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Empirical Analysis and the Theoretical Implications of Spatial Concentration and Dispersion Trends in the Population Distribution in the Federal Republic of Germany

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1. Introduction: Decentralisation vs. Dispersion

The sixth "Advanced Institute in Regional Science" had the overall theme "Problems and Possibilities of Regional Decentralisation" and so it's not suprising that the term "decentralisation" occurs in the titles of all the seven central papers of the meeting - even in those where the author did not mean "decentralisation" but "dispersion". What is the difference here?

The term "decentralisation" will be used here to devote those activities which are aimed at achieving a more even spatial distribution of population, employment and resources, for instance by delegating public tasks and decisions to local and regional authorities. The term "dispersion" or "dispersive" will be used here to characterise actual spatial distributions of population, employment, etc. The terms "decentralisation/centralisation" are not congruent with those of "dispersion/concentration" for it is certainly possible that all decisions having an effect on the spatial distribution of population and economic activity are taken at a fully decentralised level (e.g. are individualised) and lead - for this very reason - to spatially concentrated structures.

A discussion of the conditions under which spatial concentration and dispersion trends occur has to be preceded by answers to the following important questions:

(I) How can the degree of spatial concentration (or dispersion) of population, employment and other economic factors, which are variable with time (i.e. which are time-point specific), be measured?

(II) Which factors effect changes in these spatial distributions?

(III) Does (economic) activity at higher spatial levels (macro economic or other activities) have an influence on the spatial distributions of population and employment at lower levels?

In the following three sections § 2. to § 4. these questions will be analysed on the basis of data for the Federal Republic of Germany. The results are presumably relevant not only for the Federal Republic.

2. Relative Entropy as a Measure of Population Concentration/Dispersion

Many indicators and indices have been developed to measure levels of concentration for spatial distributions - they can be categorised as follows (1):

a) Measures of concentration derived from Lorenz curves (e.g. the GINI-Index or the "Index of Dismilarity").
b) Nearest neighbourhood measures indicating average distances between objects in space.
c) centrographic measures which are defined by means of distribution parameters such as mean, median and variance for two-dimensional distributions.
c) Measures of potential by which spatial distributions are characterised not only by one or a few members but by a value of potential for every object distributed in the space (i.e. for every region, town, etc.).

Here a relatively little seen measure of concentration will be used which, apposed to the more usual measures, has the advantage that it can also be used to compare population concentration in countries of different sizes (2). Only relative quantities are used in the definition, namely those which relate proportion of parts of a region or country to those of the whole.

If $P_1, \ldots, P_n$ are the numbers of inhabitants of areas 1, ..., n then only the quantities $p_i = P_i/\Sigma P_i$ enter into the calculations for the measure.

To characterise the degree of irregularity (=concentration) of the distribution $P_1, \ldots\ldots, P_n$ the following parameters are used:

$$(1)\quad H = -\Sigma\, p_i \log p_i \qquad\qquad 0 \leq H \leq \log n$$

H is based on the concept of entropy as used in physics and information theory. If the distribution is absolutely uniform (all areas have the same population proportion) then H is maximum, H = log n. If the total population occurs in only one area H is minimum, H = 0. The parameter H thus measures concentration/dispersion but has the property that its values are dependent on the number of spatial units being considered. For example, if the population of both the United States and the Federal Republic were to be equally distributed among their states then the H value for the US (with 50 states) would be much higher than that for the FRG which has only 11 states.

The parameter, however, can easily be normalised so that the number of spatial units being considered has no influence, thus:

$$(2)\quad H^* = \frac{\log n - H}{\log n} \qquad\qquad 0 \leq H^* \leq 1$$

H* is called "relative entropy" in order to express the fact that the entropy of the distribution has been normed w.o.t. the maximum value log n. H lies in the interval [0, log n] where 0 indicates absolute concentration and H* lies in the interval [0, 1] where 0 indicates uniform distribution and 1 the condition of absolute concentration whereby the number of spatial units under consideration does not affect the value of H^*. Examples are given in Figure 1.

The measure H* will first be used to characterise the inter-regional distribution of population and afterwards for the intra-regional distribution at the community level within a region.

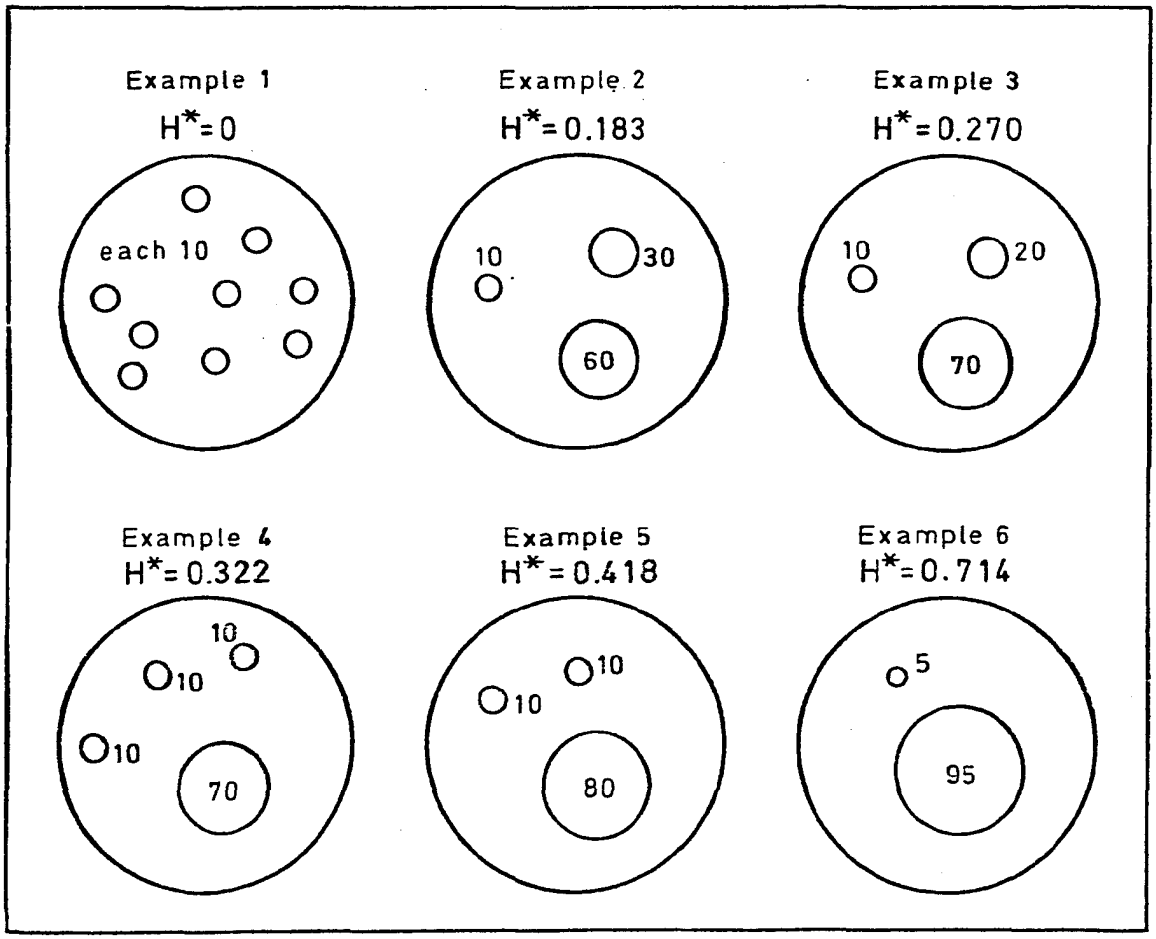


Figure 1

EXAMPLES OF THE APPLICATION OF THE CONCEPT OF ENTROPY AS A MEASURE OF CONCENTRATION FOR THE INTRA-REGIONAL DISTRIBUTION OF POPULATION

