY) and sunshine (SUN). Alaska has the least amount of sunshine, and the greatest number of cloudy days per year (243). Arizona has the fewest number of cloudy days per year (76), and the most amount of sunshine.

Finally, among the 50 states the average wind speed (WIND) each day is more than 9 miles per hour. West Virginia is the state with the lowest average wind speed (6 mph), and New Hampshire has the highest (21 mph).

Table 4 is a matrix of correlations showing the degree of association between each pair of climate variables. Many of the climate variables are associated with one another. To illustrate, as might be expected, JAN-TEMP has a very high correlation with COLD-DAYS, r = -0.95, and JULY-TEMP is highly correlated with WARM-DAYS, r = .75. Also, the AM-HUMIDITY and PM-HUMIDITY measures are positively related, r = 0.53. Also, almost by definition, the SUN measure is highly and negatively associated with the CLOUDY measure, r = -0.93.

Many of the climate variables are correlated at levels of at least 0.5 or 0.6 with one or more of the other climate variables. But not all the variables are highly related with one another. For instance, the variables tapping temperature (JAN-TEMP, JULY-TEMP, TEMP-INDEX, WARM-DAYS, and COLD-DAYS) are not related much with the three variables dealing with humidity (AM-HUMIDITY, PM-HUMIDITY and RAIN). Also, the WIND measure does not have a correlation with any of the other climate measures above ± 0.5.

The correlations in Table 4 indicate that there may well be three underlying dimensions of climate captured by the eleven climate variables, namely, temperature, humidity and wind. This suggestion may be assessed empirically with factor analysis. Prior analyses have not addressed this issue of whether there are underlying empirical dimensions in the climate indicators.

We have thus factor analyzed the eleven climate variables, using a principal components factor solution, with an orthogonal rotation. The results are shown in Table 5.

Three climate factors emerge from the orthogonally rotated factor analysis, and all three factors have eigenvalues greater than 1.00. The three factors collectively account for 83.5 percent of the original variance in the eleven climate variables that served as inputs for the factor analysis.

We have defined the first climate factor as TEMPERATURE, and it accounts for over 50 percent of the original variance in the eleven climate variables. This factor is defined primarily by variables dealing with temperature, namely, JAN-TEMP, JULY-TEMP, TEMP-INDEX, WARM-DAYS, and COLD-DAYS, with factor loadings of .926, .841, .827, .736, and -.904, respectively. The results in Table 5 indicate that the factor loadings of these five climate variables on the first factor are by far the highest of these five variables on any of the factors. There is a sixth variable, CLOUDY, that also has a high loading of -.712 on this factor. Although it does not directly pertain to “temperature,” it makes sense that the CLOUDY variable loads so highly, and negatively, on the factor we have defined as TEMPERATURE. When temperatures are high, cloudy days are few. Also, the SUN variable has a high positive loading of .610 on the first factor. High temperatures are also associated with sunny days.

The second factor may be defined as representing HUMIDITY. This factor accounts for over 24 percent of the original variance in the eleven input variables. It is mainly defined by the three variables of AM-HUMIDITY, PM-HUMIDITY and RAIN, with factor loadings of .832, .792 and .849. The CLOUDY and SUN variables also have high loadings on the second factor of .627 and -.725, respectively. High humidity days are associated with cloudy days with little sun.

The third factor is defined by only one of the eleven climate variables, WIND, so we have labeled this factor WIND; it has a factor loading on the third factor of .914. No other climate variables have loadings on this factor above .38. This factor accounts for over 9 percent of the variance in the inputted climate variables.

The factor analysis indicates that there are three statistically independent sources of climate variability characterizing the 50 states of the U.S. These represent TEMPERATURE, HUMIDITY and WIND. Based on the rotated factor structure reported in Table 5, we next produced three factor scores for each of the 50 states representing, as just noted, TEMPERATURE, HUMIDITY and WIND. These will be the three measures of the physical climate we will use as predictors of migration.

The Relationship Between Climate and Migration

We address now the major question of this paper, namely, the extent to which there is a relationship between climate and migration. Is there more migration to states with favorable climates, that is, to states with warm temperatures, low humidity and low amounts of wind, than to states with less favorable climates? Table 6 presents zero-order correlation coefficients between each of three dimensions of climate and the three migration rates.

Of the nine correlations reported in Table 6, four are significant at a probability of .05 or less. The TEMPERATURE dimension of climate is only related significantly with the net migration rate. The HUMIDITY dimension of climate is associated significantly with all three migration rates. And WIND is not significantly related with any of the migration rates.

