

REGIONAL UNEMPLOYMENT AND THE HOUSING MARKET:
SPATIAL EFFECTS OF INDUSTRIAL DECLINE⁺

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ABSTRACT

The paper is a report on simulation experiments in which the impacts of economic, i.e. sectoral and technological, change on locational choice, mobility, and land use in urban regions are investigated with the help of a multilevel, dynamic simulation model of regional development. In the experiments reported here it was attempted to model the spatial distribution of unemployment in the region and its effects on the local housing market.

The paper contains a brief description of the model structure. It is shown how the employment sector is linked, via job location and household income, to the housing market of the model. The remaining part of the paper deals with the application of the model to Dortmund and its urban region. In particular, the results of simulations based on large reductions in the number of jobs in the iron and steel industry are discussed.

INTRODUCTION

The settlement structure of the *Ruhr* region has, in the historical past, been largely determined by locational requirements of two major industries, coal mining and steel manufacturing, and of their transport infrastructure, rails and waterways. Housing location has always been subordinate to industrial location, worker housing being nested around pits and plants as closely as possible. However, with the decline of the coal mining industry after the Second World War, the rationale for the tight connection between housing and job location has weakened. Today, another major disruption of the traditional linkage between housing and job location may be caused by the decline of the steel industry, the second major employer of the region.

Industrial decline has received increased attention as an object of economic studies on the international, national, and regional scale. However, not much attention has been paid so far to the disruptions and imbalances on the subregional and local level caused by the transition from economic growth to decline. This is particularly true for issues of equity which graciously had been veiled by everybody's being better off, but which become grimly apparent in a time of general austerity.

If one looks closer, one finds that geographers and regional scientists indeed do not know much about how on a less than macro scale regions behave under conditions of decline. Location theory, highly competent when asked where expanding firms locate (or, at least, *should* locate) is much less eloquent with respect to patterns of *contraction*, which may be much more important to know in advance. Residential location and housing market models have proven their worth in situations of population growth and a prospering home building industry, but there are not many models which adequately deal with phenomena such as blight and decay, squatterism, or urban ghettos. The same applies to land use and transportation models which were designed for growth and expansion, but have no answers for conditions of unemployment, inflation, and exploding energy prices.

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Unemployment, in particular, has hardly been noticed by the authors of these models, for the simple reason that there was practically no unemployment when the models were built. But now, obviously, there is unemployment. Has this consequences for the *spatial* structure of urban regions, i.e. for locational choice, mobility, and land use? It would be surprising if there were no such consequences. After all, unemployment severely changes the economic and social situation of a household, and households are the principal actors in the process of urban development, who by their locational decisions largely determine the course of spatial urban change. Therefore, the effects of unemployment on the locational decisions of households should be of great interest to the urban planner and to the urban researcher as well.

The motivation to look into the effects of unemployment on urban structure originated in the framework of a larger research project aimed at the investigation of spatial impacts of economic change with the help of a simulation model of regional development (cf. Wegener, 1980). At the outset of that project, interest focused on location decisions of new, expanding, or relocating firms. However, it soon became apparent that *withdrawal* of a firm from a region is a much more frequent and consequential event in contemporary regions. The closure of an industrial plant affects the spatial structure of a region in two ways: *directly* by vacating industrial land, and *indirectly* by its impacts on subsequent location decisions of households formerly employed at that plant. It was realized that the indirect impacts may be much deeper and longer lasting.

Therefore, a limited study was set up within the larger project to take a closer look into the second, indirect, kind of effects of unemployment on urban structure with the aim to model these effects as a part of the existing simulation model of regional development. First results of this effort are presented in this paper. Being a part of the larger project, the purpose of the study is rather restricted. It deals exclusively with the effects of unemployment on location decisions of households *within* an urban region, and not with its impacts on long-distance migration into or out of the region, nor with economic cross-impacts between plant closures in different industrial sectors. Such effects are not ignored, but are treated exogenously here.

Moreover, only the crudest and most obvious effect of unemployment is taken into account, *income*, although for the individual or household stricken by unemployment other effects may be equally or more disturbing. It is assumed that a household whose head has been made redundant will suffer a loss of income which can only temporarily be offset by the consumption of savings. Consequently, in the long run the household will have to reduce its expenses for food, clothing, housing, and transport. Of these four, the current housing status will probably be defended longest, because to give up one's dwelling means much more than that: it means to give up the familiar neighbourhood and contacts to friends and relatives, and with that the basis for social status and self-esteem. Therefore, only in exceptional cases households will vacate their dwellings because of unemployment. More frequent will be the case that, as a consequence of unemployment, a household postpones or abandons earlier plans to improve its housing situation. This suppression of demand, if it occurs in considerable numbers, will have its effects on the demand for housing, on the number of dwellings being built, and eventually on the rate and direction of land development.

Even more important is that unemployment and its effects are not evenly distributed across the urban region. Unemployment originates at places of work, but strikes at places of residence. The distribution of unemployment caused by redundancies in a certain industrial sector will therefore depend not only on the location of workplaces of that sector, but also on where the workers employed at those workplaces live. Especially when a particular firm has large-scale redundancies or closes down, there may be concentrations of unemployment in certain parts of the urban region. These spatial variations of unemployment and its effects are the prime object of investigation of this study.

The paper sets out from a brief discussion of the regional context, the *Ruhr* region in West Germany, and its current employment problems which provided the motivation for the study. Thereafter, the regional simulation model used in the larger research project is outlined. Then the approach chosen to model unemployment and its spatial effects in the framework of that simulation model is presented. The remainder of the paper deals with the application of the model to the eastern part of the Ruhr region, to Dortmund and its urban region. In particular, the results of simulations based on large reductions in the number of jobs in the iron and steel industry are discussed.

1. THE REGIONAL SETTING

With a population of 5.4 million in 1979, the *Ruhr* region is the largest agglomeration of the Federal Republic of Germany. Extending over some 5,000 square kilometres, it incorporates nearly ten percent of the population of the Federal Republic on only two percent of its territory. The Ruhr differs from other agglomerations in that it has no single centre, but consists of more than a dozen individual cities, among them Essen (pop. 655,000), Dortmund (pop. 610,000), and Bochum (pop. 400,000). Its economic structure has in the past been dominated by two major industries, coal mining and steel manufacturing, which even today account for roughly 45 percent of total industrial employment.

Historically, the rise of the Ruhr as an industrial region was based on the rich coal supplies discovered on both sides of the Ruhr river already in the middle ages. However, large-scale exploitation of these supplies did not start before the middle of the last century, but developed rapidly thereafter. In 1920, the coal mining industry of the Ruhr employed nearly 470,000 workers, almost five times as many as today.

It was also in the middle of the 19th century that coke produced at the Ruhr was for the first time used for steel making, a century later than in England. Due to the heavy demand for steel for railways, bridges, and ships in the second half of the century, steel making became the second major industry of the region. Soon the iron ore found in the hills south of the Ruhr river was exhausted, and the Ruhr became dependent of imported ore shipped from other countries.