3. Concentration and Dispersion of Inter- and Intra-Regional Population Distributions

3.1 Inter-Regional Population Distribution and its Change at Differing Spatial Levels

Between the full cencus years 1961 and 1970 in the Federal Republic both concentration and dispersion processes were observed as occurring together at different spatial levels. The question therefore arises as to whether the concentration observed at the state level and the dispersion process observed at the regional planning level (79 regions) are dependent one from the other or are mutually interdependent. The following was observed:

year	1961		1970		1980
H^* (state level)	0.139	concentration →	0.143	concentration →	0.148
	1961		1970		
H^* (regional planning level)	0.059	dispersion →	0.052		

If the 11 states are divided into two groups, the northern and the southern states, and H* is calculated on the basis of the two large regions so formed then with $H^*_{61} = 0.110$, $H^*_{70} = 0.097$ and $H^*_{80} = 0.089$ dispersion is observed. If the Federal Republic is divided into three spatial categories (a) the cores of metropolitan regions (b) the outer areas of these regions, and (c) the rest of the country and H* is calculated on the basis of the first two categories only then neither concentration nor dispersion can be observed in that $H^*_{75}=H^*_{80}$. Pulling the third category into the calculation results in a sligh dispersion process being observed with $H^*_{75} = 0.010$ and $H^*_{80} = 0.009$. An even more differentiated picture is obtained if the 79 planning regions are aggregated to three categories (a) main metropolitan regions (b) mixed urbanised/rural regions and (c) rural regions; in the period 1961-80 H* demonstrates a concentration process but with dispersion betwee 1961 and 1970 and concentration in 1970-80 ($H^*_{61} = 0.073$, $H^*_{70} = 0.071$ and $H^*_{80} = 0.078$).

Conclusion

It can well be that there have been times in which, as apposed to other times, it can be said that there existed a trend towards decentralisation. On the other hand it is clear that periods of general dispersion cannot be easily identified, because at every considered spatial level the population distribution in the Federal Republic dispersed or concentrated differently.

3.2 Analysis of the Intra-Regional Population Distribution and its Change

The following analysis is based on population statistics for the 24,000 communities existing in the Federal Republic in 1961. Between 1950 and 1961 the boundaries of the communities were subject to considerable change as a result of successive communal reorganisations and they were again particularly affected for the same reason after 1968. This would have made an intertemporal comparison of population distribution at this level extremely difficult if the national Statistical Office had not calculated population figures on the 1961 basis for both 1950 and 1961. Regions are formed in the analysis by aggregating the communities to 38 administrative units where by the state Schleswig-Holstein and the "city" states of Hamburg, Bremen and Berlin each appear as a single administrative region.

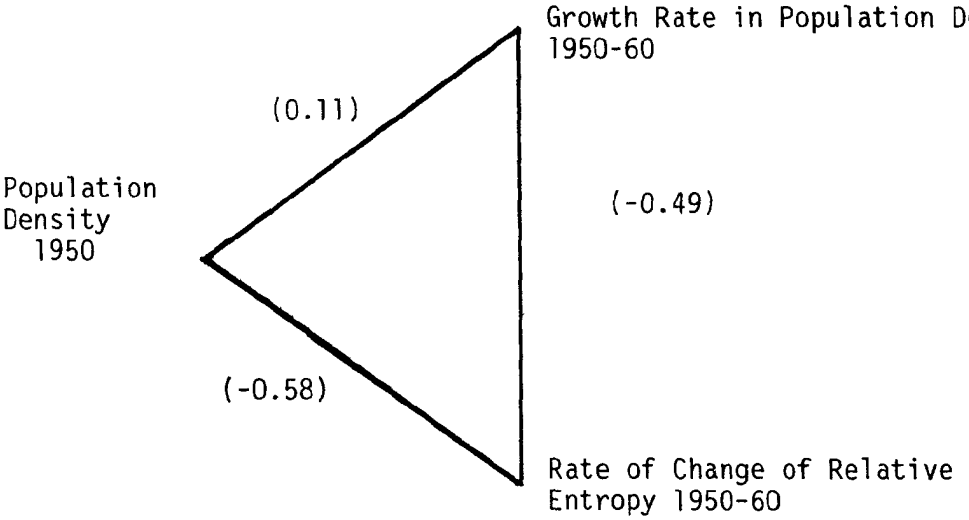
As apposed to § 3.1 investigations were not made on the inter-regional distribution of population and its change but on the distribution of population at the spatial level of the communities within each region both in 1950 and 1961. Possible relationships between the population density of the regions and the intra-regional distribution of population as well as between density and distribution change were examined in order to obtain further insight into concentration/ dispersion processes.

The following results were obtained:

(1) The lower the population desity of a region in 1950 the higher was its growth (in terms of yearly average rate) in relative entropy in the period 1950-61 (correlation coefficient = -0.58).

(2) The higher the rate of change of population density 1950-61 the lower was the growth in relative entropy of the population distribution in the region (correlation coefficient = -0.49).

These relationships between the population density at the beginning of the decade 1950-60 and the rates of change in density and relative entropy of the population distribution are global relationships obtained by regression analysis over all the 38 regions considered and can be summarised as follows (correlation coefficients in brackets):



The following statistically significant relationship was also obtained: the level of concentration of the population (H^*) in a region at the end of the period 1950-61 was higher the higher the concentration at the beginning of the period and the lower the population density was at the beginning, thus (t test values in brackets):

$$(3)\quad H^{*}_{61,i} = \underset{}{0.014} - \underset{(2.14)}{0.000097\ D_{50,i}} + \underset{(-3.46)}{1.179\ H^{*}_{50,i}} + \underset{(29.42)}{U_i}$$

$$r^2 = 0.98; \qquad i = 1, \ldots, 38 \text{ regions}$$

These results indicate that regional population changes in distribution can be represented by a phase model (3). The model is illustrated symbolically in Figure 2, the dates are given in Table 1 and graphed in Figure 2. The data, of course, do not validate the model, but they are good enough to allow the supposition that the model is correct.

