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EXPLORATORY ANALYSES OF THE 1966-1971 AUSTRIAN MIGRATION TABLE

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Abstract

Four different techniques of a rather simple type are used to analyze recent interregional migration flows in Austria. Purely descriptive methods are used to reduce the large data set to proportions which facilitate interpretation. Methods of Markov and matrix growth operator type are used to project future spatial redistribution of population arising from both migration and differences in the rates of natural increase. A least squares approach is used to measure the attractiveness and emissiveness of regions based on a revealed preference rationale. Finally, the biproportional economic input-output and transportation origin-destination tables are used to generate the most plausible changes in migration propensities which would give rise to a specified target population distribution.

Acknowledgements

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Exploratory Analyses of the 1966-1971 Austrian Migration Table

Ross D. MacKinnon*
Anna Maria Skarke**

1. Introduction

Clearly the government of any country would like to be able to predict, understand and, in some cases, control the differential rates of growth of cities and regions. The provision of many public services, the distribution of sources of revenues (and political support), economic inefficiencies and environmental quality -- these and other concerns are frequently closely related to the magnitude, distribution, and structural characteristics of the population within a country. The two components of population change are net natural increase and migration. In this study we focus on the patterns of internal migration of Austria in recent years. The modes of analysis are rather simple, aggregate and exploratory. In the first instance, the methods are inductive and descriptive. What are the dominant spatial trends in Austrian migration? What are the implications for future population distributions if these trends continue? Inevitably an interpretation of empirical patterns leads one to generate hypotheses -- rationales for the observed patterns. More rigorous causal analyses may be undertaken in subsequent studies.

In recent years, interregional migration has been the focus of an increasingly large number of research studies. (See Cordey-Hayes (1975) for an extensive review.) Some approaches attempt to describe migration patterns (e.g. Tobler, 1975). Others extend descriptive models into a predictive context (e.g. Rogers, 1968). Some researchers attempt to specify the causal structure in multivariate systems of equations

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(e.g. econometric models such as in Alperovich, Bergsman and Ehemann, 1975). Finally, a few models are of a normative or goal-seeking type (e.g. Evtushenko and MacKinnon, 1975).

All of these approaches to migration modelling have been experimented with by people at IIASA in the past year. It would seem appropriate at this time to apply some of these methods to the local Austrian migration system. In view of the limited previous analysis of interregional migration in Austria, this report is highly exploratory -- an attempt to gain some experience with the various methods and some preliminary insights into the Austrian migration system itself. The approaches we have selected all have the characteristic of simplicity. This is in part a pragmatic decision -- reflecting very real time constraints which limit the scope of the research. But perhaps more importantly, this selection arises from a predisposition to develop broad, aggregate and rather rough models initially, and, subsequently, to modify the models by incorporating our improved knowledge of the system. This dynamic learning approach to urban system modelling is elaborated in some detail in Cordey-Hayes (1975).

2. Description of the Data

The Austrian migration table is of a rather conventional type, generated by asking respondents in 1971 to indicate their residential location in 1966. A typical element of this matrix m_{ij} $(i \neq j)$ is the number of people who were located in region j in 1971 but were in region i in 1966. Intermediate moves are not recorded, nor are emigrants to foreign locations. Austrians returning from foreign countries and foreign workers with families have been enumerated, but these data have only been used to a limited extent in the analyses undertaken here. Similarly the data disaggregated by sex and labour force participation have not been analyzed.

In addition to the explicit shortcomings of the data, there are of course errors which are difficult if not impossible to take into account. It can only be hoped that these errors are not of a systematic kind. There is some reason to believe, however, that something less than a total enumeration of moves has been made. That is, a significant number of changes of address may have gone unrecorded.

Austria has a federal form of government with nine "Länder" (provinces), 98 political districts, and about 2,500 communities. The regional analysis reported here uses the 98 political districts. Thus the migration table has on the order of 10^4 elements, a very large number about which to make summary observations.

One approach developed by Tobler (1975) facilitates the description of large flow matrices of this type by analyzing only the asymmetric part of M. Although some people will migrate from i to j, others will migrate in the reverse direction; to the extent that we are concerned with net differential growth, these reciprocal flows are of little interest. Thus, in

$$m_{ij} = \frac{m_{ij} + m_{ji}}{2} + \frac{m_{ij} - m_{ji}}{2} \quad , \qquad [1]$$

only the second term on the right-hand side is analyzed. The reader is referred to Tobler (1975) for a detailed explanation of this method. In formal terms, each location i with coordinates (x_i, y_i) has associated with it a vector with a magnitude and direction

$$\vec{V}_i = \frac{1}{n-1} \sum_{\substack{j=1 \\ j \neq i}}^{n} \frac{m_{ij} - m_{ji}}{m_{ij} + m_{ji}} \cdot \frac{1}{d_{ij}} \cdot \left[(x_j - x_i), (y_j - y_i)\right] \quad , \qquad [2]$$

where d_{ij} is the Euclidean distance between the centroids of location i and j.

Figures 1 and 2 show the results of the application of this method to the Austrian migration table, first for the 98 political districts and second for the nine Länder.*

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*The midpoint of the vector is the centroid of the political district.

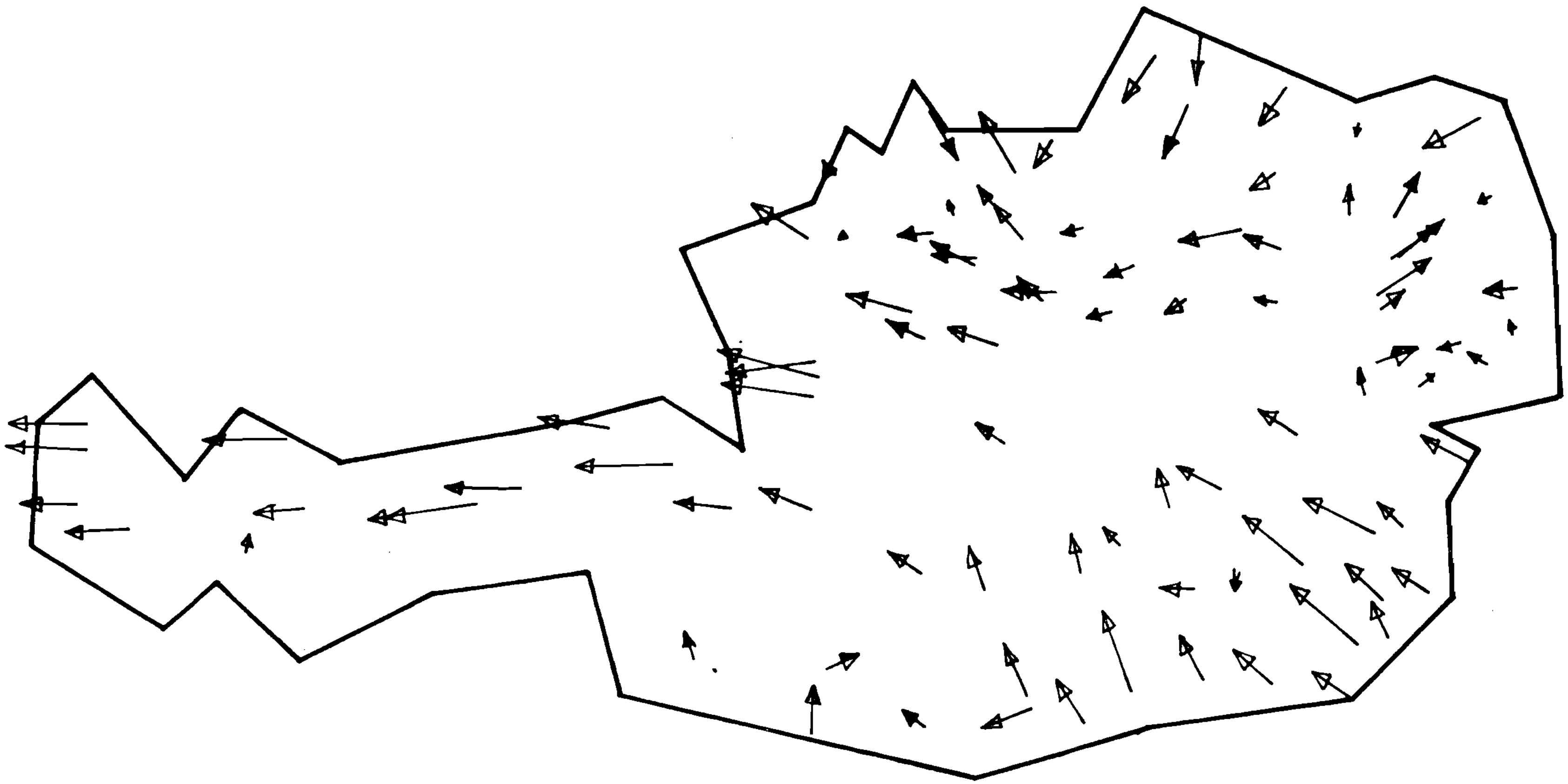

FIGURE 1. Wind vector representation of migration flows between political districts in Austria (1966 - 1971).