The locational requirements of the coal mining and steel manufacturing industries and of their transport infrastructure, rails and waterways, determined the development of the settlement structure of the Ruhr. For centuries, the region had been agricultural, dotted with villages and small towns. The miners of the first coal pits lived in cottages on little pieces of farm land dispersed across the hilly countryside. When the first large coal mines opened about 1850, workers had to be recruited from all over Germany and even from other countries. For the housing needs of these immigrants, housing of the lowest standard was provided either by speculative builders or by the mining companies themselves. Many of the latter put up housing "colonies" for their workers copying worker row houses being built in England at that time. In either case, housing was built close to the pits and plants without consideration of linking them to the existing villages and towns. The result of this period of capitalist laissez-faire planning is the Ruhr of today, a crude jumble of mines, waste-heaps, factories, and housing areas, criss-crossed by railways, channels, roads, and, more lately, motorways.

During the second half of the 19th century, coal mining in the Ruhr started to move north, as the easily accessible coal supplies in the south of the region became exhausted and new, deeper mines had to be opened up farther north. Many pits in the southern part of the region closed down, but the worker colonies stayed. With the decline of the coal mining industry after the Second World War, the rationale for the tight connection between worker housing and job location weakened even more. Today, only some 30 mines have survived in the Ruhr, and most of them are located in the northern part of the region relatively remote from the population centres of the south.

Another major disruption of the traditional linkage between housing and job location may soon be caused by the decline of the steel industry, the second major employer of the region. The problems of the steel industry of the Ruhr are related not only to the worldwide surplus of steel, but also to its locational disadvantage caused by the high cost of shipping imported iron ore into the region from North Sea ports. Even within the region, there are considerable differences in transport cost resulting in a ton of ore being some 4 DM cheaper in Duisburg on the Rhine river than in Dortmund in the eastern part of the region.

Thus it will be in the Dortmund region where the decline of the steel industry is felt most severely. Here the *Hoesch AG*, a subsidiary of the Dutch *Stel* corporation, operates three major steel works with a total employment of 20,500 workers. In 1958, there had been 38,700 Hoesch workers, and in 1979 there were still 24,000. Hoesch expects to reduce the number of its workers to 13,000 until 1987 and to close down two of its three production sites in Dortmund in order to build a new steel work at the third one. And even that drastic programme of survival will only be possible, the management claims, with a 1.6 billion DM subsidy by the government.

Losses of jobs of that order of magnitude are quite a blow for the local economy, as at the Ruhr they are not likely to be offset by comparable gains of jobs in the service sector. In a study conducted by the RWI, an economic research institute, it has been estimated that every job lost in the iron and steel industry at the Ruhr will result in about three jobs being lost in other industries, predominantly in machine manufacturing, construction, trading, and other services (RWI, 1978). Already now, Dortmund's unemployment rate of 8.2 percent (June 1981) is among the highest in the region and 3.4 percent above the national average.

2. THE SIMULATION MODEL

In this section, a brief account will be given of the simulation model which is used in the larger research project to model the spatial development of the urban region of Dortmund. This account is necessary, because the model provides the framework into which the model of unemployment to be discussed later is to be fitted. A more detailed description of the simulation model is contained in Wegener (1980).

The model referred to is a multilevel, spatially disaggregate, recursive simulation model of regional development. It is organized in three spatial levels:

- (1) a macroanalytic model of economic and demographic development of 34 labour market regions in the state of Nordrhein-Westfalen,
- (2) a microanalytic model of intraregional location and migration decisions in 30 zones of the urban region of Dortmund,
- (3) a microanalytic model of land use development in one or more urban districts of Dortmund.

The *first* level of the three-level model system serves to provide the model with information about developments occurring outside of the model region, such as overall economic development, interregional competition, and long-distance migration into or out of the region. On this level, employment by industry and population by age, sex, and nationality in each of the 34 labour market regions as well as the migration flows between them are predicted.

The results of the first model level establish the framework for the simulation of intraregional location and migration decisions on the *second* spatial level of the model hierarchy. On this level, the study area is the urban region of Dortmund consisting of Dortmund itself with its twelve urban districts and ten neighbouring communities within the labour market region of Dortmund and eight zones in four adjacent labour market regions. This 30-zone system is shown on the left-hand side of Figure 1. For these 30 zones, the model simulates intraregional location decisions of industry, residential developers, and households, the resulting migration and commuting patterns, the land use development, and the impacts of public policies in the fields of industrial development, housing, and infrastructure.

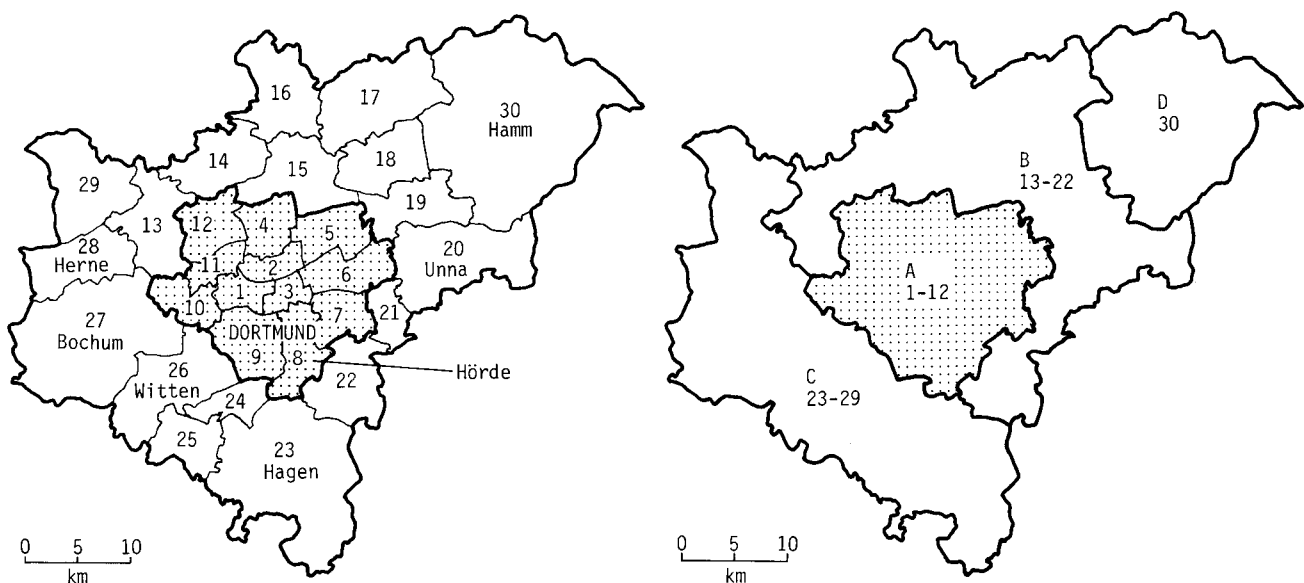


Figure 1. Zones and subregions of the Dortmund urban region.

On the *third* level of the model hierarchy, the construction activity allocated to zones on the second level is further allocated to any subset of the 171 statistical tracts within the urban region of Dortmund.

The simulation model proceeds from a base year in two-year increments (periods) over a time span of up to 20 years.

For the topic of this paper, the second, or urban region, level of the model is the most relevant. Therefore, the following summary of the model deals only with the second level. To consider only the second level implies that the results of the first level are taken as given or are exogenously assumed for each simulation period.