These bi-variate analyses shown in Table 6 indicate that following Lee's (1966) classic push-pull theory of migration, climate appears to operate more so as a pull factor than as a push factor (see also Bass and Alexander, 1972; Poston and Mao, 1996: 339). Considering only the statistically significant relationships, the more favorable the temperature, the greater the net migration. Also, the higher the humidity, the less the in-migration; and the higher the humidity the less the net migration. These all reflect pull, or in the case of net migration, net-pull, factors. Only the association between humidity and out-migration (r = -.41) suggests the operation of a push factor.

To this point we have shown some rather strong and significant correlations between certain dimensions of climate and three rates of migration. The next question, and indeed, one may argue, the more important question, is whether the demonstrated effects of climate on migration are sustained when other effects on migration are introduced and controlled. That is, it could well be the case that the effects of climate just shown would be reduced or diminished, if not eliminated, when alternate explanations of migration were introduced. We now explore these possibilities both theoretically and empirically, within the framework of human ecology.

The Effect of Climate on Migration:

Using the Framework of Human Ecology

From the perspective of human ecology, migration is the major mechanism of social change and adaptability for human populations. A knowledge of migration patterns tells us about how "populations ... maintain themselves in particular areas" (Hawley, 1950: 149). The ecological approach asserts that human populations redistribute themselves so to approach an equilibrium between their overall size and the life chances available to them. Migration is the principal mechanism for effecting this adjustment because it is a demographic response attempting to preserve or attain the best possible living standard by reestablishing a balance between population size and organization (Poston, 1981: 138; Poston and Frisbie, 1998: 30; Poston and Frisbie, 2005).

The theoretical foundation of human ecology is based on the interdependence of four conceptual rubrics of population, organization, environment, and technology. The interrelationships among and between these dimensions inform our understanding of migration patterns in the following way: all populations must adapt to their environments, and these adaptations vary among populations according to their social and sustenance organization, their technology, and the size, composition, and distribution of their population. The environment per se is comprised of both social and physical factors, and climate is the prime physical factor; these environmental factors set constraints on the population and the form and characteristics of its organization. The technology that the population has at its disposal sets in an important way the boundaries for the form and type of environmental adaptation the population assumes. These may change, however, as new and/or different technologies are introduced, allowing its relationship with the environment to change, and resulting also in changes or adjustments in the population's organization, and in its population size. Human ecology posits that, of the three demographic processes, migration is the most efficient agent for returning the human ecosystem to a state of equilibrium or balance between its size and organization (Poston and Frisbie, 1998; 2005).

The hypothesis typically investigated in ecological studies of migration (e.g., Sly, 1972; Sly and Tayman, 1977; Frisbie and Poston, 1978a, 1978b; Poston, 1980, 1981; London, 1986; Ervin, 1987; Saenz and Colberg, 1988; among many others) is that variability among human groups in their patterns of migration is a function of differences in their patterns of sustenance organization, technology, environment and population.

Within the theoretical framework of human ecology, we are now in a position to propose several kinds of effects on migration, in addition to those involving the three dimensions of the physical climate that were examined in the previous section. We discuss them according to each of the four ecological rubrics. We also present the hypothesized relationship of each independent variable with net migration.

Of the four rubrics, it is not an overstatement to note that organization is the most fundamental. We have selected 1) the unemployment rate, 2) manufacturing wages, and 3) gross state services per capita as three independent variables to represent the sustenance organization of the population. The unemployment rate should be negatively related to net migration, and the other two variables should be positively related with net migration.

In Table 7 (top panel) we show the operationalizations of these three variables and their descriptive data. Manufacturing wages is measured as mean hourly wages of manufacturing workers in the state in 1990. The average wage is just over $12, and varies from a low of $9.36 in South Dakota to a high of $16.31 in Michigan. The unemployment rate is the percent in the state unemployed. Its average value is 6.2 percent, and ranges from a low of 3.5% in Hawaii to a high of 9.6% in West Virginia. The services variable is the amount of gross services product in the state expressed in millions of dollars, per 1,000 population in the state. Its lowest value is in Massachusetts and its highest in Maine.

