Abstract
Population projections serve as important information for regional planning. Most projection models are based on estimates of future fertility-, mortality- and migration rates. In general the migration rates are the most difficult to predict. In this paper we give a brief description of the projection model used for the County of Stockholm 2001-2010 and a more detailed description of the prediction of the domestic migration rates.
The model is a multiregional cohort-component model where Sweden is divided into two regions: Stockholm and the rest of Sweden. Migration is estimated by using age/gender/region specific migration rates. Moreover, we adjust migration rates depending on the period of time an individual has lived in the region. An empirical fact – incorporated into the model - is that migration rates are higher the first years after moving to a new region. The model does not explicitly take any external factors such as unemployment rates or other economic factors into account. However, subjective adjustments based on the predicted changes in the housing stock are made. In the short perspective the migration rates are mainly predicted based on recent demographic trends but for the longer horizon the rates are adjusted based on predicted changes in the housing stock in Stockholm.
1. Introduction

Population projections serve as important information for regional planning in major urban areas. In general, migration is the most difficult component to predict. Internal migration can be modelled in detail. Some models use net migration while other utilise detailed age/gender/location specific migration rates. Another important issue is to what extent a projection should be based on historical demographic trends or modelled as a function of other explanatory variables. Even if the association between non-demographic factors and migration patterns were known, external variables should only be employed in projection models if these variables themselves can be predicted with a high level of accuracy. The choice of projection model has to be made with many different perspectives in mind. Some important aspects to consider are availability of data, projection horizon, restricting factors such as time and costs, simplicity vs. complexity etc.

In this paper we describe how migration rates for the County of Stockholm (henceforth called Stockholm) are predicted for 2001-2010. In section 2 we give a brief overview of the projection model. In section 3 the modelling of domestic migration is presented. In section 4 the projection of the foreign migration is described. The paper ends with a discussion in section 5. The results presented in this paper is a summary of some of the findings in the work of projecting the population of Stockholm for 2001-2010. All data presented is based on data from Statistics Sweden.

2. The projection model

The model is based on the cohort-component method. The population increases with the number of children born and with the number of in-migrants. The population decreases with the number of deceased and with the number of out-migrants. The projection is based on detailed statistics of fertility, mortality and migration to and from Stockholm. The projected population is largely determined using age-specific rates, e.g. fertility- and mortality rates. Figure 1 gives an overview of the model.
Figure 1, An overview of the projection model.

![Diagram of the projection model]

The different components in the model are calculated for the County of Stockholm as follows:

**Table 1, Estimation of the different components in the projection model.**

<table>
<thead>
<tr>
<th>Component</th>
<th>Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of born</td>
<td>Fertility rates by age.</td>
</tr>
<tr>
<td>No. of deceased</td>
<td>Mortality rates by age and gender.</td>
</tr>
<tr>
<td>No. of domestic in-migrants</td>
<td>Migration rates by age, gender, residence and duration of residence.</td>
</tr>
<tr>
<td>No. of domestic out-migrants</td>
<td>Migration rates by age, gender, residence and duration of residence.</td>
</tr>
<tr>
<td>No. of foreign in-migrants</td>
<td>Historical shares applied to a national forecast by Statistics Sweden</td>
</tr>
<tr>
<td>No. of foreign out-migrants</td>
<td>Historical shares applied to a national forecast by Statistics Sweden</td>
</tr>
</tbody>
</table>

An important characteristic of the model is that the age specific migration rates are adjusted depending on the period of time a person has lived in the region. Hence, the populations in Stockholm and the rest of Sweden are divided into subpopulations.
depending on the duration of residence. The projection of fertility- and mortality rates do essentially follow the predicted changes at the national level produced by Statistics Sweden.

3. Domestic migration

The in- and out-migration has shown changing patterns over the last decades. In figure 2 the number of domestic in- and out-migrants are presented.

*Figure 2, Domestic in- and out-migration to and from Stockholm.*

The domestic migration are projected for the next ten years based on the following principles:

a) The number of migrants in the short perspective (1-2 years) is mainly determined by using recent demographic trends (mainly trend based).

b) The number of migrants in the long perspective is based on a combination of predicted changes in the housing stock and demographic trends (mainly dwelling based).
c) The age distribution of the migrants is estimated by using historical age/gender/region specific migration rates.

d) The overall level of the rates are adjusted to correspond to the total numbers determined above \((a \text{ and } b)\).

e) The level of the migration rates depends on the duration of stay in the region. The longer a person has lived in a specific region the lower the migration rate.

