DREAM

Modeling Household Formation and Housing Demand in Denmark using the Dynamic Microsimulation Model SMILE

Jonas Zangenberg Hansen

and

Peter Stephensen

DREAM Conference Paper
4th General Conference of the International Microsimulation Association
December 2013

DREAM, Danish Rational Economic Agents Model. Amaliegade 44, 1256 København K
www.dreammodel.dk

4th General Conference of the International Microsimulation Association
Canberra, Wednesday 11th to Friday 13th December 2013

Modeling Household Formation and Housing Demand in Denmark using the Dynamic Microsimulation Model SMILE[1]

Jonas Zangenberg Hansen and Peter Stephensen
DREAM

Abstract

We utilize the newly developed dynamic microsimulation model SMILE[1] (Simulation Model for Individual Lifecycle Evaluation) to make a long-term forecast of detailed housing demand both in terms of key aggregate figures and compositional features of future Danish housing demand.

SMILE simulates the life course of the full Danish population with respect to three main types of events: demographic, socioeconomic, and housing-related events. Demographic events include ageing, births, deaths, migration, leaving home, and couple formation and dissolution – all of which are key *indirect* drivers of future housing demand.

Socioeconomic events such as education attendance and attainment, and labor market events are also important indirect drivers of housing demand because they are closely linked to the timing and direction of households' moving patterns. Finally, households move spatially and between dwelling types based on historically observed moving patterns and estimated transition probabilities by using the tree-based classification model.

The key results from the simulations are: changing patterns of cohabitation with a decreasing average household size is projected to increase the number of households by roughly one-third above what the general increase in population indicates. Increasing urbanization leads to an increasing demand for multi-dwelling houses. An ageing population is expected to pent-up the demand for smaller dwellings, especially rental housing.

Keywords: population projections, education, household projections, housing demand, microsimulation

---

[1] Financial support from the Knowledge Centre for Housing Economics, Realdania is gratefully acknowledged.

Modeling Household Formation and Housing Demand in Denmark using the Dynamic Microsimulation Model SMILE

1. Introduction

The global financial crisis has brought housing markets on the macroeconomic agenda. This focus has created an increasing interest in the long-term development in housing demand and its key drivers such as population growth, household formation and moving patterns. To address these issues, we utilize the newly developed dynamic microsimulation model SMILE (Simulation Model for Individual Lifecycle Evaluation) to make a long-term forecast of detailed housing demand both in terms of key aggregate figures and compositional features of future Danish housing demand.

Individual housing demand is determined by a number of economic factors. Empirical studies show disposable income to have a very large effect on a household's choice of housing. Additional variables affecting the choice of housing include the interest rate, the price of existing housing, household wealth and the level of inflation.

Aggregate housing demand is to a larger extent determined by demographics. The size and age distribution of the population, the cohabitation pattern and the educational background of the population are examples of factors with a large influence on the long-run demand for housing. As an example, an increase in the number of elderly people will result in an increase in demand for types of housing suitable for the elderly. Likewise, an increase in the number of students will cause an increase in demand for housing suitable for students, this demand typically being for smaller apartments in larger urban areas.

In the very short run, the supply of housing is fixed at the level of the existing housing stock. Consequently, a change in demand will reveal itself through price changes in the market for privately owned housing and through the length of waiting lists or the level of rents in the market for rented housing. In the longer run, the supply of housing will adjust to demand through construction of new housing or demolition of existing housing.

The long-term evolution of housing demand will ultimately determine the size of the housing stock and hence yield an indication of the future need for construction of new housing. Forecasting the evolution of demand for different types of housing is very useful as the supply side in this market is slow moving since planning and building are lengthy processes.

To forecast the demand for housing we use the dynamic microsimulation model SMILE, which models events and behavior with basis in an initial population and housing stock of 2010 plus transition probabilities calculated based on of historical data. The data consists of registry data on an annual basis for the full population of people and housing in Denmark. The model consists of a demographic module and a housing module.

The demographic module predicts the household structure of the Danish population one year at a time. Persons and families are exposed to a series of possible simulated events. These events include fundamental demographic events (i.e. number of births, number of deaths, migration, change of citizenship, the formation of couples, the break-up of couples and the event of a child leaving the parental home), as well as socioeconomic events (i.e. education and labor status). The events are simulated on the basis of exogenous transition probabilities in the period of 2008–10.

In the housing module, the demand is projected on the basis of the household structure. Housing supply is not included. The housing demand constitutes the number of dwellings, which the households is willing to purchase or rent at the existing prices. The household's housing behavior is illustrated through housing-related events, i.e. by movements between dwellings and a choice of dwelling the household moves to. The microsimulation model is used to simulate the behavior based on transitional probabilities, which is included exogenously in the 2000–10 period and is split in probabilities between movement and choice of dwelling.

In this way the model describes both the evolution of cohabitation patterns and family formation and dissolution, as well as the movements of households between various types of housing over time. Based on this, we are able to forecast the number of dwellings required so that each household has one unit of housing. This number is referred to as *the potential housing demand*.

2. The SMILE model

SMILE (Simulation Model for Individual Lifecycle Evaluation) is a dynamic microsimulation model that has been developed to provide an evaluation of the long-term housing demand in Denmark.

The model starts with the entire Danish population in a base year (currently 2010 with approximately 5.5 million individuals) and simulates the further life course for each individual in this initial population. Transition probabilities depending on individual characteristics are estimated from observed transitions in a recent period.

Events included in the simulation are three main types of events: demographic, socioeconomic, and housing-related events. Demographic events include ageing, births, deaths, migration, leaving home, and couple formation and dissolution – all of which are key *indirect* drivers of future housing demand. In this context, the model use a new and fast algorithm for couple matching, the so-called SBAM (Sparse Bi-proportionate Adjustment Matching), which can be described as a cross-entropy minimizing or matrix balancing method.

