MIGRATION: RAVENSTEIN, THORNTWAITE, AND BEYOND[1]

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ABSTRACT

It is now over one hundred years since Ravenstein published his "Laws of Migration". How have these laws fared? His paper also includes a map of "Currents of Migration", not mentioned in the text. Thornthwaite also compared migration to currents, but did not follow through with this analogy. Others have used similar terminology. More recent migration studies may yield new laws.

RAVENSTEIN'S LAWS

Ernst Georg Ravenstein was a geographer of German extraction who worked at the Royal Geographical Society in London, and was that organization's first Victoria gold medallist. In 1885 he published a paper entitled "The Laws of Migration" in the Journal of the Statistical Society. This 1885 paper, the second and most interesting of three, includes his motivation as its first sentence (1885:167):

> "It was a remark of the late Dr. William Farr, to the effect that migration appeared to go on without any definite law, which first directed my attention to [the] subject...."

What then are Ravenstein's laws of migration? I list here a short selection of ten, but a more definitive review would be desirable; Grigg (1977a,b) lists eleven slightly different laws:

(1) "... even in the case of 'counties of dispersion', which have a population to spare for other counties, there takes place an inflow of migrants across that border which lies furthest away from the great centers of absorption". (1885:191)

(2) "The more distance from the fountainhead which feeds them, the less swiftly do these currents flow". (1885:191)

(3) [We have] "proved that the great body of our migrants only proceed a short distance". (1885:198)

(4) "In forming an estimate of displacements we must take into account the number of natives of each county which furnishes the migrants, as also the population of the ... districts which absorb them". (1885:198)

(5) "Migrants enumerated in a ... center of absorption will ... grow less with the distance proportionally". (1885:199)

(6) "The process of dispersion is the inverse of that of absorption, and exhibits similar features". (1885:199)

(7) "Each main current of migration produces a compensating counter current". (1885:199)

(8) “Counties having an extended boundary in proportion to their area, naturally offer greater facilities for an inflow ... than others with a restricted boundary”. (1885: 175)

(9) [Migration streams] “sweep along with them many of the natives of the counties through which they pass [and] deposit, in their progress, many of the migrants, which have joined them at their origin”. (1885:191)

(10) “Migratory currents flow along certain well defined geographical channels”. (1889:284)

We can now ask what has happened to these laws in the intervening years? Have any been refuted? If so, which ones? If not, why not? Are they irrefutable tautologies? Do they still hold today? Have any been extended? If so, which ones? Have any new laws been added? If so, what are they? If not, why not? And finally, what could we do today with the 1881 census that Ravenstein did not? Is our theory, our methodology, or our technique better? Do we have better data?

MODERN EVIDENCE

It is not difficult to demonstrate that at least some of the laws still hold today. Again a more exhaustive investigation seems warranted and only small snippets are presented here.

Consider the first of the cited laws:

" ... in ... 'counties of dispersion' there [exists] an inflow ... across that border which lies furthest away ... "

Here in the United States we currently (though it is in fact not new) have a concern with in-migration from Mexico. Ravenstein's law asserts that the Mexicans should have an inflow from Guatemala and this indeed seems to be the case.

Or take the second and third of the laws previously cited. These describe the famous distance decay. Today we show this on log-log graphs; many examples can be found in Hägerstrand's paper of 1957, and indeed in most freshman college texts, or, e.g. Olsson (1965). We know that short distance moves predominate.

The forth law includes the population of the sending and receiving places; contemporary evidence is given in Figure One, and is of course now known as Zipf's Law (Zipf 1946).

The fifth and sixth laws again relate to distance decay and to the symmetry of in and out moves. We can sharpen these concepts of dispersion and absorption by using Hägerstrand's notion of a 'migration field', the intensity of which drops off with distance. This is shown in Figure Two using the in migration and out migration fields for Kansas. To the eye these cannot be distinguished from each other, as is expected for processes which are "inverse".

The 1975 to 1980 US Census Bureau state-to-state migration table can be used to evaluate the seventh of Ravenstein laws as listed. As shown in the figures (Three and Four) the correlation between outgoing and incoming migrants remains high.

CRITIQUES

There are of course also critiques of Ravenstein's laws. For example, in the 'Age of Migration' (Castles & Miller 1993, pp. 19-21) it is asserted that Ravenstein's "... model is essentially individualistic and ahistorical." and "... government restrictions ... are ignored ...." Later the authors state that

"... a push-pull model would predict movements from densely populated areas to more sparsely populated regions ...." Even if these criticisms were valid - I would assert that they are not and that they reflect a superficial reading of Ravenstein's work; for example see the introductory comments on pages 241 and 242 of the paper of 1889 - they do not refute any of his laws. The treatment in the migration literature as a whole is to ignore the laws, or to regard them as irrelevant. They are generally not refuted, but sometimes are considered incomplete (as in the work cited above), or not germane. I have not found any attacks on the substance of the laws as such. This again could provide an interesting area of study.