In the phase model intra-regional concentration and dispersion processes are connected with inter-regional population movement.

Regions in Phase 1 have a low population density (150 inhabitants/km^2 or less - see Fig. 2). The intra-regional concentration of population starts to increase without important influence of in-migration (for the regions in Phase 1 H* has the highest growth rate - see Table 1, 6th column) and so the overall density changes only insignificantly. The process occurring is one of primary urbanisation taking place without the pressure of in-migration.

The Phase 2 the overall population density increases through in-migration and natural growth. The lower the density is, at the beginning of the period the higher is its rate of change (the density has a negative coefficient in equation (3)). The process occurring is one of secondary urbanisation based on in-migration. The rate of increase in the concentration of the regional population distribution is less and can reach zero. At the same time the inter-regional population distribution tends towards more concentration because of the inter-regional migration.

The Phase 3 the regional population density ceases to grow and a process of intra-regional dispersion - sub-urbanisation (4) - occurs due to movements out of the city cores into the fringes of the cores (5).

TABLE 1

Density and relative entropy of the intraregional population distribution[1)]

region (Regierungs-bezirke)	density pop. per km^2		relative entropy H^*		annual rate of change 1950-61	
	1950[1)]	1961	1950	1961	density	entropy
Schleswig-Holstein	165,7	148,0	0,223	0,267	– 1,02	1,63
Hamburg	2 148,8	2 452,2	1,000	1,000	1,21	0,00
Niedersachsen						
Hannover	211,0	221,3	0,291	0,370	0,44	2,23
Hildesheim	195,0	180,9	0,152	0,194	– 0,68	2,23
Lüneburg	90,3	86,8	0,148	0,196	– 0,37	2,59
Stade	97,4	86,5	0,126	0,149	– 1,07	1,50
Osnabrück	109,7	114,5	0,178	0,220	0,39	1,92
Aurich	122,8	117,7	0,134	0,158	– 0,38	1,54
Braunschweig ..	279,3	274,2	0,307	0,354	– 0,17	1,31
Oldenburg	149,0	142,3	0,160	0,175	– 0,42	0,84
Bremen	1 383,5	1 749,4	0,270	0,276	2,16	0,22
Nordrhein-Westfalen						
Düsseldorf	785,8	982,0	0,339	0,344	2,05	0,13
Köln	419,3	534,3	0,350	0,375	2,23	0,62
Aachen	251,7	303,9	0,216	0,235	1,73	0,78
Münster	261,8	309,7	0,226	0,249	1,54	0,89
Detmold	231,5	247,9	0,156	0,177	0,63	1,18
Arnsberg	396,7	469,2	0,318	0,339	1,54	0,58
Hessen						
Darmstadt	212,8	246,0	0,164	0,207	1,33	1,89
Kassel	137,1	136,6	0,167	0,209	– 0,03	2,06
Wiesbaden	306,9	357,9	0,347	0,383	1,41	0,90
Rheinland-Pfalz						
Koblenz	141,1	158,7	0,149	0,173	1,08	1,34
Trier	87,8	94,0	0,174	0,192	0,63	0,92
Montabaur	134,5	143,2	0,100	0,113	0,57	1,09
Rheinhessen	288,5	336,2	0,251	0,314	1,41	2,06
Pfalz	192,9	227,8	0,189	0,215	1,52	1,19
Baden-Württemberg						
Nordwürttemberg	230,5	287,1	0,239	0,257	2,01	0,64
Nordbaden	286,6	331,3	0,273	0,302	1,33	0,93
Südbaden	134,4	163,3	0,138	0,158	1,78	1,23
Südwürttemberg/ Hohenzollern ..	117,3	138,5	0,124	0,145	1,53	1,59
Bayern						
Oberbayern	150,4	168,6	0,308	0,367	1,05	1,61
Niederbayern ..	100,5	89,4	0,083	0,103	– 1,06	1,94
Oberpfalz	93,0	92,3	0,174	0,198	– 0,07	1,20
Oberfranken	148,7	144,9	0,176	0,189	– 0,24	0,66
Mittelfranken ..	168,5	180,4	0,326	0,378	0,62	1,37
Unterfranken ..	122,4	128,4	0,132	0,169	0,44	2,31
Schwaben	128,6	133,1	0,172	0,209	0,31	1,73
Saarland	372,3	417,8	0,187	0,186	1,06	– 0,05
Berlin (West)	4 463,5	4 568,6	1,000	1,000	0,21	0,00

1) Distribution of the population on communities within each region. Computed for constant borders of communities.
Source: H. Birg, "Zur Messung der regionalen Bevölkerungskonzentration in der Bundesrepublik Deutschland mit Hilfe des Entropie-Mapes". In: Vierteljahrshefte zur Wirtschaftsforschung", Ed.: Deutsches Institut für Wirtschaftsforschung, Heft 3, 1971.

