ASPECTS OF URBAN DECLINE: EXPERIMENTS WITH A MULTILEVEL ECONOMIC-DEMOGRAPHIC MODEL FOR THE DORTMUND REGION+

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ABSTRACT

This paper is a sequel to an earlier paper in which a multilevel dynamic simulation model of economic and demographic development in the urban region of Dortmund was presented (Wegener, 1980). The model simulates 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.

The present paper discusses the capability of this model to capture not only urban growth processes, but also processes of urban decline. For this purpose, first the mechanisms which control spatial growth, decline, or redistribution of activities in the model are outlined. Second, it is demonstrated how the model reproduces the general pattern of spatial development in the region. Third, examples of recent model results are used to illustrate the range of analytical questions that can be investigated with the model.

INTRODUCTION

Like other highly industrialized countries, the Federal Republic of Germany has experienced a fundamental change of direction in the development of its settlement structure. While the fifties and sixties were characterized by massive growth and expansion of urbanized areas at the expense of rural regions, in the seventies this large-scale agglomeration process was outbalanced by a small-scale deglomeration process caused by increasing outmigration of population and industry from the centers of the agglomerations to their less urbanized peripheries, resulting in a decline of population in all larger agglomerations and a decline of employment in some of them.

On the scale of one urban region, four phases of urban development encompassing this shift of direction can be distinguished (van den Berg, Klaassen, 1978). Consider an urban region divided into two components: the urban core and the suburban periphery (see Fig. 1). In phase 1, the urbanization phase, both grow, but mostly does the core. In phase 2, the growth curve of the urban core flattens, as more growth is attracted to the less urbanized periphery: this is the suburbanization phase. In phase 3, the urban core declines, while growth continues in the suburbs at a diminishing rate; at some point in time the total region starts to decline. This phase may therefore be called the desurbanization phase. Phase 4 is the uncertain future.

The basic causes underlying phases 1 through 3 seem to be well known. At times of high overall population growth, job opportunities in cities used to be the major force behind the urbanization process. Rising incomes and modern transport technol-

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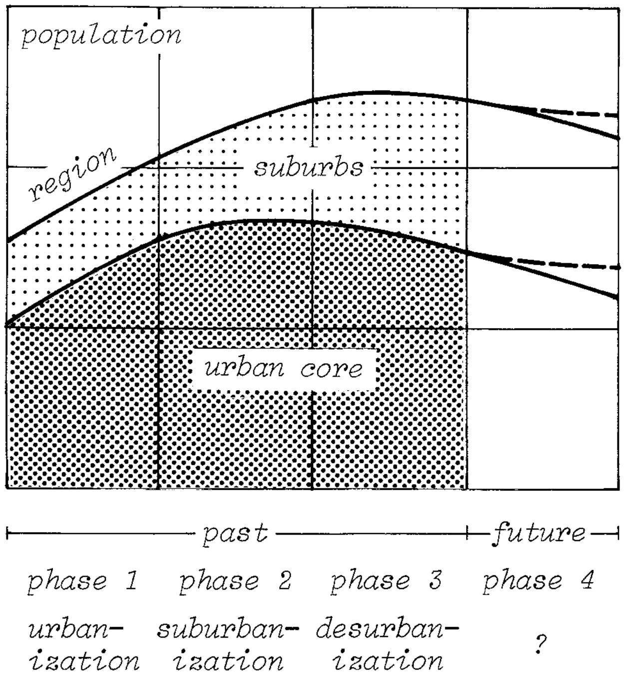

Fig. 1. Urbanization, suburbanization, and desurbanization (van den Berg, Klaassen, 1978).

ogies (the automobile) made suburbanization possible. Desurbanization seems to be much of the same under conditions of overall population decline. However, there seems to be no agreement on the prospects of phase 4: Will desurbanization persist, or will it level off, or will there be forces, such as rising costs of travel, which will stimulate a new contraction of urban form?

Unfortunately, Regional Science and related disciplines have had not much to offer to reduce the uncertainty about the future prospect of urban change. Perhaps most successful were studies that combined the results of intuitive reasoning in a scenario-like approach (e.g. Arras, 1980). Quantitative models of urban development, in particular land use allocation models, have in the past been growth-oriented and simply failed to address the issue of spatial decline altogether. Other models of spatial behavior, such as migration models, are well suited to capture important aspects of urban decline. However, the most advanced of these models tend to be largely based on the probabilistic interpretation of observed frequencies of past behavior. These models are superior to any other model for short-term forecasts, but they will necessarily fail where the decision environment of spatial behavior grossly changes. There are only very few models which attempt to reproduce the actual preferences and constraints determining urban location and relocation decisions. One recent example is the model of transport/land use interaction of Zahavi et al. (1981), but this model is still much too spatially aggregate to be of much interest to the physical urban planner.

At the core of the difficulties in modeling spatial behavior lies the fact that there is still no agreed upon unified theory of spatial decision behavior of enterprises, households, or individuals. Such a theory would need to be so general as to explain spatial processes of growth and decline, agglomeration and deglomeration, contraction and dispersal in agreement with empirically founded economic and social theories.