In sociological human ecology, the environment is defined as "whatever is external to and potentially or actually influential on the phenomenon under investigation" (Hawley, 1968: 330). According to this definition, the environment includes not only the biotic or physical characteristics of an area, such as climate, but also the "influences that emanate from other organized populations in the same and in other areas" (Hawley, 1981: 9). Accordingly, we have selected the three already discussed climate variables that emerged from the factor analysis (see Table 4) , namely, 4) the temperature factor, 5) the humidity factor, and 6) the wind factor to represent three physical aspects of the environment. In addition we have selected 7) minority concentration, and 8) the crime rate as independent variables to represent social aspects of the environment, and 9) whether the state is a coastal state (yes =1) as a variable representing both the physical and the social environments. Both minority concentration and the crime rate should be negatively associated with net migration; temperature should be positively associated, and humidity and wind negatively associated, with net migration. There should be a higher net migration rate if the state is a coastal state than if not.

In Table 7, we also show descriptive data for these variables. Since the temperature, humidity and wind factors are expressed as standard scores, they all three have means of zero and standard deviations of 1. The minority variable is the percentage of blacks, Hispanics and other minorities in the state, and has an average value across the 50 states of 16 percent. The crime rate is the number of FBI reported crimes per 100,000 population; the lowest rate is in West Virginia, the highest in Florida. Fourteen of the states (28%) are coastal states.

Technology has been argued by some scholars as very critical for the adaptation of human populations. It has been defined by Lenski (1970: 37) as “the information, techniques, and tools by means of which men utilize the material resources of their environment.” A problem with applying these dimensions to national sub-areas such as the states of the U.S. is that, like the larger concept of technology of which they are a part, they have been conceived at the societal level of analysis. One could argue that it is difficult to contend that the level of technology varies in any significant way at the sub-societal level (Poston and Frisbie, 1998: 37; 2005). One way of getting beyond this quagmire is to focus on the information component of technology and to choose as an independent variable 10) the educational level of the population, a variable that does indeed vary among sub-societal units; this is at best an imperfect solution. We hypothesize that education should be positively associated with migration. This variable is measured as the percentage of the population aged 25+ with 12 or more years of education completed. The variable has an average among the 50 states of 76.3 percent and ranges from a low of 64.3 percent in Mississippi to a high of 86.6 in Alaska.

Finally, we have chosen the variables of 11) population density, 12) percent of the population aged 65+, and 13) military personnel to represent the population rubric. Density should be negatively associated with net migration, while the latter two variables should show a positive association. Population density is operationalized as persons per square mile; it ranges from a low of 1 person per square mile in Alaska to a high of 1,044 persons in New Jersey. The percentage of the population 65+ variable ranges from 4.1 percent in Alaska to 18.3 percent in Florida. Finally the military personnel variable is operationalized as the number of military personnel in a state per 1,000 population. It has its lowest value in Iowa (0.1 military personnel per 1,000) and its highest in Hawaii (41.3 military personnel per 1,000).

There is a modest amount of collinearity in these independent variables. Specifically, 5 of the 78 correlations between each pair of independent variables are larger than 0.4; the crime rate has two correlations greater than 0.4; one is with the temperature score ($r = .62$), and the other is with the minority variable ($r = .59$); the minority variable also has high correlations with the temperature score ($r= .65$) and with the military variable ($r = .65$); the fifth high correlation is between the education variable and the temperature score ($r =-.52$). Although they are few, we will need to keep these high correlations in mind when we build the regression models to explain the dependent variables of migration. As a reviewer to this paper remarked, collinearity leads to inefficient estimation, not to bias.

Many statisticians recommend that when estimating multiple regression equations, it is preferred to have between 5 and 10 cases (units of observation) per each parameter (slopes and intercept) estimated (Bentler, 1985: 3; Raudenbush and Bryk, 2002: 267). We have proposed above thirteen different independent variables, some of which are collinear with others. But even without issues of strong multi-collinearity, we would not wish to use all thirteen in the same regression equation because we only have 50 observations. Thus we opted to mix and match the independent variables and estimate two different equations for each of the three migration rates. Moreover, given that the focus of this paper is on the effects of climate on migration, we use the three climate variables in all the equations we estimate, but we will mix the other non-climate independent variables.

We initially endeavored to estimate two regression equations for each of the three migration rates using all thirteen of the independent variables presented above, some of them in one equation, and the rest in the other; and in each equation, as just noted, the three climate variables were included. However, when we estimated the two equations using different combinations of the thirteen independent variables, we always had issues of very strong collinearity, no matter how we mixed and matched the independent variables. Thus, we decided to drop from the analysis the one independent variable of education which had correlations of at least 0.3 with six of the other independent variables. We used the remaining twelve in one or the other of the two equations. In one equation, we used the three climate variables plus the aged, manufacturing, unemployment, services, military, and crime variables. The statistical tolerances of the nine independent variables were all above .40, with a mean tolerance of .63. In the second equation we included, again, the three climate variables, plus the coastal, minority and density variables. The tolerances of these six independent variables in the second equation were all above .52, with a mean tolerance of .71. We do not have issues of strong multicollinearity in either of the two multiple regression equations we estimate for each of the three migration rates.