The second, or urban region, level of the model system consists of four major submodels:

a. *The Aging Submodel*

In the first, the aging submodel, all changes of the model stocks are computed which are assumed to result from biological, technological, or long-term socioeconomic trends originating outside of the model, i.e. which are not treated as decision-based in the model. These changes are effected by probabilistic aging or updating, or Semi-Markov, models with dynamic transition rates. Presently there are three such models for employment, population, and households/housing.

The employment projection model can be skipped here, as it will be discussed later in more detail.

The population projection model predicts zonal population by age, sex, nationality, exclusive of migration, on the basis of time-invariant life tables and naturalization rates and dynamic, age-specific, and spatially disaggregated fertility estimates.

Households are represented in the model as a four-dimensional distribution of households classified by nationality, age of head, income, and size. Similarly, housing of each zone is represented as a distribution of dwellings classified by type of building, tenure, quality, and size. In addition, these households and housing types are collapsed to 30 more aggregate types for use in the occupancy matrix. The occupancy matrix of a zone serves to associate households with housing of a zone, each matrix element representing the number of households of a certain type living in a dwelling of a certain type. Because of the association of households with housing in the occupancy matrix, households and housing are aged simultaneously in a common Semi-Markov model. Household changes included in the aging submodel are demographic changes of household status such as birth, aging, death, marriage, and divorce, and all new or dissolved households resulting from these changes, as well as change of nationality or income. On the housing side, deterioration and certain types of rehabilitation and demolition are included. However, all changes of housing occupancy connected with migration decisions are left to the final migration submodel.

b. *The Public Programmes Submodel*

The second, the public programmes submodel processes a large variety of public programmes in the fields of employment, housing, and health, welfare, education, recreation, and transport facilities. Public programmes are entered exogenously by the model user.

c. *The Private Construction Submodel*

In the third, the private construction submodel, investment and location decisions of the great number of private developers are modelled, i.e. of enterprises which erect new industrial or commercial buildings, and of residential developers who build flats and houses for sale or for rent or for their own use. Thus the submodel is a model of the regional land and construction market.

For each submarket, i.e. each industry sector or housing type, the following three steps are performed: First, the volume of construction demand of the particular building use in the current period is estimated. Second, the capacity, i.e. the

amount of zoned vacant land, of each zone for that building use is determined. Third, the estimated volume of construction is allocated to the vacant land of the zones as a function of their attractiveness, which includes land price.

The demand for new industrial or commercial buildings of a particular industry is estimated as the balance between the number of jobs presently accommodated in the region and the exogenously specified regional total for the end of the period, minus those jobs that can be accommodated in existing buildings vacated by other industries. This will be explained in more detail below. The demand for different housing types is estimated in response to the housing demand observed on the housing market of the previous period.

The capacity of each zone for a particular building type is determined by searching the zoning plan for vacant land suited for that building type. In addition, it is estimated where, in the case of high demand, additional building space could be procured by demolition or change of use of existing buildings.

d. *The Migration Submodel*

In the final, the migration submodel, intraregional migration decisions are simulated as search processes on the regional housing market. Thus the migration submodel is at the same time a housing market model.

The technique used for the simulation of the housing market is the Monte Carlo micro simulation. The approach is based on the notion that the total market process can be sufficiently approximated by simulating a representative sample of individual market transactions. To achieve this, the model consists of a sequence of random operations by which hypothetical market transactions are generated. The random selection process is controlled by probability distributions which insure that only likely transactions are selected.

The basic unit of the simulation is the market transaction. A market transaction is any successfully completed operation by which a migration occurs, i.e. a household moves into or out of a dwelling or both. At the end of each transaction, a migration decision is made by the household. It is assumed that the household accepts the transaction if it can significantly improve its housing situation. If not, it makes another try to find a dwelling, and with each attempt it accepts a lesser improvement. After a number of unsuccessful attempts it abandons the idea of a move. After successful completion of a market transaction, the next transaction is selected. The market process comes to an end when there are no more households considering a move.

The results of the housing market simulation serve to calculate migration flows by household type between different housing types or submarkets in the zones.

3. MODELLING UNEMPLOYMENT

There are in the regional science literature numerous studies which deal with regional unemployment in the framework of labour demand, labour supply, wage determination, or interregional migration of labour (e.g., Kelley & Williamson, 1980; Batey & Madden, 1981; Clark, 1981). However, no studies have been known which deal with the spatial distribution of unemployment within an urban region and its effects on income, housing, and mobility.

In this section, an approach will be presented to model changes of unemployment at places of residence as a consequence of redundancies at places of work and to estimate their likely effects on household incomes, the housing market, and intraregional mobility in the framework of the simulation model of regional development described in the preceding section.

The modelling task can be divided into five steps which will be described below:

i. *Changes of employment at places of work*

In the first step, changes of employment, i.e. redundancies and/or new jobs are determined for each industrial sector and each work zone. This step starts from where employment levels are calculated in the existing simulation model:

The simulation model distinguishes 40 industrial sectors and treats each sector separately. It sets out from existing employment $E_{si}(t)$ of sector s in zone i at time t and makes two independent forecasts of that level for time $t+1$:

$$E'_{si}(t+1) = \frac{E_s^*(t+1)}{E_s^*(t)} E_{si}(t) \quad (1)$$

$$E''_{si}(t+1) = \frac{b_{si}(t)}{b_{si}(t+1)} E_{si}(t) \leq E_{si}(t) \quad (2)$$

where $E_s^*(t+1)$ is an exogenous projection of total employment of sector s in the whole region for time $t+1$, and $b_{si}(t+1)$ is the projected floor space per workplace of sector s in zone i at time $t+1$, which will always be greater or equal to its previous value $b_{si}(t)$. The first forecast means to project the regionwide rate of change of employment of sector s on zonal employment in i , the second indicates the maximum number of workplaces that can be accommodated in the existing industrial buildings of sector s in i . The model selects the smaller one of the two as a preliminary forecast:

$$E_{si}^0(t+1) = \min(E'_{si}(t+1), E''_{si}(t+1)) \quad (3)$$

i.e. it checks if the projected number of workplaces can be accommodated in the existing building stock. For those which cannot, later in the simulation period new buildings will have to be provided. Where decline of employment is large, buildings remain vacant, but these may be reused by other industries later.

The above calculations are performed in the *aging* submodel of the simulation model. In the *public programmes* submodel, any exogenously specified redundancies $E_{si}^{rx}(t, t+1)$ or new jobs $E_{si}^{nx}(t, t+1)$ are processed, i.e. directly executed in each zone. All other changes of employment are effected in the *private construction* submodel.

First, the number of jobs for which new industrial buildings have to be provided is estimated:

$$E_s^{n*}(t, t+1) = E_s^*(t+1) - \sum_i E_{si}^0(t+1) + \sum_i E_{si}^{rx}(t, t+1) - \sum_i E_{si}^{nx}(t, t+1) \quad (4)$$

This total demand for new workplaces is reduced by workplaces $E_{si}^{nv}(t, t+1)$ which can be accommodated in buildings vacated by other industries, but how these are determined is skipped here for lack of space. The remaining demand for workplaces is allocated to vacant industrial or commercial land:

$$E_{si}^{nc}(t, t+1) = \frac{\sum_{\ell} K_{s\ell i} \exp(\alpha A_{s\ell i}(t))}{\sum_{i\ell} K_{s\ell i} \exp(\alpha A_{s\ell i}(t))} E_s^{n*}(t, t+1) \quad (5)$$

where $E_{si}^{nc}(t, t+1)$ are newly constructed workplaces of sector s in zone i between t and $t+1$, $K_{s\ell i}$ is the current capacity for workplaces of sector s on land use category ℓ in zone i , and $A_{s\ell i}(t)$ is the attractiveness of land use category ℓ in zone i for sector s as of time t (cf. section 2.c).