The model discussed in this paper is an attempt to contribute to such a theory. It was designed to simulate location decisions of industry, residential developers, and households, the resulting migration and commuting patterns, the land use development, and the impacts of public programs and policies in the fields of industrial development, housing, and infrastructure.

The model is currently operational for the urban region of Dortmund, including Dortmund (pop. 630.000) and 19 neighboring communities with a total population of 2.4 million. For use in the model, the urban region is divided into 30 zones

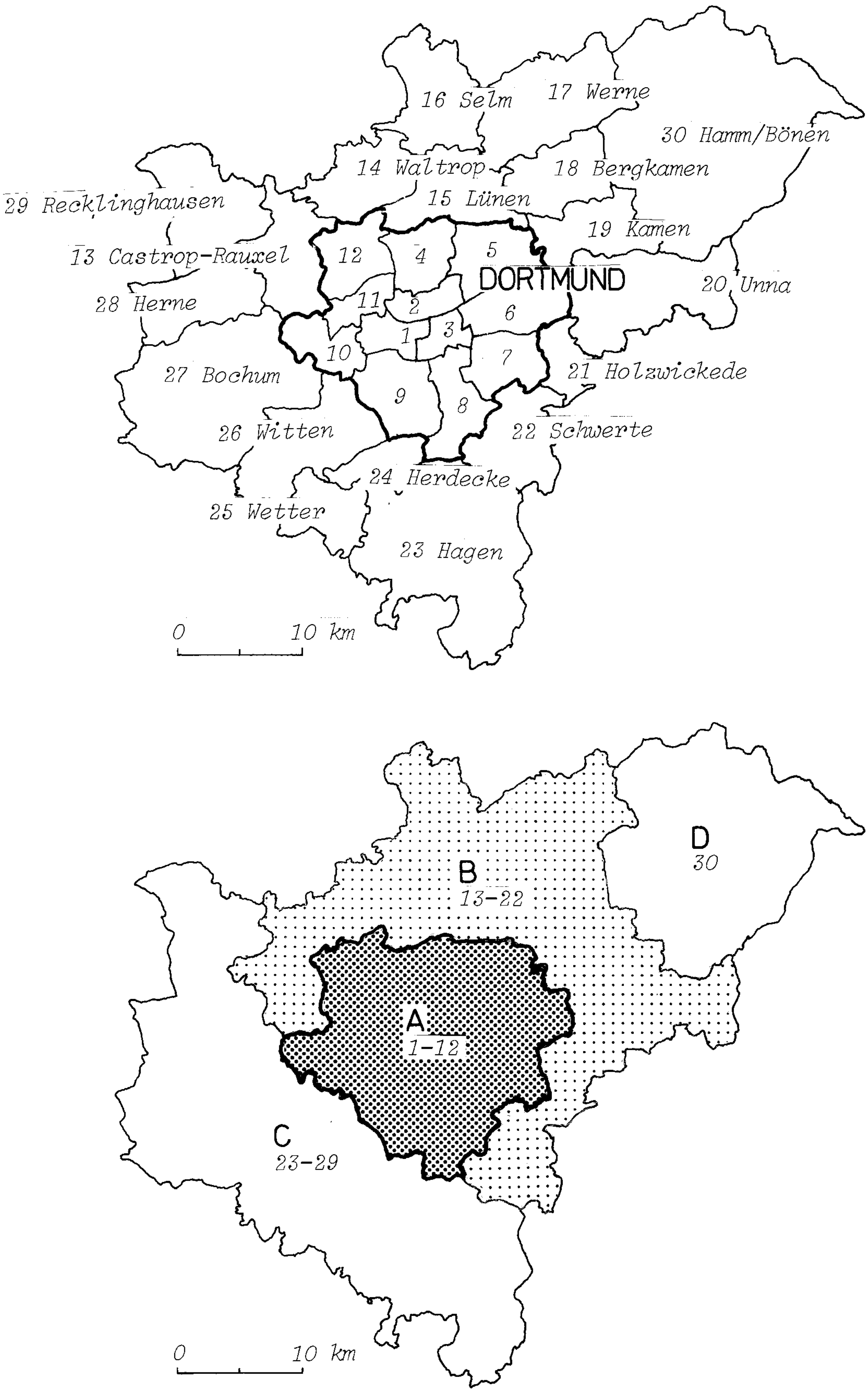

Fig. 2. The 30 zones of the Dortmund urban region model (top) and the four subregions used in this paper (bottom).