Socioeconomic events such as education attendance and attainment, and labor market events are also important indirect drivers of housing demand because they are closely linked to the timing and direction of households' moving patterns. Finally, households move spatially and between dwelling types based on historically observed moving patterns and estimated transition probabilities by using the tree-based classification model CTREE (conditional inference trees). Each dwelling is characterized by location (region and town size), owner/rental status, dwelling type (detached houses, terrace and townhouses, multi-dwelling houses, farmhouses, etc.) and dwelling size.

The structure of SMILE is thoroughly described in Hansen, Stephensen and Kristensen (2013). The following sections provide a brief overview of the applied modelling.

2.1 Data

Our data cover the entire Danish population on annual basis in the period between 1986 and 2011. On each individual our dataset contains information about the person himself (gender, age, educational background, labor market participation etc.), the person's family situation (single/couple, number of children living at home etc.) and information about the dwelling that the person's household lives in (location, owner/rental status, dwelling type and size etc.). We derive data from seven different sources made available through Statistics Denmark. The main data sources are the Danish Civil Registration System and the Housing Register.

Individual and family data is from the Danish Civil Registration System (*CPR-registret*). These records include the individual's personal identification number (CPR number) and a lot of background information on the individual's including gender, date of birth, origin, citizenship etc. The records also include CPR numbers of family members such as spouse, parents and children. These data also contain an identification of persons living in the same household.

Individual characteristics of houses are from the Housing Register (*Bygnings- og Boligregistret, BBR*). The Housing Register has detailed information on the individual characteristics of all dwellings in Denmark. According to Danish law, house owners are obliged to apply for planning permission before undertaking any significant alteration of their property. From this data we obtain individual characteristics of all dwellings in Denmark: location (region and town size), owner/rental status, dwelling type (detached houses, terrace and townhouses, multi-dwelling houses, farmhouses, etc.) and dwelling size.

Other registers include the education register (*Uddannelsesregistret*), from which we use each person's completed education and any ongoing education including academic year. We use the labor force statistics (*Registerbaseret Arbejdsstyrkestatistik, RAS*) to determine each person's socioeconomic status.

2.2 Initial population

First, we load the initial population of the reference year, which consist of all 5.5 million Danes in beginning of 2010, the current base year. For each person, we register personal characteristics such as gender, age, origin etc. Furthermore, a unique identification of how each person is related to a family as well as this person's status in the family as an adult or child living at home is also necessary. For each household, a dwelling is registered, which is described with characteristics like dwelling type, location, size etc. From this, we build a snapshot of the household structure in the reference year for a total of 2.8 million families.

The central object for the simulation model is *the family.* The individual family is assumed to consist of *a group of adults*, *a group of children* and *a dwelling*. The persons in the two groups are defined by characteristics such as age, gender, origin, education and socioeconomic status. Table 1 contains a list of these characteristics that is a part of the projection.

Table 1. List of personal characteristics.

Personal characteristics		Values
Age		1 year age levels 0–120 year
Gender		Male, female
Origin	Type	Immigrant, descendant, the rest
	Country of origin	Western, non-western
Danish citizenship		Yes, no
Time of residence		1 year steps from age 0 and up
Highest completed education		12 educational groups
Ongoing education		12 educational groups
Academic year on ongoing education		1 year steps from 1 year and up
Socioeconomic status		7 conditions

A dwelling is characterized by location (province and town size), ownership and rental status (housing type), use (physical use), area (dwelling size) and construction year (dwelling age).

Housing type is defined by the owner-rental relationship with the use of five categories. On the one hand is owner-occupied housing, i.e. dwellings occupied by the owner himself. On the other hand is rental housing in various forms. For these homes, there is a division into four categories according to their ownership (social housing, cooperative housing, public owned rented housing, and privately owned rented housing).

In a further division of housing demand, dwellings are defined according to their physical use. The most common housing categories are detached houses, terraced houses, multi-dwelling houses and farmhouses. In total, these four categories comprise more than 97 percent of all dwellings in 2010. The remaining stock of dwellings consists of student housing, other residential buildings, properties for commercial use, residential institutions and holiday houses.

The location of the dwelling is determined by a division of Denmark in 11 provinces and a further breakdown by town size for the location of the property. The living area is measured in terms of square meters and indicates the size of the dwelling. The dwellings age is defined by the construction year.

Fundamentally, a family's characteristics are based on person and dwelling characteristics. See Table 2 for an overview. The number of years in the present family type is determined for all adults and indicates the number of years, which the family has been given in its present state either as a single individual or as two individuals (a couple). If the number of adults in the family is changed due to either a formation or breakup of a couple, the variable is reset.

By counting the number of children in the family and combining these with the number of adults, you achieve the typical subdivision of family types: Single without children, couples without children, single with one child, couple with one child, single with two children etc. A family's geographic affiliation is determined from the location of the family's dwelling.

Table 2. List of family characteristics.

Family characteristics	Values
Age	Average age of adults
Number of adults (family type)	1 (single), 2 (couple)
Number of children	0, 1, …, 9, 10
Age of the youngest child in the family	1-year age levels 0–29 year
Number of years in present family type	1-year levels from 0 years and up
Province	Province of the location of the family's dwelling

When the initial population is loaded and all families are formed, the microsimulation will initiate its projection. The initial population is projected one year at the time by letting a series of events occur during the following year. The transitional probabilities determine, if a given event occur or not. Events can occur either for a single family (for example, moving to a new dwelling, the whole family immigrating etc.) or for a single person in the family (death, child living at home moves out etc.).

The structure of SMILE is thoroughly described in Hansen, Stephensen and Kristensen (2013). The report also contains a comprehensive description of the modelling of the individual events in SMILE. The paper Stephensen (2013) gives a brief technical description of the model structure.