After all sectors have been processed in that way, total changes of employment of zone i during the period, i.e. redundancies $E_i^r(t, t+1)$ and new jobs $E_i^n(t, t+1)$ can be summed up:

$$E_i^r(t, t+1) = \sum_s (E_{si}(t) - E_{si}^0(t+1) + E_{si}^{rx}(t, t+1)) \quad (6)$$

$$E_i^n(t, t+1) = \sum_s (E_{si}^{nx}(t, t+1) + E_{si}^{nv}(t, t+1) + E_{si}^{nc}(t, t+1)) \quad (7)$$

Note that in the present version of the model no distinction is made between workers of different skill, sex, or nationality, although that would certainly be desirable.

ii. Changes of employment at places of residence

In the second step, it is asked where the workers being made redundant or accepting a new job live. It is assumed that all workers employed in a zone have the same chance of being made redundant, and that therefore the current work trip pattern is a good approximation to estimate the share of workers coming from each residence zone. Similarly, it is assumed that new workers will come from the same residence zones as those already employed. The current work trip matrix $T(t)$ is provided for each t by the simulation model. Then

$$P_i^r(t, t+1) = \sum_j \frac{T_{ij}(t)}{\sum_j T_{ij}(t)} E_j^r(t, t+1) \quad (8)$$

$$P_i^n(t, t+1) = \sum_j \frac{T_{ij}(t)}{\sum_j T_{ij}(t)} E_j^n(t, t+1) \quad (9)$$

are workers living in zone i made redundant or accepting new jobs in zone j , respectively, during the period.

iii. Employment and unemployment at places of residence

In this step, for each zone the number of employed and unemployed persons is to be estimated. For this purpose, the following definitions are used:

$P_i^p(t)$ is the *potentially economically active population* in zone i at time t , i.e. population between age years k' and k'' indicating average entrance and exit of active working life, respectively.

$P_i^a(t)$ is the *economically active population* in zone i at time t consisting of *employed population* $P_i^e(t)$ and *unemployed population* $P_i^u(t)$. Thus, $P_i^u(t)$ is a residual of $P_i^a(t)$ and $P_i^e(t)$.

Furthermore, two fractions are defined: a labour force participation rate $r_i(t)$ and an unemployment rate $q_i(t)$:

$$r_i(t) = P_i^a(t) / P_i^p(t) \quad (10)$$

$$q_i(t) = P_i^u(t) / P_i^a(t) \quad (11)$$

Given the results of the preceding step, forecasting the employed population is straightforward:

$$P_i^e(t+1) = P_i^e(t) - P_i^r(t, t+1) + P_i^n(t, t+1) \quad (12)$$

Forecasting unemployed population requires at first a forecast of the economically active population. There are four components of change affecting the volume of $P_i^a(t+1)$: young persons entering their working life at age k' , old persons retiring from working life at age k'' , and persons entering or leaving working life between k' and k'' for personal reasons. The latter two components heavily depend on the age composition and on socioeconomic attributes of the population as well as on the current situation on the labour market. In the present model, $r_i(t)$ and $q_i(t)$ are taken as proxies for these two sets of determining factors. Thus the forecasting equation for $P_i^a(t+1)$ can be written:

$$P_i^a(t+1) = P_i^a(t) + P_i^+(t, t+1) - P_i^-(t, t+1) \quad (13)$$

where

$$P_i^+(t, t+1) = r_i(t) P_{k'i}(t) + f'(r_i(t), q_i(t)) P_i^a(t) \quad (14)$$

$$P_i^-(t, t+1) = r_i(t) P_{k''i}(t) + f''(r_i(t), q_i(t)) P_i^a(t) \quad (15)$$

Then unemployed population is by definition

$$P_i^u(t+1) = P_i^a(t+1) - P_i^e(t+1) \quad (16)$$

iv. Changes of household income

The fourth step establishes the link between unemployment and its effects on mobility and the housing market by way of household income. In the simulation model, there are four household income groups: low, medium, high, very high. It is assumed that unemployment means that the household drops from one income group to the next lower one. Conversely, new employment means that the household is promoted by one income group.

To achieve this in the model, first for each zone the number of economically active persons $a_{pi}^h(t)$ per household of size p is estimated such that

$$\sum_{np} a_{pi}^h(t) H_{npi}(t) = P_i^a(t) \quad (17)$$

where $H_{npi}(t)$ are households of income group n and size p in zone i at time t . Next, the number of unemployed persons $u_{npi}^h(t)$ per household is estimated for all n and p such that

$$u_{1pi}^h(t) \leq a_{pi}^h(t) \text{ for all } p \quad (18)$$

which means that unemployed persons are assumed to most likely live in households of income group 1, and

$$\sum_{np} u_{npi}^h(t) H_{npi}(t) = P_i^u(t) \quad (19)$$

Then the number of employed persons per household is

$$e_{npi}^h(t) = a_{pi}^h(t) - u_{npi}^h(t) \text{ for all } n \text{ and } p \quad (20)$$

To ensure that no more households are affected by income changes than persons, all $e_{npi}^h(t)$ and $u_{npi}^h(t)$ less than one are set to one.

The probability that the income of a household changes up or down as a consequence of unemployment or new employment is

$$h_{nn'i}(t, t+1) = \frac{P_i^r(t, t+1)}{\sum_{np} e_{npi}^h(t) H_{npi}(t)} \text{ for } n = 2, 3, 4; n' = n-1 \quad (21)$$

$$h_{nn''i}(t, t+1) = \frac{P_i^n(t, t+1)}{\sum_{np} u_{npi}^h(t) H_{npi}(t)} \text{ for } n = 1, 2, 3; n'' = n+1 \quad (22)$$

where $h_{nn'}(t, t+1)$ is the probability that a household changes from income group n to income group n' during the period. The matrix $\underline{h}_i(t, t+1)$ of each zone can be interpreted as a 4×4 transition matrix if its unused elements are set to zero and the main diagonal is filled to complement each line to unity. Postmultiplying the household matrix $\underline{H}_{pi}(t+1)$ with $\underline{h}_i(t, t+1)$ yields a new matrix $\underline{H}'_{pi}(t+1)$ with all incomes changed:

$$\underline{H}'_{pi}(t+1) = \underline{H}_{pi}(t+1) \underline{h}_i(t, t+1) \quad (23)$$

Concurrently with the household matrix, also the occupancy matrix linking households to housing (cf. section 2.a) has to be changed. If the income of a large number of households decreases due to unemployment, this will have the following effects: Many households will feel unhappy with their present dwelling, because it has become too expensive for them. Other households may have had plans to improve their housing situation by renting a larger dwelling, buying a house, or moving to a more attractive neighbourhood, but will have to postpone or abandon their plans now. As the occupancy matrix is the major input into the *migration* or housing market submodel (cf. section 2.d), these effects should become apparent there as changes of the choice behaviour of households and of the resulting mobility pattern.

v. Migration of employed and unemployed population

While migration of households is performed in the migration submodel, additional provisions are necessary to alter zonal employed and unemployed population when households move. The following equations do this:

$$P_i^{e'}(t+1) = P_i^e(t+1) + \sum_{np} e_{np}^h(t) H_{npi}^s(t, t+1) \text{ for } n = 2, 3, 4 \quad (24)$$

$$P_i^{u'}(t+1) = P_i^u(t+1) + \sum_{np} u_{np}^h(t) H_{npi}^s(t, t+1) \text{ for } n = 1, 2, 3 \quad (25)$$

where $H_{npi}^s(t, t+1)$ are net migrations of households to or from zone i , and $e_{np}^h(t)$ and $u_{np}^h(t)$ have the same meaning as above for the whole region.