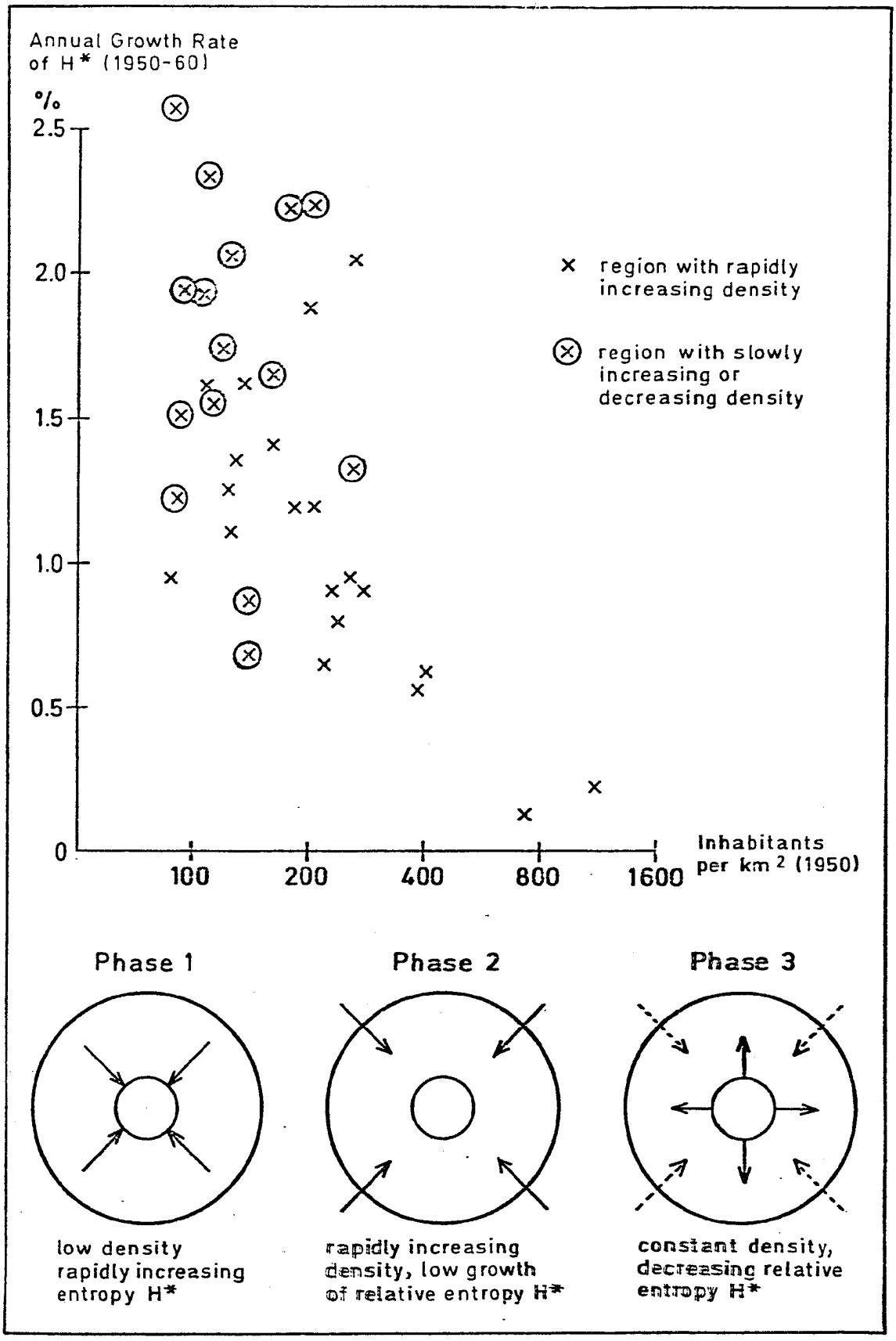


Figure 2

RELATIONSHIP BETWEEN POPULATION DENSITY AND RELATIVE ENTROPY

The relative entropy decreases. In the data considered for 1950-60 none of the 38 regions reached Phase 3 (the relative entropy decreased slightly only in Saarland). At the present time it is so that many regions have already passed through Phase 3 and are entering a new phase which, in the future, might proove to be a phase of re-urbanisation.

In the Federal Republic the primary urbanisation of Phase 1 through local migration and the secondary urbanisation of Phase 2 caused by inter-regional migration overlap with a still continuing process of international in-migration which is directed principally towards the cores of the metropolitan areas. Intra-regional, inter-regional and international migration are therefore closely connected. But the core-fringe migration and the migration from abroad into the cores are only different aspects of the same general process.

4. Demographic Aspects of Spatial Concentration and Dispersion

The numer of inhabitants of a region changes according to five basic demographic processes which, in general, have different effects on the distribution of population. On the basis of the 79 planning regions in the Federal Republic these processes had the following effects between the cencus years 1961 and 1970:

Births ⟶ Dispersion
Deaths ⟶ not yet investigated
Domestic Migration ⟶ Dispersion
International Migration ⟶ Concentration

The strongest influence on population distribution is that of the inter-regional migration, the weakest that of the deaths for which no conclusive research results exist at the moment (6).

If the effect of the population age structure of the regions on the number of births is eliminated by normalisation, their index of the frequency of births for the 79 regions (with average value 100)

shows variations from 71 (Regions Munich, Berlin) to 161 for the rural region Lingen (7). The ratio minimum:maximum value is 71:161 = 1:2.27. No trend can be observed that such disparities are decreasing although this is often anticipated in the literature. Because the less densely populated rural areas generally have a high birth rate and the densely populated regions low bith rates the effect of births on the distribution of population is one of dispersion. This trend to dispersion occurs simultaneously with the two effects of migration, the inter-regional, domestic, migration also effecting a trend to dispersion and the international migration effecting concentration.

In the following the effect of the inter-regional migration will be demonstrated using two different migration models, one based on gravitation principles (with directed migration flows) and the other a population/employment model with in- and out-migration obtained by summing directed flows.

(a) Dispersion and Concentration Using Migration Flows Derived from Gravitation Models

Let the following simple gravitation model be assumed:

$$(4) \quad M_{ij} = a_o \frac{p_j^{a1}\, p_i^{a2}}{d_{ij}^{a2}} \quad ; \qquad a_0, \ldots, a_3 > 0;\ i \neq j$$

Here M_{ij} is the migration flow from region i to region j and M_{ji} the flow in the opposite direction. From the structure of the model the following general conclusion can be drawn: migration flows have an influence in the direction of dispersion for the inter-regional distribution of population if the parameter a_i (for the source region) is bigger than the parameter a_j (for the sink region). This arises because the magnitudes of the two migration flows are related according to:

$$(5) \quad \frac{M_{ij}}{M_{ji}} = \frac{p_j^{a1}\, p_i^{a2}}{p_i^{a1}\, p_j^{a2}} = \left(\frac{p_j}{p_i}\right)^{a_1 - a_2}$$

Let $a_2 > a_1 > 0$ and $P_j > P_i$. Then $M_{ij} < M_{ji}$ from equation (5). Thus the smaller region has a positive net migration ($M_{ji} - M_{ij} > 0$) and the larger region a negative ($M_{ij} - M_{ji} < 0$). If $a_2 > a_1 > 0$ and $P_i > P_j$ then $M_{ij} > M_{ji}$ and again the net migration for the smaller region is positive and for the larger negative. It can therefore be concluded that if the parameter a for the source region is larger than for the sink region then a change in the population distribution in the direction of dispersion occurs regardless of the relative population sizes of the two regions.

The question as to whether the parameter a for the source region is bigger than that for the destination region can be answered both "yes" and "no" for the Federal Republic - the result depends upon the regionalisation adopted as well as on the other parameters used in the model. On the basis of the 11 states the parameter a for the origin of migration (source) was smaller than that for the destination region (sink) in all the years investigated, i.e. the population distribution changed in the direction of an increased concentratio (Table 2). This result is the same as that obtained by using entropy, as related above.

If the Federal Republic is delineated in to the 79 planning regions results can be obtained in a much more differentiated manner. Since each state is composed of a subset of the 79 planning regions the gravitation maodel can be tested separately for individual states. The units being observed are migration flows so that the number of observations for an application of the model for the regions within a state is still satisfactorally large enough.

TABLE 2

Parameters of the Gravity Model
on the State Level

Parameter[1)]	1964	1969	1971	1975
a_o	0.198	0.522	0.583	0.822
a_1	0.967	0.945	0.920	0.905
a_2	0.950	0.855	0.861	0.857
a_3	-0.949	-0.952	-0.942	-1.036
interval for all t-values	$9.98 \leq t \leq 18.9$			

1) See equation (4)

This number of observations varied between 156 for Nordrhein-Westfalen and 110 for Niedersachsen. Further, it was possible to perform another, more detailed, investigation in which only the flows between urbanised and rural regions were considered, those between urbanised and between rural regions being neglected.