(see Fig. 2). For discussion in this paper, these 30 zones have been grouped into four subregions: (A) Dortmund core area, (B) suburban periphery, (C) Bocum area, and (D) Hamm (see Fig. 2). It can be shown that the three-phase scheme of urbanization, suburbanization, and desurbanization of Fig. 1 has been well replicated in the Dortmund region (see Fig. 3):

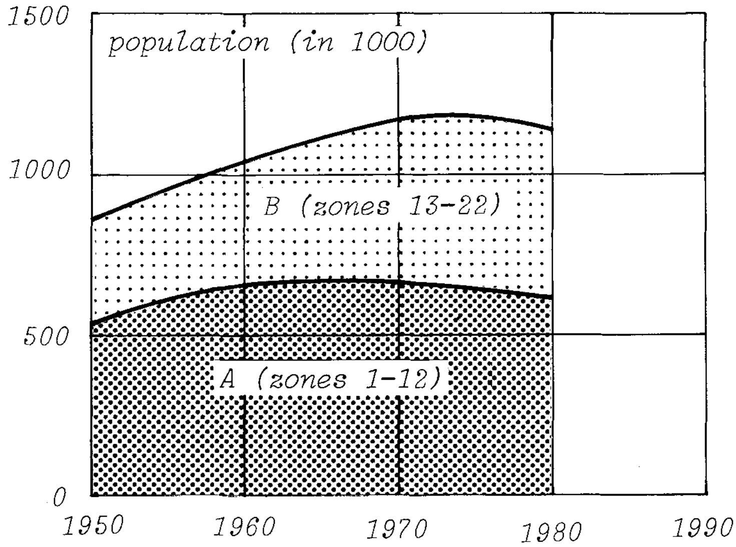

Fig. 3. Urbanization, suburbanization, and desurbanization in the Dortmund region, 1950-1980.

The following paper consists of three sections: In the first section the mechanisms which control growth, decline, or redistribution of activities in the model are outlined. In the second section it is demonstrated how the model reproduces the general pattern of spatial development in the region. In the third section examples of recent model results are used to illustrate the range of analytical questions that can be investigated with the model.

1. MODELING URBAN DECLINE

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

(1) a macroanalytic model of the economic and demographic development of 34 labor 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.

As a description of the model is contained in Wegener (1980), in the present paper only a brief summary of the overall model structure will be given. In addition, it will be pointed out which parts of the model and which causal links are particularly important for modeling urban decline processes.

The first, or top, 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, intraregional competition, and long-distance migration into and out of the region. On this level, employment by industry and population by age, sex, and nationality in each of the 34 labor market regions as well as the migration flows between them are predicted (cf. Schönebeck, 1981).

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 with its 30 zones as depicted in Fig. 2. 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 devlelopment, and the impacts of public policies in the fields of industrial development, housing and infrastructure.

On the third level of the model hierarchy, the construction activity allocated to zones on the second model level is further allocated to any subset of 171 statistical tracts within the urban districts of Dortmund (cf. Tillmann, 1981).

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

For the present discussion on patterns of urban growth or decline, 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 in terms of regional totals of employment by industry and of population, inmigration and outmigration by age, sex, and nationality 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 (Markov) models with dynamic transition rates. Presently there are three such models for employment, population, and household/housing.

For updating zonal employment, at this point simply the regionwide rates of change for each industrial sector are projected on zonal employment. However, it is checked if the resulting employment levels can be accommodated within the existing industrial or commercial buildings, for those who 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 in the period.

The population projection model predicts zonal population by age, sex, and nationality, without migrations, on the basis of time-invariant life tables and naturalization rates, and dynamic, age-specific, and spatially disaggregate fertility estimates.

Households are represented in the model as a four-dimensional distribution of households classified by

- nationality (native, foreign),
- age of head (16-29, 30-59, 60+ years),
- income (low, medium, high, very high),
- size (1, 2, 3, 4, 5+ persons).

Similarly, housing of each zone is represented as a distribution of dwellings classified by

- type of building (single-family, multi-family),
- tenure (owner-occupied, rented, public),
- quality (very low, low, medium, high),
- size (1, 2, 3, 4, 5+ rooms).

In addition, these household and housing types are collapsed to 30 more aggregate types for use in the occupancy matrix. The occpupancy matrix of a zone serves to associate households with housing of the zone. Each element of the matrix represents the number of households of a certain type living in a dwelling of a certain type. Besides the occupancy matrix, there are households without dwelling and vacant dwellings (cf. Gnad, Vannahme, 1981).

Because of the association of households with housing in the occupancy matrix, households and dwellings are aged simultaneously in one common Markov model. Household changes included in the aging submodel are demographic changes of household status in the life cycle of the household 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 subsequent migration submodel.

For modeling urban decline, the aging model is of great importance. It establishes the link by which major economic and social developments, such as recessions of the economy or long-term changes of fertility or household formation patterns are entered into the simulation process. In addition, the aging model is the place where the building stock is constantly deteriorated which, if no corrective action is taken, eventually leads to urban decay.

b. *The Migration Submodel*

In the second, 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 principal actors of the migration or housing market model are the households representing housing demand and the landlords representing housing supply. The model is based on a set of hypotheses about the behavior of these model actors, the principal one of them being that households looking for a dwelling try to improve their housing satisfaction as satisficers by searching the housing market within given budgetary and informational constraints. The satisfaction of a household with its housing situation is assumed to be a utility function with the dimensions housing size and quality, neighborhood quality, location, and housing cost.