2.3 Transition probabilities

A dynamic microsimulation model with discrete time is based on the assumption that each family or person in each period has certain (transition) probabilities of experiencing transitions from one state to another. Each of these transition probabilities will normally constitute an event, and depends on each family's or person's characteristics. The model is then simulated with stochastic drawing, often called the Monte Carlo technique.

There are different ways to calculate transitional probabilities. Firstly, we have directly *observed* or *raw transitional probabilities.* Here, we calculate the probability distributions directly from raw data. The disadvantage of this method is that data easily can become too "weak", i.e. that the probability is calculated using so few observations, that there is a significant uncertainty of the result. In SMILE the probabilities of demographic events such as birth and death are calculated based on observed rates.

Often you will need a lot of explaining variables with many possible outcomes. As a consequence, weak data will be a problem in virtually every analysis. To solve this problem, we use a technology called CTREE (*Conditional Inference Tree*), cf. Hothorn (2006). Therefore, in SMILE movement's and the choice of dwelling probabilities is estimated as decision trees, which are capable of classifying an outcome on the basis of the characteristics of the household and the dwelling. A decision tree is a statistical method for splitting the data basis within groups. For example, you begin by splitting the households by type of household (couples and singles), then splitting each group by age etc. The split of lesser and lesser groups lead to terminal groups, where the households are homogenous in relation to the outcome. Each terminal group must contain households with approximately same housing behavior, while the terminal groups distinguish themselves by different housing behavior. Within each terminal group, a transitional probability is calculated for the outcome, i.e. a movement or choice of dwelling probability.

The following sections provide an overview of the applied transition probabilities in SMILE. The CTREE method and its application in our microsimulation model are described in more detail in Rasmussen (2013).

2.4 Demographic events and population size

Demographic events determine the development in the overall Danish population including household structure during the projection period. The development is a consequence of relatively few mechanisms: The population increases due to births and immigration and decreases due deaths and emigration, while the population composition of origin groups changes through achieving Danish citizenship. The number of households increased when a child leaves home, if an existing couple breaks up, or by immigration. Conversely, the number of households will be reduced by pairing, emigration of an entire household, or by death of a single person.

Table 3 contains a list of how the demographic events are modelled. For two of the events, the probabilities are estimated with a compressed decision tree, where the subdivision is decided on the basis of background characteristics. The compression is conducted using a classification model, which are implemented by the so-called CTREE algorithm. For the other six events, the transitional probabilities are calculated directly from data.

For example, births are determined by observed fertility rates. The probability of a birth depends on the following characteristics: The female's age, the province of residence, the number of children the female already has, the age of the youngest child and if the female is a part of a couple or not. Females in couples therefore have a higher probability to give birth than single females, birth is most likely to occur around the female's 30th year and a female will typically give birth to two or three children.

Table 3. List of transitional probabilities that determine demographic events.

Event	Estimation method and period	Background characteristics for probability
Fertility	Observed rates 2008–10	Mother's age, province, number of children in the family, age of youngest child in the family, material status and time
Mortality	Observed rates 2008–10	Age, gender, province, marital status and time
Emigration, single	CTREE 2008–10	Age, gender, province, origin and children
Emigration, couple	CTREE 2008–10	Age, gender, province, origin of both adults in the couple and children
Change of citizenship	Observed rates 2008–10	Age, gender and origin
Child leaves home	Observed rates 2008–10	Age, gender and province
Dissolution of existing couple	Observed rates 2008–10	Age, province, years in present family type, children and whether the couple have a child during the year
Couple formation for single	Observed rates 2008–10	Age, gender, province and whether the person gives birth to a child during the year

Immigration does not directly depend on the number of persons residing in Denmark and is therefore not estimated by a transitional probability. Instead, we have an exogenous influx of immigrants, whose number and origin composition is determined by DREAM's national population projection.

Pair formation is simulated with a transition probability indicating how likely it is that a single person is transferred to a couple in the forthcoming period. If so, then the single person is added to the so-called matching pool. At the end of the year, all singles in this matching pool will be matched, while all individuals outside the pool remain single. For matching, the model use a new and fast algorithm for couple matching, the so-called SBAM (Sparse Bi-proportionate Adjustment Matching), which can be described as a cross-entropy minimizing or matrix balancing method. This implies that we use information according to the historic observations on pair matching. The advantage of the method is its efficient use of information and its reduced computational requirements. In the matching we include gender, age, educational level and province as background characteristics. The SBAM algorithm is described in detail in Stephensen and Markeprand (2013).

2.5 Socioeconomic events and labor market status

Socioeconomic events determine a person's choice of education and labor market affiliation. The projection models each person's route through the educational system. Every person is assumed to begin at elementary school, after which transitional probabilities determine the further course. When a person leaves the educational system, he or she enters the labor force by a certain probability. Then transition probabilities determine the person's future progress on the labor market.

In addition to demographic characteristics, each person has an educational status that is updated as the person begins, complete or drop out of an education. The educational status is described by three variables. *Highest completed education* is the highest ranking education and not necessarily the latest completed education. *Present education* indicates the education, where the person is accepted in that year. *Academic year of present education* indicates the number of years passed since the person began the education.

In SMILE the simulation of education works as follows: We assume that all 14-year-olds are going in elementary school. They are split up as 15-year-old on highest completed education, present education and academic year of present education after the division as observed among 15-year-old in 2010. After this, choice of education is described with three groups of transitional probabilities. The first is the probabilities for beginning an education after elementary school. The next represents persons who are not part of the educational system and apply for admission to an education. The last is persons who are undergoing an education, which is different from elementary school. Characteristics included in the probabilities are summarized in Table 4.