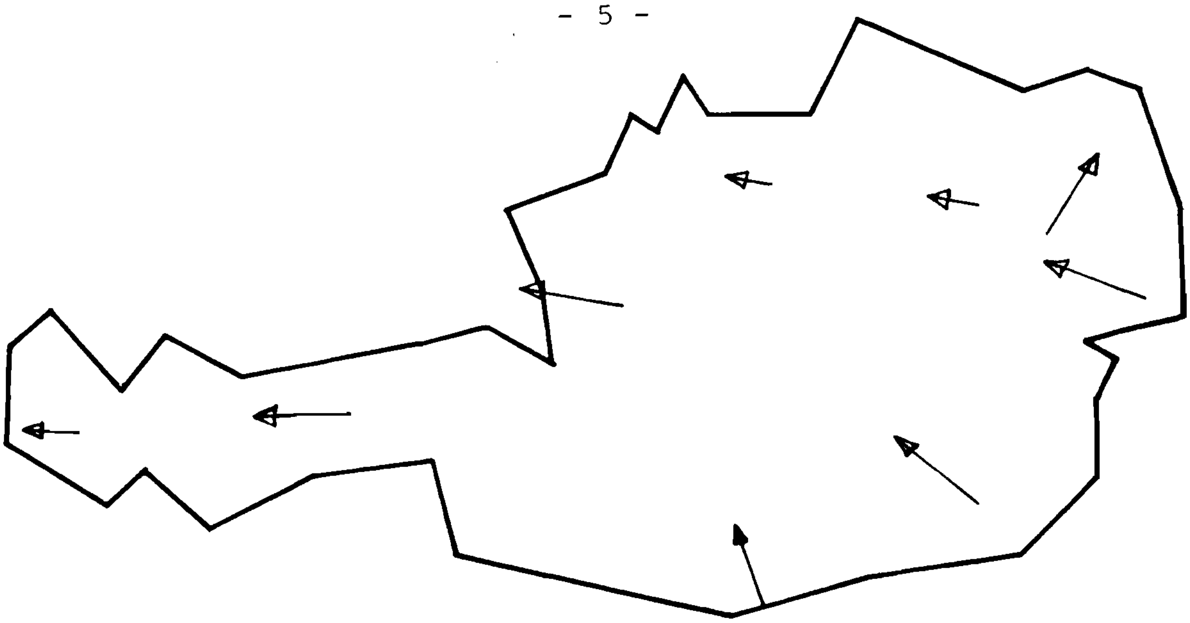

FIGURE 2a. Wind vector representation of migration flows between the "Länder" of Austria.

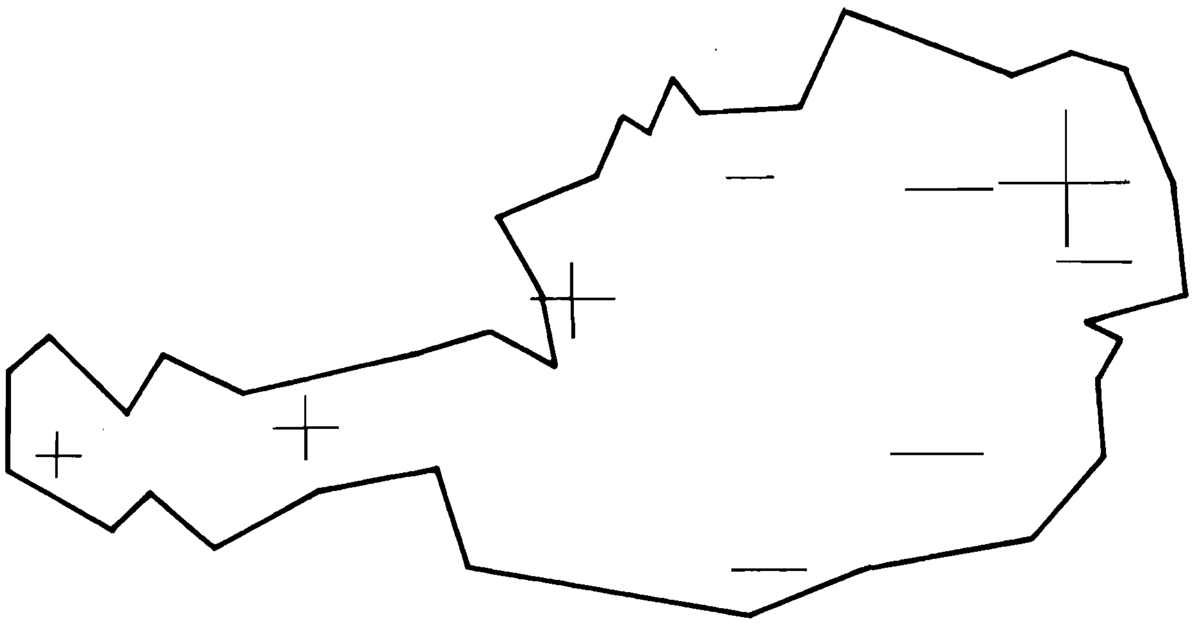

FIGURE 2b. "Pressure field" associated with migration winds.

A rather striking pattern is immediately apparent. There is a very strong trend of movement towards the western regions as well as into the Vienna area. The vectors from the southern districts appear to be the results of movements to Vienna and the west. With the exception of the western regions, most border districts have vectors orthogonal to and away from the border. Particular care should be taken in interpreting all vectors close to the borders of the study area. No foreign migration data are included; thus vectors apparently directed to Switzerland and the FRG should not be interpreted as migrant flows to these locations. Rather, these vectors are indicators of a strong directional imbalance of migrants into these border regions, the average source of which is in the direction exactly opposite to the vector.

Although certainly much information is lost in averaging the results, certain unmistakable broad spatial patterns are made very clear by this representation. The pattern for the "Länder," while obviously less complex, is completely consistent with the spatially disaggregated pattern. These maps are revealing in a qualitative way, suggesting perhaps that there are "pull" factors at work in Vienna and the west and "push" factors at work elsewhere. The "forcing function" could be mapped as a spatially continuous surface (a "pressure" field associated with the migration "winds"), and variables sought that account for the spatial variation in this surface.

Another essentially descriptive method which could be suggestive of interesting hypotheses is the plotting of per capita out-migration flows against per capita in-migration flows. As Cordey-Hayes (1975) points out, the simple economic theory of migration would suggest that there should be a negative relationship between these two variates. On the other hand, there are good reasons, related to social and occupational mobility, age structure and other factors, to suggest that in- and out-migration rates will be positively correlated.

The difference in rates of course is due to net increase in population arising from migration. Figure 3 shows the pattern for Austria. We see from this that there is certainly some restructuring of population (the trend is less steep than the 45° line*), but there is also some tendency for the regions with the highest growth rates to have larger out-migration rates. Figure 4 shows the political districts with the largest per capita in-migration in relation to per capita out-migration (i.e. those farthest to the right and below the 45° line). Three spatial tendencies are apparent: first, rural-urban migration; second, suburbanization; and third, a strong movement into western regions. Further evidence of these three tendencies will be given in later sections of this report.

3. Markov and Quasi-Markov Population Distribution Projection Models

3.1 Techniques of Population Projection

The determinants of population growth and distribution are undoubtedly varied; moreover the interrelationships among these determinants may be subtle and complex. It is of some interest, however, to attempt to model such systems using methods where the causal structure is not delimited explicitly. For example, it may be assumed that past behaviour provides a useful guide to future system behaviour. Of this class of model, extrapolation methods are certainly the crudest. Time series analysis extends this approach, differentially weighting past behaviour using forgetting functions, i.e., distributed lag (autoregressive) models. Curry and Bannister (1974) and others have further enriched this approach by taking spatial as well as temporal lags into account. All these methods require large sets of spatial and temporal data on a few (perhaps one) variables, in contrast to detailed causal models with data on many variables for a

*Points on the 45° line have a perfect balance between in- and out-migration.

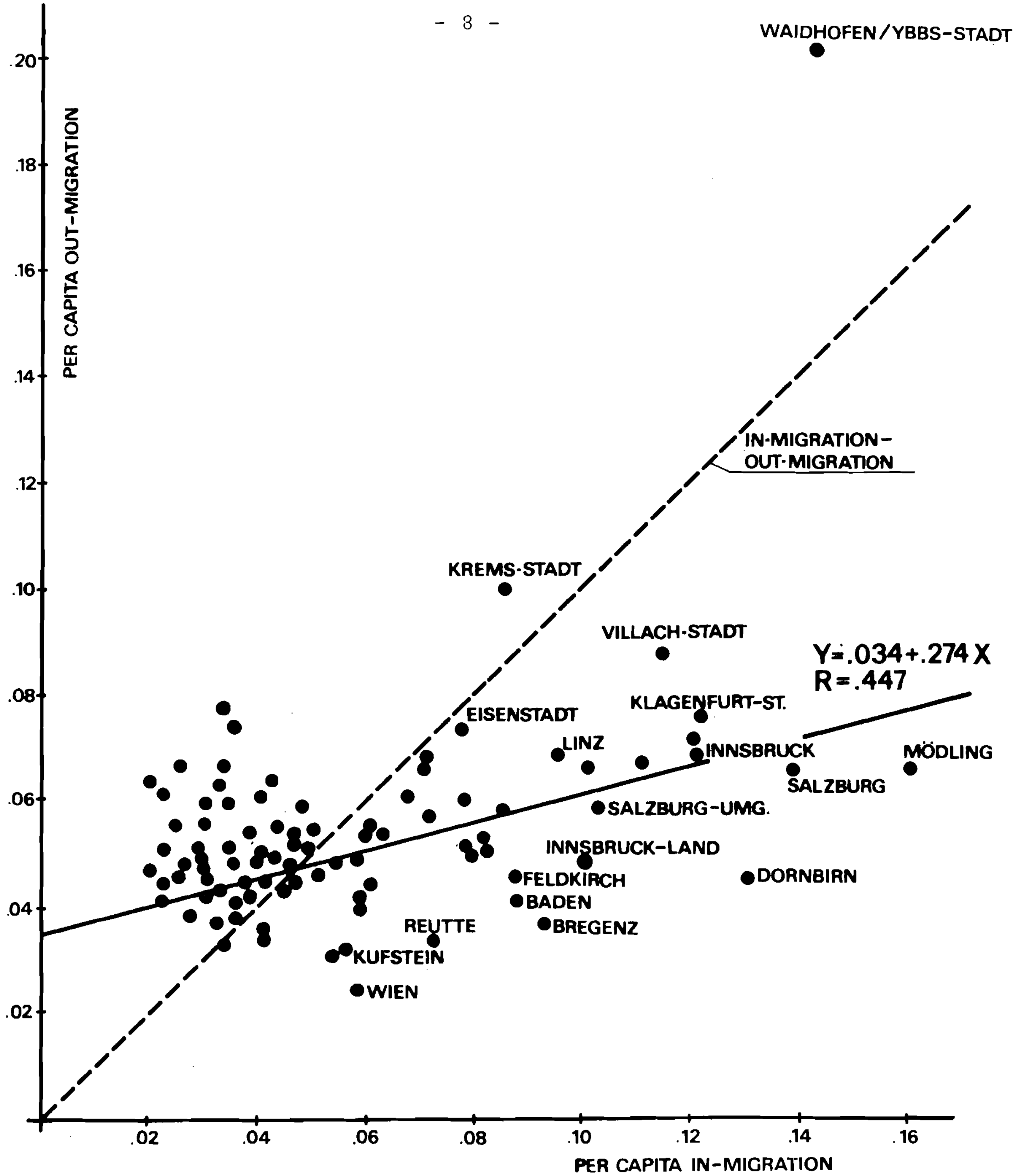

FIGURE 3. Scatter diagram of per capita out-migration vs. per capita in-migration.

