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Regional Demographic Development in Southwest Skane

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REGIONAL DEMOGRAPHIC DEVELOPMENT IN SOUTHWEST SKÅNE

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PREFACE

Since 1979, the Regional Development Task at the International Institute for Applied Systems Analysis (IIASA) has been engaged in a case study of economic and demographic development, land-use, and related problems in the region of Southwest Skåne in Sweden. The case study is the third in a series of attempts made by the Regional Development Task to apply systems-analytical methods to regional planning problems in regions with different economic structures, resource endowments, and organizational settings.

The research in the Swedish case study is being carried out in collaboration with the Southwest Skåne Municipal Board, as a part of their ongoing work in physical and public transport planning for the metropolitan region of Malmö and its neighboring municipalities. The research is partially sponsored by the Swedish Council for Building Research.

An integrated systems-analytical package of models, which has been developed within the Regional Development Task with the cooperation of a group of Swedish researchers and planners, is used in this case study. In this package, separate models have been developed for solving interregional economic and demographic problems, and intraregional land-use problems.

This Collaborative Paper deals with the population development of Southwest Skåne and the rest of Sweden from the 1960s up until the turn of the century. A new type of projection model, developed at IIASA, is hereby used. This population model is one in the set mentioned above and has previously been tested on limited data from Sweden and other countries (see Andersson and Holmberg: Migration and Settlement. 3: Sweden, RR-80-5, IIASA).

The current application is more extensive. Ingvar Holmberg of the Demographic Research Group at the University of Gothenburg, Sweden, is responsible for the adaptation of the model to Swedish conditions and for the numerical computations. The results have been evaluated by Åke E. Andersson, Ingvar Holmberg, Jörgen Schultz, and Folke Snickars, all of whom have contributed to this policy-oriented report.

Hopefully this work will further stimulate the continued discussion about regional population development in Sweden and elsewhere.

Boris Issaev

Regional Development Task
IIASA, Laxenburg

October 1981

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1. INTRODUCTION

At the International Institute for Applied Systems Analysis (IIASA) Andrei Rogers and others have developed a new type of population model. It considers interregional migration flows in more detail than most other models and may be used for many different purposes, such as analyzing demographic changes in past years and making projections. With the help of the model it is relatively easy to answer questions such as: How many people will live in Southwest Skåne, which is the area administered by Sydvästra Skånes Kommunalförbund (SSK)*, in Stockholm county, or in Norrbotten in 5, 10, or 15 years, if the present migration pattern persists?

This paper reports on the main features of Swedish regional demographic development between 1960 and 1980 and on scenario calculations covering the period 1980-2000, with special reference to the Skåne region.

The scenarios have several common features. Each one is based on the assumption that all counties remain at the level of fertility and mortality observed during the period 1976-1979. However, in the scenarios the migration patterns vary and the following assumptions have been made:

*i.e. the Southwest Skåne Municipal Board.

Scenario 1: Migration follows the 1968-1969 pattern;
Scenario 2: Migration follows the 1972-1973 pattern;
Scenario 3: Migration follows the 1976-1977 pattern;
Scenario 4: Migration follows the 1978-1979 pattern.

The alternatives reflect different regional migration courses. At the end of the 1960s the metropolitan areas grew as a result of inmigration, outmigration from Norrland, and also immigration.

At the beginning of the 1970s, immigration from non-Scandinavian countries was regulated and at the same time urbanization slackened. Since then, demographic development in sparsely populated regions has improved, while many regions traditionally characterized by growth have experienced stagnation. Recently, migration on the whole has decreased. Some results of our calculations of the future development are presented in Figures 1-14 and Tables 1-14 below.

Scenario 1, which is based on the 1968-1969 migration pattern, shows a significant redistribution of the population from the North to the South. All sparsely inhabited counties lose population. In the South of Sweden the counties maintain or increase their populations and the metropolitan counties grow quickly, by approximately 200,000 inhabitants in 10 years.

In Scenario 2, a repetition of the 1972-1973 migration pattern leads to a population decrease in Sweden. The Stockholm and Gothenburg regions decline substantially, while the Malmö region barely maintains a constant population. Most Norrland counties manage to avoid population loss. In only three of the 24 counties is growth indicated.

Scenarios 3 and 4, which are based on the 1976-1977 and 1978-1979 migration patterns, respectively, are almost identical. All countries except for Blekinge maintain or increase their population. Stockholm is one of the expanding counties in which the population increases, whereas in Gothenburg-Bohus county and Malmöhus county the populations remain stable.

The four scenarios illustrate the shifts in regional demographic development. Major changes have occurred, but there are also some prevailing trends, among which is the

relatively stable growth of some counties, namely Uppsala, Halland, and Stockholm. During the early 1970s, however, Stockholm experienced a temporary interruption of the growth trend. The other two metropolitan regions, Gothenburg and Malmö, do not grow according to any scenario based on observations from the 1970s.

During the second half of the 1970s, regional demographic development was characterized by relatively stable migration patterns and decreased mobility. Has this development achieved a temporary state of balance? Will this persist for a few years into the 1990s? If the regional demographic development of the last few years does persist, the regional policy goals set by parliament will be achieved, at least those concerning the population targets.

In the Skåne region, Kristianstad county shows some growth according to all four scenarios. For Malmöhus county, Scenario 1 indicates a population increase of 60,000, whereas the other scenarios show no growth. The general impression is that the population of Skåne will not change significantly.

All alternatives based upon demographic development over the last 10 years indicate a minor population decline for Southwest Skåne. The distribution among the Skåne regions cannot, however, be seen as a forecasting problem only. The location of housing construction will influence the demographic development of the regions. Over a number of years people have been moving from the SSK area to bordering regions, where housing construction was considerable. However, the situation might change rapidly, because increasing commuting costs could reduce the demand for dwellings situated a long distance from work.

2. AN EXPLANATION OF REGIONAL DEMOGRAPHIC DEVELOPMENT

2.1. The Systems-Analytical Approach

During 1979 and 1980 the Regional Development Task at IIASA together with SSK employees developed a system of models

for regional socioeconomic development. Another paper will report on the basic ideas of this modeling work. In this context it seems reasonable, however, to show the position of demographic policy questions in the total framework provided by the systems-analytical approach. Figure 1 shows the interrelations of the planning problems in a systems-analytical framework.

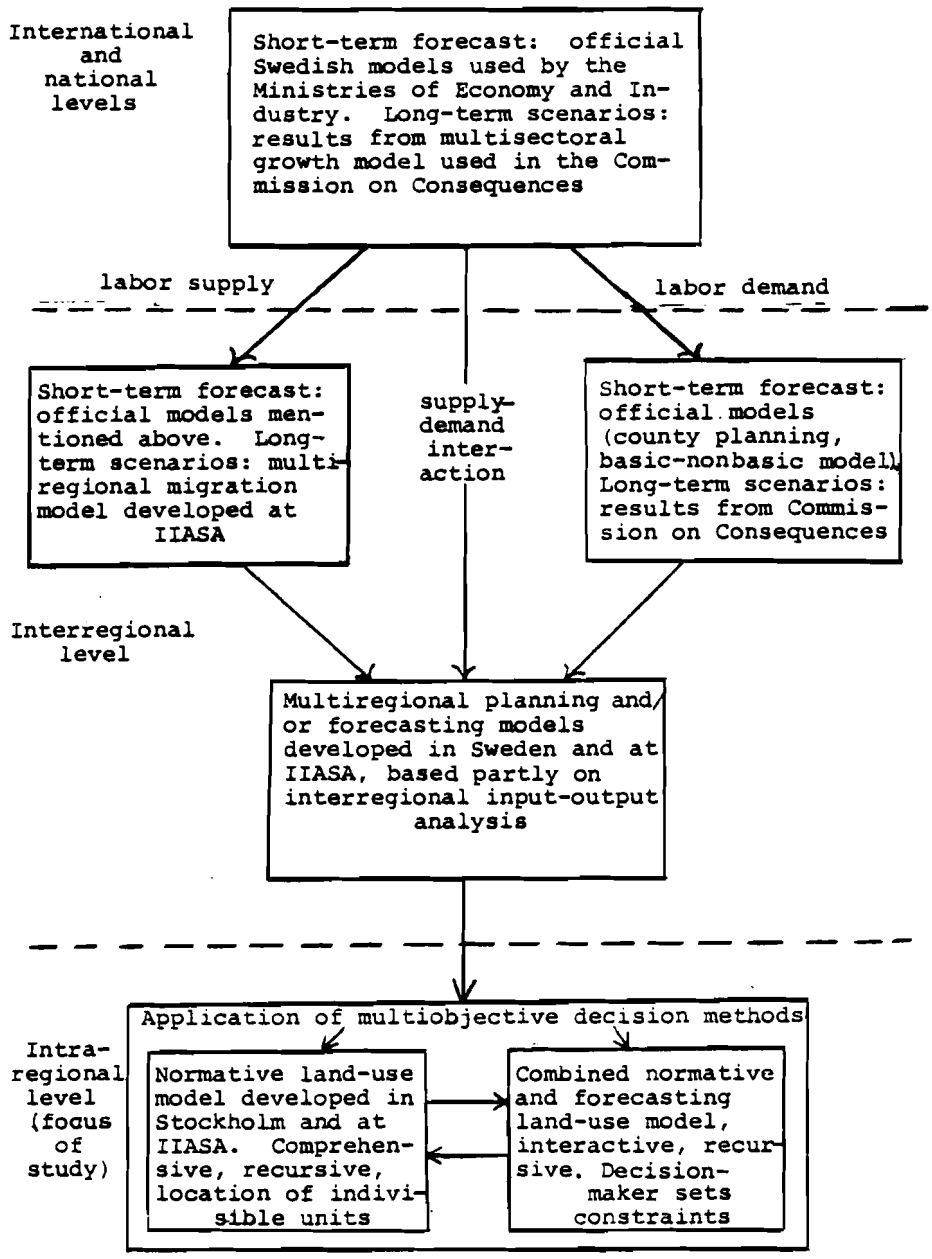


Figure 1. A hierarchical scheme of models used in the Skåne case study.

The 'free space' in which SSK can plan and set its own goals must gradually be circumscribed by studies of international and national economic development. A premise of the entire project is that socioeconomic development in Skåne and the SSK area is substantially influenced by changes in international demand, in technology, in national economic policy (especially industrial policies) and in regional policy as applied by ministries and civil-service departments.

Obviously it is central to the analysis to determine in which regions industry, agriculture, and services will be located. It is assumed that the location decision is based partly on the total national size of the sector and partly on the size and structure of the regional population. One of our most important assumptions is that regional demographic development is to a great extent determined by extremely slow processes. Temporary shifts in economic policy are assumed to exert a limited influence on the regional population. Employment location is therefore assumed, as mentioned above, to be determined by two independent courses of development, i.e. national employment development of each sector and demographic development, hence the potential labor supply in the various age and educational groups of the regions.

The economic structure of each region is then decided with the help of a multiregional economic model. The model transfers national sectoral development to the individual regions. The regional economic model indicates the approximate number of persons in employment in the various regions, subdivided into various sectors. However, it reveals nothing about the location of dwellings and workplaces within the region. Their location within the region, for example their distribution among the different localities and municipalities of Skåne, is dealt with in a comprehensive land-use model, which is specially adapted to the needs of physical planning and the present planning situation in Skåne. The model exists in two versions, which differ in the emphasis placed on the interaction between model and user. It will be described in a separate report.

2.2. The Guiding Role of Population Projections

We have already mentioned that, at this stage of the project, we will not allow regional economic development alone to determine regional demographic development and hence the labor supply. For an analysis oriented towards economic theory this assumption might be unexpected, but the demographic development of somewhat larger regions in Sweden is remarkably stable, also over longer periods of time (Figure 2). This goes for most parts of the country, with the exception of the Stockholm region.