Table 8 presents the unstandardized and standardized regression coefficients from the two multiple regression equations for each of the three migration rates. We have asterisked those regression coefficients that are statistically significant (one tailed tests) at P <.05. The main substantive finding is that in all three of the migration equations, one, two or all three of the climate variables have significant effects on migration in the hypothesized direction. In the two equations predicting in-migration, HUMIDITY has a negative and significant effect. In the two equations predicting out-migration, all three climate variables have significant effects; the effects of TEMPERATURE and HUMIDITY are negative, and that of WIND is positive. And in both of the two equations predicting net migration, TEMPERATURE has a positive and significant effect, and HUMIDITY has a negative and significant effect.

HUMIDITY has negative and significant effects on all three migration rates, TEMPERATURE has significant effects on two of the migration rates, and WIND has a significant effect on one of the migration rates, namely, the out-migration rate.

The regression results in Table 8 illustrate rather conclusively that one or another of the climate variables has a significant effect in the hypothesized direction on each of the three migration rates. Moreover, these demonstrated effects of climate on the migration rates are statistically independent of the effects on migration of the other independent variables drawn from human ecological theory. These results are powerful in their impact and meaning: even after controlling for the effects on migration of various ecological factors dealing with the organization, the social environment and population of the states, climate still has statistically significant impacts on migration. The movement of peoples from one state to another is significantly and positively impacted by the climate of the states; the more favorable their climates, the greater will be their population gains through migration.

A reviewer of an earlier version of this paper asked us to compare the relative effects on migration of the climate measures with the effects on migration of the other ecological variables. We have included in Table 8 the standardized effects for all the independent variables in each of the two equations for each of the three migration rates.

In both of the two equations predicting in-migration, HUMIDITY has the largest standardized effect of all the independent variables in the two equations.

In the first equation (Model 1) predicting out-migration, the military variable has the largest standardized effect, followed closely by the standardized effect of the TEMPERATURE variable. The other two climate variables also have statistically significant effects in this equation, but their standardized effects are one-third the size of that for the military variable. In the second equation predicting out-migration, the minority variable and the TEMPERATURE variable have the sane standardized effects. The standardized effect of the HUMIDITY variable is a little less, and that of the WIND variable a lot less, albeit both are statistically significant.

Finally, in the first equation predicting net migration, the TEMPERATURE and HUMIDITY variables have the two strongest standardized effects. In the second equation predicting net migration, the TEMPERATURE variable has the strongest standardized effect, followed by the minority variable, followed by the HUMIDITY variable.

Our analysis of the standardized effects indicates that not only are the climate variables significant predictors of all three types of migration, in most cases they are the most influential predictors of migration. Even after controlling for the effects on migration of various ecological factors that have been shown in prior research to be important predictors of migration, climate still has not only statistically significant impacts on migration, but in most equations the largest standardized effects. We turn now to some of the implications of our findings.

Discussion and Conclusion

In this paper we have conducted an aggregate-based analysis among the states of the United States of the effects of physical climate on migration. We examined eleven different climate variables, and used factor analysis to reduce them to the three dimensions of temperature, humidity and wind. We showed that all three of the climate dimensions were associated with one or more of the three migration rates. The more important question that we addressed was whether the demonstrated effects of climate on migration would be sustained when other kinds of non-climate based effects on migration were introduced. We reasoned that it could well be the case that the effects of climate would be reduced or diminished, if not eliminated, in the context of alternate explanations of migration. Thus we evaluated the effects on migration of additional independent variables drawn from human ecology. These tests enabled us to examine the effects of climate on migration in the context of competing ecological hypotheses.

The results showed fairly conclusively that one or another of the three physical climate variables have significant effects in the hypothesized direction on three migration rates. Moreover, these demonstrated effects of climate on migration were shown to be statistically independent of the effects on migration of the other independent variables. Also, in most of the regression equations we estimated, the standardized effects of one or more of the climate variables on migration were the largest of all the effects in the equation. We noted that these results are powerful in their impact and meaning: even after controlling for the effects on migration of factors dealing with the organization, social environment and population of the states, climate still has a statistically significant, and in many instances the largest, impact on migration. The aggregate movement of peoples from one state to another is significantly and positively impacted by the climates of the states; the more favorable the climates of the states, the greater their population gains through migration.

