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Content

The Potential of Dynamic Microsimulation in Family Studies:
A Review and Some Lessons for FAMSIM+

Dynamic microsimulation can serve as a valuable tool for the investigation and projection of population processes, supporting their conceptualization and the study of their determinants and consequences. Existing macro-level models are limited to few variables what makes microsimulation an interesting modeling option especially in respect to the modeling of the interaction of demographic with social, environmental and economic variables that are of central importance in Family Studies.

This paper investigates the potential of microsimulation modeling in the context of family studies, and based on a review of existing models it derives some conclusions and lessons for FAMSIM+, the dynamic family microsimulation model currently being developed at the Austrian Institute for Family Studies.

After giving a definition of dynamic microsimulation and a classification of types and approaches, microsimulation modeling is brought into the context of the life course paradigm, the dominant paradigm in demography that can serve as a useful organization principle for the study and projection of population phenomena including their family dimension. Microsimulation is then compared with cell-based approaches, and a review of 32 existing dynamic microsimulation projects and applications is given, with 12 of these projects discussed in detail. Based on that, the strengths and limitations of dynamic microsimulation as well as its potential in family studies are explored and some conclusions are drawn for the development of FAMSIM+.

1 Demographic Microsimulation and Family Studies

1.1 Introduction

Existing macro-level projections of future population trends are limited to few variables what makes microsimulation an interesting modeling option especially with respect to the modeling of the interaction of demographic with social, environmental and economic variables. On the demographic side, micro approaches can incorporate the wealth of substantive analysis gained from a large number of micro- and macro-level studies. Going beyond the traditional analysis of population by age and sex, microsimulation can produce useful projections for the analysis of different population-related phenomena considering additional dimensions. Some examples are educational composition, rural/urban differentials, household structures and family networks, which become increasingly important in the context of the ongoing demographic change. Most of these new challenges in the context of population forecasting have been discussed in detail in Lutz et al. (1999).

The use of microsimulation models in family studies does not entirely lie in projections and ultimately forecasts and policy recommendations. Beside "empirical models" designed for this purpose, "abstract models" can be designed and used rather to study the implications of certain assumptions in order to develop and test theories. Regardless of the main intention – prediction vs. explanation – an important purpose of modeling is to clarify concepts. The process of modeling itself can produce valuable insight on the subject being modeled or might help to identify internal inconsistencies and gaps of theories, as the translation of theory into a simulation model requires to make everything explicit.

This paper explores the potential of dynamic microsimulation in the context of family studies. Starting with a definition of dynamic microsimulation and a classification of types and approaches, microsimulation modeling is brought into a context to the life course paradigm that dominates demographic research. This paradigm can serve as useful organization principle for the study and projection of population phenomena including their family dimension. Microsimulation is then compared with cell-based approaches and a review of 32 existing dynamic microsimulation projects and applications is given with 12 projects discussed in detail. Based on that, the strengths and limitations of dynamic microsimulation as well as its potential in family studies are explored.

Dynamic microsimulation in the field of family studies can be seen resp. should be designed as a tool for the investigation and projection of population processes, supporting the conceptualization of this processes and the study of their determinants and consequences. Following, such a model has to include the core demographic processes and should be able to produce its own forecasts regarding aggregated population outputs rather than being aligned to other projections. A second broad field of family microsimulation regards the policy dimension of family studies resp. the use of dynamic microsimulation for the evaluation of family policies. Microsimulation in this respect can serve as tool to calculate costs and distributional effects of family policies. In both cases microsimulation might increasingly turn out to be the appropriate modeling approach in a field that is currently almost exclusively dominated by cell-based macro models.

1.2 What is dynamic microsimulation?

Microsimulation is a rather confusing term, both due to the wide range of models it does address and the very different concepts, in that the terms simulation and modeling are used. Very generally, a microsimulation model could be defined as a model which uses simulation techniques and which takes micro level units – in the social sciences usually individuals, families or firms - as the basic units of analysis. (O'Donoghue 2001) Following this broad definition, dynamic microsimulation would include a broad variety of models and modeling approaches ranging from data based empiric dynamic microsimulation to concept driven microsimulation based on the distributed artificial intelligence approach[1]. A detailed classification is given in the next chapter.