The majority of the 15-year-old is going to elementary school. The probability decides if a person completes or continues for one more year. If elementary school is completed, the probability also decides if the person continues directly on a new education and which one. If the person completes elementary school and does not continue directly on another education, then that person is not undergoing an education but will with a certain probability enter the educational system again at a later point.

After the completion of elementary school, two groups of probabilities are used to project choice of education as we distinguish between if a person is undergoing an education or not.

For persons undergoing an education, we have a probability distribution, which decides if the persons continue one more year at their on-going education, drop out of or complete that education. If they drop out of or complete the education, then the probabilities also decide if they begin a new education immediately (and which one), or if they move outside the educational system (sabbatical year, work etc.). For persons who are not undergoing an education, we have transitional probabilities that decide if a person begins an education (and which one).

Table 4. List of transitional probabilities that determine socieconomic events.

Event	Estimation method and period	Characteristics for probability
Initial distribution for 15-year-old	Observed dist. 2010	Gender, origin, highest completed education, present education and academic year of present education
Present elementary school	Projected 2000–10	Age, gender and origin
Present non-elementary school	Observed rates 2008–10	Gender, origin, highest completed education, present education and academic year of present education
Begin education	Projected 2000–10	Age, gender, origin and highest completed education
Change labor market status	Observed rates 2000–09	Age, gender, province and present labor market status

Note: With projected probabilities we mean raw probabilities, where we draw a possible trend, which is projected for a number of years where after it deflects.

Person's labor market affiliation is simulated with transitional probabilities calculated for the period 2000–09. The relatively long timeframe when calculating these probabilities should be considered, since the transition between the different states of the labor market depends on business cycles. By calculating the probabilities for several years, we increase the control of cyclical fluctuations in the behavior.

2.6 Housing-related events and residential choice

Housing related events determine a households residential choice, defined here as the choice of the place where the household lives and of when and where to move. This is a fairly complex issue. To deal with this complexity we break down the individual process into a succession of steps, each step representing one elementary decision.

The residential process is split into two main components. First, it is simulated whether each household moves from its current home, since movements are the outcome of a binary choice: Households can either choose to move or stay where they already live. If so, the household's choice of a new dwelling is simulated with probabilities indicating how likely it is that the household moves to a dwelling with certain characteristics. The choice of dwelling is the outcome of a series of discrete choices: The households choose the location of the dwelling (province and town size), owner and rental status (housing type), use (physical use), area (the size of dwelling) and year of construction (the age of dwelling).

The moving probability depends on background characteristics of the household and by characteristics of the household's current dwelling. Together this results in a lot of explaining variables why the moving probability is calculated as a CTREE. Table 5 contains a list of how the housing-related events are modeled.

Table 5. List of transitional probabilities that determine housing-related events.

Event	Estimation method and period	Background characteristics for probability
Moving probability	CTREE 2000–10	Age, gender, province, material status, education, origin, labor market status, children and characteristics of the household's current dwelling (type, use, size, town size and age)
Dwelling characteristics for new dwelling		
- province	CTREE 2000–10	Same characteristics as moving probability
- type	CTREE 2000–10	Same characteristics as moving probability + province for new dwelling
- use	CTREE 2000–10	Same characteristics as moving probability + province and type of new dwelling
- area	CTREE 2000–10	Same characteristics as moving probability + province, type and use of new dwelling
- town size	CTREE 2000–10	Same characteristics as moving probability + province, type, use and area of new dwelling
- construction year	CTREE 2000–10	Same characteristics as moving probability + province, type, use, area and town size of new dwelling

If a household moves from its current dwelling then the choice of a new dwelling is successively divided into six parts. First we choose the province for the new dwelling with a probability distributed according to the same background characteristics as used in the moving probability (these characteristics are mentioned in Table 5). Subsequently we choose the dwelling type based on the same background characteristics as before plus information on the province for the new dwelling (which has just been drawn). Similarly, we continue to involve already drawn dwelling characteristics of the new housing when the last four housing characteristics are drawn.

The time series used to estimate the transition probabilities that determine housing-related events spans over eleven years in order to control for cyclical fluctuations in the behavior. However, to estimate the housing behavior on the basis of a long-term period is not without complications. To the extent the housing behavior has chanced within the historical period, you risk to continue tendencies in the projection, which are no longer applicable.

3. The main results of the projection

SMILE simulates the life course of the full Danish population with respect to three main types of events. The result is a projection of the number of households in Denmark, i.e. we have a projection of the number of singles and couples as well as the number of children living at home belonging to each household. Each household is allocated to one dwelling. The dwelling depends on the household's size and age of the adults, for example, families with children tend to have a larger home than single people. This lasts a projection of the housing demand, which is defined to be the number of dwellings necessary for a dwelling for every household.

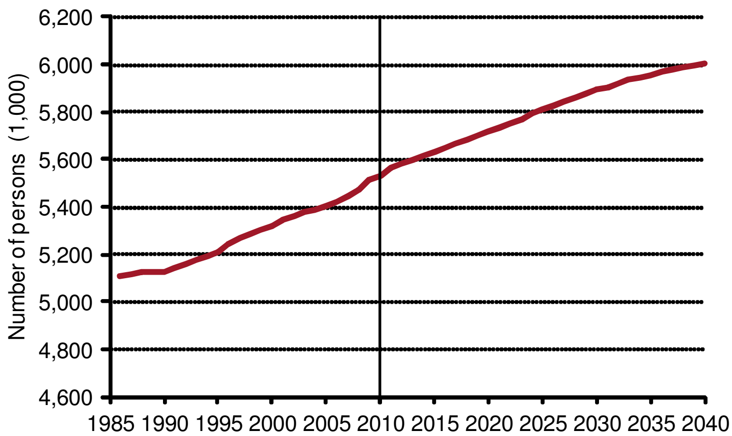
The key results from the simulations are: changing patterns of cohabitation with a decreasing average household size is projected to increase the number of households by roughly one-third above what the general increase in population indicates. Increasing urbanization leads to an increasing demand for multi-dwelling houses. An ageing population is expected to pent-up the demand for smaller dwellings, especially rental housing.