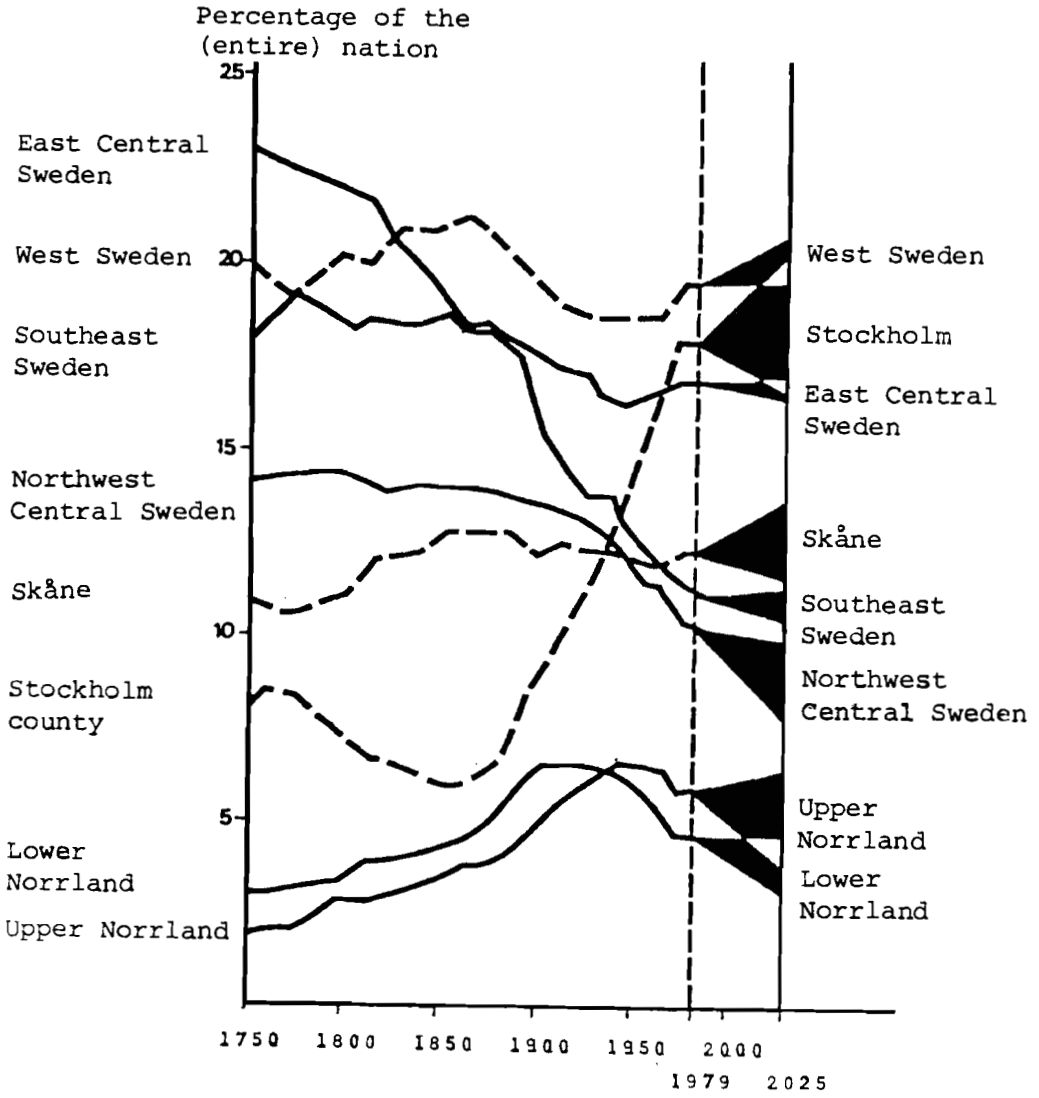


Figure 2. The distribution of the population in Sweden, 1750-2025.

Table 1 shows that Skåne's share of the national population (12 percent) hardly changed from 1920 to 1975. Neither the depression of the 1930s, the war and the blockade of the 1940s, nor the very rapid economic expansion of the 1950s and 1960s influenced this share to any noteworthy extent.

Table 1. The distribution of the population among eight districts as a percentage of the total national population, 1920-1975.

Region	1920	1930	1940	1950	1960	1970	1975
Stockholm region	11.2	12.2	13.7	15.5	16.8	18.3	18.2
East Central Sweden	17.3	16.7	16.3	16.5	16.6	17.2	17.1
Southeast Sweden	17.0	17.4	16.7	16.0	15.1	14.6	14.4
Skåne	12.3	12.3	12.2	12.0	11.8	12.2	12.1
West Sweden	14.8	15.0	15.2	15.3	15.6	16.2	16.5
Northwest Central Sweden	13.4	13.1	12.5	11.8	11.6	10.6	10.5
Lower Norrland	6.7	6.7	6.5	6.1	5.7	4.9	4.9
Upper Norrland	6.2	6.5	6.8	6.7	6.7	6.0	6.1

Source: SOS, Statistisk Årsbok (Statistical Yearbook), 1921-1976.

We are unlikely to be able to foresee all the major changes in the economic structure over the next 20 years, although we expect them to be as drastic as those of the three 20-year periods between 1920 and 1980. Therefore, at this stage we have refrained from forecasting the economic development of Skåne and its influence on demographic development. A thorough analysis

of Skåne's situation will, however, pay great attention to the relation between the economy and population location.

2.3. Characteristics of the Projection Model

In addition to fertility and mortality rates, the model we use for studying demographic development also contains migration probabilities. In its simplest version it is identical to the model used by the Central Bureau of Statistics in Stockholm for national population forecasts. Similar models are used to estimate the demographic development of individual regions. These models are characterized by their rather simple rendering of cross-regional migration. Often a constant annual migration gain (or loss) is indicated, sometimes divided into age groups.

At IIASA this conventional approach has been criticized. It has been pointed out that it is possible to describe the probability of a move from one region to another in much the same way as the probability of a woman in a specific age group having children would be described. In other words, an attempt has been made to describe cross-regional migration as a probability with a certain stability. Such a probability may express the expectation that a certain share of the Skåne population in one age group will move to Stockholm within the next five years. Likewise, a certain share of the same Stockholmian age group is expected to move to Skåne during the same period of time. In the model, therefore, the migration pattern is determined by the probability of moves to other regions and by the size of the age group under consideration in the outmigration region.

With a model of the first type, i.e. with constant annual net migration, the outcome is sometimes unreasonable. It might indicate that in the long run outmigration would depopulate the region. The IIASA model with its gross migration probabilities never generates such logically absurd statements. When the model is used over extremely long periods, and fertility, mortality, and migration probabilities are kept constant, the migration flows produced eventually balance.

In the long run the model generates constant population shares for all regions. A regional share will, in such a case, change only if the model is not in its final balanced state or if the probabilities are changed. Of course, in reality such changes do occur and the regional shares of the national population shift slowly.

To carry out a comprehensive analysis of the interdependency between the economy and the population, one would have to consider the migration, fertility, and mortality probability functions of the specific regional state of the economy. At the same time, one would allow economic decisions to be determined by the population and its regional distribution. However, such a modeling effort requires a long series of data for determining the historical interaction. In addition, one would need sound assumptions on the technological and social developments in the period for which the forecast is to be made.

To illustrate how, through migration, the regional populations are interdependent, we have summarized the model in a simplified example.

The complete model accounts for a division of Sweden into 25 regions each with 18 age groups. Consequently, the model contains thousands of probabilities. No planner would be able to consider all these interdependencies simultaneously. However, using the computer, it is relatively easy to produce various logically reasonable population projections for a number of future periods.

We have used fertility, mortality, and migration probabilities observed during different periods between 1965 and 1980 to see their effect on demographic development when used for projections towards and beyond the turn of the century. The projections should not be seen as forecasts but rather as scenarios showing the development of the population level if the migration patterns of the past 15 years are assumed to persist.

It still remains to develop the model to be used for forecasting. Rather sophisticated observations, based on relevant data, of the way in which economic development affects demographic behavior and vice versa will be necessary. The model should be reconstructed, so that the migration probabilities are determined by the economic situation of the outmigration and the inmigration regions. This remodeling work is underway at IIASA.

Another procedure, which we will employ, is theoretically less well-founded but more practical. This consists in using the population model in parallel with a regional economic model. The results should then be synchronized. The labor supply indicated by the demographic model is to be understood as a preliminary measure of the available manpower. With the help of a specially developed model, the labor supply is compared to and synchronized with labor demand as indicated by the regional economic model. A mathematical description of the theoretical characteristics of the demographic model is given in Appendix A.

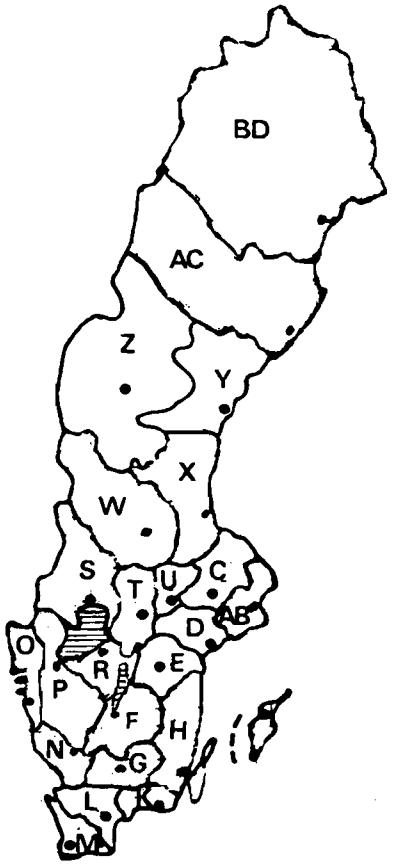
2.4. Regional Division

The choice of regional division is important, since it influences the projection results (Figure 3). Depending on the purpose of the investigation one can choose between a number of levels.

We primarily wish to throw light upon long-distance migrations between different parts of the country, which are distinguishable (by size) at the level of the regional economy (Table 2). We are not interested in regional internal moves resulting from a normal change of dwellings. Hence, we chose to calculate on the county level. Malmöhus county, however, we divided into Southwest Skåne and the

Counties :

AB	Stockholm
C	Uppsala
D	Södermanland
E	Östergötland
F	Jönköping
G	Kronoberg
H	Kalmar
I	Gotland
K	Blekinge
L	Kristianstad
M	Malmöhus
N	Halland
O	Gothenburg-Bohus
P	Älvsborg
R	Skaraborg
S	Värmland
T	Örebro
U	Västmanland
W	Kopparberg
X	Gävleborg
Y	Västernorrland
Z	Jämtland
AC	Västerbotten
BD	Norrbotten



County Regions:

F,G,H,I	Southeast Sweden
K,L,M	South Sweden
N,O,P,R	West Sweden
C,D,E,T,U	East Central Sweden
S,W,X	Northwest Central Sweden
Y,Z	Lower Norrland
AC,BD	Upper Norrland

Municipalities of SSK:

1. Burlöv
2. Kävlinge
3. Lomma
4. Lund
5. Malmö
6. Staffanstorp
7. Svedala
8. Trelleborg
9. Vellinge

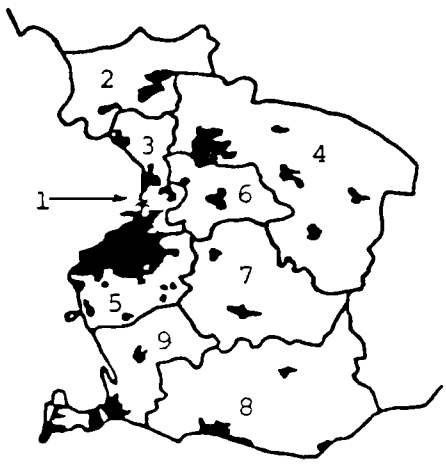


Figure 3. The regional division of Sweden and the municipalities in SSK.

rest. Foreign countries are considered as one extra region, which makes a total of 26 regions. The IIASA model makes it possible to take into account the migration flows of all age groups between each of the 26 regions. Actually, a smaller number of regions would have been sufficient. Thus, in this paper we will treat Skåne primarily as one region rather than as three subregions.

The total population of Skåne is our primary concern. The distribution of population and workplaces, particularly in the Southwest, will not be approached as a problem of demographic forecasting but as a planning issue.

We decided on a division of Skåne into three regions for the current work in order to determine the direction of present migration trends. In interpreting the outcome, one has to consider that the number of inhabitants of each region does not reflect employment changes alone. It also results from moves related to housing markets, which extend over many regions.

Table 2. Number of moves in Sweden, 1978 (in 1,000s).

Location	No. of moves
Within the parish	480
To another parish within the same municipality	276
To another municipality within the same county	153
To another county	154
To another country	58
Total number of moves	1,121

Thus, people working in the SSK area have moved to Southeast and Central Skåne (i.e. the rest of Malmöhus county). Likewise, municipalities in the Northwestern part of Kristianstad county try to attract people moving out of the Helsingborg area (Malmöhus county).

The reason why we consider countries as regional units is because the country board plays an important role in nationally initiated regional policy. Unfortunately, the division does not correspond to economic realities, an example of this is the fact that the state has been unable to adjust the county borders in the Gothenburg region. Parts of Halland and Älvsborg counties are functionally integrated into the Gothenburg housing and labor markets. In Skåne the situation is less extreme, but there also the county division fails to correspond to the natural economic regions.