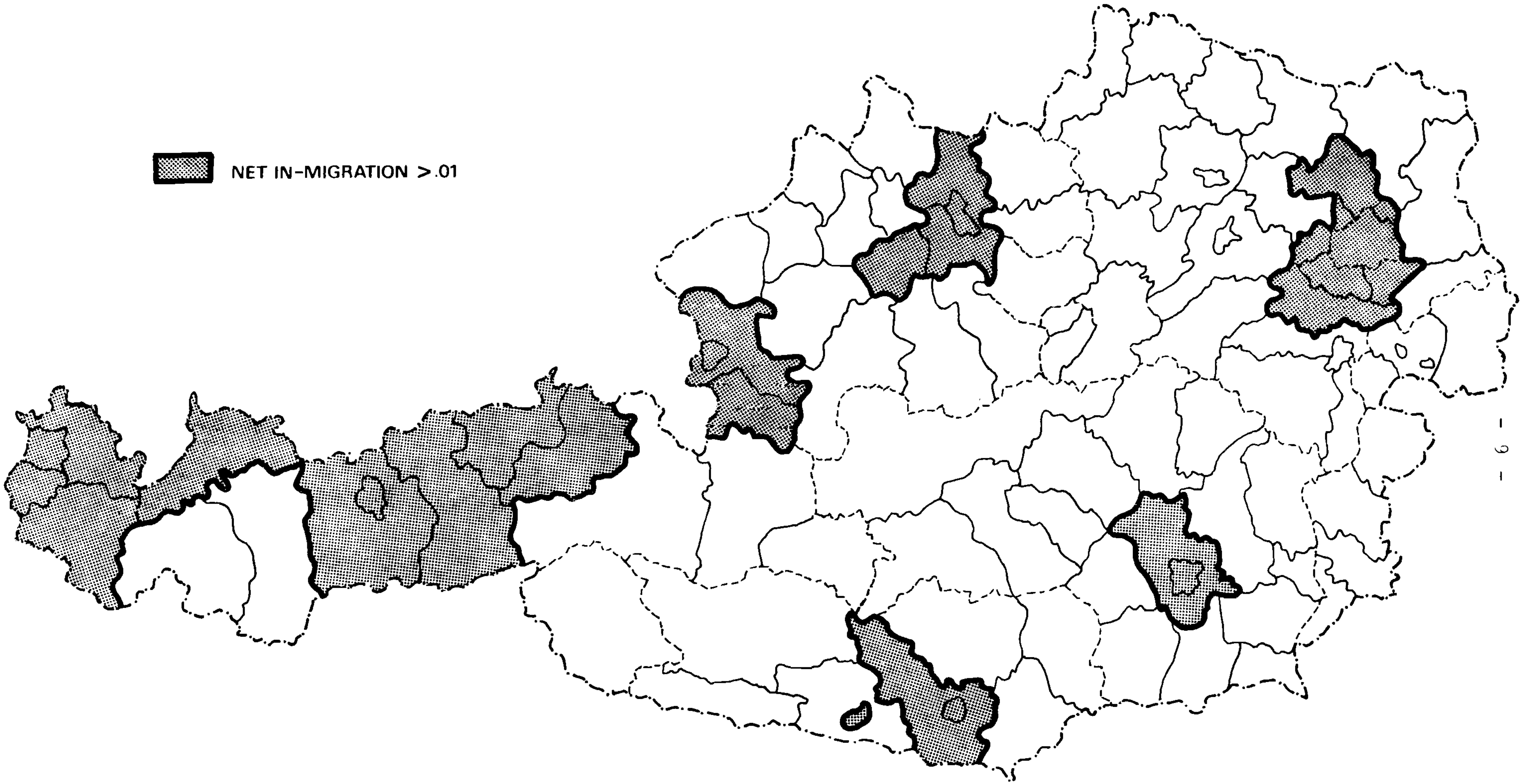

FIGURE 4. Political districts with largest per capita net in-migration (1966-1971).

few (perhaps one) time periods.

Because of a dearth of long time and space series data, even these autoregressive approaches are frequently infeasible. In this section, a Markov approach to population distribution projection is employed. With these models, the current location of a resident is the only factor which influences his residential location in the next time period. Implicit in this statement is that there is an interregional structure of migration which will tend to persist through time. The assumption is that people will continue to migrate in the future as they have in the recent past.

More formally, if x(t) is the expected regional population distribution vector at time t, the simple Markov projection model takes the following form:

$$x(t + 1) = x(t)\, P \quad , \qquad [3]$$

where P is composed of elements P_{ij}, the conditional probability that resident in i at time t will be residing in j at time t + 1*.

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*One common way of estimating migration transition probabilities is

$$\hat{p}_{ij} = \frac{m_{ij}(66-71)}{x_i(66)} \quad .$$

But in the Austrian case, the regional population data for 1966 are not available. In this study, we have used the following method. We first estimate the diagonal elements of the migration table:

$$\hat{m}_{ii} = x_i(71) - \sum_{\substack{j=1 \\ j\neq i}}^{n+1} m_{ji} \quad ,$$

where the (n + 1)st row includes foreign in-migrants. Our estimates of the 1966 populations are then

$$\hat{x}_i(66) = \hat{m}_{ii} + \sum_{\substack{j=1 \\ j\neq i}}^{n} m_{ij} \quad .$$

Finally, our transition probability estimates are

$$\hat{p}_{ij} = \frac{m_{ij}(66-71)}{\hat{x}_i(66)} \quad .$$

The expected path of population distribution is given as:

$$x(t) = x(0)\ P^t \quad . \qquad [4]$$

Moreover, it can be shown that if P has certain characteristics, there is an equilibrium population distribution $\lim_{t \to \infty} x(t)$ which is independent of the "initial" population distribution $x(0)$. Of course, it may be literally centuries before this equilibrium is approached; thus its policy relevance is somewhat marginal except in qualitative terms. Even in projecting more immediate future populations, the model may not be valid in that the migration probabilities will almost certainly change. One question of considerable interest is the sensitivity of projections to changes in these transition probabilities. Willekens (1975) has recently surveyed and adapted some methods which measure the sensitivity of the equilibrium to small changes in the parameters. Only less analytical and less general approaches are possible for the more relevant question of the sensitivity of more immediate projections to such changes.

In addition to the question of non-stationarity, the Markov model is deficient in that it represents a closed system. Rogers (1968) and others use the simple Markov time-dependent structure but also incorporate rates of natural increases and decreases and foreign in- and out-migration. One representation of such a model is

$$x(t + 1) = x(t)[B - D + P] + Z(t) \quad , \qquad [5]$$

where B is a diagonal matrix such that b_{ii} is the birth rate in region i,

D is a diagonal matrix such that d_{ii} is the death rate in region i,

$z(t)$ is the vector of foreign immigrants into the system.

If we denote G = B - D + P, then:

$$x(t) = x(0)G^{t} + \sum_{k=0}^{t-1} z(k)G^{t-i} \quad . \qquad [6]$$

The dimension of G, at least in principle, can be enlarged, disaggregating by age and sex cohorts so that not only is the age and sex composition of different regions taken into account in fertility and mobility rates, but also the regional age and sex structure of the population changes over time as a result of aging and survival rates and of the migration patterns themselves.* Age-specific migration data are not available for Austria. Although estimates of age-specific parameters could be made, a decision was made to use a more aggregate approach on the basis of data which are readily available. Thus, two sets of projections are made, the first using the closed system Markov model, and the second an open system quasi-Markov model incorporating rates of net natural increase, but not foreign in- or out-migration. Thus in the growth projection model [5] and [6] are simplified to

$$x(t + 1) = x(t)G \qquad [7]$$

$$x(t) = x(0)G^{t} \quad . \qquad [8]$$

In the applications of both the Markov and growth projection models, the "initial" state of the system x(0) is the population distribution in 1971 by political district. The stages of the process are five-year intervals. The discrete approximation to a continuous time process results in an implicit assumption that net additions to the population remain in the region of birth until the beginning of the next stage, when they begin to migrate with the rest of the population.

*Rogers (1975) outlines the theory and mathematics of such systems.

3.2 The Numerical Results*

How to present in an effective way the multitude of numbers generated for large multiregional systems is a bothersome problem. Figure 5 shows the pattern of long-run major losers and gainers in population as the system approaches its equilibrium. We note a very large variance in the projected population growth and decline. Major losing regions are in the southern, eastern, and northern border areas, undoubtedly reflecting a decrease of employment in agricultural activities and a truncation of "natural" market areas close to the borders with Eastern European countries (see OECD, 1974).

Although the directions of these tendencies are unequivocal, the absolute and even relative magnitude of changes is undoubtedly exaggerated. First, we note that to approximate this equilibrium distribution, about 500 time periods (2,500 years) need to elapse. Clearly even politicians are not concerned with such long planning horizons. More importantly, long before such an equilibrium is approximated, the parameters will change -- perhaps exogenously as a result of government or business policies, tastes, technologies, etc. Alternatively the migration propensities may adjust themselves endogenously with respect to changes in the population distribution. (See for example Feeney (1973) and Gleave (1975).)

Thus, projected changes over the next thirty years are more relevant at least in a quantitative sense. These are displayed in Figure 6 and in more detail in Appendix A. Although the patterns of redistribution are similar for the Markov and growth models, they are not identical.

For example, whereas Vienna is a rather important growth centre in the Markov model, its age structure is such that it becomes a declining centre when the birth and death rates are introduced into the model. Of course, since in-migrants tend to be younger, the age structure and fertility rates in Vienna

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*The reader is referred to Österreichisches Institut für Raumplanung (1975) for a complementary set of population projections. The methods used there strongly emphasize age structure effects, using only net migration rates rather than the entire interregional table.