The following sections review the main results of the projection. A full description of the models results can be seen in Hansen, Stephensen and Kristensen (2013).

3.1 Population size and cohabitation pattern

The Danish population has increased from 2.4 million individuals around 1900 to 5.53 million in 2010. There has been positive population growth in all years except for a short period in the beginning of the 1980s. The observed tendency of an increasing population is expected to continue in the years to come, cf. Figure 1 which shows our model's forecast of the Danish population. The total population is predicted to reach around 6 million individuals in 2040. Total population increases due to positive net immigration (meaning that total immigration is expected to be higher than total emigration) as well as a positive surplus of births over deaths.

Figure 1. Total Danish population, 1986–2040.



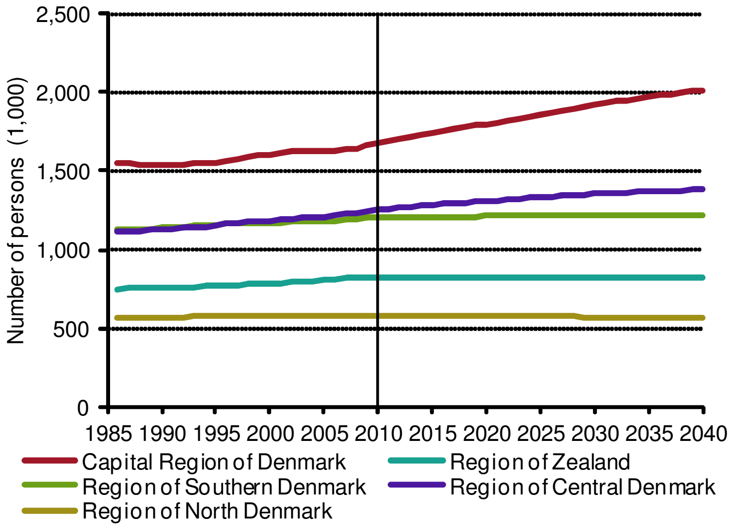
Sources: Statistics Denmark and own calculations.

Note: The vertical line indicates the shift between historical data and forecast.

In the forecast period the age composition of the population changes so that a larger share of the population consists of elderly people. This is caused by a continuation of the increasing life expectancy that has been observed historically, implying that future generations of elderly are expected to live considerably longer than current ones.

There is also geographical variation in the evolution of population. The last few years have shown a tendency for a larger part of the population to locate near large urban areas, in particular the area surrounding Copenhagen and in Eastern Jutland (which includes Aarhus). The tendency is expected to continue in coming years, cf. Figure 2 which shows population forecasts for each of the five Danish regions[2]. Specifically, the population in the capital region of Denmark is expected to grow by 335,000 individuals until 2040, corresponding to a slightly higher increase than observed since the mid-1990s. In the region of Central Denmark, population is expected to grow by close to 130,000 individuals from 2010 to 2040. Until 2020 population growth in this region is roughly at the level of the historical period, after that population growth decreases. In the regions of Zealand, Southern Denmark and Northern Denmark, only a modest change in population is expected.

Figure 2. Total Danish population by regions, 1986–2040.



Sources: Statistics Denmark and own calculations.

Note: The vertical line indicates the shift between historical data and forecast.

The growing population until 2040 will increase the total number of families in Denmark, cf. Figure 3 which shows the number of households with one adult (singles) and two adults (couples) respectively. The number of families is, however, also affected by the pattern of cohabitation.

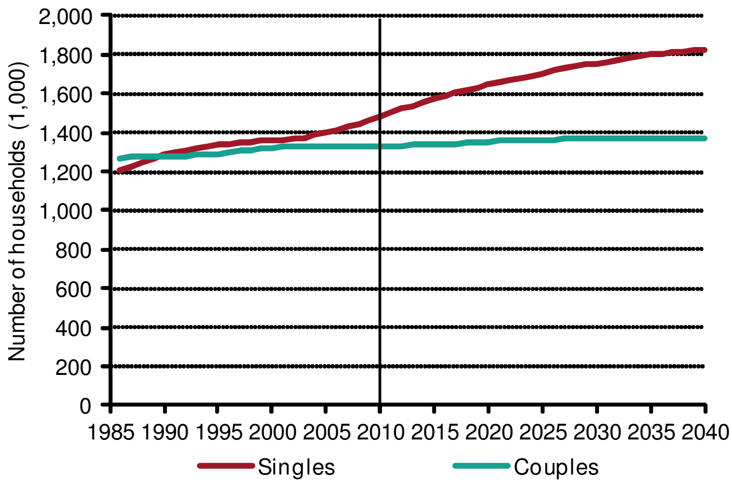
Historically, the evolution in the number of singles and couples has been dominated mainly by two counteracting effects: Firstly, an increasing share of individuals below the age of 65 live as singles. A number of explanations may be given for this. Young individuals tend to spend longer time on education today than previously so that they are older when they move in with a partner and form a family. But even after having finished their education, an increasing share of

[2] Denmark is divided into five regions, 11 provinces and 98 municipalities. The five regions are the Capital Region of Denmark ("Region Hovedstaden"), the region of Zealand ("Region Sjælland"), the region of Southern Denmark ("Region Sydjylland"), the region of Central Denmark ("Region Midtjylland") and the region of Northern Denmark ("Region Nordjylland"). The regions have between 0.6 and 1.6 million inhabitants. In terms of acreage, the smallest region is the Capital Region of Denmark covering 2,561 square kilometers while the largest region, the region of Central Denmark, covers 13,142 square kilometers.

individuals live as singles. This is often explained by increasing wealth which makes life as a single financially feasible. Secondly, an increasing share of individuals above the age of 65 live as couples. This effect appears because individuals on average live longer. As longevity increases, fewer individuals live as singles because the time of death of the partner is postponed until higher ages. Historically, women have a higher average longevity than men, but the historical period shows a tendency for the longevity of males and females to converge. This also implies that individuals on average live fewer years after the death of their partner than previously.