2.5. Choice of Alternatives

This paper reports on four alternatives for future regional demographic development in Sweden. The alternatives are not forecasts in the usual sense. We have not selected one alternative as being the most realistic. Instead, we consider the alternatives as four scenarios relevant for providing an indication of demographic developments in the near future in Sweden.

The scenarios are based upon courses of development observed during the 1960s and 1970s. The courses differ, not only with regard to regional demographic development, but also inasmuch as they reflect changes in national economic conditions. Table 3 presents some essential economic data from this period.

3. RECENT POPULATION DEVELOPMENT

Section 3 describes past demographic development in terms of fertility, mortality, as well as internal and external migration. At the end of each subsection we offer some concluding comments and give the reasons for the particular scenario design.

Table 3. Some essential economic data from the 1960s and 1970s.

Scenario base period	G N P	Gross investment	Construction	Unemployment	External migration	Industrial wages
1. 1968-69	annual growth 5%	Gross investment amounted to 53 bln Skr (1975 prices)	108,000 dwell. constructed in Sweden, of which 8,000 in SSK	Approx. 40,000 unemployed, of which 7,000 from metropol. areas	Large annual immigration: averaged 28,000 pers.	Gross hourly wage for an industrial worker: 12.50 Skr per hour, i.e. 42 minutes work for 10 liters of petrol (0.88 Skr per liter)
2. 1972-73	2,5% growth	59 bln Skr	100,000 dwell. constructed, of which 7,500 in SSK	65,000 unempl., of which 20,000 from metrop. areas	Many immigr. returned home; net emigrat.: 11,000 pers.	Gross hourly wage 18 Skr, i.e. 35 minutes work for 10 liters of petrol (1.15 Skr per liter)
3. 1976-77	No growth	59 bln Skr	55,000 dwell. constructed, of which 2,900 in SSK	70,000 unempl., of which 20,000 from metrop. areas	Net annual. immigration again: 20,000 persons	Gross hourly wage 29 Skr, i.e. 36 minutes work for 10 liters of petrol (1.60 to 1.70 Skr per liter)
4. 1978-79	3% growth	56 bln Skr	55,000 dwell. constructed of which 2,200 in SSK	90,000 unempl. of which 25,000 from metrop. areas	Net annual immigration: amounting to 14,000 pers.	Gross hourly wage rose from 32 Skr in 1978 to 36 Skr in 1979, to 40 Skr in 1980, i.e. 37 minutes work for 10 liters of petrol in 1978 to 45 min. in 1980 (petrol rose in cost from 1.98 Skr for 10 liters in 1978, to 2.43 Skr in 1979, to 2.96 Skr in 1980)

3.1. Some General Features

In recent years demographic development in Sweden has been characterized by declining fertility rates. Mortality on the contrary is no longer decreasing, in fact an increase has been observed for men in some age groups. External migration has varied from year to year. These factors have led to major fluctuations in national population growth.

The individual regions have also experienced fluctuations in population growth, which are mostly accounted for by changes in internal migration. External migration is very important especially with respect to the metropolitan regions. The data contained in this subsection are quoted from a variety of sources originating from the Central Bureau of Statistics.

3.2. Declining Fertility Rates

Fertility rates have changed markedly over the last 20 years. In the mid 1960s the birth rate reached a level uncommon in Sweden, but since then (with the exceptions of the early 1970s and 1979) fertility has been steadily declining; see Figure 4 in which the SSK curve approximately follows the national curve. Apart from temporary fluctuations in fertility long-term changes have also occurred. During the twentieth century the whole fertility pattern has changed drastically.

Not only the level of fertility but also the age at which women bear children have changed. From the turn of the century to the 1930s the number of births decreased by half. The trend towards earlier childbearing began gradually. Since the 1930s it has been accelerating as a result of the fact that couples raise families at an increasingly early age.

Fertility is now far below the replacement level, i.e. the level required to maintain a constant population over the long run, excluding consideration of immigration. No single year since 1900 has reached the full replacement level and, given present mortality rates, a fertility rate of 2.1 children per woman would be required to attain this level. That the Swedish population is still growing is because of the decreasing mortality

levels of the century, the substantial immigration over the last 30 years, the trend towards early childbearing, and finally to the fact that it takes a long time before fertility changes significantly affect the total population.

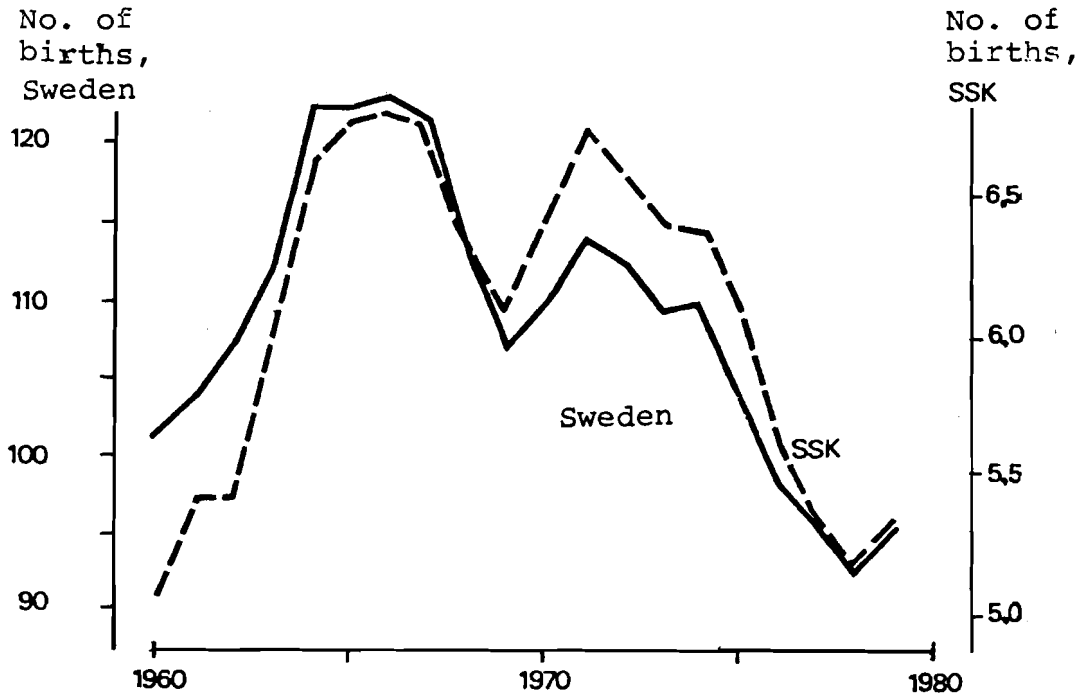


Figure 4. Number of births per year: Sweden and SSK (in 1,000s).

At present, the Central Bureau of Statistics is conducting extensive research into the changing birth rates of the last few years. The Bureau is also trying to assess Swedish attitudes towards childbearing. Some probable causes for the low birth rates are reliable contraceptive methods, legal abortion, the higher level of education, and the increasing number of women working outside the home. The lack of child-daycare facilities may also be relevant. Another cause mentioned is the generally improved income level. The number of marriages has decreased considerably since the mid 1960s, but simultaneously the number of couples living together without being married--especially young couples--has increased. Therefore this change cannot immediately have caused the low birth rates. However, the increasing number of divorces may constitute a cause. In the 1960s, 2 percent of the marriages ended in divorce within 3 years of the wedding, today the rate is 8 percent.

Fertility varies slightly from one part of the country to another (Figure 5). It is low in the metropolitan areas of Stockholm, Gothenburg, and Malmö, but also in cities like Karlstad, Borås, Kalmar, and Linköping. Stockholm has the lowest rate (only 1.32 children per woman), but this can be accounted for by the specific situation of the metropolitan regions. Families with children very often move to a suburban municipality at the time when they are awaiting another child. Therefore, cities like Malmö and Lund have lower birth rates than the surrounding suburbs. Fertility in Southwest Skåne is below the national average (1.54 and 1.64 children per woman, respectively, for the period 1976-1979).

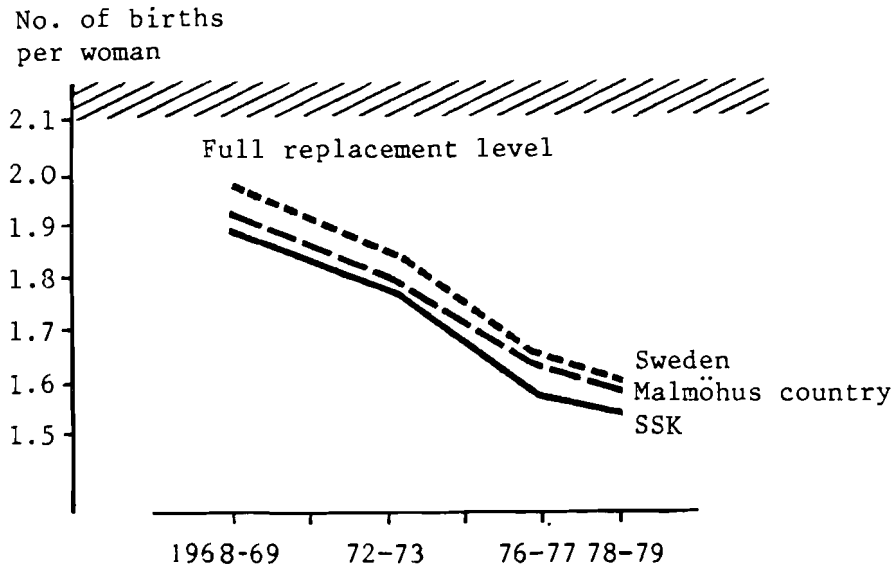


Figure 5. Total fertility rate in Malmöhus county, SSK, and Sweden (number of births per woman).

The variation between regions is, however, diminishing. The old picture of low fertility in the cities and high fertility in the northern countries and the 'church-going' countries of Bohus and Småland is no longer valid. Today all countries with the exception of Stockholm are on approximately the same level. The gap between the highest and the lowest rates has been reduced from over 60 percent at the turn of the century to 15 percent at present, see also Figure 6.

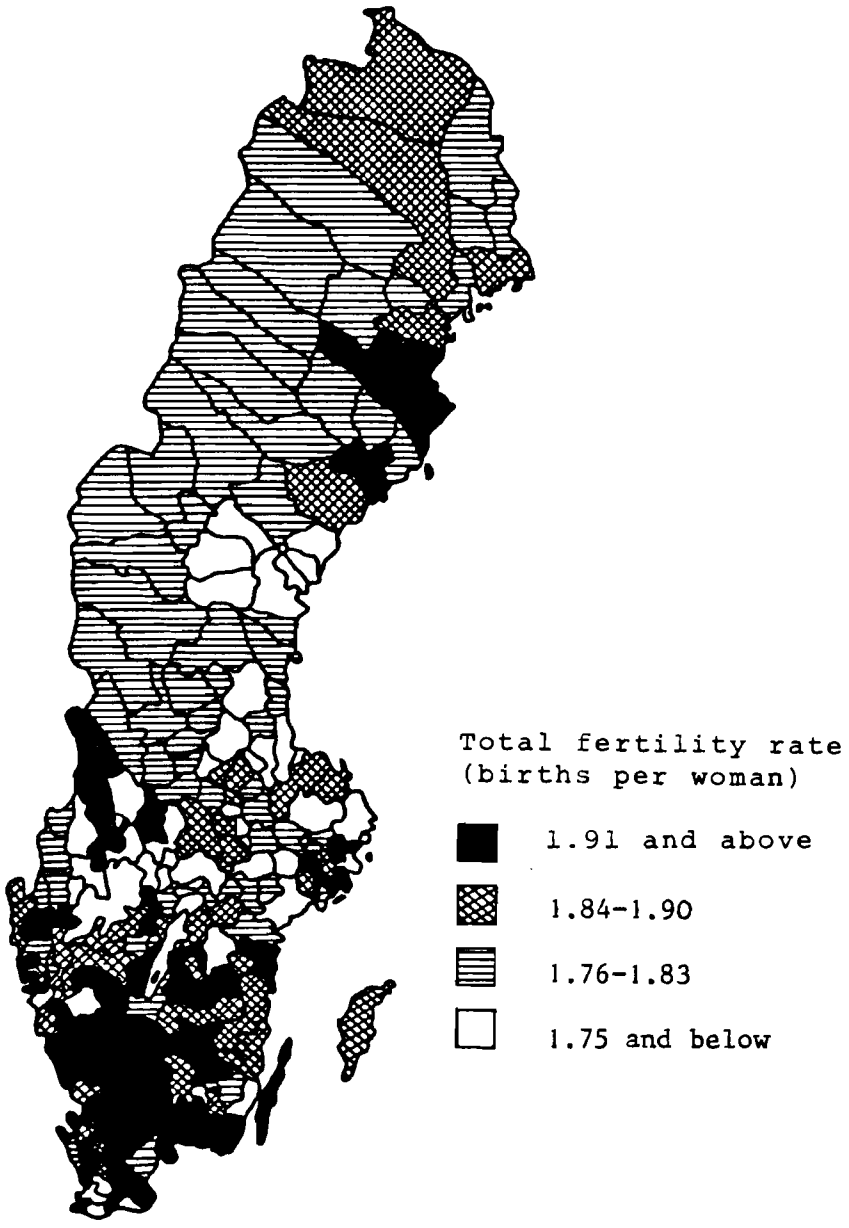


Figure 6. Fertility in Swedish municipalities, 1974-1976.