THORNTHWAITE AND MIGRATION STUDIES

Turning now to a somewhat different subject, Figure Five shows Ravenstein's (1885:183) fifth map, of the "Currents of Migration." This is by far the most interesting of his maps, yet there is no mention of it in the text of the paper, which seems very curious (would today's editor have noticed this and deleted it?) Yet the map must have been based on detailed study of census data. It shows mostly local moves, i.e., county to county movements. The map seems to have been completely ignored by scholars, historians, and cartographers. It is difficult to see how one could program a computer to produce this map using the kinds of statistics available today. Certainly it would be a challenge.

The use of the word "currents" in the title of the map is also most extraordinary. What kind of currents are these? Ocean, electrical, atmospheric or what? It certainly suggests a fluid, with flowing phenomena. It is most curious that the literature on migration is replete with this kind of terminology. We speak of "migration flows" and "migration streams" and "counter-currents", and refer to intellectual or cultural "backwaters", as if there were eddy currents. One can be "outside of the mainstream". And there are "waves of immigration", etc. The language used in migration studies provides another challenging topic for epistemological examination.

In this context the introduction to Warren Thornthwaite's monograph on migration is most interesting and revealing. Thornthwaite's reputation of course rests on his later work in climatology. He is not particularly known as a student of migration but the fifty-two page monograph from 1934 is still worth examination, and also contains challenging maps. His migration study was done while he was an assistant professor at the University of Oklahoma. He refers specifically to pressures and gradients, and I quote here his first paragraph (1934:1).

> "In America, as elsewhere, migration is a process which is dependent upon the establishment of means of communication between areas having different intensities of population pressure. These pressure gradients are brought about either through an increase in pressure in one area or through a decrease in another area. The relative intensity of population pressure may be increased within a given area either through a contraction of economic and social opportunities or through the continued growth of population, and may be reduced through an expansion of opportunity or through a diminution of population. Through the flow of population from regions of high pressure to regions of low pressure, the inequalities tend to be reduced. The importance of migration bears an inverse relation to the resistance, both physical and cultural, which it encounters. Physical isolation, inertia, prejudice, and ignorance are some of the factors, which inhibit more or less the freedom of movement of population. The flow of population is in a way analogous to the flow of an electric current, the mathematical expression of which appears to have some application to

> migration*. The amount of migration from one area to another is directly proportional to the pressure gradient between them and inversely proportional to the resistance."

In the footnote (denoted by *, above) he even explicitly writes out "Ohm's law: i = E/R." He did not follow up on his use of this equation, and uses no mathematical models in the monograph. Recall also that none of Ravensteins's laws were stated in mathematical terms; Ravenstein used only the simplest form of arithmetic in his several papers. Observe further that Thornthwaite did not, in the 1930's, refer to 'spatial interaction' or 'gravity models', but he clearly understood an economic benefit argument, later picked up by economists. One of course also notes his reliance on physical concepts, perhaps reflecting his interest in climatology. Nowhere does he refer to Ravenstein's papers. In his masters thesis at the University of Washington in the 1920's Harold Hotelling did develop the pressure/gradient idea mathematically, but Thornthwaite was not aware of this work; it was not published until 1978. More recently the economist Robert Lucas expressed a view similar to that of Thornthwaite (Lucas, 1981:85), viz:

> "Migration is comparable to a flow of water or electricity - an adjustment flow responding to pressure differentials at opposite ends of a pipeline. This view suggests that it is neither the absolute level of push nor pull factors which matters, but the existing difference in relative attraction elements."

This differential attractivity model of migration is common in the economic literature, but much less favored by sociologists and political scientists.

Guido Dorigo and I did (1983) relate something like Ohm's law to migration, putting migration proportional to a pressure, and inversely related to resistance. This is not the place to repeat this work except to state that it did allow us to translate many of Ravenstein's laws into equation form, and also to produce electrical (or hydrodynamic) current-like maps of migration (Tobler 1981, 1990). The 'population pressure' in our work is deduced by computation from the actual migration amounts and is not given in advance, in contrast to most other studies. The model also takes into account simultaneous two way movements.

NEW EVIDENCE AND NEW LAWS

To the question of new evidence and new laws of migration we must remember that Ravenstein used data from only a few censuses. Using data broken down by age classes and for multiple time periods, now available, we can extend some of his results. Whether we call them laws or simply empirical regularities seems to me immaterial. In Ravenstein and Thornthwaite's time only place-of-birth to place-of-current-residence tables were available whereas we now have place-of-previous-residence to place-of-current-residence tables, and, in the USA, spanning fifty-five years. The brief comments given here do not constitute a through literature search for new laws, but are based on my casual reading over a decade or so. This is certainly another domain for the interested student.

One of the most studied regularities is the age profile of migrants. This has been parameterized by Andrei Rogers et al (1978) and surely warrants the name of a migration "law". The rule about the similarity of the sizes of the in and out migrations also seems to hold for individual age groups (compare Figure 3.4, p. 36, of Stillwell, et al. 1991), which we should have been able to deduce. Many studies have replicated the migration age structure profile. Inter-

zonal and intra-zonal movements show the same effect (see for example, Figure 7, p. 28 of Rees & Stillwell, 1982), as do males and females. It seems a timeless rule.