As a result of the various calculations it is discovered that the migration flows in 1966 between the planning regions in Niedersachsen and in Baden-Württemberg led to increased concentration but in the state of Bavaria to increasing dispersion - the results for the other states were not statistically significant. A change in the direction of dispersion is the result of investigating the migration flows between the two subsets of urbanised and rural regions. The same result is obtained if the simple gravitation model is extended to include further variables such as those that describe the labour market, living conditions and income level differences (7).

Conclusion:

By means of the analysis of population statistics as described in § 3 it can be concluded that concentration and dispersion processes occur simultaneously according to the spatial level of observation. Analysis of data on the components of population change (migration, births, deaths) leads to the result that causality specific concentration and dispersion effects can occur simultaneously. Here the trend is, such that births contribute to a more even population (dispersion) and that the differing forms of migration have differing effects on the level of concentration and/or dispersion. Migration flows contribute far more to population change at the regional level than births and deaths (for every birth at the regional planning level in the Federal Republic three - on average - people migrate into the region and for every death three people move out of the region as shown in Figure 3).

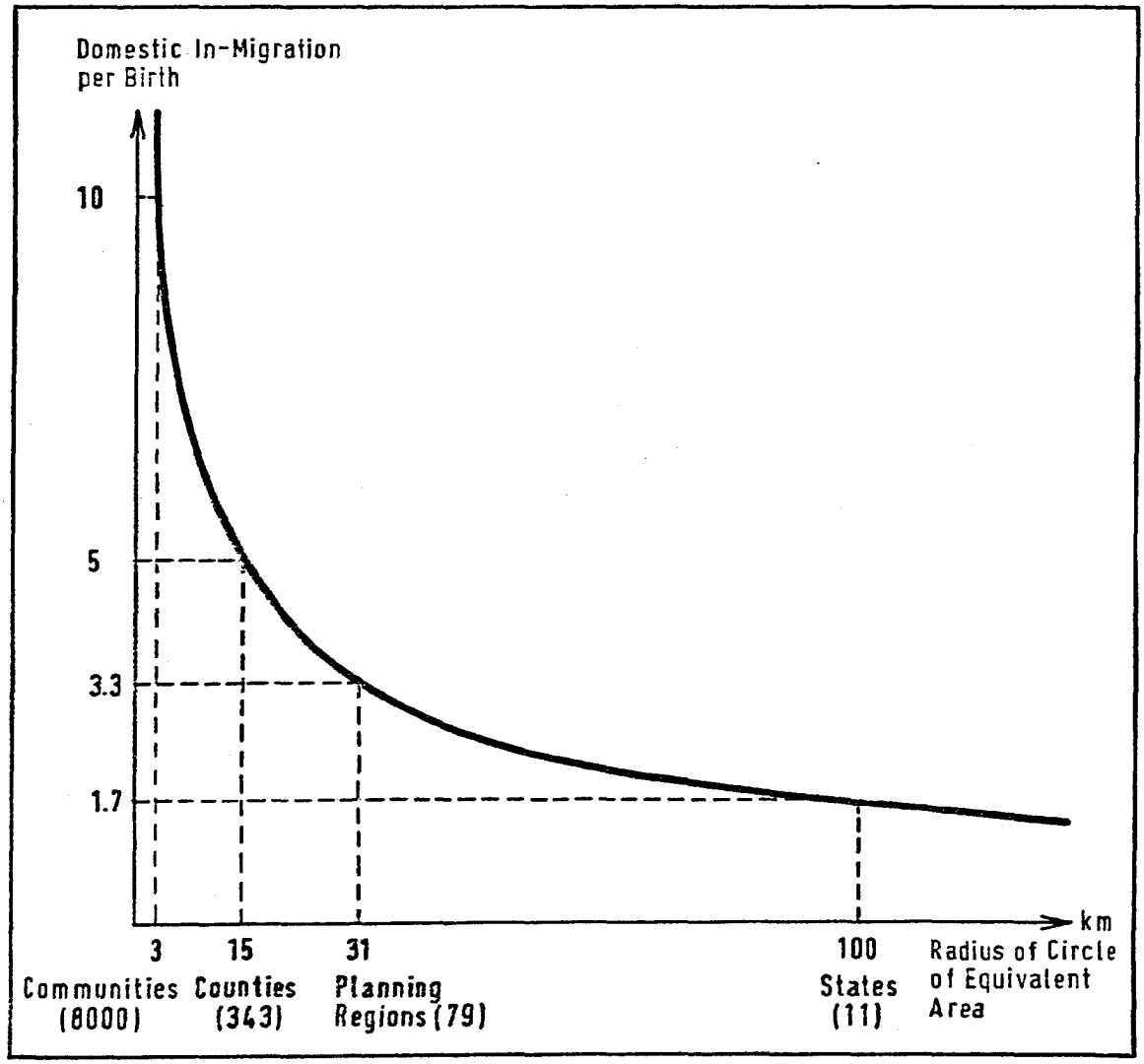


Figure 3

REGIONAL SIZE AND MIGRATION
(Administrative Units in the Federal Republic of Germany)

(b) Dispersion and Concentration Using Migration Flows Derived from Population/Employment Models

Another model can be used to analyse concentration/dispersion processes arising from migration between the 79 planning regions, which differs from the gravitation model in three respects:

(1) The model is simpler because it uses the cumulative in-migration and the cumulative out-migration into and out of a region as dependent variables:

$$\left.\begin{aligned} \text{In-migration:} \quad & I_i = \sum_j M_{ji} \\ \text{Out-migration:} \quad & O_i = \sum_j M_{ij} \end{aligned}\right\} \quad i,j = 1, \ldots, 79$$

(2) The model is more realistic because it uses the change in the number of jobs available (ΔE_i) as an explanatory variable.

(3) Finally the model has a more satisfactory theoretical structure because two equations are used - the in-migration (I_i) and out-migration (O_i) are estimated separately. The regional population total (P_i) at the beginning of the considered period of time and change in regional employment in the period are the independent variables in the model. The model was applied for the period between the cencus years 1961 and 1970 and so the inter-regional migration observations used those officially registered at the communal level in the period. [1] Aggregation of the number of movements over the period helps to smooth out the effects of the business cycle (9). The following system (with standard deviations in parentheses) resulted from application of the two-stage least squares (TSLS) estimation method:

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1) In the Federal Republic change of abode has to be officially registered and registration and de-registration is only possible if both addresses, new and old, are known.

$$(6)\quad I_i = \underset{(8272)}{15878} + \underset{(0.144)}{1.589}\ \Delta E_i + \underset{(0.027)}{0.9550}_i\ ; \qquad r^2 = 0.95$$

$$(7)\quad O_i = \underset{(7695)}{23628} + \underset{(0.019)}{0.216}\ P_i + \underset{(0.061)}{0.309}\ I_i\ ; \qquad r^2 = 0.95$$

The cross-region estimations are statistically significant and the results can therefore be used for an analysis of concentration processes. Manipulating (6) and (7)

$$(8)\quad I_i = 54609 + 2.254\ \Delta E_i + 0.293\ P_i$$

and

$$(9)\quad O_i = 40556 + 0.697\ \Delta E_i + 0.306\ P_i$$

are obtained. The regional net migration is then obtained as:

$$(10)\quad N_i = I_i - O_i = 14053 + 1.558\ \Delta\ E_i - 0.014\ P_i$$

The results imply that - ceteris paribus - net migration increases with an increase in the number of jobs available in a region but decreases with increase in regional population at the beginning of the period. Thus this model, which on the basis of the estimations can be regarded as well founded, delivers results from which it can be concluded that inter-regional migration between 1961 and 1970 contributed to a dispersion of population. International migration effected a concentration because the in-migration from abroad was principally directed into the agglomeration areas (10).