The model used for the simulation of the housing market process is the Monte Carlo Simulation technique. 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 selection 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. After the simulation, all migration-induced changes of the age and household distributions of the zones are performed.

For the modeling of urban decline, the migration flows are relevant. They may result in negative rates of change for households and population in some zones, either in total or for specific income, age, or nationality groups. Even where net migrations are zero or positive, considerable redistribution effects between such groups can be effected by migration. In addition, vacant dwellings, either in specific submarkets (dwelling types) or in specific zones, can be the consequence of migration.

c. *The Public Programs Submodel*

The public programs submodel processes a large variety of public programs in the fields of employment, housing, and health, welfare, education, recreation, and transport facilities.

At first sight, the public programs submodel seems less relevant for modeling urban decline. Most of the programs imply some sort of construction and are in so far growth-oriented. However, also demolition of housing and closing down of public facilities are possible programs. Moreover, it is possible to specify that a complete plant of a certain industry be closed down at a specific point in time in cases where the model cannot be expected to generate such a singular event endogenously. This feature of the model may, for instance, be used to investigate the impacts of large-scale regional unemployment on the housing market as a consequence of the closing down of a major employer of the region.

d. *The Private Construction Submodel*

In the private construction submodel, investment and location decisions of the great number of private developers are modeled, i.e. of enterprises which erect new industrial or commercial buildings, and of residential developers who build apartments 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. 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. 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. The demand for different housing types is estimated in response to the housing demand observed on the housing market of the same 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.

Although the private construction submodel is concerned with new construction, it is still relevant for modeling urban decline because of its redistribution effects. After all, it is in this submodel where the basic locational decisions leading to suburbanization and eventually to desurbanization are made. In addition, it is here where higher-bidding land-uses such as offices may succeed in displacing residential land use in core areas and thus help to accelerate the process of spatial dispersal.

2. MODEL VS. REALITY

In this section of the paper, it will be demonstrated that the simulation model is capable, at least in principle, to reproduce the general pattern of spatial development in the region.

For this demonstration, the four subregions defined in Fig. 2 are used as units of reference:

- A This subregion contains the city of Dortmund (pop. 630.000) with its 12 urban districts (zones 1-12). It may be called the urban core.
- B This subregion contains 10 communities neighboring Dortmund from northwest to southeast. Of these zones some are still rural in character, some are more suburban and are clearly oriented towards Dortmund.
- C This subregion includes two major industrial centers, Bochum (pop. 420.000) and Hagen (pop. 230.000), plus a number of smaller communities neighboring Dortmund in the southwest (zones 23-29). This subregion reflects the fact that Dortmund is part of the Ruhr region, a multicenter 17-million population agglomeration.
- D This subregion consists of Hamm (pop. 160.000), a fast-growing employment center east of the Ruhr region (zone 30).