The IIASA model enables us to evaluate alternative assumptions of future fertility, and several simulations have already been made. To simplify matters we have chosen for this paper one alternative only. We have assumed that, independent of the migration pattern, all countries remain on the 1976-1979 fertility level. The Central Bureau of Statistics in its latest national forecast has done more or less the same; however, it has modestly raised the average to 1.8 children per woman.

3.3. Constant Mortality Rates

Mortality changed less drastically than fertility between 1960 and 1980. For women, it continued to decrease, whereas for men in some age groups it remained constant or even increased. For both sexes mortality is very low until the age of 50. The very high mean expectation of life will result in a large number of elderly in the future.

Mortality decreased less at the end of the 1970s than during the 1960s. Furthermore, the variations from country to country are leveling out. Southwest Skåne and the rest of Malmöhus county have a somewhat lower-than-average mortality rate for women.

Our results coincide roughly with those of the Central Bureau of Statistics (1978). Its investigation of mortality from 1970 to 1975 showed that mortality was low in the South, in the Southwest, and in parts of Uppland and Södermanland and higher in Central Sweden, in the North and (for men) in the metropolitan regions.

The regional mortality variations are probably related to the fact that causes of death differ from region to region. High mortality for women in some regions might be explained by the high incidence of cardiovascular diseases. For men, cardiovascular plus tumor-related diseases are relevant.

We have assumed that all countries, independent of their migration patterns, will retain the same mortality levels as those of the period 1976-1979. The latest national forecast of the Central Bureau of Statistics is based on approximately

the same assumption. The Bureau presupposes that the mean expectation of life at birth for men will not change (72.4 years). For women a slight prolongation is foreseen (from 78.6 to 78.9 years).

3.4. Increases in Migration during Periods of Rapid Economic Growth

The belief that the number of moves has increased substantially over the last decades is widespread. However, this is not true. In fact, mobility per 1,000 persons has been fairly constant throughout the century. Obviously the number of migrants does, to some extent, fluctuate. The labor-market situation accounts for most of the changes, since mobility increases during times of prosperity and decreases during a depression (Figure 7). In the 1960s and 1970s, migration associated with these economy-related fluctuations amounted to approximately 10 percent of total migration.

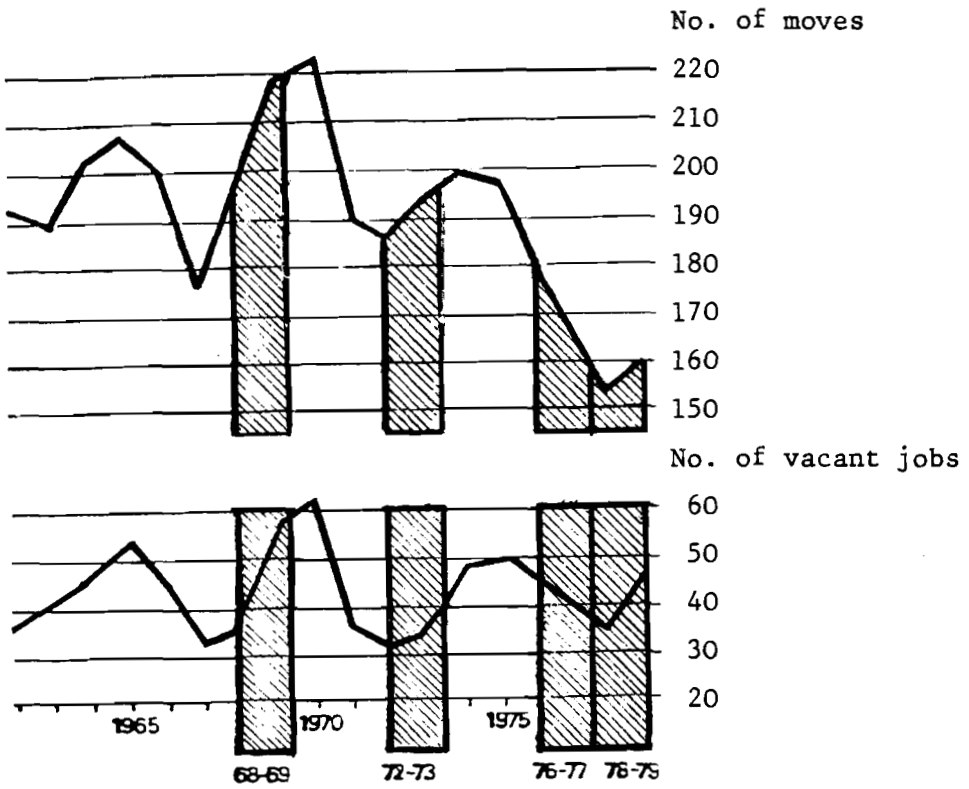


Figure 7. Number of cross-county border moves (in 1,000s).

The migration pattern has changed (Table 4). In the 1960s the metropolitan populations* grew considerably, while the forestry-dominated counties† and other sparsely populated areas suffered from serious population losses. Around 1970 a dramatic shift occurred. The metropolitan counties experienced a net outmigration, whereas the 'forestry counties' generally maintained or increased their populations. Outmigration from the metropoles, but also from Södermanland, Jönköping, Blekinge, Västmanland, and Norrbotten counties has continued. All 'forestry counties' with the exception of Norrobotten have had a net inmigration.

At the end of the 1970s internal migration decreased. It fell from 220,000 persons annually in the prosperous years of 1969 and 1970 to 150,000-160,000 annually between 1977 and 1979. This was partly caused by the worsened situation on the labor market, but it might also indicate a tendency towards a decline in migration. We may be witnessing the beginning of a low-mobility labor market and slower adaptation processes in regional demographic development.

The economic development of the various regions will affect internal migration. However, some migration patterns are relatively constant. The exchange between the counties is not coincidental. Geographic proximity as well as existing differences in sectoral structure and services influence the migration flows.

Table 4. Internal migration surplus, annual average (in 1,000s).

Area	1968-69	1972-73	1976-77	1978-79
Metropolitan counties	13	- 8	- 7	- 7
Sparsely populated counties	-15	0	3	3
Other counties	2	8	4	4
The nation	0	0	0	0

*Stockholm, Malmöhus, and Gothenburg-Bohus.

†Norrbotten, Västerbotten, Västernorrland, Jämtland, Gäleborg, Kopparberg, Värmaland.

3.5. External Migration and Its Importance for the Metropolitan Regions

When emigration to the United States (totaling 1.2 million Swedes) ceased in the 1920s, Sweden once again became an immigration country. Up until the Second World War immigration was modest. Most immigrants were returning Swedish-Americans. The increase came with the end of the war, when Sweden received many refugees. During the 1950s and 1960s the acute labor shortages occasioned Swedish firms to recruit from other Scandinavian countries, from the FRG, and eventually from the Mediterranean countries. In 1967 non-Scandinavian immigrants became subject to new visa regulations, the effect of which, however, did not manifest itself until the beginning of the 1970s.

External migration has been followed by fluctuations on the Swedish labor market and thus has varied considerably from year to year. Immigration reached a peak during the economic boom in 1970 but in 1972-73 there was net emigration. Since then immigration has again exceeded emigration (Table 5).

Immigration greatly influences the demographic development of many regions. For the nation as a whole it has provided an additional 800,000 persons since the Second World War (approximately 500,000 immigrants and 300,000 children). The growth of the metropoles has largely been a result of immigration, which has recently compensated for the outmigration from these regions to other areas. Between 30 and 40 percent of the immigrants usually go to the Stockholm area and a considerable share migrate to Southwest Skåne.

Table 5. External migration surplus, annual average (in 1,000s).

Area	1968-69	1972-73	1976-77	1978-79
Metropolitan counties	11	- 6	12	9
Sparsely populated counties	3	- 1	2	1
Other counties	15	- 4	7	4
The nation (total)	28	-10	21	14

Immigration and emigration are vitally important to the future of many regions. However, it is difficult to foresee the extent of this migration in the years to come. Both short-term economic fluctuations and long-term economic development will be influencing factors. For this reason we have chosen to evaluate the effects of four alternatives that are relatively different in character. The external migration patterns of our four periods are compatible with these differences and will be used for the scenarios (Table 6).

For Sweden as a whole we have assumed that the distribution follows the observed pattern of the respective period.

Table 6. External migration, 1968-1979 (in 1,000s).

Scenario	Immigration	Emigration	Surplus
1	50	22	28
2	30	40	-10
3	45	23	22
4	37	23	14

3.6. Some Characteristics of Southwest Skåne

In Southwest Skåne, the male mortality rate is slightly higher than the national average, while for women it is a little lower. For both sexes together, the mortality rate is somewhat lower than the average and fertility is also below the mean rate. The same characteristics have been chosen for the scenarios.

The SSK migration pattern has changed drastically over the period under analysis. The reasons for this situation are two-fold: the constant state of the labor market and the relocation of housing construction. In 1968-1969, the demand for labor was high, and people moved to the area from other parts of Sweden and from abroad. Housing construction was also extensive and the newcomers settled within the area.

Around 1970, the labor market changed for the worse and fewer people moved in to seek employment. At almost the same time outmigration from Southwest Skåne to the surrounding municipalities began. Housing construction gradually shifted to these other parts of the county. New residential (one-family-house) areas were built at long distances from workplaces and the SSK share of housing construction in Skåne became too small. The central and southeast municipalities on the contrary built more than was justified by the development of the local labor market. Between 1975 and 1979 some 6,000 persons (net loss) moved from the SSK area to Central and Southeast Skåne and took to long-distance commuting. Data on the annual average net migration in Southwest Skåne is given in Table 7. Over the last few years Southwest Skåne has also lost inhabitants to the rest of Sweden. The outmigration was to some degree, although not completely, compensated for by immigration.

Table 7. SSK net migration, annual average.

Period	Rest of county	Rest of Sweden	Other countries	Total	SSK's percentage share of the county's new construction
1968-69	300	2,700	1,800	4,800	70
1972-73	- 600	300	- 600	- 900	67
1976-77	- 900	- 800	400	-1,300	55
1978-79	- 900	- 300	300	- 900	50

4. FOUR SCENARIOS

4.1. The Swedish Population Will Decrease Without Immigration

At present Sweden has a population of 8.3 million. Our four scenarios give conflicting answers to the question of national demographic development (Figure 8). Alternatives 1 and 3 indicate some growth, Alternative 2 a decline, and Alternative 4 almost no change. The exact numbers are shown in Table 8

together with the latest forecast from the Central Bureau of Statistics (SCB). Several trends are worthy of attention here.

First, the importance of external migration is evident. The projections for the population of the next decade vary between -200,000 and +200,000, depending on the size of immigration and emigration flows only. The government cannot control them completely. Other influential factors, which are equally if not more important, are the development of the Swedish economy and the political and economic situation of neighboring nations. This being the case, our possibilities for making forecasts for the nation and the regions are limited.