We also note, again, the fact that two of the migration rates used in the above investigations are mathematically associated with each other; for any one state, its net migration rate is the difference between its in-migration rate and its out-migration rate. These mathematical relationships are apparent in the numerators of the rates; see the formulas presented earlier in this paper.

This so-called additivity of rates also characterizes the regression coefficients shown in Table 9. The unstandardized regression coefficient for the net migration rate for any one independent variable is equal to the difference of the regression coefficients for that variable for the in-migration and out-migration rates. To illustrate, consider the coefficient of 13.91 for TEMPERATURE for the first equation (Model 1) predicting the net migration rate (Table 9). This coefficient of 13.91 is exactly the difference of the TEMPERATURE coefficient of -5.46 for the in-migration rate and the coefficient of -19.37 for the out-migration rate.

Instances of additivity are due to mathematical identities, owing to the already mentioned relationships between the rates on account of their numerators. But they may sometimes also carry substantive meaning and import. Let us consider the effects on the migration rates of TEMPERATURE. We just noted that the effects of this climate variable on in-migration, and on out-migration, are negative; but only one of these two coefficients is significant statistically. That is, TEMPERATURE does not have a significant effect on in-migration, although it does have a significantly negative effect on out-migration. However, owing to the mathematical identity in the rates, the effects are additive. When these regression effects are subtracted one from the other, the effect of climate on net migration is positive and significant. It is thus the net change in population due to migration that carries the greatest importance. The additive relationship of the net migration rate with the in-migration and out-migration rates is substantively, not only mathematically, meaningful when one considers the issue of additivity and the fact that it carries over to an interpretation of the regression results.

We note also that the effects of climate on migration are in important ways modified by other non-climate factors, but are not spurious. At least this was the result in the analyses shown here. In evaluating the overall effects of climate on migration one should first look at the zero-order relationships of climate on migration (as in Table 6), and then at the relationships of climate on migration in the context of competing explanations of migration (as in Table 8). For instance, one could first assess the overall influence, positive or negative, of an aspect of the physical climate on net migration. Suppose the association is found to be positive (as it is in one instance in Table 6). Then one needs to ask whether this positive association is sustained in the context of other migration-related factors that do not pertain to climate. The unemployment rate is one such example. Typically, the unemployment rate is negatively associated with net migration. If the climate index continues to have a positive association with net migration, its effect on migration may have been modified, but not so much so that it disappears. In our analyses the effects of climate on migration are pervasive; they persist even in light of alternate explanations.

However, we need to be mindful of the fact that our state-based analyses are rather crude tests of the effects of climate on migration. Our dependent variables are several migration rates for each state, and our principal independent variables are several climate variables for each state. The migration rates refer to the overall migration experiences of the states, and not to the specific migration experiences of the geographical subunits of the states, say their cities and or counties. The data for the climate variables are based on weighted averages of the actual climate scores of the major cities of each state. What is needed next are a series of more geographically fine-tuned investigations in which the geographical units of analysis are smaller aggregate units with systemic integrity, such as metropolitan areas. We are currently undertaking such an analysis.

Despite the shortcomings of our study, we have shown that climate has a strong, pervasive and statistically significant effect on migration. Physical climate variables have significant effects in the hypothesized direction on three migration rates in the last half of the 1990s; and these climate effects on migration were shown to be sustained in the context of competing ecological explanations of migration. Our analyses indicate that the effects of climate on migration are real, and not spurious. The aggregate movement of human populations appears to be significantly impacted by the climates of the sending and receiving areas.

Endnotes

1. The time period for which annual measurements are made for this variable varies for each of the fifty states; the data for Nebraska cover the fewest years, 27, while those for Virginia cover the most years, 69; the mean number of years covered for this climate index is 39.

2. The time period of measurement for this variable varies by state. The California data cover the fewest years, 12, and Virginia the most, 64; the mean number of years covered is 37.

3. The number of years included in the measurement of this variable varies by state, with Nebraska having the fewest years, 28, and Utah the most, 69; the mean number of years covered is 47.

4. The time period of measurement varies among the states, with Nebraska having the fewest number of years involved in the measurement of the WIND variable, 26 years, and Utah the most, 69 years; the mean number of years for the states is 49 years.