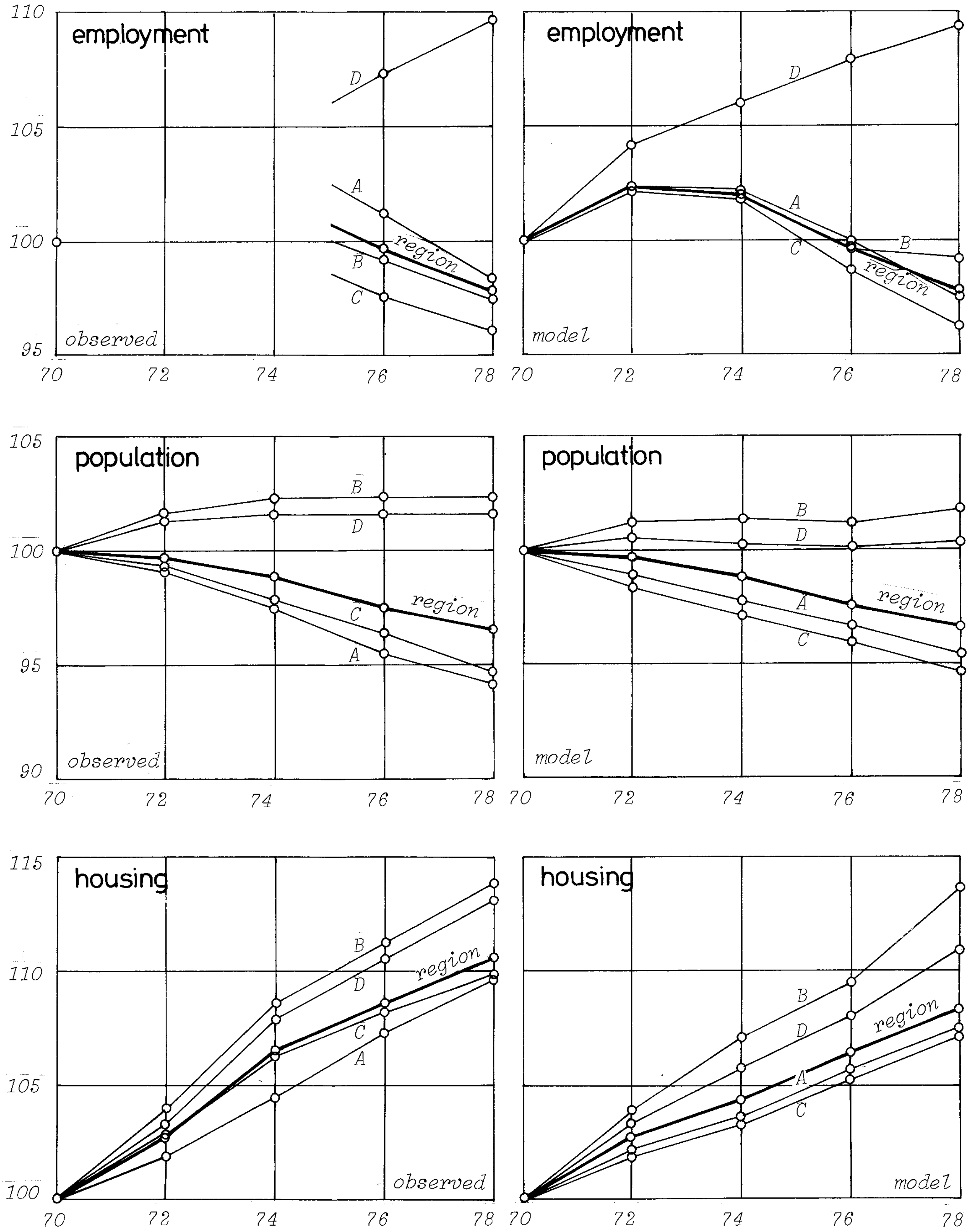

Fig. 4. Employment, population, and housing in subregions of the Dortmund urban region, 1970-1978, observed and predicted, in percent of 1970. For subregions, see Fig. 2.

It will now be examined how well the model reproduces the different rates of growth or decline of major model stocks, employment, population, and housing, for these four subregions. Model predictions and actual values are confronted in Fig. 4. The left hand side of Fig. 4 shows the development of employment, population, and housing (dwellings) in the urban region as a whole and in the four subregions for the years 1970-1978, in percent of 1970 figures. Employment figures for 1972 and 1974 are missing for lack of data. The right hand side of Fig. 4 shows the respective variables as predicted by the simulation model starting from the year 1970 as the base year.

Clearly, at the present state of model validation, model performance with respect to location of employment is the least satisfactory of the three. The model more or less seems to reproduce the employment trend of the whole region without paying much attention to differences between the subregions (although there is much more variation if one looks at individual zones or industrial sectors). The model should not be given credit for well predicting employment of subregion D, as the large increases in employment by public agencies in Hamm were entered exogenously using the public programs submodel. The causes for the poor performance of the employment location submodel may be connected either with the locational preferences specified for each industry or with the land prices generated by the model or the amount of industrial or commercial land provided in the model zoning plan. All three potential causes are presently under investigation.

Prediction of population by the model may be considered satisfactory, although it considerably underestimates the decline of population in the core subregions A and C and, accordingly, also underestimates the continuing growth in peripheral subregions B and D. Note that total employment for the region as a whole is exogenously entered. Nevertheless, the model does correctly predict the ongoing dispersal pattern observed in reality. While the population prediction produced by the model represents the combined effect of both, biometric changes and migration, the causes for this underestimation of spatial shifts are likely to rest with the migration model which still needs continued attention.

Prediction of residential location by the model may also be considered to be quite satisfactory. In this case, the model underestimates the total regional housing stock (which is generated endogenously), but except that it reasonably well distinguishes between peripheral and central subregions and correctly allocates new housing predominantly at the periphery, thus producing urban sprawl, as it should. The causes for the underestimation can clearly be identified to lie in the residential investors part of the private construction submodel.

It is recognized that these few comparisons of model performance with actual data are far too limited, far too aggregate, and too far from being perfect to already now establish any reasonable degree of credibility of the model. However, calibration and validation of the model will continue, and it is hoped that it will be soon possible to improve the model's performance and to demonstrate it in more disaggregate terms.

3. SIMULATION EXPERIMENTS

In the last section of the paper, two simulation experiments will be presented as an illustrative example of application of the model. Given the still preliminary state of validation of the model, many caveats have to accompany their results to make sure that they are taken as no more than they are, illustrative examples to show the range of analytical questions that can be investigated with the model.

Two alternatives have been defined for the simulation experiments. They differ only in the assumptions made for total regional employment and population:

- Alternative 1 — This alternative is the base-line simulation. It is based on a base-line run of the top level, the Nordrhein-Westfalen model, which in turn was based on a synopsis of recent employment forecasts for Nordrhein-Westfalen (Rojahn, 1981).
- Alternative 2 — For the second alternative, the base-line totals were arbitrarily modified by reducing regional employment by 7.500 jobs each year and by increasing outmigration by 20 and reducing inmigration by 15 percent.