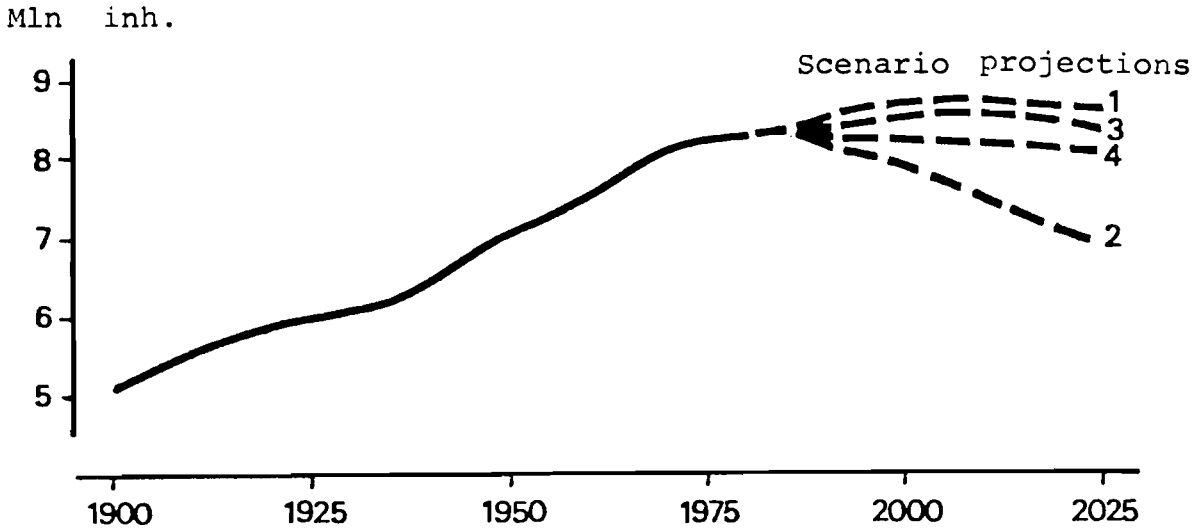


Figure 8. The population of Sweden, 1900-2025: four alternative projections.

Table 8. The population of Sweden, 1980-2025 (in 1,000s).

Year	Scenario 1	2	3	4	SCB forecast, 1980
1980	8,303	8,303	8,303	8,303	8,303
1990	8,499	8,115	8,449	8,381	8,399
2000	8,606	7,825	8,509	8,365	8,386
2025	8,615	6,915	8,405	8,060	8,065

Second, without a certain immigration surplus (or increased fertility) the population will decline. This tendency will be reinforced even further in the 1990s because of the age composition of the population.

Thirdly, the outcome of Scenario 4 coincides almost completely with that of the latest national forecast as far as the total national population is concerned. The Bureau, however, has not made any regional division. Our fourth alternative is therefore particularly interesting if taken as a regional breakdown of the SCB forecast.

4.2. Concentration in the South or Equally Distributed Growth?

The scenarios differ with regard to the size of the national population, but also regarding the distribution among the counties. Table 9 shows the county demographic development in detail. Figure 9 summarizes the population changes of the counties in the 1980s according to the four projections.

Scenario 1, based upon the 1968-1969 migration pattern, indicates a radical redistribution from the North to the South. All counties dominated by the forestry sector lose population, while the southern counties maintain or increase their populations. There are many growth counties: the metropolitan areas as well as Uppsala, Halland, and Älvsborg. The metropoles increase considerably, at a level of approximately 200,000 persons in 10 years.

Scenario 2, based on the 1972-1973 migration pattern, differs from Scenario 1. The Stockholm and Gothenburg regions decline substantially, and Malmöhus county barely maintains a constant population. Also Kalmar, Västmanland, Örebro, Värmland, and Gävleborg lose population. The rest of the Norrland counties, however, succeed in avoiding losses. Only three out of 24 counties grow: Uppsala, Halland, and Älvsborg.

Scenarios 3 and 4, based on the 1976-1977 and the 1978-1979 patterns, are almost identical. All counties, with the exception of Blekinge, more or less maintain their present populations or grow slightly; this is even relevant for the Norrland counties. Västerbotten can even look forward to a positive pattern of

Table 9. Population per county according to the scenarios (in 1,000s).

County	1979	Scen. 1 1989	Scen. 2 1989	Scen. 3 1989	Scen. 4 1984	Scen. 4 1989	Scen. 4 1999	Regional policy goals for 1985
AB Stockholm	1,524	1,645	1,451	1,584	1,547	1,562	1,578	1,545 - 1,565
C Uppsala	242	256	252	264	254	265	281	246 - 250
D Södermanland	252	258	243	250	251	249	245	250 - 254
E Östergötland	392	404	386	405	394	394	391	394 - 400
F Jönköping	302	319	299	303	301	297	290	303 - 308
G Kronoberg	172	181	171	177	175	176	177	171 - 175
H Kalmar	241	240	231	241	240	238	234	240 - 244
I Gotland	55	55	55	56	56	57	58	54 - 56
K Blekinge	154	156	154	149	153	151	147	152 - 156
L Kristianstad	279	282	282	289	285	289	295	283 - 287
M Malmöhus	744	799	744	738	744	741	733	743 - 755
N Halland	229	254	253	249	238	245	255	236 - 240
O Gbg, Bohus	713	744	660	705	708	702	686	710 - 720
P Älvsborg	424	445	438	433	429	431	431	422 - 428
R Skaraborg	264	267	272	278	274	279	285	268 - 272
S Värmland	285	269	270	283	284	282	278	283 - 287
T Örebro	274	273	258	272	273	271	265	273 - 277
U Västmanland	260	273	242	258	258	255	249	261 - 265
W Kopparberg	286	267	279	295	288	289	290	288 - 292
X Gävleborg	294	277	277	291	292	289	283	293 - 297
Y Västernorrland	268	251	261	268	267	265	259	270 - 274
Z Jämtland	135	117	133	137	136	136	136	136 - 139
AC Västerbotten	242	227	238	252	247	251	257	244 - 248
BD Norrbotten	267	240	269	274	267	266	262	267 - 272
TOTAL	8,303	8,499	8,115	8,449	8,362	8,381	8,365	8,333 - 8,460

development. In both scenarios, the growth counties are Stockholm, Uppsala, Skaraborg, Halland, and Kristianstad. Gothenburg and Malmö no longer belong to this category.

The four scenarios illustrate possible shifts in the future demographic development of the regions. The differences between the projections are substantial. There are, however, several prevailing trends.

1. Two counties, Uppsala and Halland, grow according to all four scenarios. Are these more 'robust' than the others? The growth of Halland may partially be explained by the outmigration from Gothenburg. Will

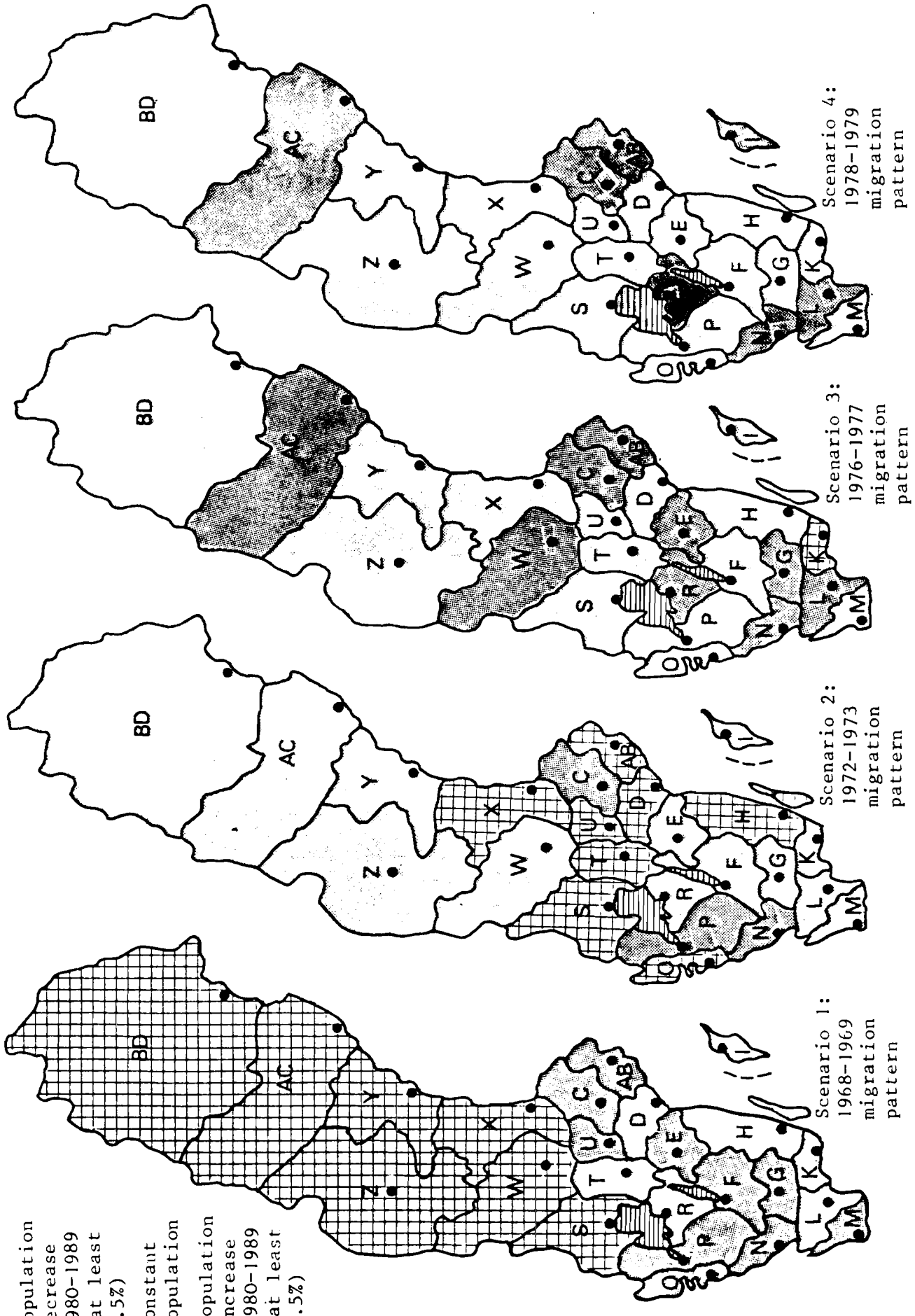


Figure 9. Four alternatives for county population development, 1980-1989.

this outmigration continue, granting to the north of Halland a steady increase?

2. Stockholm county also seems to be a stable growth region, except for a short period in the early 1970s. In all scenarios but the second it has the highest growth rate.

3. The two smaller metropolitan regions, Gothenburg and Malmö, no longer stand out as growth areas.

4. Towards the end of the 1970s internal migration declined. The counties generally maintained or increased their populations. Scenarios 3 and 4 to a great extent agree on future development paths. Has the regional development achieved a relative stability, which will be maintained into the 1980s?

4.3. A Comparison Between the Projections and the Goals of Regional Policy

Are the projections compatible with the goals of regional policy? Since 1972, parliament has set provisional population growth rates (a lower and a higher rate) for all countries and the latest revision was undertaken in 1980. We have compared these goals with the results of our calculations. The comparison, shown in Table 9, has revealed that a repetition of the 1968-1969 migration pattern (Scenario 1) would not fulfill the goals at all. None of the sparsely populated counties would reach the desired population level, while all metropolitan counties would exceed their limits. Scenarios 3 and 4, i.e. a continuation of the 1976-1979 course, would lead to an acceptable degree of fulfillment of the policy goals. Among the sparsely populated counties only Västerbotten and Gävleborg fail to achieve this goal. In the South, Västmanland shares the same fate and to some degree also Jönköping, Gothenburg-Bohus, and Malmöhus. Only one county, Älvsborg, exceeds the established goal in all scenarios.

4.4. Minor Population Changes in Skåne

Many people still associate Skåne and the Malmöhus region with rapid population growth and a labor market characterized by

high demand. This, however, is no longer valid. Figures 10 and 11 show that the population of Skåne increased by 33,000 during the first half of the 1970s and by only 15,000 during the second half. Southwest Skåne is totally responsible for the decline. Our scenarios outlined below set the stage for the 1980s and the 1990s (see also Table 10).

In Scenario 1 the Skåne population increases by 60,000 in the 1980s and by 49,000 in the 1990s. The growth accrues mainly to Southwest Skåne, while the rest of Malmöhus and Kristianstad counties receive minor shares.

In Scenarios 2, 3, and 4 the Skåne population remains almost constant. An increase of several thousands in the first decade is followed by an equivalent decrease in the second decade. The distribution among the counties hardly changes. The trend, however, is clear: decline in Southwest Skåne, maintenance of the current situation in the rest of Malmöhus, increase in Kristianstad. The second picture appears at the moment to be the most probable one. The current employment and population statistics suggest that Skåne in the near future will maintain its current population of 1,025,000. The question is whether the redistribution of the population as indicated by Scenarios 2, 3, and 4 is likely to take place. It depends on whether there is a continuous increase in long-distance commuting from Southwest Skåne to the rest of Malmöhus county and from Northwest Skåne to Kristianstad county. The rapidly rising transportation costs might make the location of residential areas at great distances from workplaces infeasible, as was the case from 1960 to 1980.

4.5. More Adults But Fewer Children

The age structure of the population (Table 11) differs little between the alternatives, at least in the short run. In the longer term the different migration patterns will influence the age composition markedly.