Time series data allow further strengthening of Ravenstein's observation that currents produce counter-currents. Table I, column two, gives the correlation between the in and out sums (N=48) for the six decades of US coterminous state-to-state migration, and column three shows the comparable value for the 1128 pairs of cross diagonals from the migration matrices. Figure six shows the time course of the correlation of the current and counter current sums, and the next figure (seven) contains the scatter diagram for the period of lowest correlation, the 1935-1940 migrations. This occurred during the later part of the depression and one immediately notices the outlier. The next lowest correlation, 1955-1960, also contains an outlier; this time it's Florida. An effect similar to what happens in geology appears to be at work. Real change is a rare event, but when it happens, it has a disproportionate result. I think of such things as a gold rush, which modify an existing migration system dramatically. Perhaps the laws break down during these periods.

On the whole the migration system can be characterized as being 'sluggish', in both space and time. By this I mean that changes generally occur only slowly, with the exception noted above. It is technically difficult to calculate the exact degree of persistence from one migration period to another, but Table II shows the correlation between all six US state-to-state tables for the contiguous USA. Thirty eight percent of the 1985-1990 migration table (Hansen 1993) can be explained by the 1935-1940 table, and fifty two percent of it can be explained by the 1975-1980 table (using the squares of the correlations listed). The graph (Figure eight) shows a form of autoregression calculated for the six US migration matrices, with data taken from the last column of Table II. A reason for the general stability of migration, moving in "well defined channels" (law ten, above), is the existence of contacts between people who follow each other as migrants, or who return. But these contacts weaken with the passing of generations, and so does the correlation of the tables.

The amount of asymmetry in a migration table measures the departure from a balancing reciprocal exchange between the places. For the aggregate US migration table, grouping together all ages and occupations, this asymmetry is low, never exceeding twenty percent (Figure nine and Table III). Twenty percent can of course represent a large number of people, but the bulk of the migration pattern is quite stable. It is the "volatile" percentage that most practitioners wish to predict.

In space it is interesting to observe the frequent occurrence of the same sign in the net migration of adjacent places, Figure Ten. This strong spatial autocorrelation also seems to persist over time. I have attempted to isolate it by drawing the zero net migration line for several of the US state-to-state migration tables. In order to do this one imagines the net migration table converted into a "surface" with positive and negative heights, as shown in Figure Eleven for the 1975-1980 migration table. Pycnophylactic interpolation (Tobler 1979b) is used to produce this surface from the state tables. The zero contour line from this surface surrounds the areas of net migration loss. The map for the USA in Figure Ten, and similar maps computed for other time periods and for other countries, suggests that (net) migration occurs simultaneously over a very large area. Individual states do not bound the net migration area. This conclusion might change if higher resolution migration data were available; for example see Dorigo's migration maps in Tobler (1990).

It is well known that the smaller the reporting unit the greater the amount of migration, an effect due to the more frequent occurrence of boundaries (it is necessary to cross a boundary before being counted as a migrant). Some recent time series evidence suggests a relative stability of the ratio of these flow magnitudes. In the United States the Census Bureau reports data for the forty eight contiguous states, and these are often grouped into nine regions and then into four divisions. Figure Twelve shows that the number of people classified as migrants goes down as the migration matrices become smaller - just as one would expect since fewer boundaries are crossed when going from region to region, or from division to division. Less than twenty percent of the total number of migrants cross the regional boundaries, and less than ten percent the division boundaries. These numbers appear not to fluctuate erratically through time, but there does seem to be a slow decline in the percentage values. A similar, but somewhat sharper, decline has occurred in the number of persons migrating to an adjacent state. The latter suggests an increase in the average distance migrated, while the former suggest the opposite. Table III gives the numerical values. Undoubtedly there are additional regularities to be found in migration data.

COMPUTATIONAL TECHNOLOGY

Our data processing capabilites are far greater than were those of Ravenstein or Thornthwaite. Statistical and geographic analysis can proceed almost effortlessly. For example, a USA county to county migration table - a 3141 by 3141 matrix with potentially 9,862,740 entries - need no longer be considered large. Table IV lists some of the larger matrices that have been processed in recent years. But we still need to ask the right questions. Many descriptive indices have been invented since the 1880's but they are generally pretty simplistic (e.g., migration efficiency), and not of great diagnostic value. Migration calculations do not seem to have as many accounting regularities as other aspects of much of demography and are in this respect somewhat disappointing. Geographers however will like the fact that complex migration maps can be made quite easily by computer (Tobler 1987). To comprehend 9,862,740 numbers one certainly needs such visualization techniques. Migration maps now take only a few minutes to produce, and can be used in exploratory studies of migration, and can be quite up to date, given the data.

CONCLUSION

Many migration studies do not seem aimed at detecting structural regularities. A disappointingly large proportion of the works is rather bureaucratic and parochial. Many are anecdotal and culture specific. Often they seem to aim at "what's going on in my backyard", i.e., in country C at time T, or at "what will happen next", as if that knowledge were obtainable in more than the very short run. Or of the form "here's what the latest statistical table shows". There are now also many studies on the impact of migration on the leaving area or on the destination area, and on the decision to migrate. Of course the questions asked today should differ from those of a hundred years ago, but it would be to our advantage if more researchers would ask questions like those I posed in the first paragraph of this paper, repeated here for emphasis and as a challenge.