The change in the aggregate composition of family structure is a reflection of the fact that the period 1986–2010 exhibits a higher growth in the number of singles than in the number of couples. The last part of the 1990s and the beginning of the new millennium show a temporary tendency for the number of couples to increase while the number of singles stagnates. This is caused by the mortality of the elderly starting to decrease from the mid-1990s. As a consequence, some of those who would otherwise have become single following the death of their partner will instead continue to live as part of a couple. This effect temporarily dominates the effect of changing family structure in which an increasing share of the population live as singles.

Figure 3. Number of households in Denmark divided by couples and singles, 1986–2040.



Sources: Statistics Denmark and own calculations.

Note: The vertical line indicates the shift between historical data and forecast.

The tendency for a changing family structure is continued in the forecast and leads, along with an increasing population, to a larger total number of families. As in the historical period, the number of single-adult families grows at a relatively higher rate than the number of families involving couples. The number of single adults is thus expected to increase by nearly 350,000 individuals during the period 2010–40. In the same period, the number of adults who live as couples increases by a little less than 70,000. This implies that a larger part of the population will consist of single adults as the share of singles, excluding children living at home, will grow from 35.8 percent of the population in 2010 to 40.1 percent in 2040.

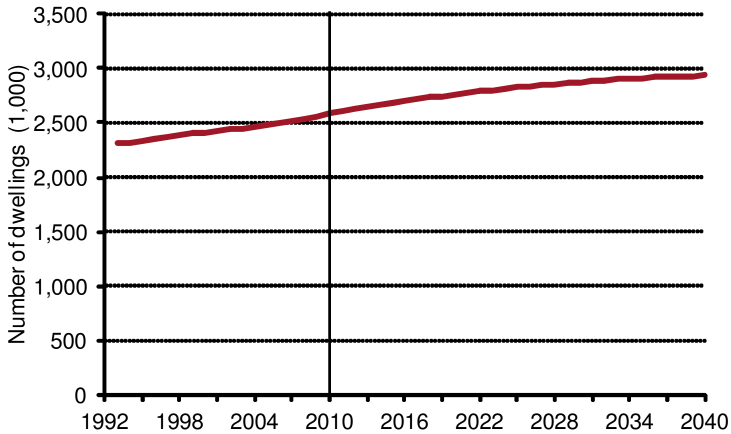
3.2 Future housing demand and residential choice

The increase in the number of households causes an increase in the demand for dwellings. Figure 4 shows housing demand for the period 1993–2040. Housing demand is defined here as the number of dwellings needed if there is to be one dwelling for each household. In total, the increasing population and the change in the pattern of cohabitation increase the demand for dwellings from 2.59 million in 2010 to 2.94 million in 2040.

During the period 1993–2010, housing demand has seen an annual increase in the range of 10,000 to 27,000 with an average of 15,250 dwellings per year. In the beginning of our forecast, the annual increase in housing demand is maintained at the historical level; however, the growth rate of demand diminishes over time. Around 2040 housing demand is thus expected to increase with approximately 5,000 dwellings a year. In total, housing demand is expected to increase by 350,000 dwellings during the period 2010–40. This corresponds to an annual net increase of 11,775 dwellings per year if demand is to be met.

Approximately two thirds of the increase in total housing demand is explained by the overall increase in population. The remaining third is caused by the changing pattern of cohabitation whereby an increasing share of the population lives in households with only one adult.

Figure 4. Total Danish housing demand, 1993–2040.



Sources: Statistics Denmark and own calculations.

Note: The vertical line indicates the shift between historical data and forecast.

Figure 5 shows housing demand until 2040 by types of dwelling. The model distinguishes between owner-occupied housing[3] and rented housing which in turn is further subdivided into social housing[4], cooperative housing[5], publicly owned rented housing[6] and privately owned rented housing[7]. Owner-occupied housing is the most common type of housing accounting for a little more than half of all dwellings.

After 2010 demand for each of the five types of housing is expected to grow. Demand for owner-occupied housing, social housing and privately owned rented housing is expected to grow with approximately 85,000 units in total for these three types of dwellings between 2010 and 2040.

[3] Owner-occupied housing (“ejerboliger”) consists of dwellings occupied by the owner himself.

[4] Social housing (“almene boliger”) is constructed and run by social housing organizations. The term “social housing” is a collective designation for three different types of housing: social family dwellings, social dwellings for the elderly and social dwellings for the young. Social housing for the elderly may, however, also be constructed and run by the Danish municipalities or regions (these two types are categorized as publicly owned rented housing) and by independent organizations (categorized as privately owned rented housing).

[5] Cooperative housing (“andelsboliger”) consists of apartments or houses in a cooperative housing society. A member buys a share of the society thus causing occupancy of a dwelling in the association. Cooperative housing is to some degree similar to owner-occupied housing; however, pricing of cooperative housing is not free (as it is for owner-occupied housing).

[6] Publicly owned rented housing (“offentlige udlejningsboliger”) consists of housing owned by the municipalities, regions or the state that are rented out to individuals. These dwellings are typically targeted at certain groups of individuals, e.g. young people, disabled individuals or the elderly.