In the social sciences, dynamic microsimulation was introduced in the late 1950s, dominantly in the form of "empirical" dynamic microsimulation models – that are models designed and used operatively for forecasting and policy recommendations (Klevmarken

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[1] As data based dynamic microsimulation and agent based simulation evolved 'in almost total ignorance of each other' (Troitzsch 1996) the term dynamic microsimulation is also often used as term for the first approach distinguished from agent based simulation. Inasmuch as data based empirical models move from 'black box' models of behavior to models that incorporate theory and individual goal orientation, the distinction becomes more difficult. Both traditions increasingly use concepts of each other and a synthesis might be desirable. In order to support that view, a broad definition of dynamic microsimulation was chosen in the context of this paper, even though it clearly concentrates on data based microsimulation.

1997) This tradition can be traced back to a "direct" and an "indirect" source. The direct source of dynamic microsimulation can be found in Guy Orcutt's idea about mimicking natural experiments in economics that led to the development of the DYNASIM model. (Orcutt 1957). The indirect source is via static tax benefit microsimulation models resulting from the increased interest among policy makers for distributional studies. As attempts are made to enlarge the initially static tax benefit models with behavioral models to capture second-order effects of policies and to simulate behavior over time, tax-benefit models approach Orcutts's DYNASIM resp. its various successors. This tradition is also labeled data based microsimulation, as it is usually based on empirical micro data and dominated by statistical and econometric models of behavior. In general, there are various additional ways of modeling the behavior of the micro units, ranging from simple rules to economic optimization behavior to agent based models. In data based models, theory is often sacrificed to get a very detailed model with a good fit to the data. Behavior is mostly modeled implicitly, and so are corresponding assumptions, which can make models difficult to understand. In contrast, "abstract models" incorporate behavior explicitly. This models are designed and used rather to test and developed theories, that is, rather for explanation than prediction. This holds true also for context-driven agent-based microsimulation. Agents are defined by their behavior and act according to the environmental context they are placed in. Context driven microsimulation goes back to the 1980s.

The term **micro** indicates the level of analysis, in the social sciences usually individuals or households. In contrast to static microsimulation models in that these micro-units are only used as rather passive accounting units, the common element of all dynamic microsimulation approaches and traditions is that they analyze the behavior of a system by using characteristics of micro-units that are changed – or autonomously change – according to a behavioral model. The main idea of microsimulation is that processes resulting from the actions and interactions of a large number of micro-units can be explained best by looking at the micro-units and their behavior. One expects to find more stable behavioral relationships on the micro-level than in aggregated data that are affected by structural changes when the number or size of the micro-units in the population changes, even if the behavior of the individual micro-units and their individual characteristics do not change. These micro units might be particles moving in line with probability laws, e.g. in fluids or thermodynamics, the field where microsimulation was

first introduced. They might also represent artificial species of 'artificial societies' as is the case in most agent-based simulations. But they can also represent individuals, families or households of empirical populations, as it is the case in 'data-based' microsimulation.

Beside this 'direct' source of **dynamic** microsimulation, the modeling and simulation of dynamics over time and in response to context changes (i.e. policy response) are not introduced in static microsimulation models. Tax-benefit systems are the most typical application of static microsimulation, where individuals or households (represented in a micro-database) are only used as accounting units having the necessary characteristics to calculate taxes and benefits. Reduced to its bare essentials, a data-based static microsimulation model consists of two parts (Martini and Trivellato, 1997):

- a baseline database: a data set containing information on individual or family/household units, in particular socio-demographic characteristics and economic information that bears a relationship with a set of policies;

- a set of accounting rules: these are computer language instructions that produce, for each unit, the provisions of existing or alternative tax and transfer systems, or other relevant institutional features.