### 3.1 Number of migrants in the short perspective

The number of in-migrants to Stockholm follows a rather regular seasonal pattern. In figure 3 the number of in-migrants per quarter is illustrated.

*Figure 3, Number of domestic in-migrants to Stockholm per quarter (1997:1-2001:2)*

The prediction of the last two quarters of 2001 is solely based on the most recent demographic trend. The prediction utilises the ratio between the migration during the two first quarters of a year in relation to the total migration for a year. This ratio \((k)\) is estimated by using the last three years, see equation (1).
where \( x_{i,j} \) is the number of events (number of in- or out-migrants) of year \( i \), quarter \( j \). \( K \) represents the average ratio of the yearly migration generated from the first two quarters of the year in relation to the total migration over a year. The total number of events for 2001 (\( \hat{x}_{2001} \)) is estimated in equation (2):

\[
\hat{x}_{2001} = \frac{(x_{2001,1} + x_{2001,2})}{k}
\] (2)

### 3.2 Number of migrants in the long perspective

There are several factors believed to affect migration patterns, unemployment rates, the business cycle, political decisions, interest rates, etc. However, despite a large amount of research, it is still debatable to what extent and how migration rates are causally related to other non-demographic factors. Moreover, these non-demographic factors are themselves often more difficult to predict than the migration itself. In figure 4 we show an index series for the population of Stockholm and the day-time population, i.e. the people who are economically active within the County regardless of where they live.
While the population of Stockholm has grown at a steady state, the day-time population has shown a distinctly different pattern. This is an illustration of the difficulty of connecting a region's population growth to an aspect of the economic development in the region. In our analyses of data for Stockholm, the only strong relationship occurs between changes in the housing stock and population growth.

In figure 5 we illustrate the association between population growth for the municipalities in Stockholm and the number of new dwellings.
Based on these and similar findings we have decided only to take predicted changes in the housing stock into account in the projection model. The growth of the population is in large assumed to be proportional against the number of new dwellings. Each new dwelling is assumed to give room to approximately 2.1 new residents.

A slight increase in the out-migration rates is predicted during the period 2001 to 2003. From 2004 the out-migration rates returns to the level of year 2000. A heavy decrease in the in-migration rates is expected in the beginning of the period. An adjustment factor for the migration rates year 2001 is calculated so that the number of migrants agrees with the estimates from equation (2) above. Figure 2 indicates that the in-migration for 2001 displays a clear deviation from a regular pattern. The observed in-migration for the second quarter of 2001 is much lower compared to the historical pattern. This is one of the reasons for decreasing the in-migration rates in 2001.
3.3 Migration rates by age and gender

The age distribution of the migrants is derived by applying historical age/gender/region specific migration rates. The levels are adjusted to give the total number of migrants as derived in 3.1 and 3.2. However, the levels also depend on the duration of stay in the region. In figure 6 aggregated out-migration probabilities (for the first three years) are shown for in-migrants moving to Stockholm during the period 1991-1997.

*Figure 6, Proportion of in-migrants to Stockholm that out-migrate after 1,2 or 3 years.*

The graph shows that the proportion of in-migrants leaving is rather stable during the period. The proportion leaving after one year varies between 9-11%. The proportion of in-migrants leaving after 2 years is stable around 6% and during the third year around 4%. To use this information\(^3\) in the projection model, the populations of Stockholm and the rest of Sweden are divided into the following eight subpopulations depending on the duration of residence in the region.

\(^3\) We use more data for the proportion leaving the Stockholm than shown in the graph.
a) Long time residents (six years and more)
b) Migrated to Stockholm in year t
c) Migrated to Stockholm in year t-1
d) Migrated to Stockholm in year t-2
e) Migrated to Stockholm in year t-3
f) Migrated to Stockholm in year t-4
g) Migrated to Stockholm in year t-5
h) Migrated to Stockholm from abroad in year t,

where t denotes the current year.

This partition is motivated by the fact that the probability for an individual to migrate is highest in the first year after in-migration and then gradually decreases year by year. The lowest migration rates are found among the long time residents. The age specific migration rates for the subpopulations are calculated by proportional adjustment of the county level migration rates so that the number of migrants from each subpopulation matches the observed rates (comparison in 2000). The calculated migration rates are then used in the forecasts.

4. Foreign migration

The foreign migration is not modelled by age specific rates. Since people are migrating to Stockholm from the rest of the world, it is not feasible to apply age-specific rates to this population. Therefore, the foreign migration is derived from a forecast of the national migration to and from Sweden. The forecast is provided by Statistics Sweden.