What has been done with Ravenstein's laws in the last 100+ years? Have any been refuted? If so, which ones? If not, why not? Are they irrefutable tautologies? Do they still hold today? Have any been extended? If so, which ones? Have any new laws been added? If so, what are they? If not, why not? What can we do today that Ravenstein did not? Is our theory, our methodology, or our technique better?

We certainly have better data, and more computational power, but just as Einstein's theory supplanted Newton's, we should go beyond the work of earlier scholars, rather than to ignore it. The migration literature is by now huge and there must be more space-time regularities buried in this mass of material. Can we tease them out? One attempt at a similar level of generality is that by Wilber Zelinsky (1971). Others should be encouraged. Some of the difficulties are outlined by Robin Pryor (1981).

[1]*Urban Geography*, 1995, 16,4:327-343. Presented at the 1994 San Francisco meeting of the Association of American Geographers.

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TABLE I
CORRELATION BETWEEN IN AND OUT MIGRATION
Using State to State Data

Decade	N=48	N=1128
35/40	0.57	0.722
49/50	0.95	0.939
55/60	0.72	0.793
65/70	0.89	0.841
75/80	0.95	0.672
85/90	0.82	0.770

TABLE II
CORRELATION BETWEEN ENTRIES IN SIX US MIGRATION TABLES

Decade =	35/40	49/50	55/60	65/70	75/80	85/90
Decade:						
35/40	1.00	0.88	0.86	0.81	0.68	0.62
49/50	0.88	1.00	0.91	0.93	0.85	0.76
55/60	0.86	0.91	1.00	0.96	0.89	0.71
65/70	0.81	0.93	0.96	1.00	0.95	0.76
75/80	0.68	0.85	0.89	0.95	1.00	0.72
85/90	0.62	0.78	0.71	0.76	0.72	1.00

N = 2256; State to State Migrations
48 by 48 Census Bureau tables, less diagonals

TABLE III

PERCENTAGES OF TOTAL INTERNAL MIGRATION

Decade	Degree of Asymmetry	Inter-Region	Inter-Division	To Adjacent State
35/40	16.05	18.52	8.78	48.66
49/50	3.17	15.60	7.14	40.64
55/60	15.89	13.49	6.30	34.70
65/70	9.33	12.43	5.26	32.71
75/80	17.29	11.49	4.44	30.61
85/90	12.90	11.37	4.03	30.82

TABLE IV

LARGE MOVEMENT TABLES ANALYZED TO DATE

Table Size	Geographic Location	Geographic Area, sq km	Mean km Resolution	Reference
714x714	Netherlands	40,844	7.3	van der Erf, 1984
813x813	Scotland	78,749	9.8	Coombes, 1985,1986
3072x3072	Switzerland	41,236	3.7	Dorigo, 1986
3141x3141	United States	9,529,081	55.1	Slater, 1984
5111x5111	Chicago	3,203	0.8	CATS, 1959
9289x9289	England & Wales	151,147	4.0	Coombes, op.cit.

FIGURE ONE:
Comparison of actual and predicted migration. Scatter diagram (N = 2256) relating Zipf's population over distance hypothesis (abscissa) to the actual number of people migrating (ordinate), 1975-1980. Logarithmic scales; distances measured between centroids of states.

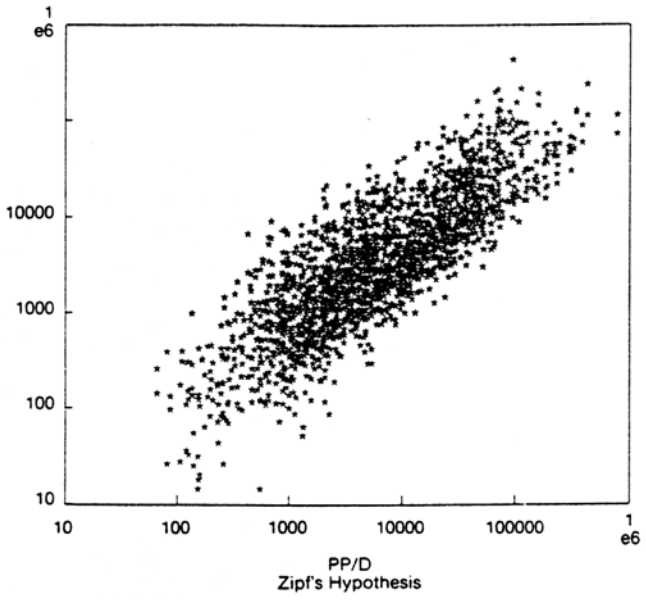


FIGURE TWO:
Kansas migration field, 1975-1980, interpolated from the state-to-state migration table, including diagonal. The diagonal contains the within-Kansas county-to-county migration, but not the within-county moves. Top, the out-migration field (one row of the full 48 by 48 US table); Bottom, the in-migration field (one column of the table). Interpolation as in Tobler (1979a). The vertical axis represents the number of people migrating.