The construction of representative data sets containing all necessary variables and modeling at least part of a complex tax-benefit system, absorbed all the resources in the early days of microsimulation. The study of the redistribution effects of the US tax system done by Pechman and Okner (1974) represents the most celebrated example of this type of research. Historically, from the description of the distributional impact of the existing tax and transfer system, microsimulation moved to a second stage, in which it became a tool for understanding the differential impact of alternative proposals for reforming existing systems. A more recent example is the investigation of the treatment of the family in income tax systems across Europe by O'Donoghue and Sutherland (1999). In this study different European tax systems were examined for the UK, using the tax-benefit microsimulation model POLIMOD (Sutherland, 1995).

In static models, time – if introduced at all – has no effect on individual characteristics, as in order to reflect the future composition of the population , the dataset is simply re-weighted at each time step (a process called static aging). Dynamic microsimulation includes behavior over time - a set of behavioral relationships - which varies greatly in scope and importance across models. These can be of two types:

- behavior that produces events that take place over time such as demographic events, i.e. marriage, divorce, deaths, etc., and economic events such as leaving the labor force;

- behavior producing feedback reactions of individuals and/or families to changes in external circumstances, notably to changes in public policies.

In dynamic microsimulation, the behavior of the micro-units is modeled – most importantly it's behavior over time. Various approaches can be used in order to model behavior over time ranging from simple transition tables to elaborated econometrical models, neuronal networks or artificial intelligence.. Typical behavioral models are statistical models, that for a given set of personal characteristics determine probabilities for a defined set of possible transitions like marriage, pregnancy or death. Monte-Carlo simulation is then used to determine, if a transition takes place in the simulation experiment. This allows to dynamically update personal characteristics over time and to add and remove micro units to or from the population due to birth, death or migration. Dynamic microsimulation simultaneously addresses point-in-time "snapshot" distribution issues as well as longitudinal "life path" issues, making it a powerful and flexible tool for policy analysis. Another type of dynamic behavior is policy response, that might be modeled using econometrical approaches or based on theory like utility maximization. Again, there is a wide range of possibilities to model individual behavior, from the modeling of a rational forward looking utility optimizing "homo economicus" to more realistic human behavior including learning processes etc. as it is done in agent based simulation based on the artificial intelligence approach.

Dynamic microsimulation **models** result from a synthesis of various (sub-) models usually including a population data-base as model representation of an empirical or artificial society, model representations of alternative tax-benefit systems as well as behavioral models as outlined above.

The use of the term **simulation** can be quite misleading in the labeling of microsimulation models, as simulation (amongst other applications as techniques) is a particular type of modeling itself (Gilbert 1999) but not all microsimulation models are "simulation models" in this sense. Simulation modeling constitutes a research method that is quite different from the logic of statistical modeling. While agent based models are typical simulation models in this sense, data based models are usually statistical models and simulation does not "add" anything to this models but is used as technique to "run"

this model into the future – i.e. in the form of Monte-Carlo simulation. One main difference lies in the notation: statistical models are expressed in statistical equations whereas simulation models are usually expressed in the form of computer programs. In other words, in data based microsimulation it is possible to distinguish the model itself from the computer software used to "run" this model, a process that might be done or include (Monte-Carlo-) simulation - with the whole exercise also being called a simulation in the sense that it mimics a natural experiment using a model. In contrast to statistical models and their notation, simulation models considerable extend the scope as they are not restricted to theory that can be formalized in mathematical notation but the much wider notation of computer languages. In this respect, computer simulation models represents a third domain, complementing both natural language and mathematical/statistical analysis.

Due to their complexity and quantity of data to be processed in microsimulation models, these are inevitable run on **computers**. To the degree that computer programming itself can be seen as a modeling exercise, microsimulation modeling approaches also correspond to some degree to programming paradigms. Static microsimulation technically can be described as the manipulation of a population micro-database by computer procedures that produce, for each unit, the provisions of existing or alternative tax and transfer systems, or other relevant institutional features. There is a clear correspondence with the procedural programming paradigm that clearly distinguishes data from code. To the extent in that individual behavior is introduced, object oriented programming becomes the more adequate programming paradigm, as individuals can be described much better as objects that encapsulate both, the data structure holding all individual characteristics that describe the status of an object and the methods that describe the behavior with changes these characteristics. Agents as modeled in agent based simulation have their direct correspondence with agents in the computer terminology, that can be described as "extended objects", being characterized by purposefulness, autonomy, and reactivity.