5. Theoretical Conclusions

A theoretical explanation for the descriptive results presented above would be too much to ask for in a short paper. This concluding chapter can therefore only briefly review a few of the implications of the

empirical facts, which could be relevant for theories of settlement systems or for regional economics. Implications for theory and model building arise principally from the relationship discovered between the business cycle and the yearly migration incidence, a relationship obtained by considering a much neglected variable namely the yearly number of personnel changes in the existing employment (Fig. 4). Such changes arise not only basically from the personnel renewal process in which old employees retire and young people are engaged but also for other reasons connected with the process of capital renewal, in which - analogous to the factor lobour - old production investments are replaced by new. If the rate of renewal on the personnel side is slower or faster than that of capital friction can arise causing fluctuations on the labour market. But even then when these rates of renewal are synchronised a large number of personnel changes take place because of the pursuance of careers - in the Federal Republic every fourth job is affected each year (11). Personnel changes and changes of job frequently imply changes of residence and it is for this reason that personnel changes are of theoretical importance in the consideration of concentration or dispersion processes.

In the following a theoretically more satisfactory justification for the gravitation model is developed by considering the relationships between the business cycle, the number of personnel changes and the number of migrations. Finally the consequences for concentration/ dispersion arising from an improved migration model will be made clear.

It is assumed that the number of migrations from region i to region j is dependent on the number of comparisons of conditions in i and j made by potential movers of house before they actually decide to move. The number of comparisons made between alternatives in i and j is a function of two parameters, the number of inhabitants in i who make comparisons and the number of alternatives in j that can be compared.

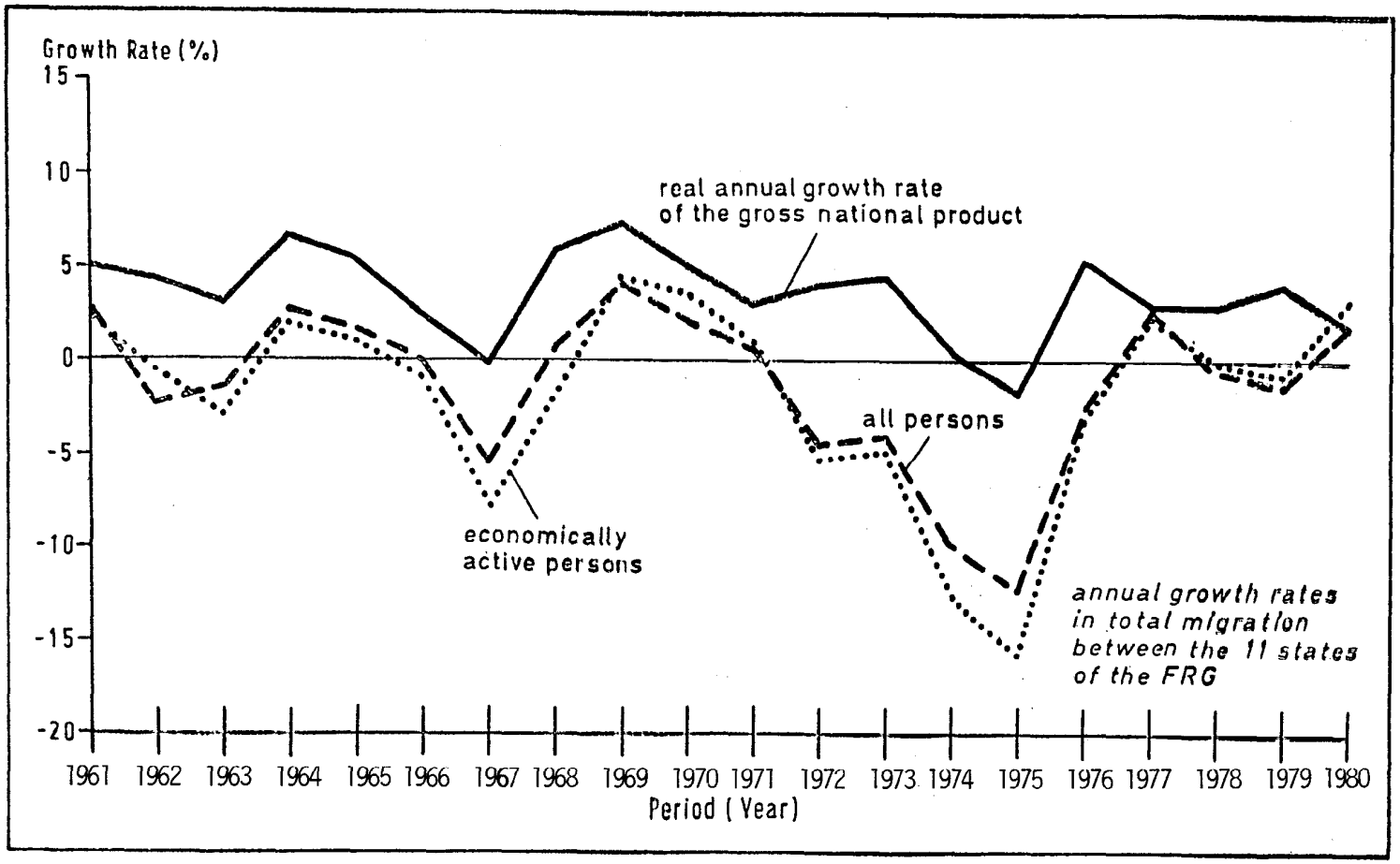

Figure 4

RELATIONSHIP BETWEEN MIGRATION AND PRODUCTION GROWTH RATES

It is assumed that the number of people who make comparisons is a simple monotonly increasing function of the number of inhabitants in i (P_i^{β}) and that the number of alternatives that can be compared in j is a monotonly increasing function of the number of unoccupied jobs there which in turn is assumed to be proportional to the total number of jobs both occupied and unoccupied. If now this total number of jobs is assumed to be proportional to the number of inhabitants than the number of available jobs can be directly derived from the population size. Using exponential functions for the sake of simplicity then

$$(11)\quad M_{ij}(t) \sim [\gamma_j P_j(t)]^{\alpha} \cdot P_i^{\beta}(t) \qquad \text{where } \alpha, \beta > 0$$

In this relationship $\gamma_j P_j(t)$ is the number of available jobs in region j and period t expressed directly in terms of the populations size in j. The parameter γ will be called the fluctuation parameter. It expresses the relative frequency of personnel change in the region.