4. MODEL CALIBRATION

Calibrating a large simulation model like the one outlined in section 2 of this paper is a long and arduous and never quite completed task. Moreover, most statistical techniques for estimating model parameters are not applicable here because of the number of relationships taken into account. Hence, many model functions have to be determined by judgment, inferences, analogies, and careful checking of plausibility.

Of course, this does not release such models from the need to establish their credibility by demonstrating that they are able of satisfactorily reproducing reality. In this section, it will be demonstrated that the simulation model discussed in this paper is capable of reproducing the general pattern of spatial development in the urban region of Dortmund.

For this demonstration, the 30 zones shown on the left-hand side of Figure 1 are aggregated to the four subregions shown on the right-hand side of that figure:

- A This subregion contains the city of Dortmund (pop. 610,000) with its twelve urban districts (zones 1-12). It may be called the urban core.
- B This subregion contains ten communities neighbouring Dortmund from northwest to southeast (zones 13-22). Of these zones some are still rural in character, some are already suburban and clearly oriented towards Dortmund.
- C This subregion includes two major industrial centres, Bochum (pop. 400,000) and Hagen (pop. 220,000), plus a number of smaller communities neighbouring Dortmund in the southwest (zones 23-29). This subregion reflects the fact that Dortmund is part of the polycentric Ruhr region.
- D This subregion consists of Hamm (pop. 170,000), a fast growing employment centre at the eastern fringe of the Ruhr region (zone 30).

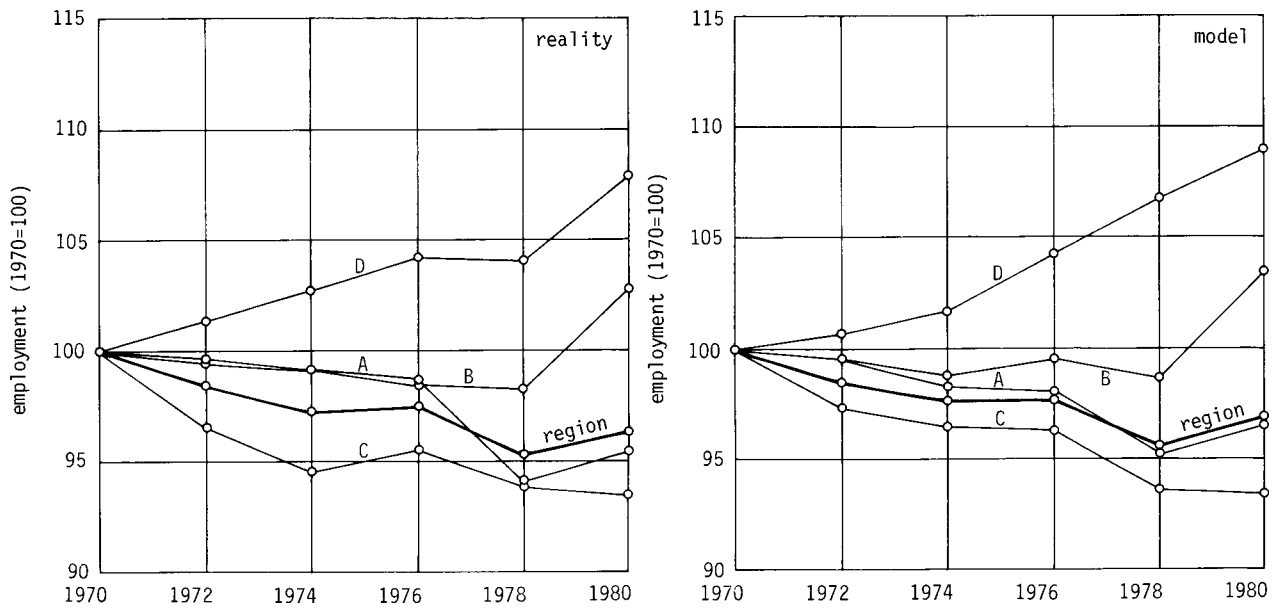


Figure 2. Reality vs. model: employment 1970-1980.

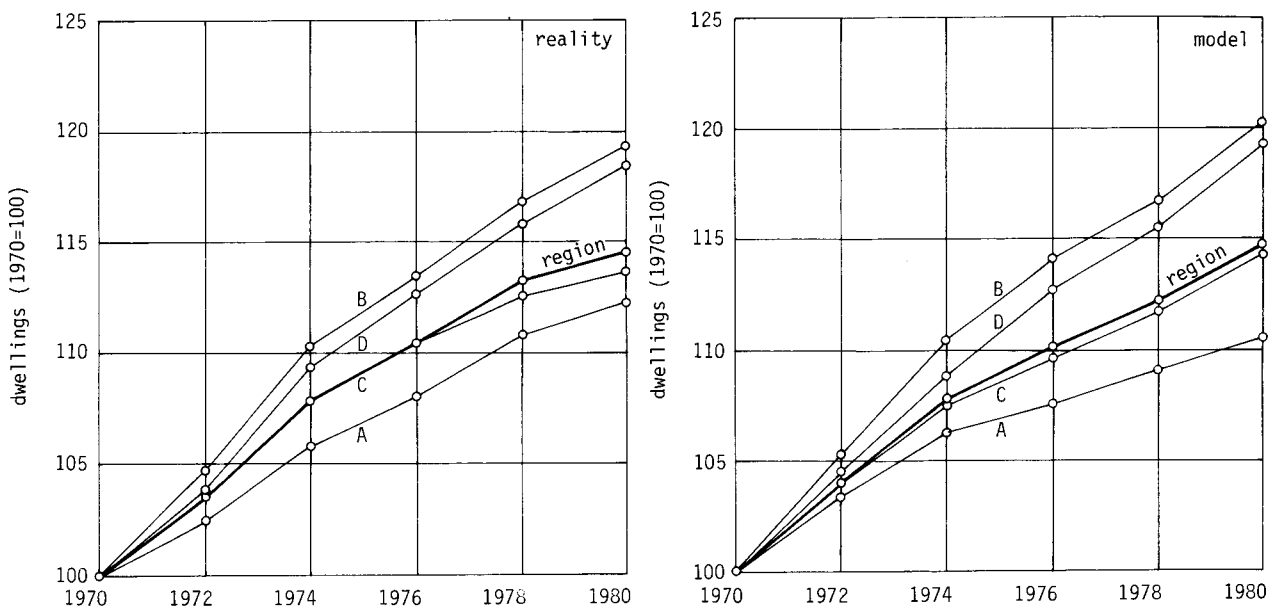


Figure 3. Reality vs. model: housing (dwellings) 1970-1980.