1.3 Classification

The purpose: projection versus explanation

A first distinction can be made by the intended use of a microsimulation model that can rather lie in projections (and consequently in producing forecasts and policy recommendations) or in the explanation of social phenomena. In this sense, microsimulation models can be empirical models or abstract models. If designed and used operatively for forecasting and policy recommendations, such models 'need to be firmly based in an empirical reality and its relations should have been estimated from real data and carefully tested using well-established statistical and econometric methods. In this case the feasibility of an inference to a real world population or economic process is of great importance.' (Klevmarken 1997) In contrast, abstract models are designed and used rather to study the implications of certain assumptions without the ambition to produce reliable forecasts.

Typical demographical applications of abstract models in demography and population studies are models for partner matching and geographical segregation with ABCD (Agent Based Computational Demography) currently becoming a vital area of research that does not primarily intended to forecast the behavior of actual populations, but to study dynamics and patterns of artificial societies that result from the interactions of artificial species. By "growing" these societies, simulations serve as a tool to develop and test theories that might help to explain human behavior, on the assumption that artificial societies might show similar behavioral patterns as empirical ones. An example, where agent based simulation was successfully used to reproduced observed residential patterns, is Israeli communities (Benenson and Omer 2001).

Regardless of the intention – prediction vs. explanation – an important purpose of modeling is to clarify concepts. The social sciences are over-rich in descriptive theories that have limited practical application (Lane 1999) The process of modeling itself can produce valuable insight on the subject being modeled. The act of translating a theory into a simulation model requires to make everything explicit, and quickly exposes internal inconsistencies and gaps. In contrast to pure mathematical models and mathematical notation, simulation models considerable extend the scope as they are not restricted to theory that can be formalized in mathematical notation but the much wider notation of

computer languages. In this respect, computer simulation represents a third domain, complementing both natural language and mathematical/statistical analysis.

General versus specialized models

In its data based tradition, many microsimulation models were developed for a wide range of purposes therefore being rather general models typically covering the whole household sector of a country. Such general models exist for various countries and are reviewed below. Beside these general models, also very specialized microsimulation models exist, that typically concentrate on one specific behavior (like most prominently the labor market behavior) or population segment. An example of the latter is the Swedish SESIM model that initially was developed to forecast the paybacks of student loans, before it is currently extended to a general model.

The same distinction can be made for context driven models, that might be constructed rather in order to model specific behaviors like matching processes or to model whole economies, like the American ASPEN model (Pryor, Basu and Quint 1996) that was developed in order to study the consequences of various legal, regulatory and political changes.

Cohort versus population models

Cohort models age a single cohort over its entire lifetime, predicting each individual's major life course events. In contrast, dynamic population microsimulation models age entire cross-sections. Studies typically done with single cohort models investigate lifetime income and interpersonal distributions. Examples of this kind of models include the HARDING and the LIFEMOD models developed in parallel for Australia (HARDING) and Great Britain (LIFEMOD). (Falkingham, Harding 1996) This kind of models typically assume a steady state world: i.e. the HARDIG cohort is 'born' into and lives in a world that looks like Australia in 1986.

Several limitations of this cohort models are derestricted when simulating a whole cross-section population, including issues of demographic change and distributional issues between cohorts. Population models are usually far more complex and demanding regarding data. Some models only focus on a certain age range, like women in their

reproductive age, i.e. in FAMSIM, or the retired population, i.e. in the NCCSU Long-term Care Model.

Steady state versus forecasted projections

Steady state assumptions are common especially in single cohort models and as 'benchmark' scenarios in population models. In these models, individuals are aged in an unchanging world regarding the environmental context like economic growth and policies and individual behavior is "frozen" not allowing for cohort or period effects. As a today's population cross-section does not result from a steady state world, "freezing" individual behavior and the socioeconomic context can also serve to isolate and study future dynamics and phenomena resulting from past changes, like the population momentum.