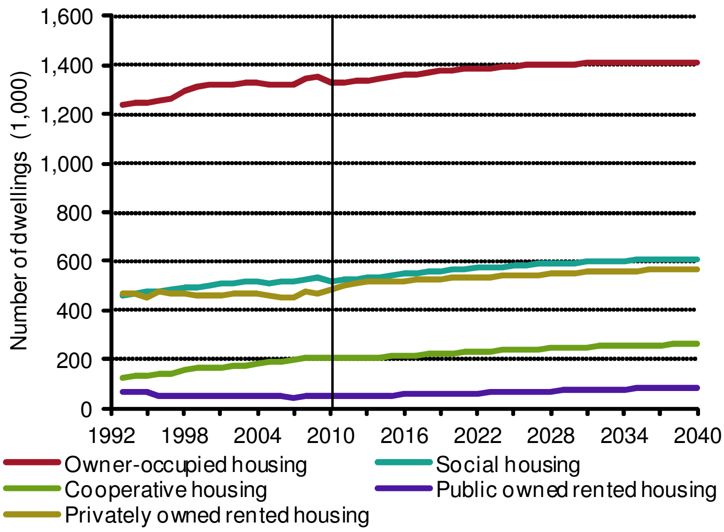
[7] Privately owned rented housing (“private udlejningsboliger”) consists of housing owned by private individuals, companies or independent institutions that are rented out. This includes e.g. dwellings in traditional rental properties and sublet owner-occupied housing.

During the same period, demand for cooperative housing is expected to grow by slightly less than 58,000 dwellings and publicly owned rented housing by slightly more than 38,000 dwellings. Our model thus predicts that the increase in demand for rented housing will be larger than that for owner-occupied housing. Owner-occupied housing will experience a decrease in its share of total housing, going from 51.9 percent in 2010 to 48.0 percent in 2040.

The fact that owner-occupied housing is expected to exhibit a decreasing share of overall housing is primarily caused by three factors that explain future changes in the demand for specific types of housing. Firstly, a considerable ageing of the population is expected, thereby causing a larger share of the population to consist of elderly people. Secondly, a larger share of the population will be living as singles due to the changing pattern of cohabitation. Thirdly, the model predicts that a larger share of the population will be living in the larger urban areas surrounding Copenhagen and in Eastern Jutland. These factors all point to an increasing demand for rented housing during the next three decades.

The ageing of the population mainly causes an increase in demand for publicly owned rented housing and social housing as these housing types mostly consist of senior homes. The changing pattern of cohabitation and the gravitation towards urban areas increase demand mainly for privately owned rented housing and cooperative housing since these housing types are the most common among singe-adult households and in urban areas.

Figure 5. Number of dwellings by type, 1993–2040.



Sources: Statistics Denmark and own calculations.

Note: The vertical line indicates the shift between historical data and forecast.

In a further division of housing demand, dwellings are defined according to their physical use. The most common housing categories are detached houses[8], terraced houses[9] (including linked houses and double houses), multi-dwelling houses[10] and farmhouses[11]. In total, these four

[8] A detached house ("parcelhus") is built independently from other houses and has its own garden. A detached house is intended for housing one family and typically has one or two floors.

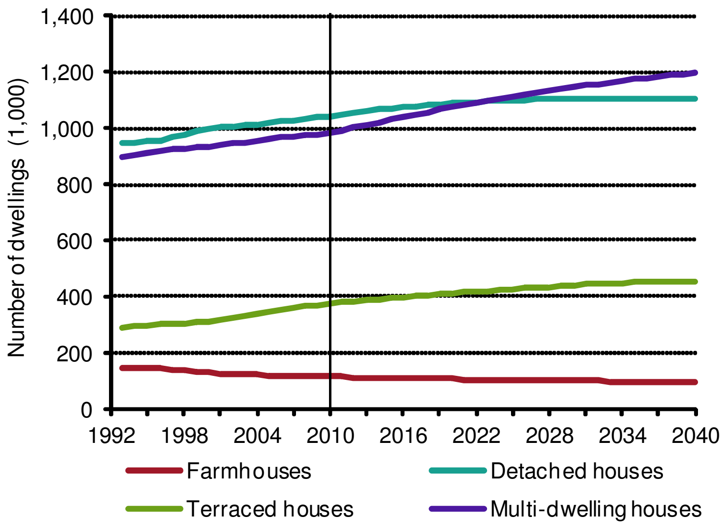
[9] A terraced house, linked house or double house ("række-, kæde- eller dobbelthus") is a house in a property consisting of several independent housing units. Typically, such a property contains a row of identical or mirror-image houses that share side walls. Terraced houses are therefore characterized by a horizontal separation between housing units. There will typically be a smaller garden associated with each dwelling, and each unit is intended for housing one family.

[10] A multi-dwelling house ("etagebolig") is a dwelling in a property where multiple separate housing units are contained within one building. Each unit is intended for housing one family. A common form is a flat in an apartment building. A multi-dwelling house is characterized by a vertical separation between housing units. There can be multiple housing units on each floor and there are often multiple floors.

categories comprise more than 97 percent of all dwellings in 2010. The remaining stock of dwellings consists of student housing, other residential buildings, properties for commercial use, residential institutions[12] and holiday houses[13].

Figure 6 displays housing demand until 2040 by category where we see an increasing demand for detached houses, terraced houses and multi-dwelling houses while the demand for farmhouses decreases. This continues the tendency observed during the historical period. In the period 2010–2040, the demand for detached houses is expected to grow by 62,500. This is caused by an increase in overall housing demand along with the expectation that households will live in detached houses for a longer period of their life as longevity increases. Between 2010 and 2040 the demand for multi-dwelling houses and terraced houses is expected to grow by approximately 215,000 and 80,000, respectively. This is the result of an increasing concentration in larger urban areas where these categories are predominant. In addition, population growth is especially pronounced among individuals aged 65 and older where a disproportionately large share of households lives in housing in these categories. As in the historical period, the demand for farmhouses is expected to decrease in future years, exhibiting an overall decrease of approximately 19,000 over the period 2010–40.