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Table 1.
Descriptive Statistics, Three Migration Rates:
50 States of the U.S.,
1995-2000

Migration Rate	Mean	Standard Deviation	Minimum Value	Maximum Value
IN-MIG	107.5	44.4	40.6 (New York)	301.8 (Nevada)
OUT-MIG	102.7	31.2	60.8 (Michigan)	210.9 (Alaska)
NET-MIG	4.8	34.4	-65.4 (Hawaii)	151.5 (Nevada)

LEGEND
IN-MIG: In Migration Rate, 1995-2000
OUT-MIG: Out Migration Rate, 1995-2000
NET-MIG: Net Migration Rate, 1995-2000

Table 2.
Major Cities Used to Calculate Climate Measures, By State of the U.S.

State	Metropolitan Areas Used
Alabama:	Birmingham, Huntsville, Mobile, Montgomery
Alaska:	Fairbanks, Juneau, Anchorage
Arizona:	Flagstaff, Phoenix, Tucson, Yuma
Arkansas:	Ft. Smith, Little Rock, North Little Rock
California:	Los Angeles, San Francisco, Bakersfield, San Diego, Sacramento
Colorado:	Alamosa, Colorado Springs, Denver, Grand Junction, Pueblo
Connecticut:	Bridgeport, Hartford
Delaware:	Wilmington
Florida:	Miami, Orlando, Tampa, Jacksonville, Tallahassee
Georgia:	Athens, Atlanta, Augusta, Columbus, Savanna
Hawaii:	Hilo, Honolulu, Kahului, Lihue
Idaho:	Boise, Lewiston, Pocatello
Illinois:	Chicago, Peoria, Rockford, Springfield, Moline
Indiana:	Evansville, Ft. Wayne, Indianapolis, South Bend
Iowa:	Des Moines, Dubuque, Sioux City, Waterloo
Kansas:	Topeka, Wichita
Kentucky:	Lexington, Louisville, Paducah, Jackson
Louisiana:	Baton Rouge, Lake Charles, New Orleans, Shreveport
Maine:	Caribou, Portland
Maryland:	Baltimore
Massachusetts:	Boston, Worchester
Michigan:	Detroit, Lansing, Grand Rapids
Minnesota:	Duluth, Minneapolis-St. Paul, Rochester, St. Cloud
Mississippi:	Jackson, Meridian
Missouri:	Columbia, Kansas City, St. Louis, Springfield
Montana:	Helena, Missoula, Great Falls, Billings
Nebraska:	Lincoln, Omaha-Eppley, Grand Island
Nevada:	Las Vegas, Reno
New Hampshire:	Concord, Mt. Washington
New Jersey:	Atlantic City, Newark
New Mexico:	Albuquerque, Roswell
New York:	Albany, NYC-JFK AP, Rochester, Buffalo, Syracuse
North Carolina:	Charlotte, Raleigh, Greensboro, Winston-Salem
North Dakota:	Bismarck, Fargo
Ohio:	Cleveland, Columbus, Dayton, Toledo, Akron

Table 2 (continued)
Major Cities Used to Calculate Climate Measures,
By State of the U.S.

State	Metropolitan Areas Used
Oklahoma:	Oklahoma City, Tulsa
Oregon:	Portland, Salem, Eugene, Medford
Pennsylvania:	Philadelphia, Harrisburg, Erie, Allentown
Rhode Island:	Providence
South Carolina:	Charleston AP, Columbia, Greenville-Spartanburg
South Dakota:	Sioux Falls, Rapid City, Aberdeen
Tennessee:	Memphis, Nashville, Knoxville, Chattanooga, Bristol-Johnson City
Texas:	Austin, Dallas/Ft. Worth, Houston, San Antonio, El Paso
Utah:	Salt Lake City
Vermont:	Burlington
Virginia:	Richmond, Norfolk, Roanoke
Washington:	Olympia, Seattle, Sea-Tak AP, Spokane, Yakima
West Virginia:	Charleston, Huntington
Wisconsin:	Green Bay, Madison, Milwaukee
Wyoming:	Cheyenne

Table 3.
Descriptive Statistics for Climate Variables:
50 States of the U.S. 1990

Climate Variable (1990)	Mean	Std. Dev.	Min.	Max.
1. JAN-TEMP	30.94	13.09	7.55 (North Dakota)	71.98 (Hawaii)
2. JULY-TEMP	75.15	5.83	58.90 (New Hampshire)	85.30 (Arizona)
3. TEMP-INDEX	0.62	0.17	0.31 (North Dakota)	1.12 (Hawaii)
4. WARM-DAYS	36.17	29.02	2.50 (Maine)	122.25 (Arizona)
5. COLD-DAYS	104.59	51.14	0.00 (Hawaii)	207.00 (New Hampshire)
6. AM-HUMIDITY	77.87	8.57	41.00 (Nevada)	89.50 (Mississippi)
7. PM-HUMIDITY	56.30	8.95	27.30 (Arizona)	82.50 (New Hampshire)
8. RAIN	35.87	15.28	5.83 (Nevada)	70.76 (Maryland)
9. CLOUDY	159.00	32.50	76.30 (Arizona)	243.00 (Alaska)
10. SUN	59.70	8.45	35.50 (Alaska)	84.50 (Arizona)
11. WIND	9.34	2.26	6.20 (West Virginia)	21.00 (New Hampshire)