There is a clear tendency that the number of young persons will decrease up to the turn of the century. On the other hand it is likely that the number of persons of productive ages will increase leading to a growing labor supply. The productive age

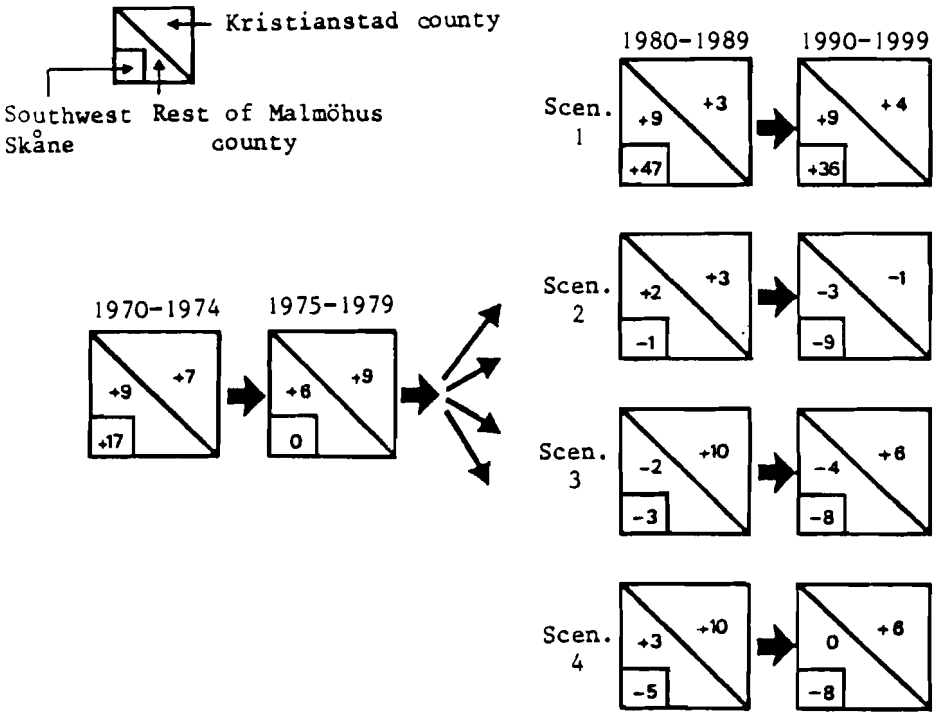


Figure 10. Population changes in Skåne (in 1,000s).

Table 10. A comparison of the projections over the long term.

Year	Population (in 1,000s)			
	Skåne	Kristianstad county	Malmöhus county	SSK
1979	1,023	279	744	453
Scenario 1 1989	1,081	282	799	500
1999	1,128	284	844	536
Scenario 2 1989	1,026	282	744	452
1999	1,013	281	732	443
Scenario 3 1989	1,027	289	738	450
1999	1,021	295	726	442
Scenario 4 1989	1,030	289	741	448
1999	1,028	295	733	440

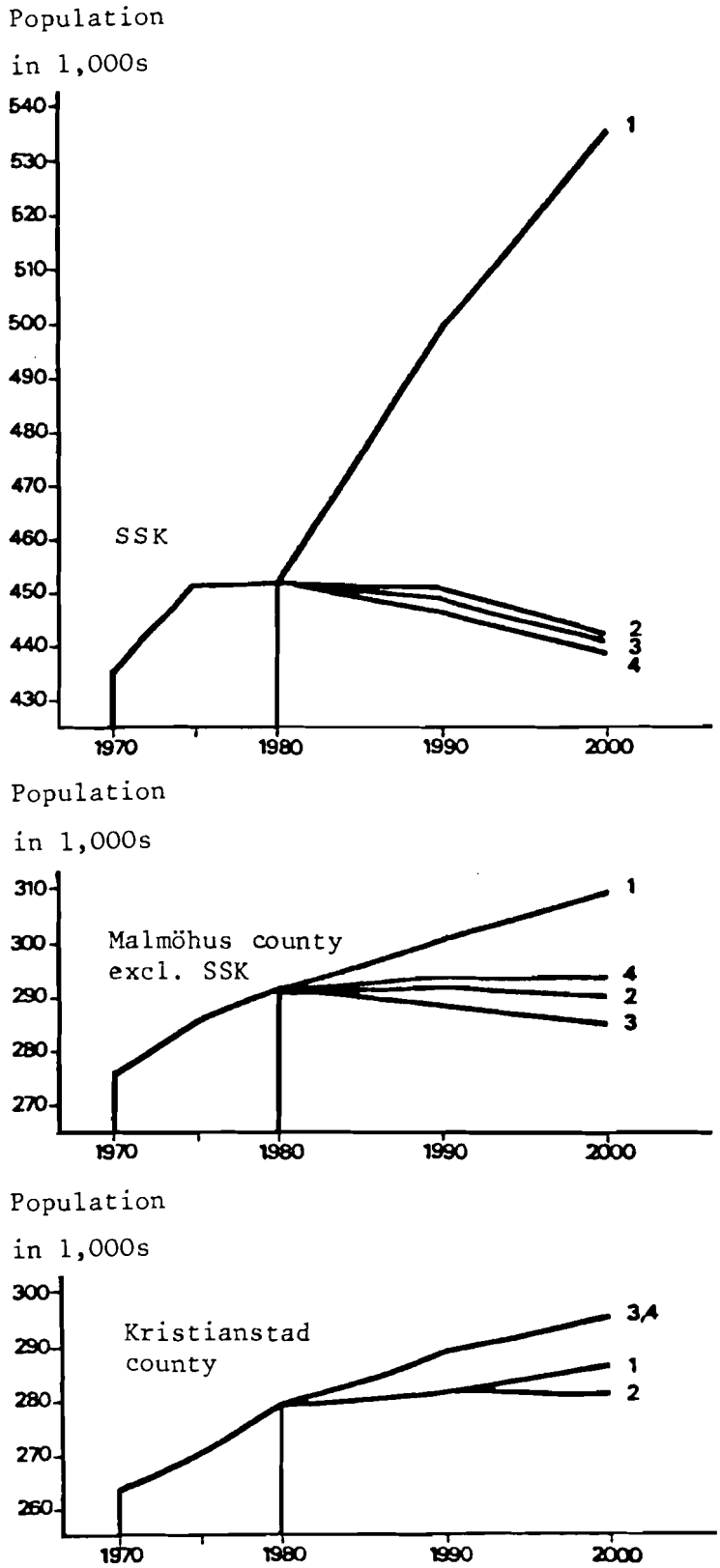


Figure 11. Population of Skåne, 1970-2000: development according to different alternatives.

Table 11. Age-group composition, 1980-2000, according to Scenario 4.

Age group		SSK		Rest of Skåne		The nation	
		Pop. size	% of total pop.	Pop. size	% of total pop.	Pop. size	% of total pop.
0-19 years	1980	116,000	26	152,000	27	2,220,000	27
	1990	102,000	23	143,000	25	2,001,000	24
	2000	94,000	21	139,000	24	1,895,000	23
20-64 years	1980	268,000	59	315,000	55	4,757,000	57
	1990	268,000	60	329,000	56	4,908,000	59
	2000	271,000	62	345,000	59	5,094,000	61
65+ years	1980	70,000	15	102,000	18	1,345,000	16
	1990	78,000	17	110,000	19	1,472,000	18
	2000	75,000	17	104,000	18	1,376,000	16
Total population	1980	453,000		569,000		8,302,000	
	1990	452,000		574,000		8,115,000	
	2000	443,000		570,000		7,825,000	

group will remain constant only if there is large emigration (as in Scenario 2).

The number of old persons, aged 65 years or more, will increase during the 1980s. The growth will take place in the higher age groups, and this will increase the demand for welfare services for the elderly. There are currently 525,000 persons over 75 years of age. The number will increase to 650,000 in 1990 and to 670,000 in the year 2000. The number of pensioners aged 65-75 years may be expected to remain constant at around 820,000 persons in 1990 and then to fall to approximately 705,000 at the turn of the century.

Today Southwest Skåne has approximately the same age composition as the national average. The number of persons in the age groups between 20-64 years is somewhat above the national average, while the proportion of young people and the proportion of pensioners is somewhat below that average.

The age structure will develop along with the national average during the period 1980-2000. The tendency towards an aging population is clear, especially in Scenarios 3 and 4 (Figure 12). If the present net outmigration from Southwest Skåne continues, the proportion of young persons will diminish more rapidly than at the national level. The proportion of pensioners, on the other hand, will grow more rapidly so that it will exceed that of the national average in twenty years from now.

5. LABOR-SUPPLY CALCULATIONS

5.1. General Comments

The calculations of the future development of the regional population reported here are based on the assumption that certain influences will not change. They show what would happen if the historical development of four 2-year periods were to continue their course in an otherwise unchanging environment. The most essential external influence is probably labor demand. If the labor supply and demand do not balance, in the long run various adaptive mechanisms become operative. Either the demand or the supply, or both, will be subjected to modification. The operation might include directing the development of Skåne on a course that is different from any of those indicated by our scenarios.

The matching of labor supply with labor demand, or vice versa, may be described as follows. Basically, labor demand manifests itself as a need for the factor 'labor' in the manufacturing production process and in private and public service production. Usually, the demand is measured by the working hours required in each sector. Work must obviously be carried out at existing workplaces. Demand is then compared with supply. The labor force may be characterized in various ways, for example with regard to domicile, occupation, education, and age.

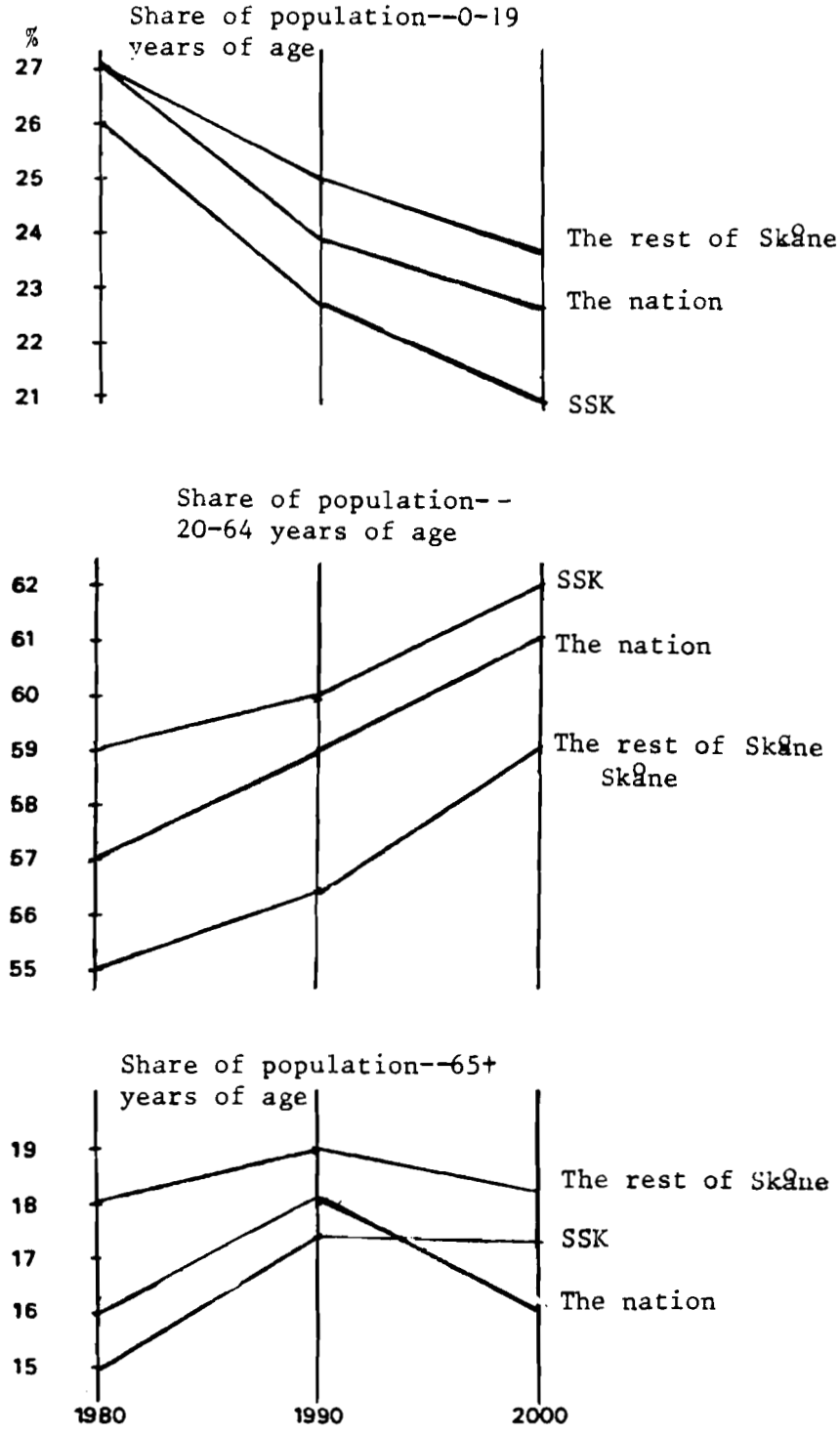
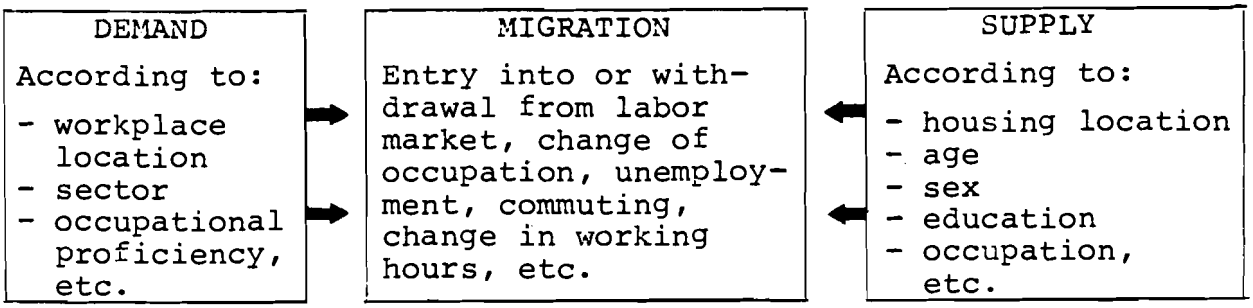


Figure 12. Age composition, 1980-2000: development according to Scenario 4.