Figure 6. Number of dwellings divided by category, 1993–2040.



Sources: Statistics Denmark and own calculations.

Note: The figure shows the four most common types of dwellings which in total formed approximately 97 percent of the total stock of dwellings in 2010. Student housing, other residential buildings, properties for commercial use, residential institutions and holiday houses are omitted from the figure. The vertical line indicates the shift between historical data and forecast.

In summary, our model predicts the demand for detached houses to increase by less than the increase in demand for terraced houses and multi-dwelling houses. The share of the total stock of dwellings consisting of detached houses is therefore expected to decrease from 40.7 percent in 2010 to 37.6 percent in 2040 while multi-dwelling houses will account for an increasing share of the total stock of dwellings.

[11] A farmhouse ("stuehus til landbrugsejendom") is a general term for the main residential building of a farm. It is intended for housing one family and typically has one floor. It can either be connected to one or more barns to form a courtyard or be a separate building.

[12] A residential institution ("døgninstitution") is a home targeted at e.g. children or young people, weak or mentally ill people, or the elderly. In 2010, 19 percent of residents at residential institutions were 0–20 years old and 39 percent were older than the retirement age (65 years).

[13] A holiday house ("fritidshus") is a house built as a summer home that has been approved for permanent habitation.

4. Weaknesses and Further Work

On the basis of microsimulation, we have developed a model that projects the Danish housing demand. The approach is to project the number of households and assign one dwelling to every household. The dwelling choice depends on household characteristics. In this way, we project the demographic trends in the future housing demand.

In the projection, each household is associated with the dwelling they require, we do not take the actual housing supply into account. We project the future housing behavior using the behavior observed in a historical period, and the housing behavior is assumed to be unchanged over time. However, we must expect that households' housing demand to some extent will depend on the future housing supply.

An ongoing development of SMILE is to divide the model so the projection is done on Denmark's 98 municipalities rather than the current 11 provinces. This work includes a remodeling of the household’s moving pattern and choice of residence. In addition, the modeling of demographic events has to be changed to take into account a different demographic behavior across municipalities.

In order to achieve a better modeling of a person's life course, it would be desirable to extend the microsimulation model with income, i.e. to include a modeling of each individual's earned income and public transfers in each of the projected periods. In that case, the model could be used for detailed life course analysis. Several empirical studies also show that a household's disposable income is crucial for the development of housing consumption. The work of developing the model with labor income and a tax and transfer system has been initiated. This includes a better modeling of each person's labor market processes; see Bækgaard (2013) for a description of our approach to modeling labor market processes in SMILE. The method combines and integrates Bayesian simulation based estimation and simulation of the dependent variables.

5. Conclusions

This paper presents the dynamic microsimulation model SMILE. The model is developed to predict the demographic specific housing demand in Denmark. SMILE simulates the life course of the full Danish population with respect to three main types of events: demographic, socioeconomic, and housing-related events.

Demographic events determine the development in the overall Danish population including household structure during the projection period. In this regard, we use a new and fast algorithm for couple matching, the so-called SBAM (Sparse Bi-proportionate Adjustment Matching), which can be described as a cross-entropy minimizing or matrix balancing method. SMILE is characterized by a detailed modeling of each person's path through the education system. Finally, households move spatially and between dwelling types based on historically observed moving patterns and estimated transition probabilities by using the tree-based classification model CTREE (conditional inference trees).

The key results from the simulations are: changing patterns of cohabitation with a decreasing average household size is projected to increase the number of households by roughly one-third above what the general increase in population indicates. Increasing urbanization leads to an increasing demand for multi-dwelling houses. An ageing population is expected to pent-up the demand for smaller dwellings, especially rental housing.

6. References

Bækgaard, H. (2013): *A Bayesian approach to labour market modeling in dynamic microsimulation*, DREAM Conference Paper, December 2013. The paper can be downloaded from www.dreammodel.dk

Coulombel, N. (2011): *Residential choice and household behavior: State of the Art*, SustainCity Working Paper, No. 2.2a, ENS Cachan.

Hansen, J. Z., Stephensen, P. & Kristensen, J. B. (2013): *Modeling Household Formation and Housing Demand in Denmark - The Dynamic Microsimulation Model SMILE*, DREAM Report, December 2013. The report can be downloaded from www.dreammodel.dk

Hothorn, T., K. Hornik & A. Zeileis (2006): *Unbiased Recursive Partitioning: A Conditional Inference Framework*, Journal of Computational and Graphical Statistics, Vol. 15, No. 3, page 651–74.

Rasmussen, N. E. (2013): *Conditional inference trees in dynamic microsimulation - modelling transition probabilities in the SMILE model*, DREAM Conference Paper, December 2013. The paper can be downloaded from www.dreammodel.dk

McDonald P., Kippen R. & Temple J (2006): *Net transition probabilities: an approach to subnational level projections of households and housing demand based on census data*, Population, Space and Place, Vol. 12, Issue 6, page 479–95.

Skifter Andersen, H. (2011): *Motives for Tenure Choice during the Life Cycle: The Importance of Non-Economic Factors and Other Housing Preferences*, Housing, Theory and Society, Vol. 28, No. 2, page 183–207.

Stephensen, P. (2013): *The Danish microsimulation model SMILE - An overview*, DREAM Conference Paper, December 2013. The paper can be downloaded from www.dreammodel.dk

Stephensen, P. & Markeprand, T. (2013): *SBAM: An Algorithm for Pair Matching*, DREAM Conference Paper, December 2013. The paper can be downloaded from www.dreammodel.dk