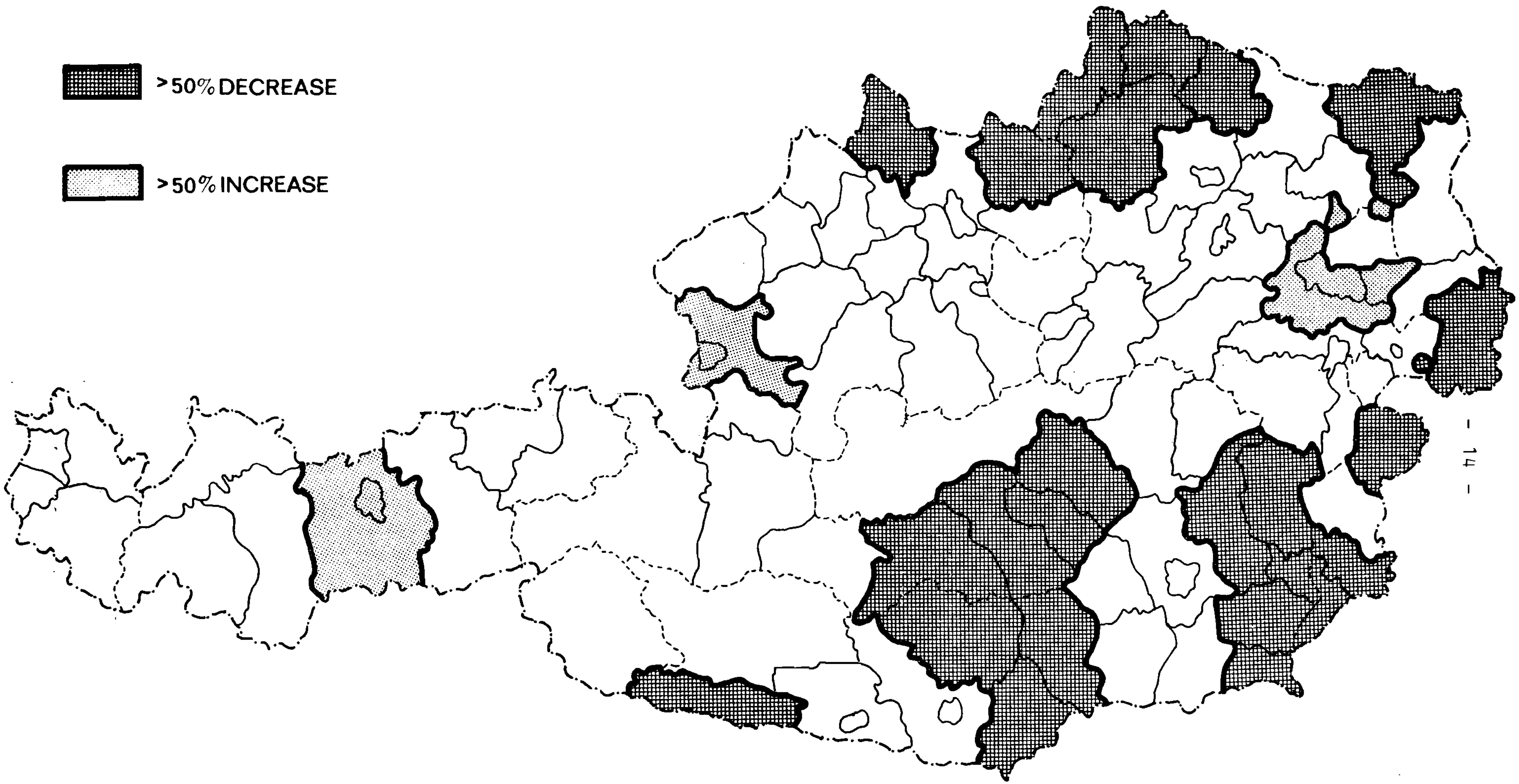

FIGURE 5. Political districts with largest percentage increases and decreases in Markov equilibrium projections.

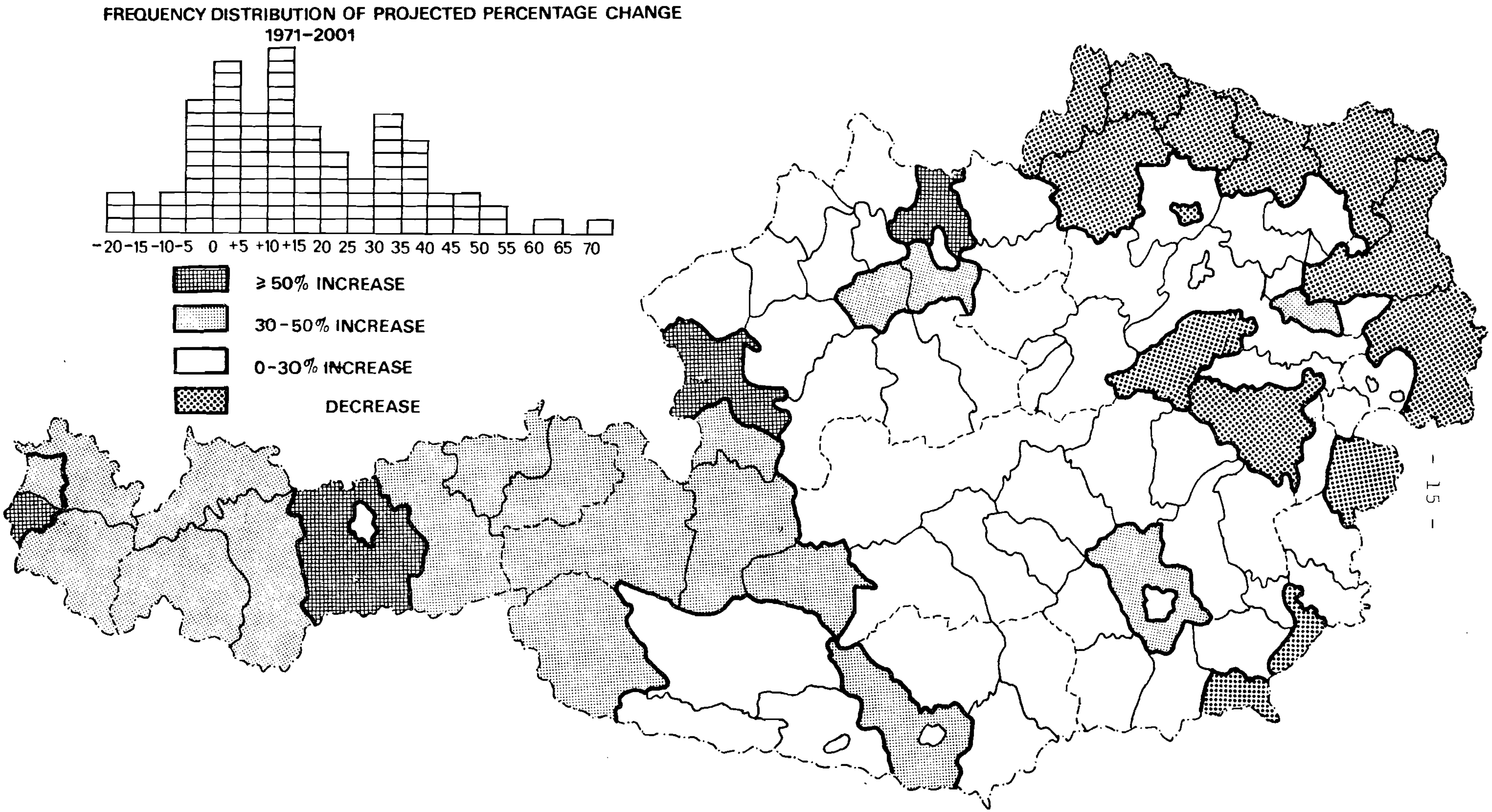

FIGURE 6. Area of projected population decrease and increase 1971-2001 with growth matrix method.

may be expected to change over time. Therefore, a good population projection might lie somewhere between those represented by Figures 5 and 6.

In contrast, some southern areas in the Steiermark (Styria) and Kärnten (Carinthia) are transformed into growth regions when corrections for regional rates of natural increase are made. High birth rates more than compensate for large net out-migration rates. But if out-migrants tend to be younger and/or if there is a secular decline in fertility rates, these areas will not be able to continue to grow if high out-migration rates persist.

In other instances, for example in the north-east (Wald- and Weinviertel), high natural rates of increase are not sufficient to offset high out-migration rates. Note that the frequency distribution appears to be bimodal, indicating that some districts tend to be growing very rapidly; while another, larger, group of regions is declining, or growing, if at all, only slowly. The spatial pattern of fast growth is strongly concentrated in and around urban areas, and in addition in some western regions.

4. A Statistical Model to Measure Emissiveness and Attractiveness

Cesario (1973) has developed a methodology which divides interaction factors into three categories -- origin effects (emissiveness); destination effects (attractiveness);* and impedance effects (travel times and/or costs in his original transportation context). He argues that emissiveness and attractiveness are often not directly measurable, but must be estimated from the data. That is, the origin and destination totals (or populations) are not used directly as indicators in that they may be heavily conditioned by relative

*This framework is closely related to Cordey-Hayes' (1972) concepts of escape and capture ratios.

location within the system and purely locational effects are to be incorporated into the impedance or distance term. The emissiveness and attractiveness measures are to include only the intrinsic characteristics of places, standardizing for distance effects. These aggregate measures, estimated within a revealed preference framework, may later be analyzed independently -- related for example to quality of life, age structure, and job opportunity variables in a migration model.

More formally, the model proposed is

$$m_{ij} = kU_iV_jf(d_{ij}) \quad , \qquad [9]$$

m_{ij} is the interaction between two locations;
U_i, V_j are emissiveness and attractiveness parameters;
$f(d_{ij})$ is the distance impedance function;
k is a scaling constant.

Using the familiar power function form of the interactance model, [9] becomes

$$m_{ij} = kU_iV_jd_{ij}^{\beta} \quad , \qquad [10]$$

where β is a parameter to be estimated.

The similarity between [10] and the traditional social gravity model is obvious, but at the same time potentially misleading. It must be emphasized that the U_i and V_j are estimated. This means that areas with large populations need not have large numbers of in-migrants and/or out-migrants. Moreover, the migration flows predicted by the model will not in general be symmetric. That asymmetric flows are important has already been demonstrated many times in this report; otherwise, migration would not be a factor in restructuring the Austrian population distribution.