For many models, steady state assumptions (if made) only serve as benchmark and it is rather tried to include (and produce) forecasts regarding the future world. Steady state models would be inappropriate if studying micro-macro interactions, like the impact of demographic change on social security systems etc.

Open versus closed population models

The terms open resp. closed population in microsimulation usually corresponds to whether the matching of spouses is restricted to persons within the population or spouses are imputed. In open population models, partners are usually attached as attributes to the "dominant" individuals of the population with characteristics synthetically generated or sampled from a host population. In contrast, closed models allow to track kinship networks and also enforce more consistency, given a large enough population to find appropriate matches. Major drawbacks of closed models are the computational demands associated with mate matching and sampling problems. In a starting population derived from a sample, the model may not be balanced with respect to kinship linkages other then spouses, as one's parents and siblings are not included in the base population if not living in the same household. (Toder, et. al. 2000).

A related topic is how to model immigration. Approaches range from the cloning of existing 'recent immigrants' to sampling from a host population or even different 'pools' of host populations representing different regions.

Statistical versus agent based models

As mentioned above, in data based microsimulation a clear distinction can be made between the data representing the population, the model that determines the behavior, the Monte-Carlo simulation typically used to run the model, and the software necessary for the whole exercise. Associated with this type of microsimulation are usually micro-econometric and statistical models, with behavior usually expressed in transition probabilities or duration times. Two main approaches can be distinguished according to the way of modeling time itself: (1) the continuous-time competing-risk approach to dynamic microsimulation modeling and (2) approaches based on a discrete-time framework. These issues are dealt in detail in Galler (1996).

Agent-based microsimulation, based on the distributed artificial intelligence approach, represents a very different modeling tradition. Agents are defined by their behavior and act according to the environmental context they are placed in. As stated before, today this "artificial society" approach is mainly used to explore theories. A good example is the Evolution of Organized Societies (EOS) project set out to explore theories accounting for the growth of social complexity among the human population in the Upper Paleolithic period in south-western France (Doran et al., 1994, quoted from Gilbert and Troitzsch, 1999). Micro-units are "intelligent" and acting agents, having goals and following rules. The following features characterize agents:

- agents have receptors, they get input from the environment;

- agents have cognitive abilities, beliefs and intentions;

- agents can follow different rules and make decisions which rules to follow;

- agents live in groups of other agents and interact;

- agents can act and interact simultaneously;

- agents can learn.

A synthesis might be desirable and could be approached by combining or allowing various "rules of motion" and population types according to the research questions and goals. As an example, fertility might be modeled in a two-step way combining a decision model of heaving a child – a model that might incorporate theory and could be agent based – and a (statistical) waiting time model. To the extent in that dynamic microsimulation

incorporates concepts of goal orientation, planned behavior and strategic adaptation, the more attractive as a tool it might become in demographic research in the context of its dominant paradigm: the life course paradigm.

1.4 Microsimulation modeling in the context of the life course paradigm

The massive social and demographic change in the last decades went hand in hand with tremendous technological progress, with computers now being a powerful and indispensable tool in various fields of research. Their ability to process large amounts of data has boosted data collection, enabled new survey designs and ways of data analysis. In general, the impact of massive social change on people's lives has become a vital area of research, and great progress has been made in the ways of studying how lives change over time. In this context, an important paradigm shift can be observed in the last decades that led to the integration of structural and dynamic approaches to the life course paradigm meanwhile being the dominant paradigm in demography. It combines several major theoretical and empirical streams of research, connecting social change, social structure, and individual action. (Giele 1998) This chapter sketches the main recent paradigm shifts in social sciences and puts microsimulation into the context of the emerging life course paradigm that can be seen as useful organization principle for the study and projection of population phenomena using microsimulation.