If, in addition, it is assumed that M_{ij} is also dependent on the distance between i and j then equation (11) can be expressed in a way in which the similarity with the gravitation model is evident:

$$(12)\quad M_{ij}(t) = \frac{[\gamma_j P_j(t)]^{\alpha} P_i(t)^{\beta}}{d_{ij}^{\delta}} \quad ; \qquad \alpha, \beta, \gamma, \delta > 0$$

The question of how the population distribution is influenced by migration can be reformulated into the question of the essential parameter dependency of the ratio $M_{ij}:M_{ji}$. From equation (12)

$$(13) \quad \frac{M_{ij}(t)}{M_{ji}(t)} = \left(\frac{\gamma_j}{\gamma_i}\right)^{\alpha} \left(\frac{P_j(t)}{P_i(t)}\right)^{\alpha-\beta}$$

can be obtained, which shows that two mutually independent effects influence the relative size of M_{ij} and M_{ji}. The first effect is based on the difference between the two "mass" parameters α and β. This effect was also derived in §4 from the simple gravitation model. The second effect concerns the difference between the fluctuation parameters γ_i and γ_j. In equation (13) the following can be observed:

(1) The mass effect and the fluctuation effect act independently of each other. They can either complement or neutralise each other.

(2) Even when the mass effect is zero the fluctuation effect can change the regional population distribution in the direction of

   (a) concentration if the ranking $\gamma_i > \gamma_j > \gamma_r >$ coincides with the population size ranking $P_i > P_j > P_r$

   (b) dispersion for instance when the two rankings run in opposite directions.

How do these rankings actually compare? It's perfectly clear that the maximum number of personnel changes derived from a theoretical procedure combining a given number of persons with a given number of jobs increases strongly non-linearly with increase in the number of jobs. If the actual number of changes correlates positively with the theoretical number then it can be concluded that the empirical rank order of the regional fluctuation parameters more or less coincides with that for the absolute size of the respective regional labour markets and that therefore the fluctuation effect causes a trend in the direction of concentration of the inter-regional population distribution. This occurs as long as the regional

fluctuation parameters are different. There is some empirical evidence - as Fig. 5 shows - that this is so; the fluctuation parameters for the labour office areas in the state of Nordrhein-Westfalen correlate positively with the employment figures in these areas.

This result can be derived analytically for a two region case. Assuming that the natural population growth rates in the two regions are the same the time dependent populations can be described by two interdependent differential equations:

$$(14)\quad P_1(t) = P_1(0) + \int_0^t rP_1(\tau)d\tau + \int_0^t (\gamma_1 P_1(\tau))^{\alpha} P_2(\tau)^{\beta} d - \int_0^t (\gamma_2 P_2(\tau))^{\alpha} P_1(\tau)^{\beta} d\tau$$

$$(15)\quad P_2(t) = P_2(0) + \int_0^t rP_2(\tau)d\tau + \int_0^t (\gamma_2 P_2(\tau))^{\alpha} P_1(\tau)^{\beta} d - \int_0^t (\gamma_1 P_1(\tau))^{\alpha} P_2(\tau)^{\beta} d\tau$$

In the equations r is the natural growth rate and the $P_i(0)$ are the populations at $t = 0$. The populations change with time until an equilibrium situation is achieved at $t = t^*$ for which (12):

$$(16)\quad \frac{P_1(t^*)}{P_2(t^*)} = \left(\frac{\gamma_1}{\gamma_2}\right)^{\alpha/(\beta-\alpha)}$$

Equation (16) shows that the higher the fluctuation parameter in region 1 w.r.t. region 2 the larger the population of region 1 relative to that of region 2 is in the equilibrium situation. As long as the population distribution is more disperse than that of the equilibrium situation, which is determined by the two fluctuation parameters, then migration occurs in the direction of more concentration. If, on the other hand, the population distribution is more concentrated than that of the equilibrium situation dispersive migrations take place.

These results are based on the assumption that the natural rate of growth in the two regions is the same. It would be more realistic to assume that the natural growth rate is dependent on the regional fluctuation parameter. By this means the relationships between