Thus the problem is to find estimates for 2(N + 1) parameters in [10]. Taking logarithms of [10] facilitates the estimation process:*

$$\ln m_{ij} = \ln k + \ln U_i + \ln V_j + \beta \ln d_{ij} \quad . \qquad [11]$$

Letting $Y_{ij} = \ln m_{ij}$, $D_{ij} = \ln d_{ij}$, and $m = \ln k$ re-expressing the model in deviation units, normal equations become:

$$\hat{m} = \bar{Y} = \frac{1}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} (Y_{ij} - \bar{Y}) = 0 \quad ,$$

$$\hat{U}_i = \sum_{j=1}^{n} (Y_{ij} - \bar{Y}) - \hat{\beta} \sum_{j=1}^{n} \frac{(D_{ij} - \bar{D})}{n} \quad , \qquad [12]$$

$$\hat{V}_j = \sum_{i=1}^{n} \frac{(Y_{ij} - \bar{Y})}{n} - \hat{\beta} \sum_{i=1}^{n} \frac{(D_{ij} - \bar{D})}{n} \quad ,$$

$$\hat{\beta} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \left(Y_{ij} - \bar{Y} - \sum_{i=1}^{n} \frac{(Y_{ij} - \bar{Y})}{n} - \sum_{j=1}^{n} \frac{(Y_{ij} - \bar{Y})}{n} \right) \left(D_{ij} - \bar{D} - \sum_{i=1}^{n} \frac{(D_{ij} - \bar{D})}{n} - \sum_{j=1}^{n} \frac{(D_{ij} - \bar{D})}{n} \right)}{\sum_{i=1}^{n} \sum_{j=1}^{n} \left(D_{ij} - \bar{D} - \sum_{j=1}^{n} \frac{(D_{ij} - \bar{D})}{n} - \sum_{i=1}^{n} \frac{(D_{ij} - \bar{D})}{n} \right)^2} \quad ,$$

where $\hat{m}$, $\hat{U}_i$, $\hat{V}_j$ and $\hat{\beta}$ are the ordinary least-squares estimate of the model parameters.

For this analysis, the 98 political districts have been reduced to eighty regions, incorporating the surrounding areas of cities with the cities themselves. In addition, inter-regional road distances are used instead of airline distances.**

Using the estimation procedures described above, the

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*In a later paper, Cesario (1974) recognizes that the parameter estimates using this transformation are biased and presents an alternative estimation method. A variant on only the simplest method has been used here.

**This table was obtained from the ÖAMTC (Austrian Automobile Touring Club).

results are

$$m_{ij} = U_i V_j d_{ij}^{-0.953} \quad . \qquad [13]$$

The 160 values of U_i and V_j are presented in Appendix B, but it is useful to make some summary comments about the qualitative nature of these numerical results. In spite of the freedom of the model to incorporate asymmetry, there is a strong correlation between these two variates ($r^2 = .984$). That is, areas with strong attractiveness to migrants are also important sources of out-migration. The distribution of these variates is highly skewed, with the cities accounting for most of the variance. Figures 7 and 8 show the areas of highest per capita attractiveness and emissiveness. Again, even when standardized for scale effects, the urbanization and suburbanization processes and westerly movement of migrants are strikingly apparent. All of the largest cities and their surrounding areas are very attractive to migrants even in regions which, in an overall sense, are rather unattractive. The pattern of high emissiveness rates (Figure 8) is somewhat more complicated. Here we see both highly attractive and unattractive areas represented. The populations in western regions tend to be highly mobile with large in- and out-migration rates. These areas have emissiveness rates comparable to those in Steiermark and Kärnten.

5. Normative Approaches

An institution exists for coordinating and formulating regional projects according to a general Austrian concept of regional planning: the Austrian Conference on Regional Planning (ÖROK). On a voluntary basis, delegates of the Federal government, and of Länder, city- and community-governments, attempt to agree to a plan for regional development, including strategies for the Austrian settlement structure. There are four categories of objectives to be explored:

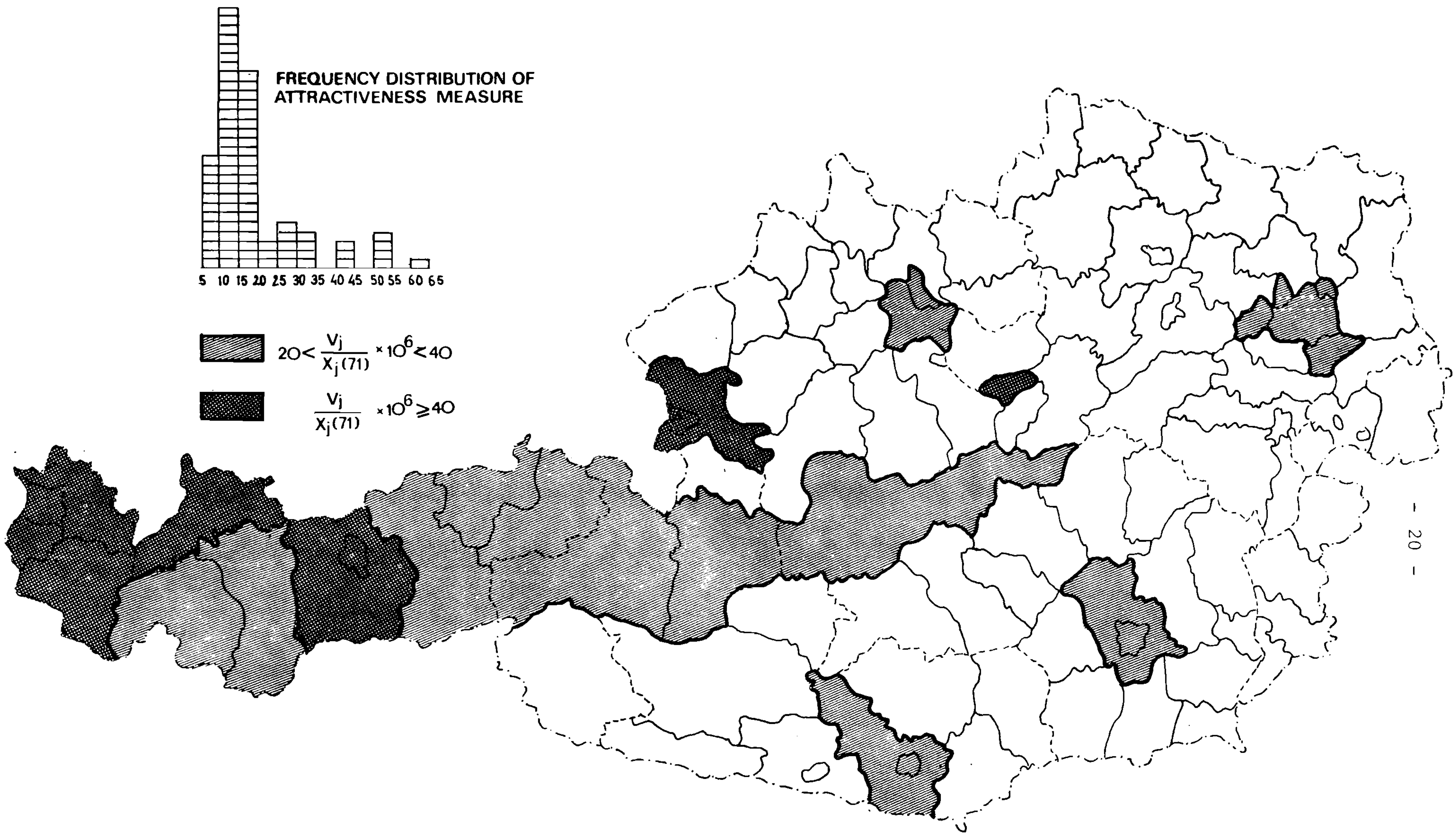

FIGURE 7. Political districts with highest per capita attractiveness.

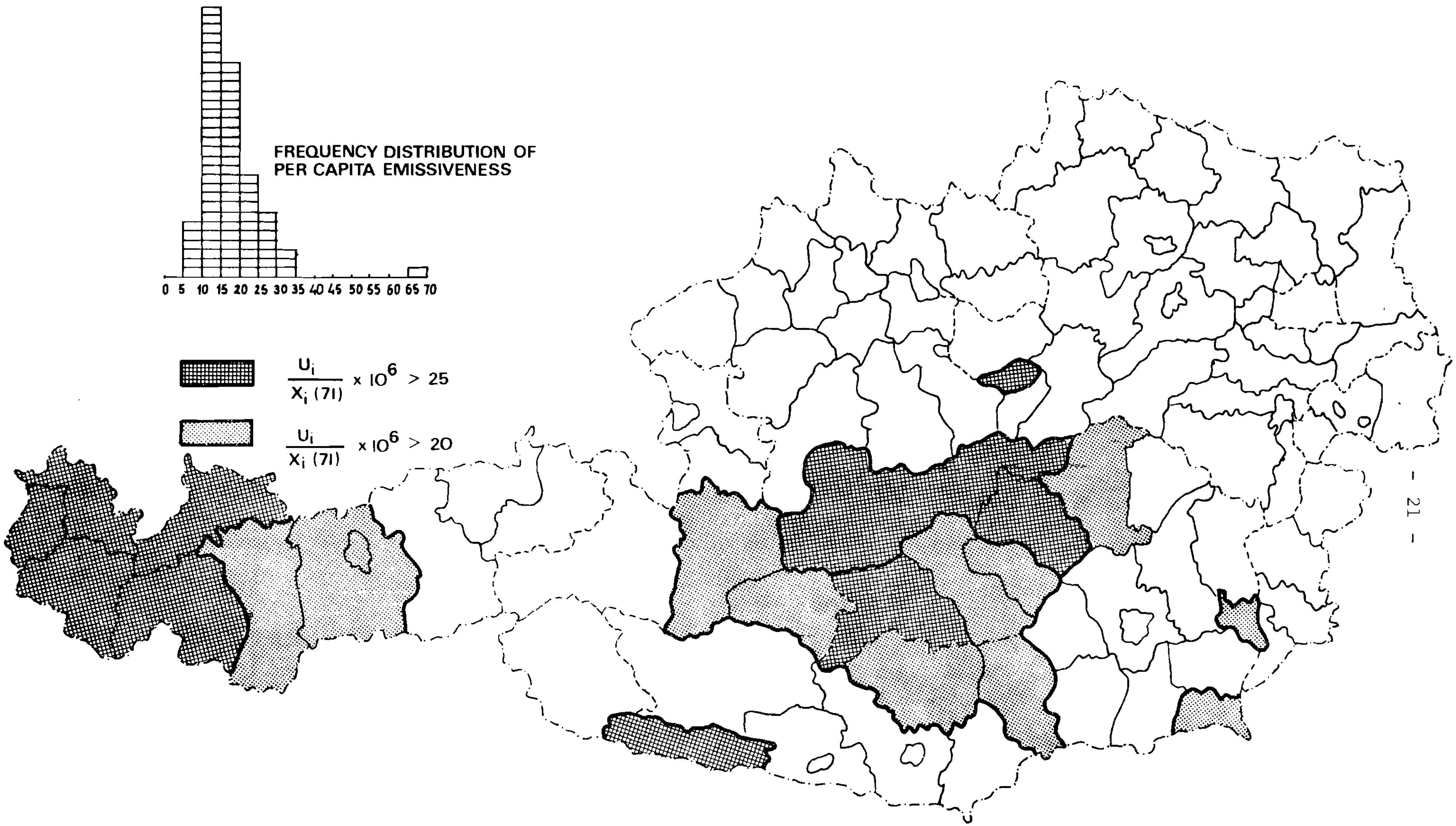

FIGURE 8. Political districts with highest per capita emissiveness.