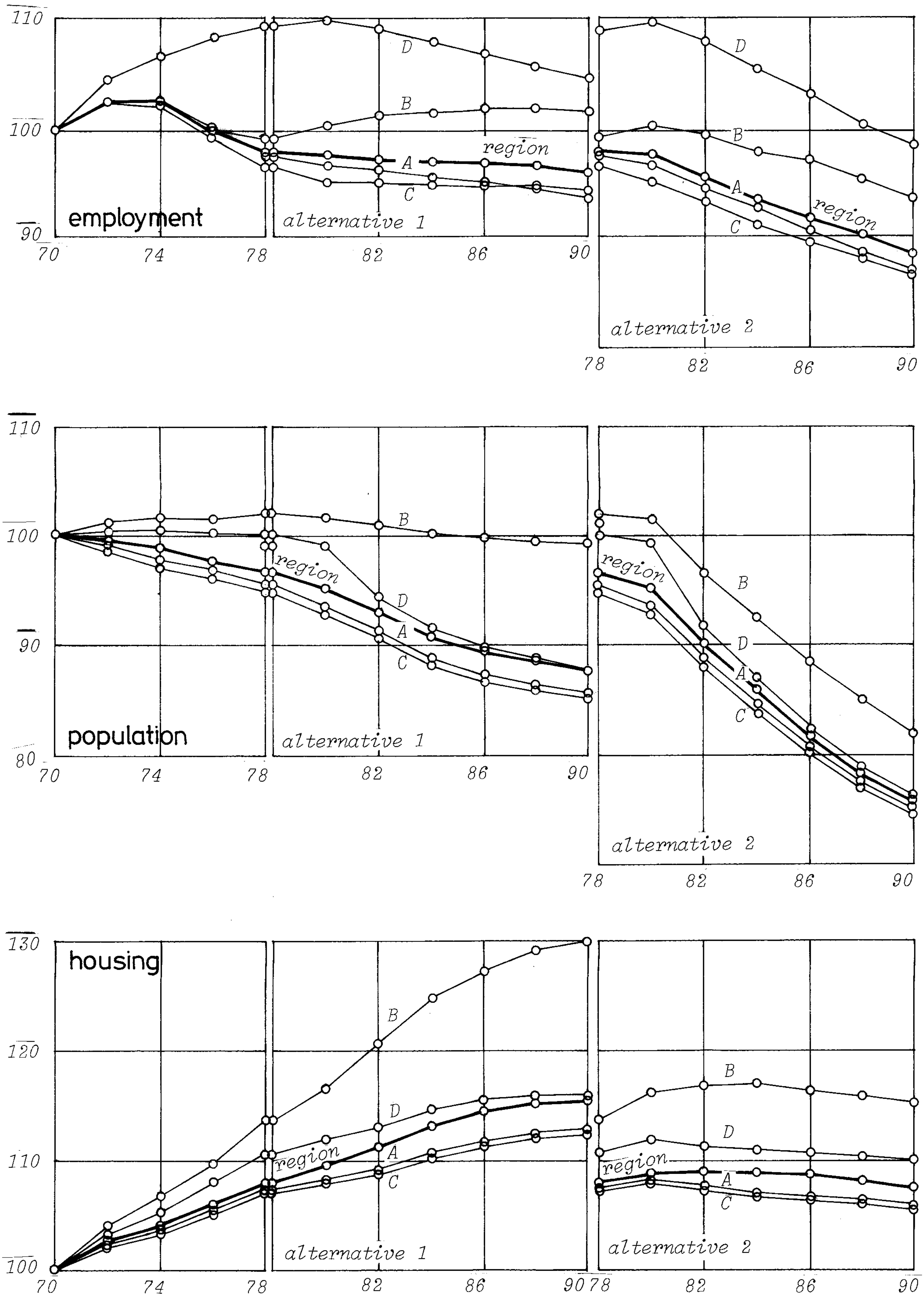

Fig. 5. Employment, population, and housing in subregions of the Dortmund urban region, 1970-1990, alternatives 1 and 2.

No particular meaning should be attached to the arbitrary specification of alternative 2. It was simply intended to create an alternative with massive reductions of employment and population in order to find out how the model would react to a situation of extreme urban decline.

The principal results of the two simulation experiments are shown in Fig. 5. Both alternatives are identical until the year 1980 when the first changes were introduced for alternative 2. The base-line simulation, alternative 1, clearly exhibits the continuation of present trends. Most remarkable is the reinforcement of the desurbanization trend: population and even employment of the urban region as a whole continue to decline, but there is accelerated growth in the peripheral subregion B in terms of housing and employment and to a lesser degree in terms of employment. Note that without the help of public employment programs subregion D is not able to sustain its former rate of growth and even loses jobs and population beyond the regional average.

Alternative 2 is indeed a decline alternative: over the decade of 1980-1990 the region loses about 75.000 or 8 percent of its jobs and about 270.000 or 13 percent of its population. The effects are not surprising: spatial dispersal comes to an end. Housing construction ceases almost completely after 1982 as no more dwellings are required for the dwindling population. As it may be expected, contraction occurs everywhere in the region with the effect that in the long run all four subregions come near to the average rate of decline of the region.