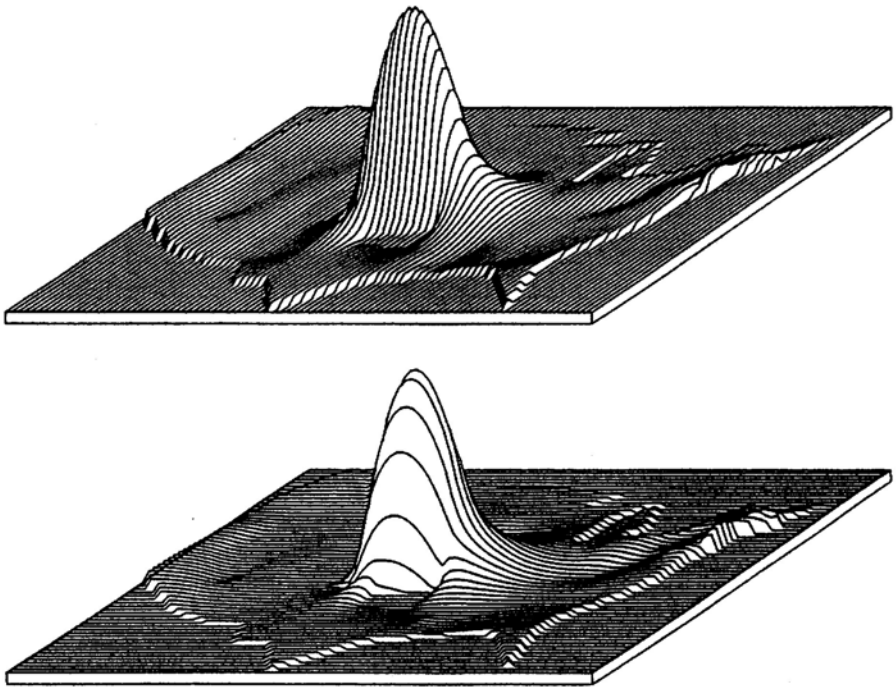


FIGURE THREE:
Comparison of the in- and out-migration totals by state. The scatter diagram of the marginals of the 1978-1980 table (N = 48) relates the in-migration (abscissa) and out-migration (ordinate) totals by state. Logarithmic scale of the number of people migration (compare with Figures 6 and 7).

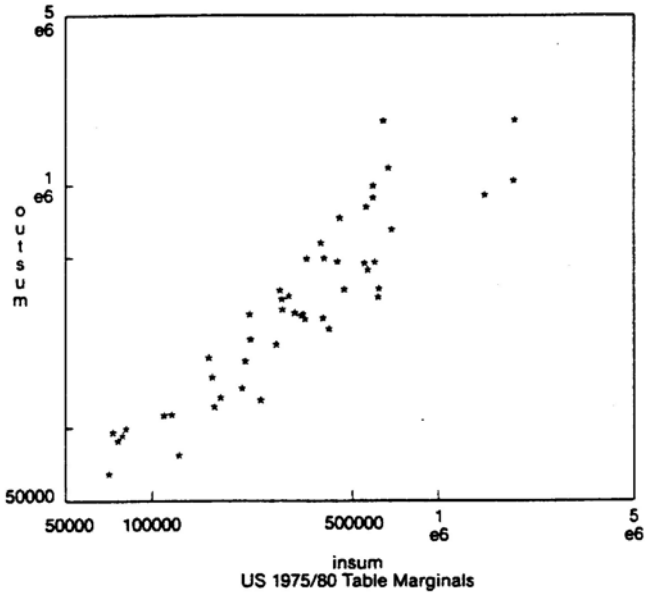
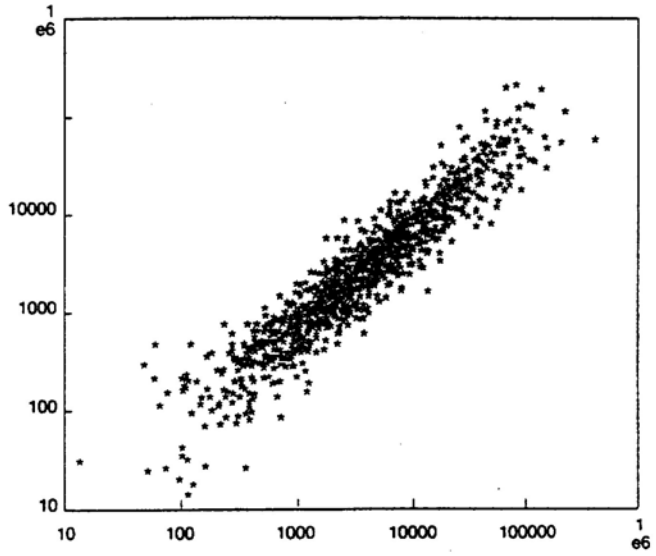


FIGURE FOUR:
Stream and counter stream. Detailed comparison of the in- and out-migration of people, using a migration table given in the form of a 48 by 48 from-to table. Scatter diagram of the cross diagonals of the 1975-1980 migration table (N = 1128), relating the "streams" and "counter streams". Abscissa: above diagonal values: ordinate: below diagonal values. Logarithmic scales for the number of people migrating.