1) National political goals;
2) General societal goals;
3) General economic goals; and
4) Spatial goals.

Since the foundation of the ÖROK in 1971, an abstract goal catalog has been generated, which is rather difficult to translate into spatial terms. One of the reasons for this is that there may exist strong conflicts between the Federal government and the Länder; some of the Länder have developed plans for their own regions. The resolution of these conflicts at the ÖROK level has to be unanimous; thus far this institution has only been able to generate a catalog of goals which must be described as rather optimistic and unspecific, setting no priorities nor asking what instruments are involved and from where the resources can be derived. One of the most-cited goals is that of "equal regional living and working conditions" -- the implications of which are somewhat ambiguous. Relating this goal to migration processes, it can be argued that on the one hand it can be achieved by increased labour mobility; and on the other, that it may also be attained by reducing outmigration from rural regions to avoid the danger of tax-base erosion.* There is no explicit or obvious link between this goal and a specific population distribution. At this time, it has not been possible to derive quantitative and defensible population distribution objectives for the 98 political districts used in this study.

Although well-defined and generally accepted goals for future population distribution are rather difficult, perhaps impossible, to generate, it may be of some interest to study the feasibility and the most plausible paths to achieve certain hypothetical goals. Such exercises may be instructive in gaining some insights into the magnitude of change and control necessary to achieve certain system trajectories. A variety of approaches are feasible in changing system trajectories -- inputs may be manipulated and the forward and

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*Organization for Economic Development and Cooperation (1974).

backward linkage multiplier effects traced through the system. Alternatively, or in addition, the migration parameters themselves can be changed. The most direct and obvious technical procedures to control such systems are those of mathematical programming and control theory (see Evtushenko and MacKinnon (1975) and Mehra (forthcoming)).

Simpler methods are also available, however. For example, if the input vector is to be constant over time, and only a target population at time t is specified $\hat{x}(t)$, Rogers (1971) describes a method which requires only the solution of a system of linear equations.

With regard to interregional migration parameter changes, the methods used to update economic input-output tables and origin-destination tables of transportation surveys may be relevant.* The basic principle of these methods is simple -- systems are characterized by a high degree of inertia, and the most plausible set of parameter changes consistent with a new population distribution is the one which is in some sense as small as possible. It can be argued that matrices which are "close" to each other in this manner are perhaps the least costly ways in which to achieve the stated goals. Most of the methods minimize the squared deviations of new from old parameter values.** The computer program*** deals directly with interregional flows rather than parameters. The row sum $\sum_j m_{ij}$ is the number of people in region i at time t (i.e. m_{ii}, the people remaining in i and $\sum_{j \neq i} m_{ij}$ the people leaving i). The column sum $\sum_j m_{ji}$ is the number of people in region

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*These methods with very minor differences are known as the Fratar, Furness and biproportional methods. See Bacharach (1971) and Evans (1970) for descriptions of the methods and formal proofs of convergence.

**The more complicated numberical method derived by Ickler and Flachs (1973) minimizes the sum of the squared rations of new to old values of the parameters.

***The program was written and made available to us by Waldo Tobler of IIASA.

i at time t + 1 (i.e. the number of people m_{ii}, and the number of people arriving from other locations, $\sum_{j \neq i} m_{ji}$). In this formulation, a closed system is assumed -- no births, deaths, or out- or in-migration. The total population is constant; we are concerned only with spatial re-distribution. It is of some interest to compute the interregional flows which are as similar as possible to the given matrix m, such that the column sums (the new population vector) are exactly as those prescribed by population distribution goals.

In view of the difficulties of specifying these goals, let us prescribe an arbitrary goal vector for purposes of illustrating the methodology. In particular, let us assume that the *status quo* distribution is deemed to be desirable. From projections of the Markov model in the previous section, it is clear that considerable changes in the flows must be made to achieve this goal -- that is, the system certainly is not in equilibrium. Just as clearly, a solution which does achieve this goal is $\hat{m}_{ii} = x_i(t) = x_i(t+1)$ and $\hat{m}_{ij}(i \neq j) = 0$, or equivalently, $\hat{p}_{ii} = 1.0$, $\hat{p}_{ij}(i \neq j) = 0$. The "best" or "most plausible" values of $\hat{m}_{ij}$ lie somewhere between these and the ones in the 1966-71 migration table.

By successively adjusting row and column sums so that first $\sum_j \hat{m}_{ij}(s) = x_i(t)$ and $\sum_j \hat{m}_{ji}(s+1) = x_i(t+1)$ for s = 1, 2, 3..., convergence to a migration matrix generating this population distribution is achieved. It is clear that quite major shifts in migration patterns would be necessary to maintain the existing population distribution. There are of course an infinite number of new migration matrices which could satisfy these conditions, but in the sense described above, this is the one which is as close as possible to the "current" matrix.

The final results of this iterative procedure are row (out-migration) and column (in-migration) multipliers. Thus,

$$\hat{m}_{ij} = A_i B_j m_{ij} \quad . \qquad [14]$$

The A_i's are factors by which each element in the i^{th} row must be multiplied to achieve the specified goal. Similarly, the B_j's are factors by which each element in the j^{th} column must be multiplied. $A_i < 1.0$ implies that out-migration must be reduced; $A_i > 1.0$, that out-migration must be increased. Similar comments with respect to in-migration hold for the B_j factors. Both these factors are related to attractiveness and emissiveness measures generated earlier except that they are highly conditioned by the target population distribution. Thus with one distribution, A_i may be less than 1.0, but with another greater than 1.0. Thus the generality of these indices is rather limited. The interaction effects between the row and column factors (i.e. the products $A_i B_j = \frac{\hat{m}_{ij}}{m_{ij}}$) are of interest in that these identify the dyads (origin-destination pairs) which must be altered the most (either decreased or increased) in order to reach the target population distribution in a single five-year period. Some of the largest of these are shown in Figures 9 and 10. Using this representation, the dominant migration "sinks" in the system are Mödling, Salzburg (city and vicinity) and Innsbruck (city and land), and these growth areas tend to be strongly connected to Zwettl and Rohrbach in the north and Wolfsberg, St. Veit a.d. Glan, and Radkersburg in the south of Austria. Although these large proportional changes in migration propensities have some tendency towards a regionalized structure, very long distance linkages are also included.

It should be emphasized that these maps show only the largest proportionate changes in flows implied by the specified population distribution. In this context, it is

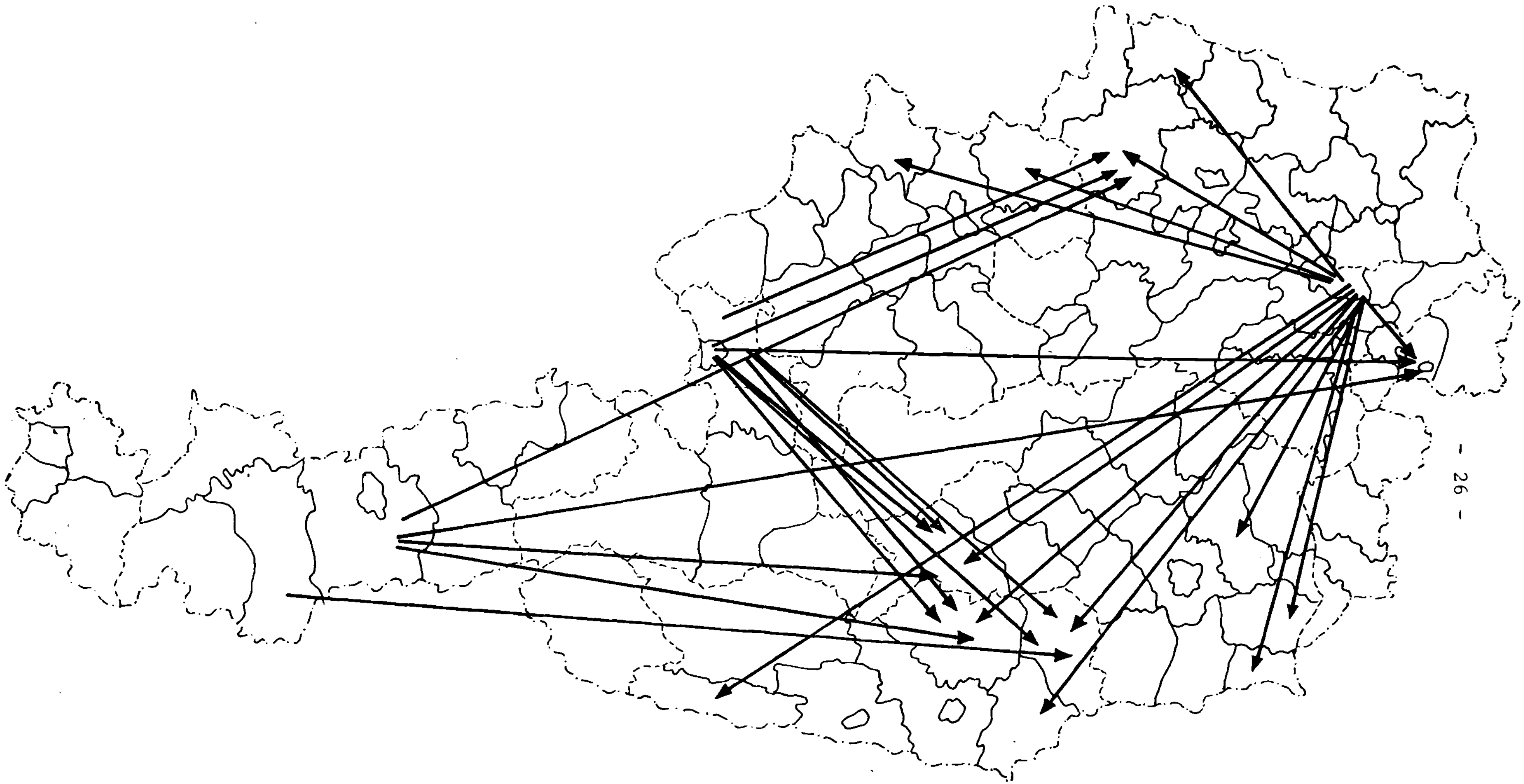

FIGURE 9. Largest values of $A_i \cdot B_j$ to maintain constant population distribution ($A_i \cdot B_j \geq 2.5$).