The matching of demand with supply (or supply with demand) can take place in many different ways:



These adaptive mechanisms have various associated costs for firms and individuals as well as for the public sector. The level of the cost naturally influences the frequency and efficiency of the particular type of modification. Commuting, for example, allows the individual to retain his/her place of residence or work at the cost of spending more time and/or money on transportation. At the other end of the scale, moving for the individual or the household brings about high immediate costs, which, however, might be outweighed by a better chance to earn a higher wage in the long run. According to neoclassical economic theory, wage differences are one of the main arguments for labor-force moves from one local labor market to another. Adaptation by means of a shorter working day, shift work, part-time or overtime work are other important mechanisms. For example, an increase in part-time work increases total employment more than the equivalent increase in full-time work, at a given labor demand measured as indicated above. Since firms and administrations, because of the raised level of education, 'anti-dismissal laws', etc. have begun to regard labor as a capacity variable similar to capital, unemployment has to some extent lost its role as the most important indicator of structural imbalance in the labor market. Recent economic developments have shown that entries into and withdrawals from the labor market have to some degree taken over the role of registered unemployment. This new system contains:

-- regular programs of further occupational training (such as those run by the Swedish Labor Market Board);

-- special measures to facilitate the entry into the labor market for the young; and
-- early retirement.

Even if the education variable for the labor force already on the market is formally constant, a considerable number of changes in occupation do occur in the course of time. The changes might be caused by career-making, the expansion of certain tasks in industry or administration (i.e. an effect of demand), or the stagnation of certain occupations. Even in an expanding market, the competition aspect is essential when estimating the extent of changes in occupation.

To depict in a credible way the probable outcome of structural imbalance in the labor market, one would have to discuss the relative weight of each of the adaptive mechanisms. An accepted method for practical purposes is to calculate from the gross labor supply, the supply of hours-of-work available to the market (for example during one year), after having made exogenous assumptions on working hours, absenteeism, etc.

Another method is to reverse the process and calculate from the labor demand, as measured by required working hours in the total economy during one year, the number of persons likely to be required for accomplishing the work. This method is naturally supplemented by a demographically oriented age- and sex-specific analysis of the historical participation rates among the active population. After these preliminary calculations, the homogeneous labor supply (the above calculations determine the total participation rate) is measured against the labor demand of each sector; both are measured by number of persons--in principle, man-years. Thus, migration, commuting, and unemployment changes become mechanisms by which supply and demand are balanced. Below, we report on calculations of the effective labor supply in Skåne, based upon information on participation rates and working hours. The calculations result from various applications of the model. These calculations complete the description of some possible scenarios for the demographic development in Skåne.

5.2. Results

This section describes the national labor supply indicated by the four scenarios (Table 12 and Figure 13). The estimates are based upon the already accounted-for population projections and also on assumptions of the future participation rates in each county. The assumed participation rates were supplied in 1980 by the 24 county boards through the Umeå Computer Center. The participation rates vary from county to county and reflect the way in which each county board judges the local situation.

Table 12. Labor supply in Sweden, part-time and full-time labor (in 1,000s).

Year \ Scenario	Labor supply 1	2	3	4
1980	3,955	3,955	3,955	3,955
1990	4,284	4,051	4,254	4,216
2000	4,521	4,040	4,461	4,378

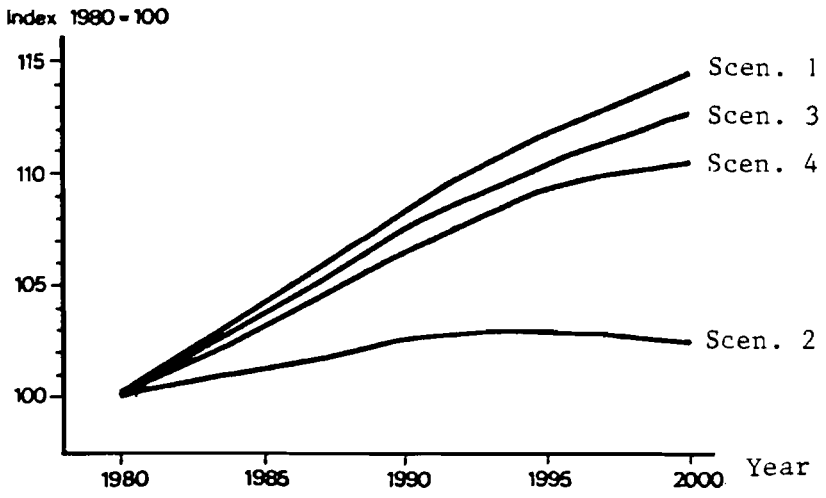


Figure 13. Labor supply in Sweden: number of persons working part-time or full-time.

The labor supply increases according to all scenarios, even to Scenario 2 in which a declining population is indicated. The reason is that the county boards believe female participation rates will rise. Scenarios 3 and 4 indicate an increase in the labor supply by some 7 percent in the 1980s and some 5 percent in the 1990s. This would mean a net addition of 25,000 'wage earners' per year for the nation. The situation of each county is shown in Table 13 and Figure 14.

Scenario 1 is geographically homogeneous. The supply of labor decreases in all of the Norrland counties. In Gotland it increases slightly (less than 5 percent up to 1990), while there is almost no

Table 13. The labor supply according to different scenarios: participation rates according to forecasts of the county boards, 1980 (in 1,000s).

County	1979	Change 1980-1989 Scen. 1	Scen. 2	Scen. 3	Scen. 4	Change 1990-1999 Scen. 4
AB Stockholm	790	105	- 10	74	62	41
C Uppsala	113	14	13	19	19	17
D Södermanland	118	9	2	7	7	2
E Östergötland	188	29	10	22	15	10
F Jönköping	146	17	5	7	4	1
G Kronoberg	78	8	2	6	5	4
H Kalmar	110	6	0	6	5	4
I Gotland	26	1	1	2	2	2
K Blekinge	70	5	4	1	2	1
L Kristianstad	130	9	8	12	12	7
M Malmöhus	365	51	17	14	17	5
N Halland	109	21	20	18	16	10
O Gbg, Bohus	337	32	-15	11	10	6
P Älvsborg	202	26	19	18	16	9
R Skaraborg	126	7	10	13	13	12
S Värmland	130	0	0	8	7	6
T Örebro	128	9	-1	8	7	2
U Västmanland	123	13	4	6	4	1
W Kopparberg	129	- 4	2	11	8	6
X Gävleborg	132	- 3	-3	5	4	6
Y Västernorrland	120	- 3	2	6	4	1
Z Jämtland	59	- 5	4	6	6	3
AC Västerbotten	110	- 3	3	11	11	8
BD Norrbotten	118	- 7	8	11	6	4
TOTAL	3,955	330	96	299	261	162

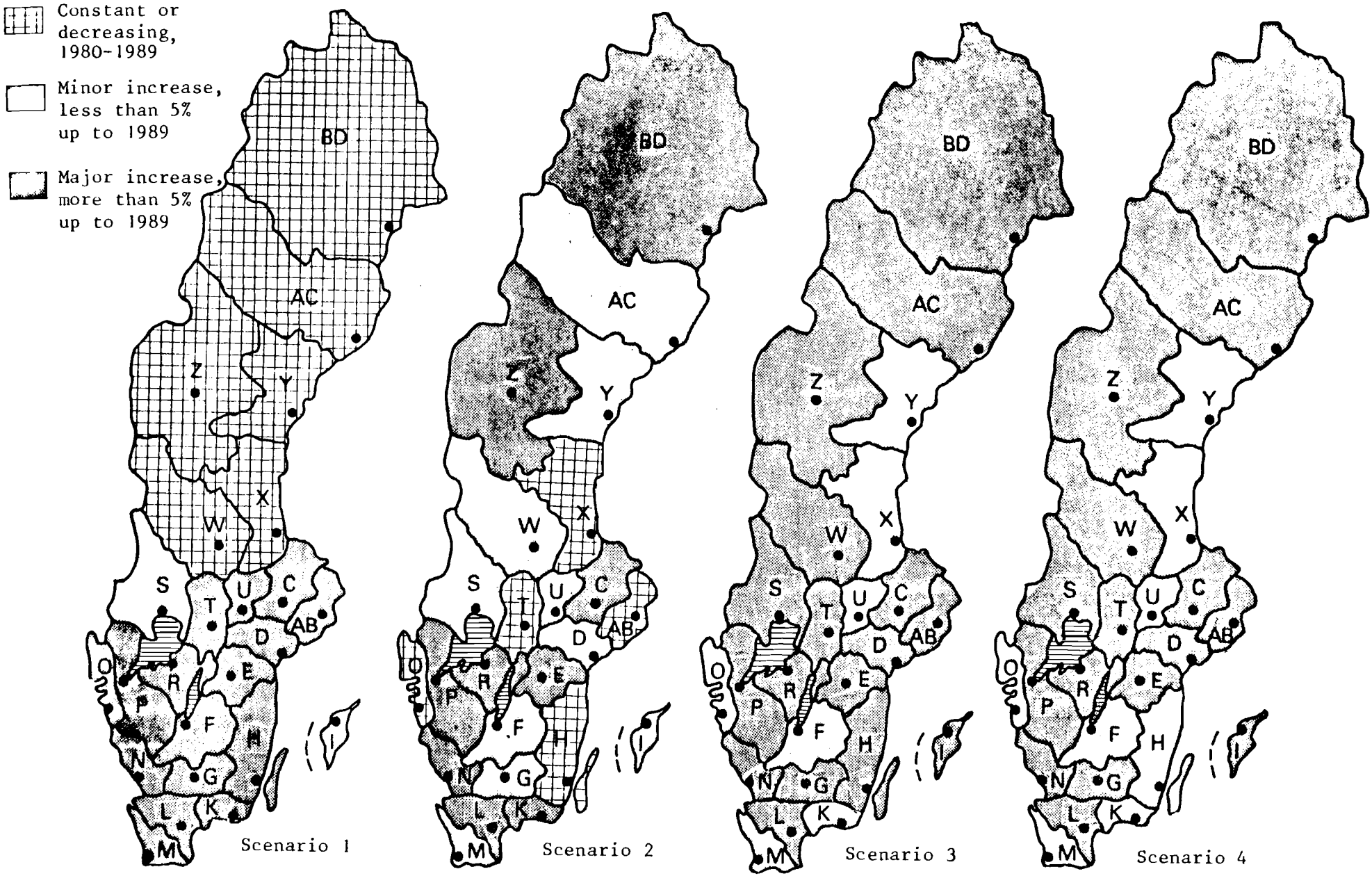


Figure 14. Labor-supply changes, 1980-1989.

change in Värmland. In all other southern and central counties it increases considerably (more than 5 percent).