US 1975/80 All Streams Combined

FIGURE FIVE:
Currents of Migration. The fifth map in Ravenstein's "Laws of Migration" paper (1885). The small vectors are printed in red.

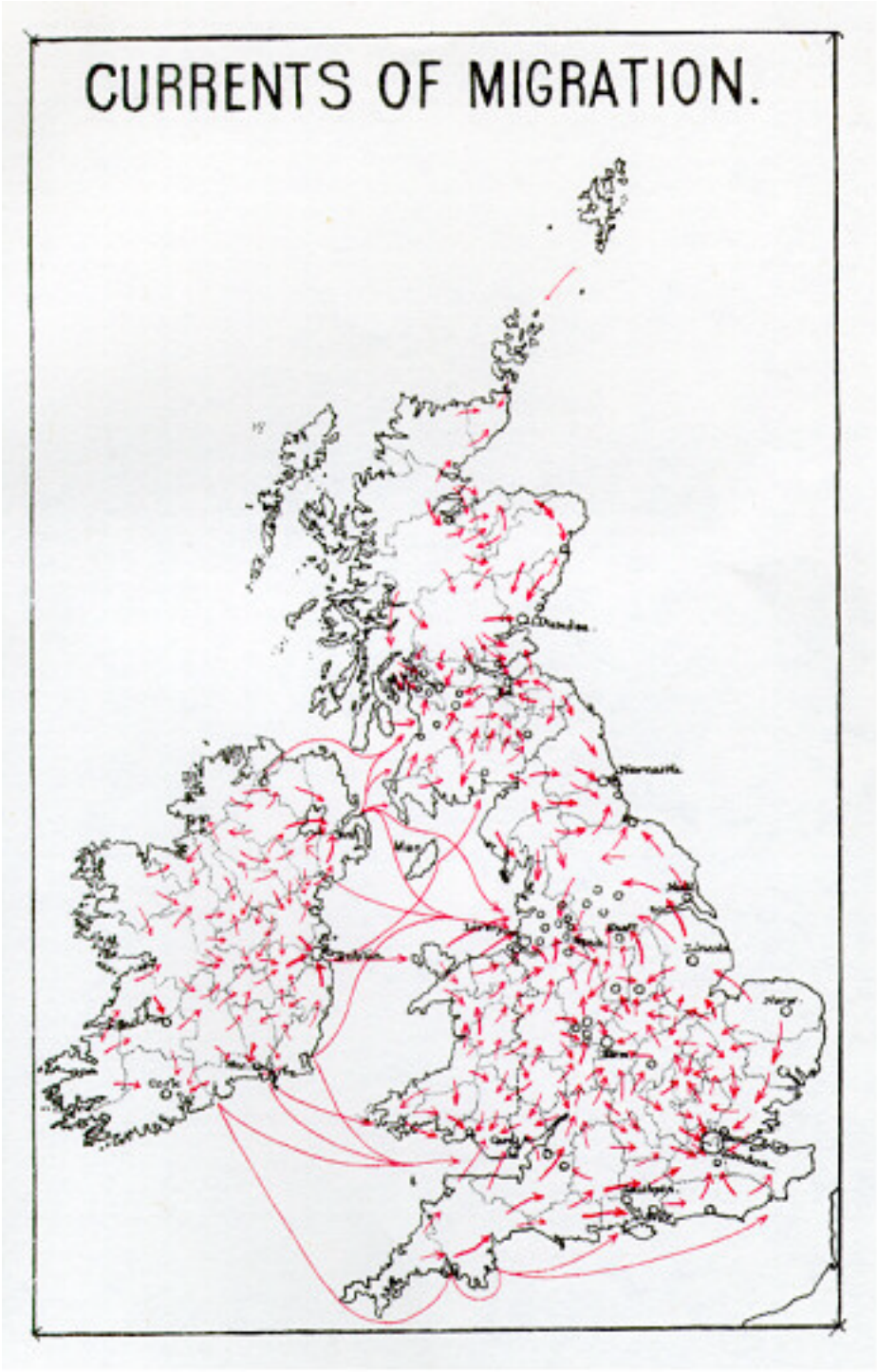


FIGURE SIX:
Time course of the correlation between the in- and out-migration totals by state. The dates on the abscissa describe the period for which the census requested migration information. For example, the 35.40 "decade" refers to the 1940 census date, in which the question asked was "where did you live five years ago?" In 1950, the question referred to the residence in 1949; all other periods were for the residence five years before. The values for the 75.80 "decade" on the abscissa are represented by the scatter diagram in Figure 3.