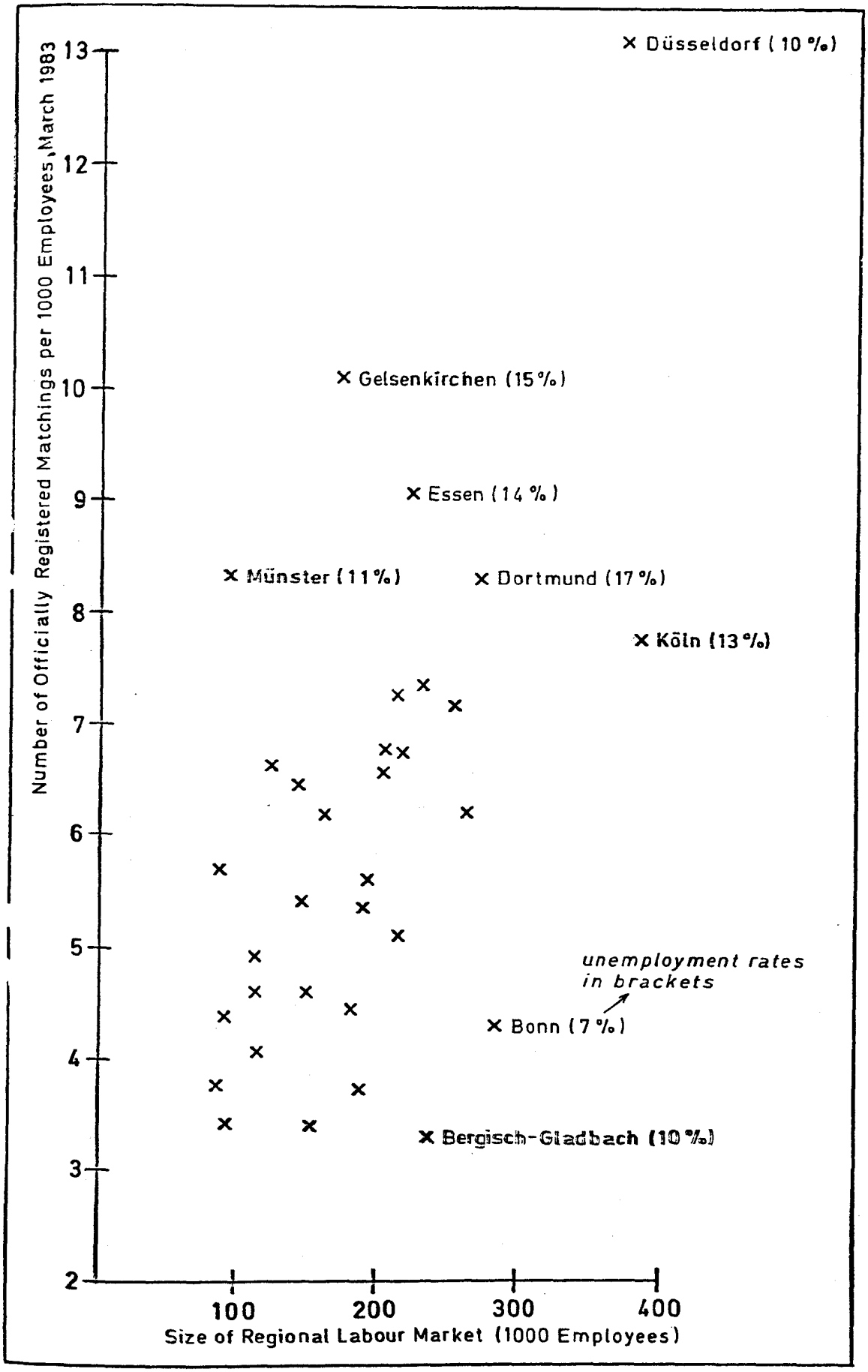

Figure 5

SIZE OF LABOUR MARKET AND PROPORTION OF SUCCESSFULL MATCHINGS

fertility, personnel changes and migration could be investigated as well as their effects on concentration/dispersion processes - the differential equations arising would then have to be solved by a different method. That there is a connection between personnel changes in the life course and fertility can be empirically demonstrated and this fact opens new perspectives for the theory of generative behaviour (13).

7. Summary

The concept of relative entropy has been used in this paper to investigate regional concentration/dispersion trends in general as well as the concentration/dispersion effects of the various components of population change. Using a model the general effects of employment orientated migration have been derived. Differences in regional lobour markets in particular in the relative frequency of personnel change - an indicator of the economic vitality of a region - are of the utmost importance in analysing inter-regional migration. The rate of personnel change correlates closely with the course of the business cycle and at the same reflects the level of mobility present in the region for the pursuance of careers. It has been shown that this indicator is an important link for a syntheses of micro- and macro-analysis and opens new perspectives for such analysis as well as for the theory of the life course and of human fertility.

Notes and References

(1) Ref. DUNCAN, O.D.: The Measurement of Population Distribution. In: Population Studies 11, 1957. HART, J.F.: Central Tendency in Areal Distribution. In: Economic Geography, 30, 1954. WARNTZ, W. u. NEFT, D.,V.: Contributions to a Statistical Methodology for Areal Distribution. In: Journal of Regional Science, No. 2.

(2) For the application of the entropy concept in business studies ref. PASCHEN, B.H. u. BUYSE, R., 1971: Zur Messung der Betriebs- und Unternehmenskonzentration. In: Statistische Hefte, 12. Jg., Heft 1. For applications in regional science ref.: GEISENBERGER, S., u. MÄLICH, W., 1971: Informationstheoretische Messung regionaler Konzentrationserscheinungen. In: Raumforschung und Raumordnung, 29. Jg., Heft 1. WILSON, A.G.: Entropy in Urban and Regional Modelling. London 1970.

(3) A full treatment of the interpretation can be found in: BIRG, H., 1971: Zur Messung der regionalen Bevölkerungskonzentration in der Bundesrepublik Deutschland mit Hilfe des Entropie-Maßes. In: Vierteljahreshefte zur Wirtschaftsforschung, Heft 3.

(4) BERG, L.v., DREWETT, R., KLAASEN, L.H., ROSSI, A., VIJVERBERG, C.H.T.: Urban europe: A Study of Growth and Decline. Rotterdam, London, Zürich, June 1980 (Mimeo).

(5) In the Federal Republic of Germany 300.000 people moved from the centers to the outer areas of the metropolitan regions and approx. the same number from thinly populated rural areas to these outer areas. Ref. BIRG, H., 1980: Berechnungen zur langfristigen Bevölkerungsentwicklung in den 343 kreisfreien Städten und Landkreisen der Bundesrepublik Deutschland. In: Vierteljahreshefte zur Wirtschaftsforschung, Heft 2, Tab. 6, P. 204.

(6) GATZWEILER, H.-P. und STIENS, G., 1982: Regionale Mortalitätsunterschiede in der Bundesrepublik Deutschland. In: Jahrbuch für Regionalwissenschaft, Jg. 3, P. 36-64. BIRG, H., 1982: Regionale Mortalitätsunterschiede in der Bundesrepublik Deutschland. In: Materialien des Instituts für Bevölkerungsforschung und Sozialpolitik, Bd. 4, Universität Bielefeld. HEINS, F. und STIENS, G., 1984: Regionale Unterschiede der Sterblichkeit. In: Arbeitspapiere Nr. 17. Hg. Bundesforschungsanstalt für Landeskunde und Raumplanung, Bonn.

(7) For details ref. BIRG, H., 1975: Analyse und Prognose der Bevölkerungsentwicklung in der Bundesrepublik Deutschland und in ihren Regionen bis zum Jahr 2000. Berlin, P. 24ff.

(8) See (7) above, P. 74f.

(9) Attempts to model the migrations of labour occurring between the member countries of the European Communities were only successful after correction for the dominant influence of the business cycle. Re. FEITHEN, R., 1984: Arbeitskräftewanderungen in der Europäischen Gemeinschaft - Eine Analyse der Bestimmungsgründe und der regionalpolitischen Implikationen.

(10) For detailed results ref. BIRG, H., 1981: An Interregional Population-Employment Model for the Federal Republic of Germany: Methodology and Forecasting Results for the Year 2000. In: Papers of the Regional Science Association, Vol. 47. Also: Zur Interdependenz der Bevölkerungs- und Arbeitsplatzentwicklung. Berlin 1979.

(11) The connections between the business cycle, employment fluctuations and the level of migration are eyplained in BIRG, H., 1984: Demographic Aspects of Labour Market Efficiency. In: STEINMANN, G. (ed.): Economic Consequences of Population Change in Industrialized Countries, Berlin, Heidelberg, New York, Tokyo.

(12) For the analytical derivation of this result ref.: BIRG, H., 1982: On the Interactions of Job Creation, Migration and Natural Population Increase within the Framework of a Dynamic Demoeconomic Model. In: Environment and Planning A, Vol. 14, P. 1151-53.

(13) BIRG, H., FELBER, W., FLÖTHMANN, E.-J., 1984: Arbeitsmarktdynamik, Familienentwicklung und generatives Verhalten. In: Materialien des Instituts für Bevölkerungsforschung und Sozialpolitik No. 16, Universität Bielefeld, p. 41, 151.