It may be argued that a simpler model or even common reason might have sufficed to arrive at such findings. This is conceded, but if one looks at more disaggregate model results, that may become different. Fig. 6 shows a selection of such results.

Now the level of spatial detail is the zonal level. Two contrasting zones have been selected for illustrative purposes: Zone 2, City North, is a fairly depressed area in the inner core of Dortmund. It is divided from the central business district (zone 1) by the railway tracks, and it has been on the wrong side of the tracks all the time. Its population is mostly low-income and worker population, and the quality of its housing stock is far below the average. In contrast to this, zone 20, Unna, is a relatively self-contained pleasant town in the countryside with a population of about 50.000. Unna is well equipped with a variety of jobs in various industries, it has a mostly medium-income population, its housing supply is relatively new and of good quality.

The diagrams in Fig. 6 give an impression of how these two different zones may be affected by the two simulated alternatives of regional development.

The two top diagrams show employment and population of the two zones. It may be observed that in Unna population increase might have been much higher in alternative 1, but obviously after 1982 something happened which made living in Unna less attractive than before. This will be discussed below.

The next two diagrams show the differences in the composition of the population of the two zones. The population of zone 2 is in the average much older, and its mean age even increases over the years, regardless of which alternative is simulated. This indicates that predominantly the younger and more mobile residents of the zone migrate out into zones where they can find more attractive living conditions. In contrast, zone 20 has a much more favorable age composition, and this remains relatively stable in alternative 1, which indicates that, although the population of Unna declines, there must be a large proportion of younger inmigrants into that zone. This changes in alternative 2 where there is much less inmigration. Similar differences between the zones can be seen in the income diagram. Zone 2 has a considerably lower average household income than zone 20. Both average incomes grow, but that of Unna grows faster, and again this difference is more pronounced in the base-line alternative 1.

The last two diagrams show the development of rents (and house prices) and of housing satisfaction in the two zones. Quite understandably, rents are higher in zone 20 than in zone 2, and rents increase in both zones over time. Rents increase faster in alternative 1 where demand for housing is much higher, and they increase most in Unna. The excessive rent increase in Unna, due to the high proportion of new housing construction (i.e. to rising land prices and construction costs) ex-