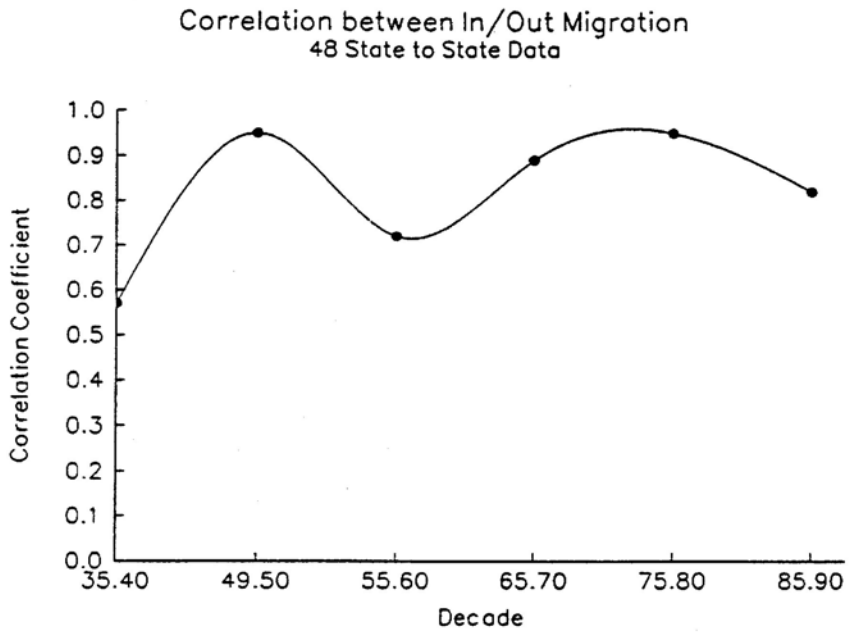


FIGURE SEVEN:
The scatter diagram for the 1935-1940 in and out migration totals. This is the data represented at the point 35.40 on the abscissa of Figure 6. California is seen as exceptional.

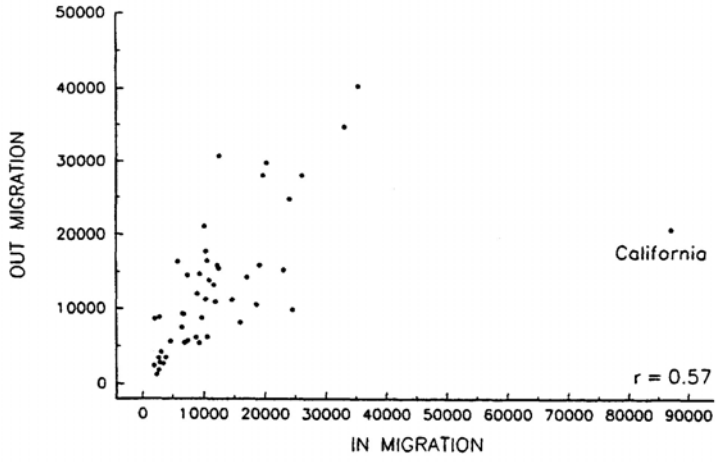


FIGURE EIGHT:
Autoregressive correlation for six migration matrices (48 by 48) representing the situation in the United States, 1935-1990. See Table II. Abscissa labeled as in Figure 6.

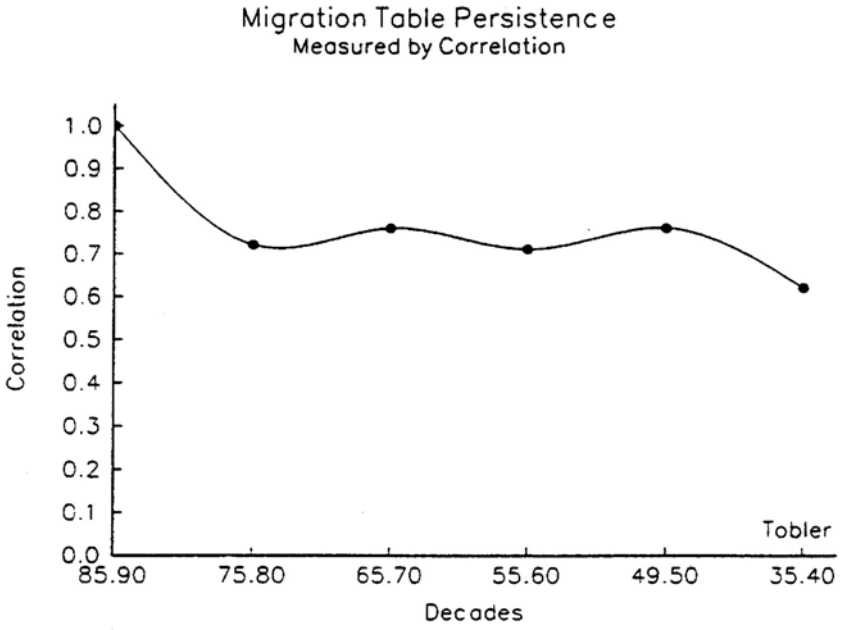


FIGURE NINE:
Asymmetry of the US 48 by 48 state-to-state migration tables from 1935 to 1990. Asymmetry is computed as the variance of in minus out migration over the total variance. See Table III. Abscissa labeled as in Figure 6.