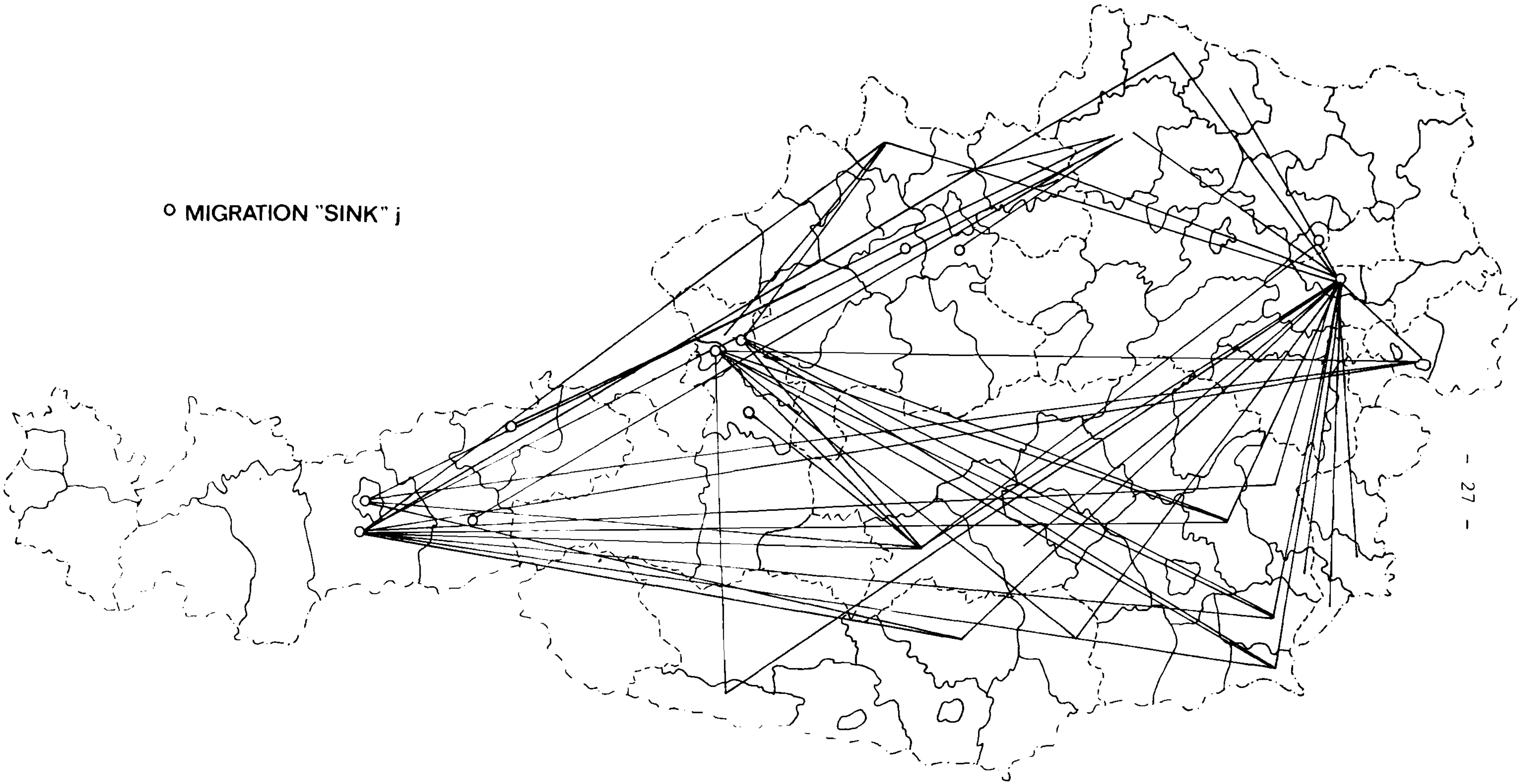

FIGURE 10. Smallest values of $A_i \cdot B_j$ to maintain constant population ($A_i \cdot B_j < .45$).

interesting to note that some very fast-growing areas are not represented in these large changes. In the western region, only the Innsbruck and Salzburg areas are strong end points of "critical" origin-destination pairs. Thus, for example, Bregenz, Reutte, Dornbirn, etc. are not included in these extreme values, even though the long-term population projections for these districts are very high indeed. The tentative interpretation of this type of result is that these and other areas attract migrants from virtually all of the political districts in Austria. Thus rather broad incentives and disincentives would have to be imposed in order to retard the growth of these areas, whereas some finer policy instruments (of an origin-destination-specific type) would perhaps be more effective with those regions with a more limited network of connections.

In addition, since only proportionate changes have been studied, the overall importance and difficulty of effecting these changes has not been considered. Clearly large proportionate changes may imply small absolute changes; and of course, the reverse holds as well. The estimated absolute migration table and its difference from the previous one have been generated, but time has not permitted their interpretation; the Tobler "winds" method could perhaps be employed, or some data reduction technique such as principal components analysis.

Another matrix $\hat{M}$ has been computed which generates the equilibrium population distribution in a single five-year time period. The sum of the deviations of old and new migration flows is, as expected, much larger with respect to attaining the equilibrium state compared to maintaining the existing population distribution. (Of course, the population distribution in the second example is an equilibrium one only with respect to the <u>initial</u> migration matrix. Thus $\hat{M}$ would not maintain that equilibrium in subsequent periods.)

We have then a method which can be used to determine the most probable parameter changes implied by postulated future population distribution. In addition, we have an index of the plausibility of future population distribution changes, i.e. $\sum_{i=1}^{n} \sum_{j=1}^{n} \sqrt{\frac{(m_{ij} - \hat{m}_{ij})^2}{n^2}}$. For the constant population distribution, this index is 5.37 while for the Markov equilibrium distribution it is 21.03.

The biproportional method, to our knowledge, has not been employed in a normative context before, and it certainly has some difficulties in this area of application. This technique, as applied, requires the specification of target populations which must be attained precisely. All linear methods where the number of target variables is equal to the instrument variables do not require the specification of an objective or welfare function. Some would argue that this is preferable to having to make such a specification with respect to broad social systems (see for example Russell and Smith (1975)). However, there are clearly few instances where there exists such a rigid goal structure. From an examination of the generated table, it is clear that quite radical changes in migration behaviour are necessary to achieve the goal of a static population distribution. Since in this case the number of target variables (98) is far less than the number of instrument variables (98 x 98), an implicit criterion function is imposed (that the new matrix be as close as possible to the old one). Although it does satisfy this closeness criterion, $\hat{M}$ remains implausible in the sense that (a) virtually all migration flows must undergo significant changes, and (b) there are no constraints on the difficulty of essentially reversing the existing pattern of migration. Ideally, there should be a trade-off between goal attainment and the cost of imposing controls. Thus, for example, Figure 10 shows that more than 2.5 times as many people should move from Mödling to Hermagor or Innsbruck Land to Zwettl than in the 1966-71 period. Such behaviour is undoubtedly quite implausible, in spite of the fact that we are dealing in these cases with rather small movements in absolute terms. Even more implausible are the specified declines in migration rates into the important growth points in the system -- Innsbruck Land, Salzburg vicinity, Mödling, etc. In these cases considerable magnitudes are involved and possibly irreversible forces are to be altered (at the very least, to alter them would involve considerable costs). Although the explicit specification of goal and cost functions would be difficult, and in any objective sense perhaps impossible, it is important that the technique outlined here be regarded only as exploratory -- used to gain only some order of magnitude approximation about the feasibility of alternative future population distributions. A cursory analysis of the results generated by the biproportional method would seem to indicate, not surprisingly, that a static population distribution is infeasible in that much too radical alterations in migration behaviour are implied. Somewhat ironically, however, larger changes in migration behaviour may be even more plausible from an administrative point of view. That is, changing on the order of 10^4 migration propensities would clearly be more difficult than changing the 100 most critical ones by perhaps imposing constraints on new housing or job opportunities. In addition, account should be taken of any underlying statistical rule (e.g. a decline of migration propensities with distance) which we have reason to believe will persist over time. Finally, the biproportional technique, as applied, is a single-stage method which cannot incorporate many of the interesting multistate dynamic aspects of regional settlement systems.

6. Closure

Some simple descriptive, predictive, statistical, and normative approaches have been used in an attempt to gain some preliminary insights into the tendencies and processes in interregional migration in Austria and the implications such tendencies and processes may have on the future spatial pattern of human settlements in the country. The processes of urbanization, suburbanization and "westernization" have been well documented using almost all of the approaches. Most of the methods, while simple, have generated large arrays of secondary and tertiary data which have as yet not been fully interpreted. The results as presented, however, effectively delimit the nature of the Austrian migration system, at least in broad outline. Moreover, some or all of these methods are useful as ways of monitoring on-going system behaviour. They have the merit that they are readily applicable to virtually any interregional migration table in different countries or in the same country at different times.

It is hoped that in the near future our numerical results for Austria will be more intensively interpreted and the methodologies adapted and applied to other countries; finally an attempt will be made to introduce a stronger causal structure into our models which will further enrich the predictability, our understanding and perhaps the controllability of interregional migration behaviour and national urban settlement systems.