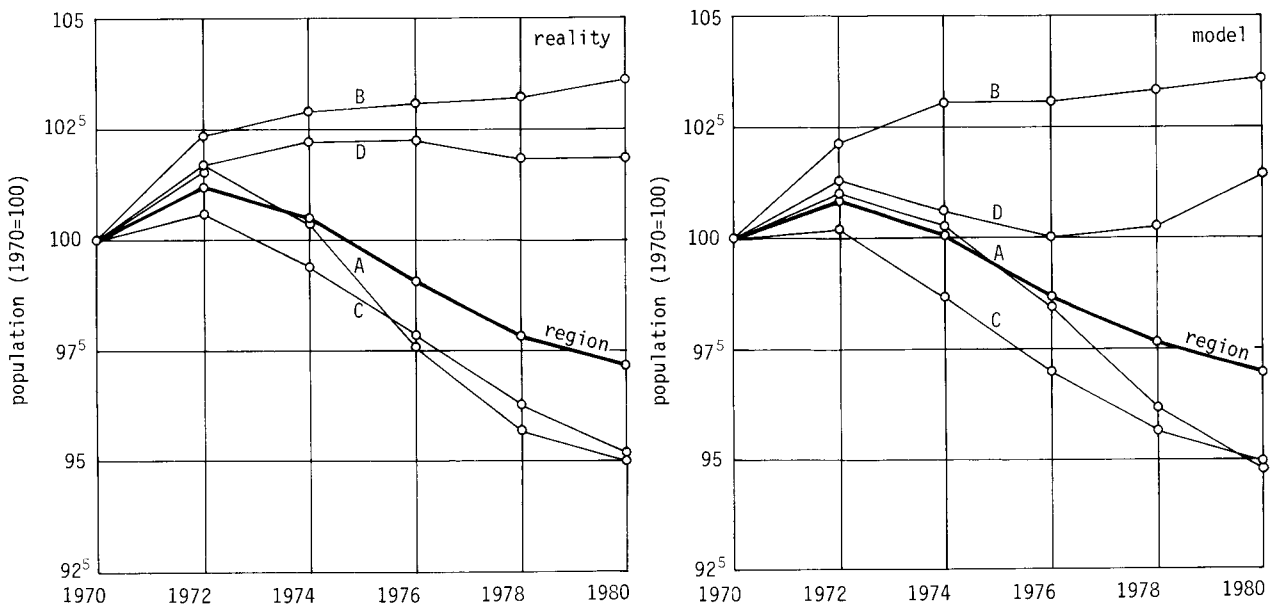


Figure 4. Reality vs. model: population 1970-1980.

In Figures 2, 3, and 4 selected results of ex-post simulations covering the time period 1970-1980 are confronted with the actual development in that period. The diagrams show *employment*, *housing* (dwellings), and *population* in the four subregions as well as in the whole region in percent of 1970 figures. Actual development is always shown on the left-hand side, while the model results are shown on the right-hand side.

Clearly, the general pattern of spatial development has been one of continued suburbanization, with peripheral subregions B and D growing at the expense of core subregions A and C, and this general pattern has been well reproduced by the simulation model, although there are some local deviations, most notably the slump of population in subregion D during the mid-decade.

Far less satisfactory is the performance of the model with respect to forecasting unemployment. Figure 5 shows unemployment rates as reported by the Federal Labour Agency corrected for seasonal fluctuations confronted with unemployment rates predicted by the model.

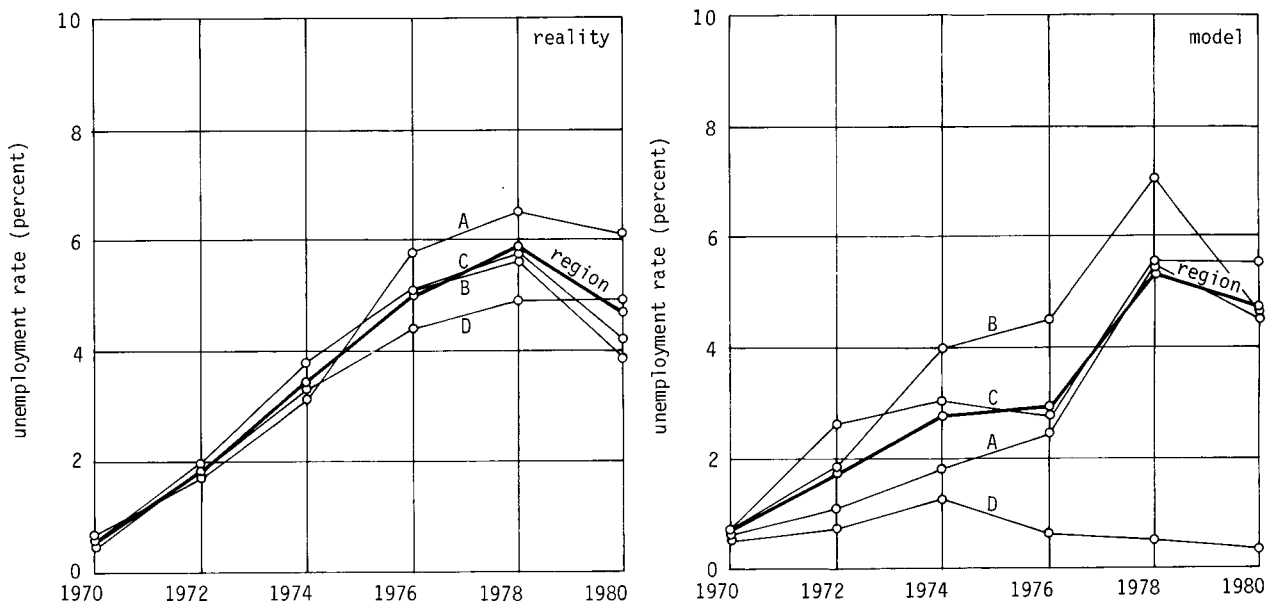


Figure 5. Reality vs. model: unemployment rates 1970-1980.

The model predictions deviate from the reported numbers in various respects: First, the model predicts higher unemployment in peripheral subregion B than in core subregion A, although after 1974 that order should be reversed. Second, the model exhibits a drop in unemployment in most subregions in 1976 which did not occur in reality. Third, the model totally missed the steady increase of unemployment rates reported for subregion D.

These deviations may be attributed to either of two causes. First, the prediction of the economically active population, in particular the assumptions about the response to changes in labour demand underlying equations (14) and (15), may be erroneous. Second, and this error may be more serious, the present model assumes that a worker made redundant may take on every other job offered on the labour market. This is, of course, not true. The latter error may explain why in 1976 most unemployment rates go down in the model, while in reality they did not. In particular, it may explain the gross underestimation of unemployment in subregion D where during the decade the industrial mix has changed considerably.

Obviously, only a disaggregation of workers by skill, sex, and nationality, as already indicated, would offer the possibility to remove both causes of error. This will be a topic of further research.

Despite the failure of the present model to correctly predict unemployment rates, the following simulation results may still be worth being presented. First, the bias inherent in the unemployment model tends to produce lower unemployment rates, i.e. conservative predictions. Second, as can be seen from equations (21) and (22), the changes of household income that are of interest here are not produced using the unemployment rates, but using the number of redundancies and new jobs directly, which may be much less susceptible of error.