The Scenario 2 projection depicts a regionally split alternative. The labor supply is expected to decrease in the Stockholm and Gothenburg-Bohus counties, but also in Örebro and Gävleborg. All other counties increase.

Scenarios 3 and 4 result in almost identical projections and can be joined to form one scenario, which indicates labor-supply growth in all counties. The majority increase by more than 5 percent in the 1980s, but Gothenburg-Bohus, Malmöhus, Blekinge, Kalmar, Jönköping, Västmanland, Gävleborg, and Västernorrland belong to the moderately growing category (less than 5 percent).

Table 14 gives an impression of the labor supply in Skåne based on the results of the scenarios. The first scenario indicates an addition of some 60,000 wage earners in the 1980s. The majority go to Southwest Skåne. The three other scenarios foresee approximately 25,000-30,000 new labor-market participants in Skåne. The distribution among the counties is fairly even, if measured by the number of persons. Relative to the total population of Southwest Skåne, growth there is modest and smaller than in the other regions.

Table 14. Short-term labor-supply development according to the four scenarios, 1980-1989 (in 1,000s).

	SSK	The rest of Malmöhus county	Kristian-stad county	Skåne total
Total labor supply in 1980	226	139	130	495
Changes 1980-1989:				
Scenario 1	39	12	9	60
Scenario 2	10	8	8	26
Scenario 3	9	6	12	27
Scenario 4	8	9	12	29

6. WHY DID WE CHOOSE THESE FOUR ALTERNATIVES?

Our purpose was to depict alternative scenarios for regional demographic development in Sweden. The basic data for the projections were obtained from development courses registered during the past 15 years, from which we chose four interesting periods: 1968-1969, 1972-1973, 1976-1977, and 1978-1979. These periods differ with regard to economic growth, investments, labor demand, housing construction, etc. These four economic situations result in four different patterns of internal migration and in varying levels of external migration.

APPENDIX A: REGIONAL STABLE POPULATION MODELS

The stable population theory was introduced in a paper by Lotka (1907). In this paper, Lotka showed what would happen in the long run to a population closed to external migration and with constant mortality and fertility. He demonstrated that, given these conditions, constant growth and a stable age distribution would result. Furthermore, the final age distribution would be determined by mortality and fertility alone; hence, it would be independent of the original age distribution. The stable population model is based on the following basic assumptions:

1. The population is closed; i.e. no external migration occurs.
2. The demographic process develops independently for men and women.
3. There exists a probability $p(a)$ that a new-born girl survives until age a. $p(a)$ is a continuous function of age a; independent of time t; and positive within the age interval $0 \leq a \leq w$.
4. There exists a probability $m(a)\Delta a$ that a new-born girl, who is alive at age a, will give birth to a female child within the age interval a, $a + \Delta a$. $m(a)$ is a continuous function of age a; independent of time t; and positive for all ages within the closed interval $0 \leq a \leq \alpha \leq \beta < w$ and zero outside the interval. Functions 3 and 4 are normally combined to form the net maternity function $\phi(a)$.

The analysis begins at an arbitrary time ($t = 0$). The number of births t years later $B(t)$ can be divided into two parts:

-- those born to women alive at time $t = 0$, $G(t)$;

-- those born to women who themselves were born after time 0:

$$B(t) = G(t) + \int_0^t B(t - a)\phi(a)\,da, \quad t < \beta \quad . \tag{1}$$

The solution to this equation indicates that the number of births at each time interval plays an important role in the stable population theory.

A common method of solving the integral equation is to specify a particular solution of the type:

$$B(t) = e^{rt} \text{ for } t < \beta \quad . \tag{2}$$

After reduction, the substitution into (1) gives:

$$1 = \int_{\alpha}^{\beta} e^{-ra} \phi(a)\, da \quad , \tag{3}$$

since $t \leq \beta$, $e^{rt} > 0$ and $\phi(a)$ disappear outside the interval $[\alpha,\beta]$.

Equation (3) is usually considered to be the fundamental equation of the stable population theory. There are many ways, both analytical and numerical, in which it can be solved. The analytical type of method is based upon inserting a specific function for $\phi(a)$, for example a normal distribution or a type-III distribution. For a numerical solution, the integral is substituted by a discrete sum. The equation has an infinite number of solutions r_i of which the first, r_1, is dominant and real. It also indicates the population growth after stability has been reached.

In the early 1940s a discrete model of the Lotka type was formulated by Bernadelli (1941). This model was further developed by Leslie (1945) and the two American demographers Nathan Keyfitz and Ansley Coale worked with this model formulation during the 1960s and 1970s.

Let P(t) be a population distribution at time t and M(t) a matrix containing survival and fertility rates, sometimes called the Leslie matrix. At this point, the analysis can be focused on the characteristics of matrix M. We then have the following relation:

$$P(t + n) = M^n(t)P(t) \quad . \tag{4a}$$

If M(t) is independent of t, we obtain the simpler relation:

$$P(t + n) = M^nP(t) \quad . \tag{4b}$$

To find the characteristics of M, we have to solve the linear equation system:

$$\lambda P = MP \quad , \tag{5a}$$

or the eigenvalue problem:

$$[M - \lambda I] = 0 \quad . \tag{5b}$$

The parameters λ and r in (3) are related as follows:

$$\lambda = e^{nr} \quad . \tag{6}$$

The original model was formulated for one population, which was closed to external migration. Recently, an analogous model formulation for a multiregional system has been developed, mainly by Andrei Rogers of the Human Settlements and Services Area at IIASA. The starting point has been the discrete formulation described above.

The general expression of the multiregional growth process is:

$$K(t + n) = GK(t) \quad , \tag{7}$$

where K is the age and regional distribution of the population at time t, and G is the multiregional matrix growth operator or the generalized Leslie matrix. The vector K, and hence the matrix G, can be given two alternative formulations, but we will describe one only.

If we adopt five-year age groups and five-year projection intervals, the vector K can be divided into the subvectors $K^t(0)$, $K^t(5)$.... These give the regional distribution of each five-year age group. The growth matrix G must be formulated as follows:

$$G = \begin{bmatrix} 0 & 0 & B(\alpha-5) & \ldots\ldots & B(\beta-5) & \ldots\ldots & 0 & 0 \\ S(0) & 0 & \ldots & & \ldots & & 0 & 0 \\ 0 & S(5) & \ldots & & \ldots & & 0 & 0 \\ 0 & 0 & S(10) & \ldots & \ldots & & 0 & 0 \\ . & . & \ldots & & \ldots & & . & . \\ . & . & \ldots & & \ldots & & . & . \\ . & . & \ldots & & \ldots & & . & . \\ . & . & \ldots & & \ldots & & . & . \\ 0 & 0 & \ldots & & \ldots & S(z-5) & 0 & \end{bmatrix} \qquad (8)$$

The matrix G thus contains a number of submatrices, each representing the regional migration and survival rates of a given age group. As an example we chose a system consisting of two regions. We then get the following survival rates for an arbitrary age x:

$$S(x) = \begin{bmatrix} s_{11}(x) & s_{21}(x) \\ s_{12}(x) & s_{22}(x) \end{bmatrix} , \qquad (9)$$

where $s_{ij}(x)$ is the proportion of x- to (x + 4)-year-old residents of region i who are alive among (x + 5)- to (x + 9)-year-olds in region j at time t + 5.

We obtain an estimate of S(x) from the following expression:

$$S(x) = [I + P(x + 5)]P(x)[I + P(x)]^{-1} , \qquad (10)$$

where P(x) are probabilities of survival. For the second last age group, we obtain a slightly different expression:

$$S(z - 5) = \frac{2}{5}M^{-1}(z)P(z - 5)[I + P(z - 5)]^{-1} \quad , \qquad (11)$$

where M is a matrix of age-specific ratio.

The first row of G is composed of submatrices B(x):

$$B(x) = \begin{bmatrix} b_{11}(x) & b_{21}(x) \\ b_{12}(x) & b_{22}(x) \end{bmatrix} \quad , \qquad (12)$$

where $b_{ij}(x)$ is the number of children born during the projection interval and alive in region j at the end of that interval, per x- to (x + 4)-year-old residents of region i at the beginning of that interval.

The following expression provides an estimation of B:

$$B(x) = \frac{5}{4}[P(0) + I][F(x) + F(x + 5)S(x)] \quad , \qquad (13)$$

where F(x) is a matrix of fertility rates.

The data used for model applications are an observed population at a certain time as distributed among regions and age groups, plus observed age-specific mortality, fertility, and outmigration rates specified in the same way.

Mortality and outmigration probabilities are computed from observed age-specific rates. If multiple transitions are allowed, the probabilities may be estimated in the following way:

$$M(x) = \begin{bmatrix} m_{1\delta}(x) + \sum_{j \neq 1} m_{1j}(x) & -m_{21}(x) & \cdots & -m_{n1}(x) \\ -m_{12}(x) & m_{2\delta}(x) + \sum_{j \neq 2} m_{2j}(x) & & -m_{n2}(x) \\ \vdots & \vdots & & \vdots \\ -m_{1n}(x) & -m_{2n}(x) & \cdots & [m_{n\delta}(x) + \sum_{n \neq j} m_{nj}(x)] \end{bmatrix} \qquad (14)$$

where $m_{i\delta}(x)$ is the age-specific mortality rate of region i, and $m_{ji}(x)$ is the age-specific outmigration rate from region i to region j. The probability matrix P(x) is then the result of:

$$P(x) = [I + \tfrac{5}{2}M(x)]^{-1} [I - \tfrac{5}{2}M(x)] \quad . \tag{15}$$

For our two-region model we obtain:

$$P(x) = \begin{bmatrix} p_{11}(x) & p_{21}(x) \\ p_{12}(x) & p_{22}(x) \end{bmatrix} \quad , \tag{16}$$

where $p_{ij}(x)$ is the probability that a certain individual in region i at the exact age x will survive and will be in region j five years later. The off-diagonal elements are transition probabilities analogous to those in Markov theory. The diagonal elements $p_{ii}(x)$ denote the probabilities of survival and of remaining in region i. The elements of each column do not add up to 1, since the effect of mortality is considered. Hence, P(x) is analogous to the transition matrix in an absorbing Markov chain.

APPENDIX B: MODEL APPLICATIONS

The original IIASA model was designed for a regional system consisting of a maximum of 12 regions. The model was extended for use on Swedish data. Twenty-six regions have been used for the computations reported in this paper. These are the 24 counties, together with Malmöhus county divided into Southwest Skåne and 'the rest', plus 'other nations'.

The introduction of a region consisting of all foreign nations nations means that the model is no longer closed. Therefore, conclusions valid for the regional stable population model have in this case approximate validity only.

For the calculations, the population has been divided into 18 five-year age groups. The last age group includes all ages over 84. The population projection has been based on formula (7). The vector K contains 18 subvectors with 26 elements each. The matrix M contains 17 submatrices of type S (each 26 by 26), 8 submatrices of type B (also 26 by 26).

Projection of the population according to (7) means, in reality, calculation by the component method, which is the usual method for population projections. If the projections are carried very far into the future a stable distribution of the population among regions and ages will evolve. The solution to the eigenvalue problem (5b) gives the growth rate of this population. The pertaining eigenvector gives the stable population distribution.

In the numerical calculations a sequential projection of the population was used. In principle, that implied the use of the so-called power method for solving eigenvalue problems. By sequential projections, we will successively quadruple matrix G. After n steps we obtain the relation:

$$\lambda(n) = \frac{(g_{11})^{2n+1}}{(g_{11})^{2n}} \quad , \tag{17}$$

where $(g_{11})^{2n+1}$ is an element of G^{2n+1} and $(g_{11})^{2n}$ is an element of G^{2n}. When n grows, $\lambda(n)$ will approach the true eigenvalue. Calculations terminate when:

$$\frac{(g_{12})^{2n+1}}{(g_{11})^{2n+1}} - \frac{(g_{12})^{2n}}{(g_{11})^{2n}} < \varepsilon \quad , \tag{18}$$

where $\varepsilon = 10^{-7}$.

The eigenvector pertaining to each eigenvalue λ is proportional to each row of G^k for large values of k. In the computations the first row of G^k has been assumed to be the eigenvector, normed to add up to 1.

REFERENCES

Bernadelli, A. 1941. Population waves. Journal of Burma Research Society 31: 1-18.

Central Bureau of Statistics. 1978. Information i Prognos-frågor (Forecasting Information) 6. Stockholm.

Leslie, P.H. 1945. On the use of matrices in certain population mathematics. Biometrika 33: 183-212.

Lotka, A.J. 1907. Studies on the mode of growth of material aggregates. American Journal of Science 24: 199-216.

SDS. 1975. Statistisk Årsbok (Statistical Yearbook), 1920-1975.