Appendix A

Regional Population Projections for Austria to the Year 2001 Using Matrix Growth Model

$$x(t) = x(0)\ G^t$$

Note: Data are presented for 10 year periods whereas projections were made for five year increments.

Burgenland	1971	1981	1991	2001
Eisenstadt Stadt	10,059	10,203	10,321	10,419
Rust Stadt	1,704	1,714	1,724	1,734
Eisenstadt Umgebung	33,523	33,571	33,623	33,681
Güssing	29,416	29,672	29,928	30,184
Jennersdorf	19,703	19,602	19,528	19,481
Mattersburg	33,572	33,923	34,253	34,565
Neusiedl am See	49,293	48,784	48,288	47,810
Oberpullendorf	41,378	39,251	37,305	35,528
Oberwart	53,471	53,831	54,211	54,618
Kärnten				
Klagenfurt Stadt	74,326	79,502	84,726	90,056
Villach Stadt	34,595	35,834	37,288	38,951
Hermagor	20,722	20,966	21,277	21,656
Klagenfurt Land	80,767	88,683	96,876	105,371
St. Veit an der Glan	60,436	60,238	60,292	60,599
Spittal an der Drau	77,752	84,263	91,174	98,518
Villach Land	76,967	82,547	88,416	94,600
Völkermarkt	43,027	44,902	46,885	48,982
Wolfsberg	57,136	59,194	61,375	63,689
Niederösterreich				
Krems an der Donau Stadt	21,733	21,093	20,585	20,190
St. Pölten Stadt	43,300	44,403	45,509	46,625
Waidhofen/Ybbs Stadt	5,218	4,648	4,345	4,217

Niederösterreich - cont.	1971	1981	1991	2001
Wiener Neustadt Stadt	34,774	34,085	33,583	33,240
Amstetten	104,822	112,527	120,513	128,835
Baden	103,786	106,559	109,186	111,690
Bruck an der Leitha	37,641	36,992	36,387	35,828
Gänserndorf	76,097	74,658	73,244	71,875
Gmünd	47,041	46,472	45,915	45,376
Hollabrunn	54,826	51,198	48,003	45,196
Horn	36,856	34,973	33,282	31,766
Korneuburg	54,927	56,789	58,327	59,603
Krems an der Donau Land	56,109	56,143	56,139	56,116
Lilienfeld	28,826	28,521	28,283	28,110
Melk	70,163	73,113	76,067	79,036
Mistelbach an der Zaya	75,092	70,257	65,915	62,019
Mödling	79,620	89,122	96,950	103,433
Neunkirchen	88,129	87,719	87,410	87,205
St. Pölten Land	84,895	88,143	91,264	94,280
Scheibbs	38,865	40,994	43,165	45,386
Tulln	50,388	51,805	53,118	54,342
Waidhofen an der Thaya	32,172	31,099	30,102	29,180
Wiener Neustadt Land	58,258	60,119	61,866	63,518
Wien Umgebung	80,275	82,144	83,525	84,544
Zwettl	50,348	49,535	48,763	48,034
Oberösterreich				
Linz Stadt	202,874	212,601	223,602	235,881
Steyr Stadt	40,578	40,763	41,188	41,845
Wels Stadt	47,279	52,102	57,114	62,347
Braunau am Inn	85,286	91,067	97,304	104,035
Eferding	26,443	28,624	30,954	33,444
Freistadt	56,131	57,671	59,367	61,232
Gmunden	87,783	91,384	95,278	99,490
Grieskirchen	54,816	57,742	60,889	64,271
Kirchdorf an der Krems	48,195	49,932	51,847	53,948
Linz Land	96,377	110,954	125,901	141,301

Oberösterreich - cont.	1971	1981	1991	2001
Perg	52,271	57,024	62,073	67,440
Ried im Innkreis	52,826	55,862	59,088	62,520
Rohrbach	53,294	53,910	54,672	55,591
Schärding	53,947	56,740	59,689	62,808
Steyr Land	52,337	55,434	58,658	62,036
Urfahr Umgebung	52,316	60,848	69,862	79,402
Vöcklabruck	109,663	117,682	126,217	135,309
Wels Land	51,028	55,786	60,865	66,282
Salzburg				
Salzburg	128,845	143,305	158,647	174,998
Hallein	40,479	45,080	50,088	55,536
Salzburg Umgebung	84,585	98,106	112,759	128,628
St. Johann im Pongau	62,783	69,885	77,566	85,877
Tamsweg	19,060	20,941	22,972	25,166
Zell am See	66,014	73,656	82,021	91,174
Steiermark				
Graz Stadt	248,500	254,612	261,726	269,821
Bruck an der Mur	73,277	76,754	80,314	83,973
Deutschlandsberg	59,033	61,235	63,551	65,990
Feldbach	64,805	67,324	69,923	72,610
Fürstenfeld	22,329	22,398	22,513	22,675
Graz Umgebung	99,589	110,620	121,712	132,911
Hartberg	63,187	66,197	69,286	72,462
Judenburg	54,055	55,919	57,872	59,923
Knittelfeld	29,446	30,548	31,691	32,879
Leibnitz	69,632	72,522	75,526	78,659
Leoben	86,097	86,917	87,954	89,216
Liezen	79,150	84,313	89,665	95,228
Mürzzuschlag	48,566	48,850	49,246	49,757
Murau	32,831	33,775	34,774	35,837
Radkersburg	26,294	25,822	25,430	25,117
Voitsberg	56,888	58,795	60,817	62,960
Weiz	78,421	81,935	85,599	89,421

Tirol	1971	1981	1991	2001
Innsbruck Stadt	115,197	123,903	134,025	145,657
Imst	38,274	42,386	46,945	51,998
Innsbruck Land	106,532	126,868	149,216	173,818
Kitzbühel	46,340	52,505	59,315	62,982
Kufstein	70,280	79,586	89,934	101,439
Landeck	35,531	38,878	42,555	46,597
Lienz	45,569	49,981	54,784	60,017
Reutte	25,760	28,535	31,545	34,812
Schwaz	57,288	65,197	74,019	83,852
Vorarlberg				
Bludenz	48,867	54,587	60,890	67,842
Bregenz	93,526	106,183	120,312	136,099
Feldkirch	68,544	83,239	100,247	119,902
Dornbirn	60,536	66,454	73,071	80,474
Wien				
Wien	1,614,841	1,561,852	1,516,873	1,479,196

Appendix B

Emissiveness and Attractiveness Measures for Political District Aggregations

	U_i Emissiveness	V_j Attractiveness
Burgenland		
Eisenstadt Stadt und Umgebung, Rust Stadt	.4440	.4232
Güssing, Jennersdorf	.7839	.6004
Mattersburg	.3319	.3813
Neusiedl	.4331	.4231
Oberpullendorf	.4111	.3214
Oberwart	.7500	.6904
Kärnten		
Klagenfurt Stadt und Land	2.8414	3.5409
Villach Stadt und Land	2.0056	2.0332
Hermagor	.6225	.4020
St. Veit an der Glan	1.2380	.7458
Spittal an der Drau	1.4556	1.5138
Völkermarkt	.6187	.3935
Wolfsberg	1.2039	.6657
Niederösterreich		
Krems an der Donau Stadt und Land	1.1514	.8467
St. Pölten Stadt und Land	1.4789	1.4660
Waidhofen an der Ybbs	.3594	.2615
Wr. Neustadt Stadt und Land	1.3251	1.7824
Amstetten	1.2820	1.2138
Baden	1.2937	1.7536
Bruck an der Leitha	.5806	.5026
Gänserndorf	.7644	.7591
Gmünd	.7718	.5007
Hollabrunn	.6483	.5974

	U_i Emissiveness	V_j Attractiveness
Niederösterreich - cont.		
Horn	.6405	.4813
Korneuburg	.5674	.8778
Lilienfeld	.5592	.4370
Melk	.8088	.7307
Mistelbach	.7708	.5550
Neunkirchen	1.1505	1.1305
Scheibbs	.6573	.5127
Tulln	.6078	.7550
Waidhofen an der Thaya	.5141	.3713
Zwettl	.7042	.4447
Oberösterreich		
Linz Stadt und Land, Urfahr Umgebung	4.1502	8.3194
Steyr Stadt und Land	1.2204	1.6042
Wels Stadt und Land	1.0947	1.7524
Braunau	.9784	1.3242
Eferding	.3893	.4113
Freistadt	.6228	.5042
Gmunden	1.3239	1.7495
Grieskirchen	.5431	.6830
Kirchdorf an der Krems	.6736	.6046
Perg	.5297	.5103
Ried	.5856	.6041
Rohrbach	.5835	.4113
Schärding	.6243	.6202
Vöcklabruck	1.0473	1.6551
Salzburg		
Salzburg Stadt und Umgebung, Hallein	4.2632	10.8066
St. Johann	1.4223	2.0029
Tamsweg	.4374	.3781
Zell am See	1.1359	1.7504

	U_i Emissiveness	V_j Attractiveness
Steiermark		
Graz Stadt und Umgebung	6.0675	9.2201
Bruck an der Mur	1.5246	1.3404
Deutschlandsberg	.9936	.6923
Feldbach	1.1908	.6856
Fürstenfeld	.4897	.3928
Hartberg	1.0167	.5426
Judenburg	1.2738	.7770
Knittelfeld	.6131	.5019
Leibnitz	1.0455	.7586
Leoben	2.3732	1.5088
Liezen	2.1602	1.9342
Mürzzuschlag	.8356	.6582
Murau	.9689	.5764
Radkersburg	.5683	.3826
Voitsberg	.7858	.6403
Weiz	1.1456	.6146
Tirol		
Innsbruck Stadt und Land	4.6738	11.4201
Imst	.8539	1.0050
Kitzbühel	.8071	1.4645
Kufstein	1.0175	1.9556
Landeck	1.0217	.9027
Lienz	.9073	.6947
Reutte	.8311	1.3421
Schwaz	1.0034	1.7961
Vorarlberg		
Bludenz	1.4180	2.0903
Bregenz	2.6508	4.9122
Feldkirch	1.9181	3.0670
Dornbirn	1.9241	3.7429
Wien Stadt und Umgebung, Mödling	28.6585	54.0883

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