LEGEND

1. JAN-TEMP: average daily temperature for the month of January.
2. JULY-TEMP: average daily temperature for the month of July.
3. TEMP-INDEX: average daily maximum temperature in January divided by the average daily minimum temperature in July.
4. WARM-DAYS: average number of days in a year the temperature is 90 degrees Fahrenheit or higher.
5. COLD-DAYS: average number of days in a year the temperature is 32 degrees Fahrenheit or lower.
6. AM-HUMIDITY: average index value for each day in the year of morning measurements of "the amount of moisture in the air compared to the maximum amount of moisture the air can hold at the same temperature and pressure."
7. PM-HUMIDITY: average index value for each day in the year of afternoon measurements of "the amount of moisture in the air compared to the maximum amount of moisture the air can hold at the same temperature and pressure."
8. RAIN: average number of inches of precipitation per year.
9. CLOUDY: mean number of days when the average sky cover during daylight hours is between 80 and 100 percent.
10. SUN: total period of sunshine hours as a percentage of the maximum amount of time from sunrise to sunset with clear sky conditions.
11. WIND: average speed of the wind each day irrespective of the direction in which it is blowing.

Table 4.
Zero-Order Correlation Coefficients, Eleven Climate Variables: 50 States of the U.S.

1990	1	2	3	4	5	6	7	8	9	10	11
1. JAN-TEMP	1.00										
2. JULY-TEMP	0.68*	1.00									
3. TEMP-INDEX	0.94*	0.53*	1.00								
4. WARM-DAYS	0.60*	0.75*	0.53*	1.00							
5. COLD-DAYS	-0.95*	-0.73*	-0.83*	-0.59*	1.00						
6. AM-HUMIDITY	0.05	0.05	-0.12	-0.21	-0.23	1.00					
7. PM-HUMIDITY	-0.27	-0.31*	-0.40*	-0.41*	0.15	0.53*	1.00				
8. RAIN	0.24	0.14	0.04	-0.10	-0.34*	0.60*	0.59*	1.00			
9. CLOUDY	-0.59*	-0.69*	-0.61*	-0.68*	0.48*	0.45*	0.60*	0.31*	1.00		
10. SUN	0.48*	0.66*	0.53*	0.68*	-0.38*	-0.51*	-0.67*	-0.43*	-0.93*	1.00	
11. WIND	-0.44*	-0.44*	-0.39*	-0.39*	0.53*	-0.14	0.41*	0.10	0.16	-0.26	1.00

LEGEND

1. JAN-TEMP: average daily temperature for the month of January.
2. JULY-TEMP: average daily temperature for the month of July.
3. TEMP-INDEX: average daily maximum temperature in January divided by the average daily minimum temperature in July.
4. WARM-DAYS: average number of days in a year the temperature is above 90 degrees Fahrenheit.
5. COLD-DAYS: average number of days in a year the temperature is 32 degrees Fahrenheit or lower.
6. AM-HUMIDITY: average index value for each day in the year of morning measurements of "the amount of moisture in the air compared to the maximum amount of moisture the air can hold at the same temperature and pressure."
7. PM-HUMIDITY: average index value for each day in the year of afternoon measurements of "the amount of moisture in the air compared to the maximum amount of moisture the air can hold at the same temperature and pressure."
8. RAIN: average number of inches of precipitation per year.
9. CLOUDY: mean number of days when the average sky cover during daylight hours is between 80 and 100 percent.
10. SUN: total period of sunshine hours as a percentage of the maximum amount of time from sunrise to sunset with clear sky conditions.
11. WIND: average speed of the wind each day irrespective of the direction in which it is blowing.

NOTE: Asterisked correlations significant at $P < .05$.