4.1 Number of migrants in the long perspective

About one third of the foreign in-migrants to Sweden migrate to Stockholm. This pattern has been rather stable during the last years, see table 2.
Table 2, Historical shares (%) for Stockholm of foreign migration to and from Sweden.

<table>
<thead>
<tr>
<th>Year</th>
<th>Foreign in-migration to Stockholm as percent of national total</th>
<th>Foreign out-migration from Stockholm as percent of national total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>1998</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td>1999</td>
<td>34</td>
<td>33</td>
</tr>
<tr>
<td>2000</td>
<td>32</td>
<td>33</td>
</tr>
</tbody>
</table>

The projected number of foreign in- and out-migrants to Stockholm for 2003 – 2010 is calculated as one third of the projected migration to and from Sweden.

4.2 Number of migrants in the short perspective

For the last two quarters of 2001 the forecast is based on the observed migration of the first two quarters as described in the section 3.1 equation (1,2). Hence, the short term forecast is solely trend based. For 2002 the forecast is a function of both the national forecast produced by Statistics Sweden (see section 4.1) and the short term trend observed during the last quarters. To derive the forecast for 2002 we first calculate the difference (\( \Delta \)) between the national based forecast and the quarterly trend based forecast for 2001.

\[
\Delta = \frac{\hat{x}_{2001}^{(Sweden)}}{3} - \hat{x}_{2001}^{(Stockholm)}
\]

where \( \hat{x}_{2001}^{(Sweden)} \) is the national forecast produced by Statistics Sweden (section 4.1) and \( \hat{x}_{2001}^{(Stockholm)} \) is the forecast for Stockholm based on equation (1,2). Hence, \( \Delta \) measures the difference between the forecast based on the national prediction by Statistics Sweden and the forecast based on the two last quarters.

The forecast for 2002 is adjusted using the difference between the forecast of Statistics Sweden and the forecast based on observed quarterly data in 2001.
\[ \hat{x}_{2002} = \frac{\hat{x}_{2002}(Sweden)}{3} + (\hat{x}_{2001}(Stockholm) - \frac{\hat{x}_{2001}(Sweden)}{3}) = \frac{\hat{x}_{2002}(Sweden)}{3} - \Delta \]

The 2002 forecast includes half the estimated forecast error in 2001. For the period 2003 – 2010 the foreign migration is solely based on the national forecast by Statistics Sweden. The age distributions of the migrants are estimated using the observed age distributions from year 2000 (national or Stockholm depending on destination).

5. Discussion

In the year 2001 the net number of domestic migration to Stockholm reached 231 people, the lowest number in several years. Whether this should be considered a temporary decline or the beginning of a more long term change is of course an impossible task. However, in order to make an adequate prediction, understanding of the process under study and a suitable projection model is needed. In this paper we have focused on the prediction of the domestic migration rates. The projection model for the county of Stockholm for 2001-2010 is characterised by:

- In the short perspective the growth of the population is mainly estimated based on recent demographic trends.
- In a longer perspective the growth of the population is to a large extent estimated based on predicted changes in the housing stock.
- The age-specific migration rates depend on the duration of residence in the region, i.e. the longer a person has lived in the region the lower the migration rate.

This highlights two important features; a) the close association between the increase in the housing stock and the population growth and b) the increased risk of out-migration the first years after in-migration. Several other important factors have been considered in the development of the projection model. However, the model does not explicitly take any non-demographic factors into consideration, except changes in the housing stock. The main reason for this is that the association between other non-demographic factors and the
population growth is difficult to establish. Furthermore the prediction of these non-demographic factors is as difficult to predict as the migration rates themselves.

The shortage of dwellings and the increases in housing prices are making it more difficult for people to migrate to Stockholm. However, it’s most likely that the County of Stockholm will continue to grow, as well as the regions surrounding the County. These regions will gain importance as a place to live in while working in Stockholm. The number of people commuting to Stockholm from outside the County of Stockholm has increased from 64,000 year 1990 to 81,000 year 2000. It’s most likely that this number will continue to increase in the future.

To improve the projection model, attention has to be paid to the expansion of the Stockholm region in the larger Mälar region. One way to develop the model is to build a multiregional projection model where the rest of Sweden is divided into more than one region. However, independent of the technical aspects of the projection model, understanding of the migration patterns is of great importance. At the Office of Regional Planning and Urban Transportation in the County of Stockholm there are several ongoing projects striving to increase this understanding.

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