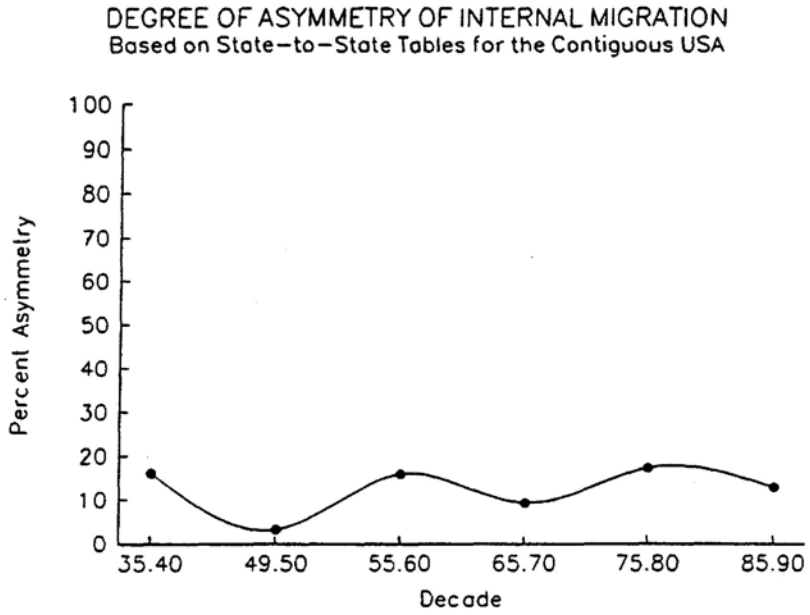


FIGURE TEN:
Spatial autocorrelation of the migration in the United States, by state, 1975-1980. States with a plus symbol were gaining, those with a minus sign were losing, people through internal migration. Omitting the state boundaries emphasizes the spatial coherence, and quickly renders it obvious. The zero net migration contour can easily be visualized (see Figure 11). In Figure 10 each symbol is located at the state centroid.

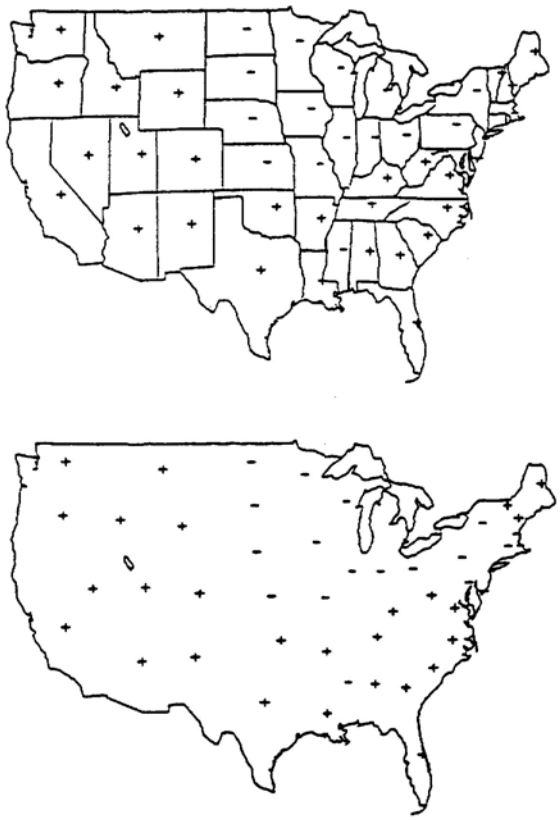


FIGURE ELEVEN:
The 1975-1980 net migration surface for the contiguous United States. This represents an alternate presentation of the data used to produce Figure 10.

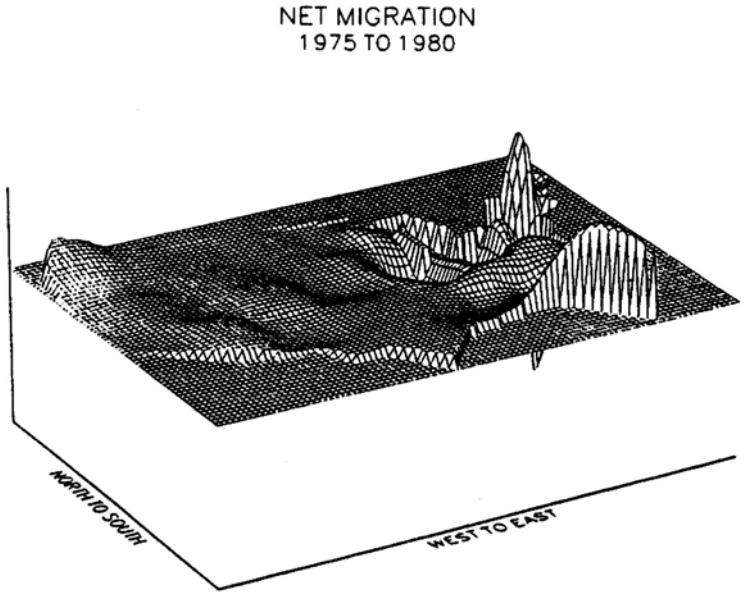


FIGURE TWELVE:
Percentage of total internal migration in three categories, based on the 48 by 48 Census Bureau tables, taking into account the assignment of states to the different categories (See Table III.) Abscissa labeled as in Figure 6.