Table 5.
Factor Loadings on Three Climate Factors,
50 States of the U.S.:
Principal Components Solution (With Iteration), Orthogonal Varimax Rotation

Variable	Factor I: Temperature	Factor II: Humidity	Factor III: Wind
JAN-TEMP	.926	.040	-.206
JULY-TEMP	.841	-.121	-.150
TEMP-INDEX	.827	-.135	-.198
WARM-DAYS	.736	-.349	-.120
COLD-DAYS	-.904	-.193	.309
AM-HUMIDITY	.031	.832	-.265
PM-HUMIDITY	-.214	.792	.382
RAIN	.293	.849	.186
CLOUDY	-.712	.627	-.119
SUN	.610	-.725	.010
WIND	-.306	.071	.914
Eigenvalue	5.524	2.657	1.001
% Variance	50.23	24.16	9.10
Cumulative Variance	50.23	74.38	83.48

Table 6.
Zero-order Correlations Between Three Dimensions of Climate and Three Migration Rates: 50 States of the U.S.

		TEMPERATURE	HUMIDITY	WIND
IN-MIG		.10	-.55*	.06
OUT-MIG		-.21	-.41*	.12
NET-MIG		.33*	-.34*	-.02

NOTE: Asterisked correlations significant at P <.05.

Table 7. Descriptive Statistics for Independent Variables: 50 States of the United States

Independent Variable	Mean	Std. Dev.	Minimum Value	Maximum Value
Under Organization rubric				
1. Mean hourly wage of manufacturing workers	12.14	1.38	9.36 (South Dakota)	16.31 (Michigan)
2. Unemployment rate	6.16	1.36	3.50 (Hawaii)	9.60 (West Virginia)
3. Gross service product (million US$) per 1,000 population	5.29	8.59	0.34 (Massachusetts)	63.20 (Maine)
Under Environment rubric				
4. Temperature factor score	0.00	1.00	-2.49 (Alaska)	2.13 (Hawaii)
5. Humidity factor score	0.00	1.00	-2.95 (Arizona)	1.37 (New Hampshire)
6. Wind factor score	0.00	1.00	-1.84 (Oregon)	5.07(New Hampshire)
7. Percent black, Hispanic and other minorities	16.14	11.81	1.36 (Vermont)	66.65 (Hawaii)
8. Crimes per 100,000 population	4,962.8	1,268.2	2528 (West Virginia)	8250 (Florida)
9. If a coastal state (yes = 1)	0.28	0.45	0.00	1.00
Under Technology rubric				
10. Percent population 25+ with 12+ years education	76.29	5.63	64.3 (Mississippi)	86.6 (Alaska)
Under Population rubric				
11. Population density (pop per sq. mile)	166.18	235.34	1.00 (Alaska)	1044.30 (New Jersey)
12. Percent of population aged 65+	12.48	2.14	4.07 (Alaska)	18.31 (Florida)
13. Military personnel per 1,000 population	6.66	6.91	0.14 (Iowa)	41.33 (Hawaii)

Table 8. Unstandardized and Standardized Regression Coefficients for Three Migration Rates: 50 States of the United States

Independent Variable	In-Migration Model 1		In-Migration Model 2		Out-Migration Model 1		Out-Migration Model 2		Net-Migration Model 1		Net-Migration Model 2	
	Unstan	Stan.	Unstan	Stan	Unstan	Stan	Unstan	Stan	Unstan	Stan	Unstan	Stan
1. manufacturing	-6.95*	-.22			-3.20	-.14			-3.76	-.15		
2. unemployment	-3.62	-.11			1.76	.08			-5.38	-.21		
3. services	.32	.06			-.27	-.07			.59	.15		
4. temperature	5.46	-.12	5.32	.12	-19.37*	-.62	-18.51*	-.59	13.91*	.40	23.84*	.69
5. humidity	-18.99*	-.43	-22.48*	-.51	-8.82*	-.28	-15.03*	-.48	-10.17*	-.30	-7.45*	-.22
6. wind	5.18	.12	3.81	.09	6.39*	.20	6.24*	.20	-1.21	-.04	-2.42	-.07
7. minority			-.11	-.03			1.55*	.59			-1.66*	-.57
8. crimes	.01	.26			.01*	.23			.00	.13		
9. coastal			.86	. 01			-.22	-.00			1.08	.01
10. density			-.04	-.19			-.02	-.17			-.01	-.10
11. population 65+	-3.48	-.17			-1.36	-.09			-2.12	-.13		
12. military	627.08	.10			2847.54*	.63			-2222.18*			
Constant	206.39		115.14		102.59		81.51		103.86		33.64	
R^2 (adj)	.34		.26		.63		.35		.22		.33	

* $p < 0.05$ (one-tailed test)

Figure 1. Scatterplot of In-migration and Out-migration Rates
States of the U.S., 1995-2000