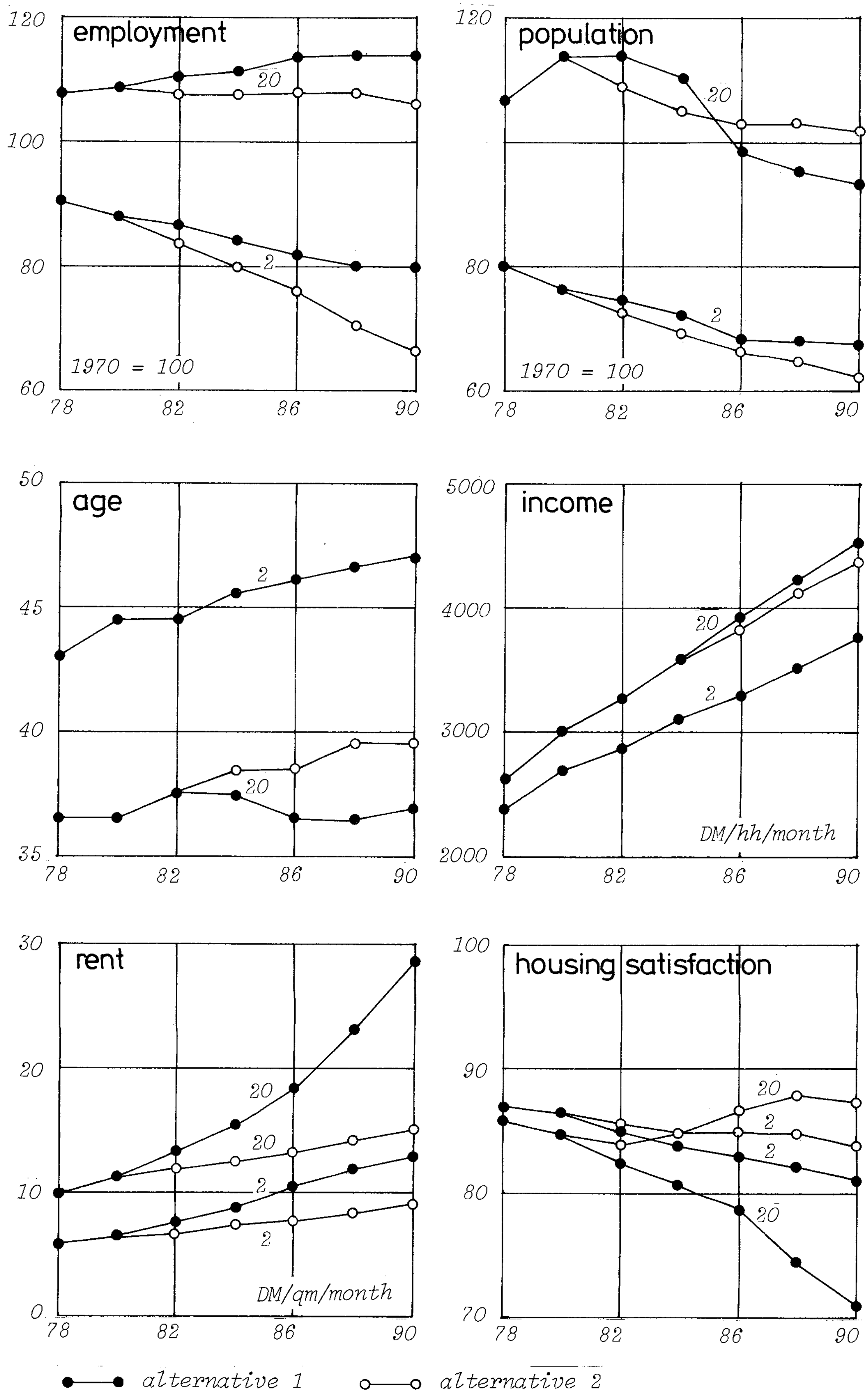

Fig. 6. Selected model results for zone 2, City North, and for zone 20, Unna, 1978-1990, alternatives 1 and 2.

plains why population development in Unna falters down after 1982: it has simply become too expensive to build new housing in Unna except for the very affluent. For the average household, Unna is no longer a place to look for a dwelling. This is reflected in the last diagram which shows the development of housing satisfaction. The index of housing satisfaction is used in the migration submodel to control the decision behavior of households on the housing market. It is important to know that it includes an evaluation of housing cost in relation to the housing budget of the households. This explains why zone 2 has a higher initial housing satisfaction than zone 20: housing quality may be worse in zone 2, but rents are lower, and the latter is more important for the people living in zone 2. It also explains why housing satisfaction goes up in alternative 2 where the housing market is much more relaxed. This is especially the case in zone 20: here the high rent level made dwellings in Unna rather unattractive for average households in alternative 1, in alternative 2 rent ceases to be a barrier for households moving to Unna, and accordingly, housing satisfaction goes up (People who know Unna may feel that the model overstates the effects of gentrification in Unna, but at least in principle the responses displayed by the model seem allright).

There is no question that these results and their discussion contain a fairly large amount of speculation. A part of this speculation can be removed by feeding more and more reliable data into the model. This will be done as the validation of the model continues. However, there will always be some degree of speculation connected with investigations into the long-range future of cities. This is why there is not, and should not be, a rigid boundary line between "soft" forecasting techniques, like the scenario-approach, and models like this one.

Future work on the model will focus on the validation of the model results on a more disaggregate level in order to study the socio-spatial consequences of urban change in more detail. In addition, policy simulations assuming shifts in the economic structure of the region will be performed to analyze the impacts on the housing market and on migration patterns. In a subsequent project, it is planned to start the model as far back as in the year 1950 in order to reproduce a longer time period of urban development encompassing phases of urban growth as well as phases of suburbanization and eventually desurbanization.

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REFERENCES

Arras, H., 1980, Wohnungspolitik und Stadtentwicklung. Teil 1: Klischees, Probleme, Instrumente, Wirkungen, Rahmenbedingungen. Research Report 03.084. Bonn: Bundesminister für Raumordnung, Bauwesen und Städtebau.

Gnad, F., Vannahme, M., 1981, Haushalts- und Wohnungstypen auf dem Dortmunder Wohnungsmarkt, Working Paper, forthcoming, SFB 26 Münster, Dortmund: Universität Dortmund.

Rojahn, G., 1981, Prognosen der regionalen Arbeitsplatzentwicklung in Nordrhein-Westfalen, Working Paper, forthcoming, SFB 26 Münster, Dortmund: Universität Dortmund.

Schönebeck, C., 1981, Ein makroanalytisches Modell der räumlichen Entwicklung von Wirtschaft und Bevölkerung in Nordrhein-Westfalen, Working Paper, forthcoming, SFB 26 Münster, Dortmund: Universität Dortmund.

Tillmann, H.-G., 1981, Ein mikroanalytisches Modell der räumlichen Entwicklung in einzelnen Stadtbezirken Dortmunds, Working Paper, forthcoming, SFB 26 Münster, Dortmund: Universität Dortmund.

van den Berg, L., Klaassen, L.H., 1978, The process of urban decline, Working Paper 1978/6, Rotterdam: Netherlands Economic Institute.

Wegener, M., 1980, A multilevel economic-demographic model for the Dortmund region. Paper prepared for the Workshop on Urban Systems Modeling, Moscow, September 30-October 3, 1980 (to appear in Sistemi Urbani).

Zahavi, Y., Beckmann, M.J., Golob, T.F., 1981, The UMOT/Urban Interactions. Research Report. Washington, D.C.: U.S. Department of Transportation.