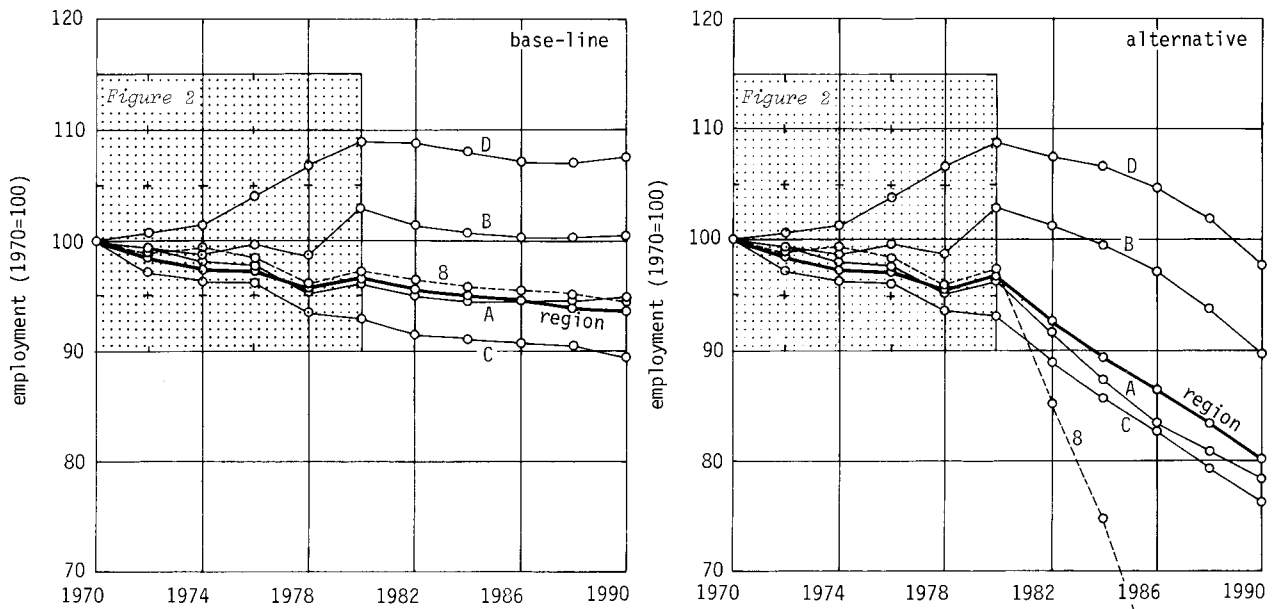


Figure 6. Simulation results: employment 1970-1990.

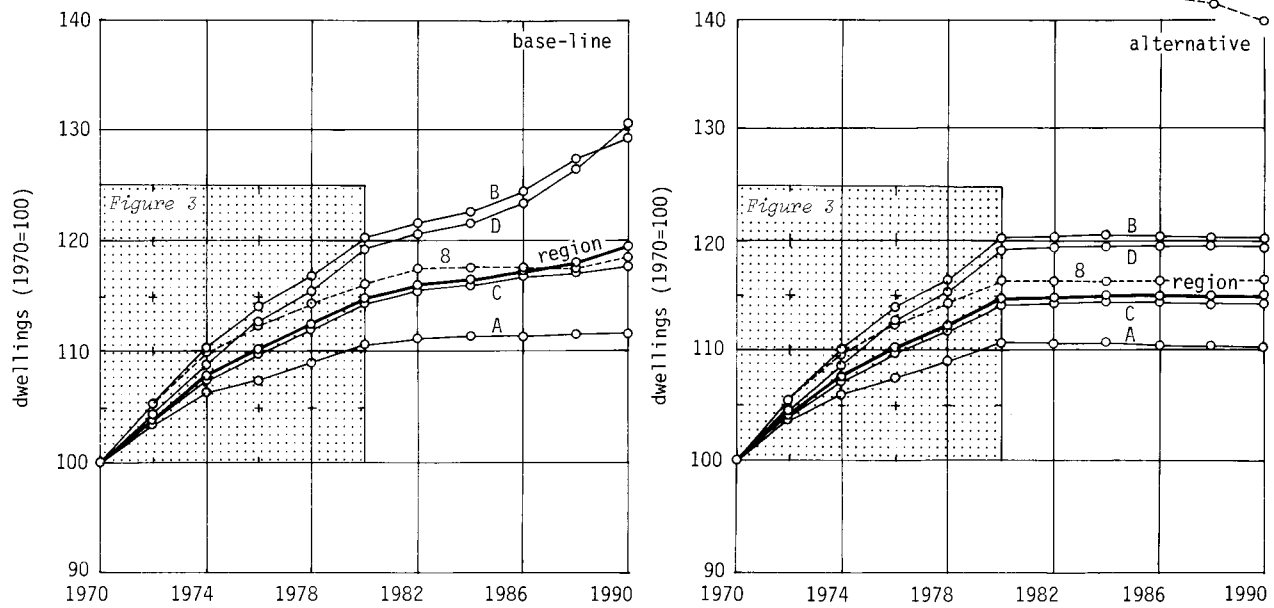


Figure 7. Simulation results: housing (dwellings) 1970-1990.

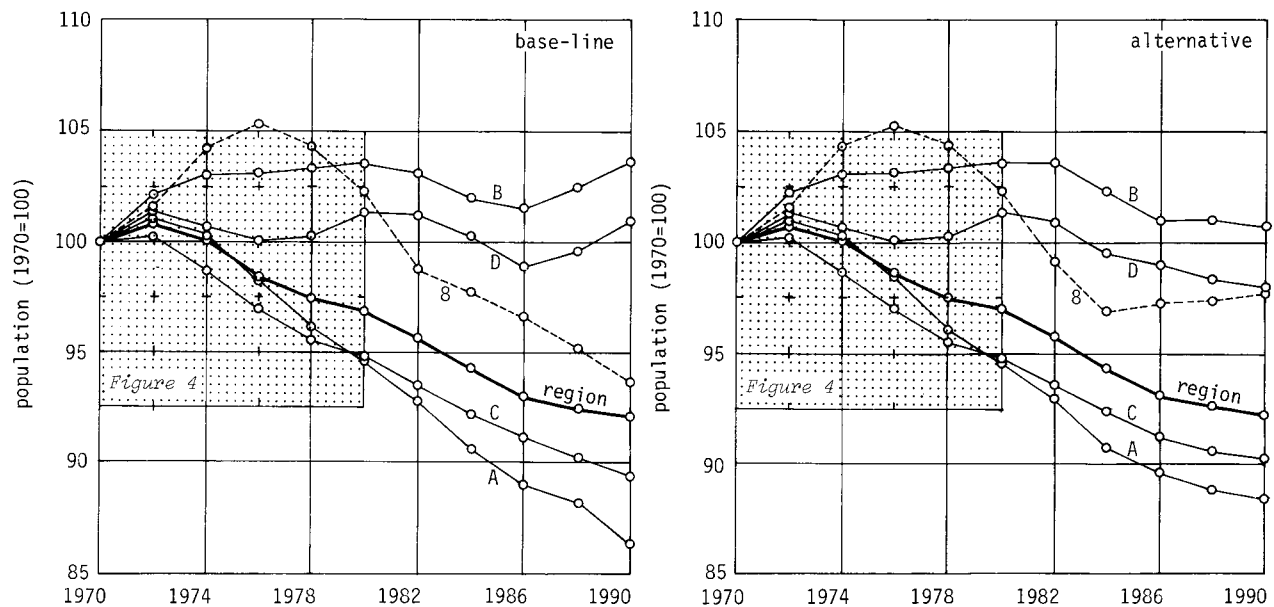


Figure 8. Simulation results: population 1970-1990.

5. SIMULATION RESULTS

In this final section, selected results of two simulation runs displaying extreme differences in employment levels will be presented.

Both runs start in the year 1970 and proceed until the year 1990. Both are identical in all model parameters. For both runs, regional control totals for the period 1970-1980 were taken from actual figures. The only difference between the two runs are the assumptions made for the development of employment in the iron and steel industry and related industries for the decade from 1980 to 1990.

The first run is the *base-line* simulation. It is based on the results of a base-line run of the Nordrhein-Westfalen level of the simulation model (cf. section 2) which in turn was based on a synopsis of recent employment forecasts for Nordrhein-Westfalen (cf. Rojahn, 1981).

The second run will be called the *alternative* simulation. It is based on the following assumptions: (a) Hoesch goes ahead with its plans to reduce employment in its Dortmund steel works to 13,000 by 1987. (b) Other firms of the iron and steel industry follow resulting in a total loss of 30,000 jobs in that industry by 1990 compared with the base-line simulation. (c) These redundancies cause further losses of approximately 90,000 jobs in other industries during the decade compared with the base-line simulation. The details of assumption (c) were specified following the study by the RWI mentioned earlier (RWI, 1978).

Figures 6, 7, and 8 show selected results of both runs: *employment, housing, and population*. In each figure, the base-line simulation is shown on the left-hand side, the alternative simulation on the right-hand side. As before, the results are shown for the four subregions as well as for the region as a whole. In addition, one particular zone, Hörde (zone 8), is included in the diagrams. Hörde is one of the two urban districts of Dortmund where Hoesch closes down a steel work in the alternative simulation. Accordingly, differences between the two simulation runs are likely to be most pronounced in Hörde.

As Figure 6 indicates, only slight losses of employment are expected in the region under "normal" conditions. In contrast, in the alternative simulation total employment goes down by some 130,000 or 14.2 percent of all jobs compared with the base-line simulation. Core subregions A and C are affected most, because the steel industry has always been centrally located. In Hörde, 7,300 or nearly 40 percent of all jobs are lost.

Consequently, unemployment in Hörde is excessive. Almost 25 percent of all workers living in Hörde are unemployed at the end of the decade. But unemployment spreads to all parts of the region and is now higher in the cores than in the peripheral subregions. This can be seen in Figure 9, however, when looking at Figure 9, the caveats about the unemployment rates predicted by the model indicated in the preceding section should be kept in mind.

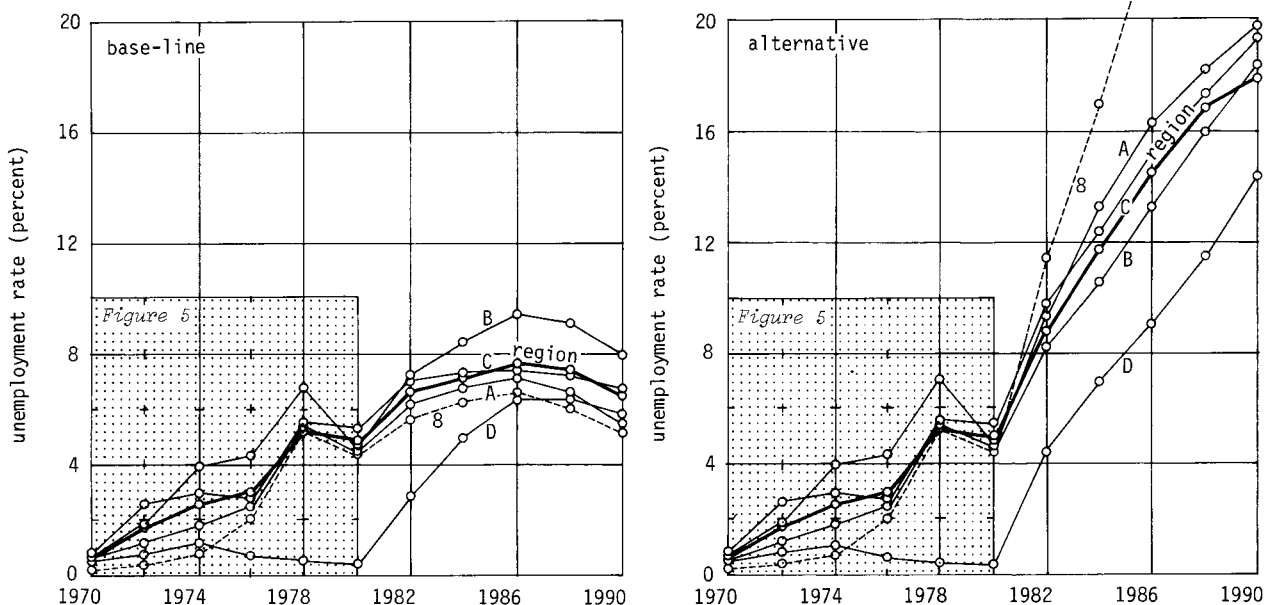


Figure 9. Simulation results: unemployment rates 1970-1990.

Large-scale unemployment affects average household income. While in the base-line simulation average household income continues to increase nominally and in real terms until 1990, real income stagnates in the alternative simulation, because pay increases of the employed are offset by losses of income by the unemployed plus inflation.

Stagnation of real income restricts additional outlays for housing. A measure to illustrate this is average housing floor space per head of the population. This figure rose from 24.5 sqm to 30.3 sqm during the decade 1970-1980 and continues to rise to 33.3 sqm in 1990 in the base-line simulation in conjunction with the rise in real income. With real income stagnating, per capita floor space stays at 31.5 sqm in the alternative simulation. Figure 7 shows that this suffices under conditions of population decline (see below, Figure 8) to practically end housing construction after 1980, except for a small number of dwellings built to replace demolished ones.

Where no houses are being built, no new land needs to be developed for housing. And as, in the base-line simulation, most new housing is built in the suburbs, this means that in the alternative simulation suburbanization comes to a stop. This is illustrated by Figure 8 where all subregions, peripheral or central, now more or less closely follow the regional average of population decline. Note that deliberately the development of total population has been kept the same in both simulations, i.e. that the effects of unemployment on interregional migration of labour have been excluded, for better comparability.

CONCLUSIONS

The lesson to be drawn from these simulation experiments may seem trivial to some. That economic development is one of the major driving forces of spatial urban development is, after all, a commonplace. The motivation for these experiments was not to repeat that commonplace, but to reconstruct and experimentally invoke the mechanisms by which economic development shapes urban form in spatial detail. In this paper, the focus has been on indirect effects of economic development on urban form via household location decisions under conditions of economic decline. It has been demonstrated that these indirect effects may be at least as important for the spatial development of urban regions as direct location decisions by firms. The discussion revealed certain deficiencies of the model that should be the object of further research. Also, additional detail included in the model, which could not be discussed here, should be examined more closely.

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