Demography and family studies involve a variety of research disciplines and are therefore not only influenced by general changes and shifts in the focus of attention but also benefit from their developments and innovations. The changes that can be observed can occur along four dimensions: (Willekens 1999)

- from structure to process

- from macro to micro

- from analysis to synthesis

- from certainty to uncertainty

The change from structure to process shifts the focus of attention from a static view of social systems to the dynamics of systems over time and the processes generating the dynamics. While this "transition from entity-oriented perception of reality to process-oriented perception" was made by nearly every social and natural science (Willekens 1999;

4), its importance increases with the speed of the observed social and demographic changes and the various new questions raised by these changes. The focus on processes brings in various new concepts, with causality and time being among the most important. Various population phenomena are characterized by their rapid change over time, and substantial research effort is required to identify and understand the underlying processes generating them. Good examples are low fertility, increasing divorce rates and changes in the distribution of income and wealth. The importance of time is also increasingly recognized in the field of policy analysis, where the attention shifts to the long-term dynamics and the sustainability of such systems as tax-benefits or social security. In studying distribution effects of policies, time adds a new dimension to research, as distribution effects are not only analyzed in a cross-sectional view for a given time, but also over time, between cohorts and over generations. This shift in focus is mirrored in the development of microsimulation models, both by the increasing efforts undertaken to extend static models to dynamic ones and generally by its growth in importance being a research tool that can handle dynamic processes over time.

The second dimension regards the level of analysis. Social sciences tend to move from macro to micro explanations and to interpret changes on the macro level as results of actions taken by individual agents and their interactions. These interactions also include reactions and feedback of individual agents in connection with changes in their environment, i.e. changes on the macro level that form the context of individual decisions and actions. Again, there is a direct correspondence between this general shift to micro-level research and microsimulation.

The third dimension regards the shift from analysis to synthesis. When shifting the focus of attention from structure to process, research increasingly tends not to stop at the analysis of these processes and the resulting structures. The identification of the elementary processes that generate the complex dynamics of a system are indispensable for understanding these dynamics, but also have to be 'put together' by way of synthesis. This way, system dynamics can be projected under different assumptions. As described in more detail below, the life course may be viewed as being a combination of a large number of elementary processes. The challenge is to detect the elementary processes and the rules that link them. Microsimulation is the main tool for linking multiple elementary processes in order to generate complex dynamics and to quantify what a given process contributes to the complex pattern of change.

The fourth shift is based on the insight that uncertainty is associated with many events. Agents have only limited control over most events and their exact timing. Hence the individual likelihood that certain events will or will not happen becomes an important issue. This holds true for many phenomena and events studied in demographic research: pregnancy is a good example. While the degree of planning might vary, the exact timing cannot be controlled though probabilities might be well known. Again, microsimulation can be used to study these random distributional effects. Due to the inclusion of stochastic elements - i.e. Monte-Carlo simulation - resulting in different outcomes of each single simulation experiment, microsimulation allows for the exploration of the distribution of events rather than its point-estimates, thus leading to more adequate representation of uncertainty and risk.

Together, these four shifts have a huge impact on the way in which individual lives and interactions of individuals are described and investigated. The corresponding paradigmatic shifts led to the development of the human life course as a central concept or 'organization principle'.

The human life course

The term 'life course' was first used by Cain (Cain, 1964) to encompass anthropological, sociological, and psychological concepts of aging, particularly as they were related to the maturing individual's movement through an expected sequence of social roles. The life course refers to a sequence of socially defined events and roles that the individual enacts over time. It differs from the concept of life cycle in allowing for many diverse events and roles that do not necessarily proceed in a given sequence but that constitute the sum total of persons' actual experience over time. (Elder, 1975) These roles and the transitions from one role to another are central issues in family demography: childhood, partnership formation and dissolution as well as parenthood, just to name some of them. Contrary to life-cycle concepts that are widely used, for example in economics or psychology, and are based on a predetermined 'typical' sequence of roles, episodes of life or expected behaviors, the life course concept permits us to study changing role patterns and the interactions between different domains or such careers as education, jobs, partnerships and births. The individual life course is determined by four key factors that make up the key elements of the life course paradigm:

- location

- social integration

- goal orientation and

- strategic adaptation

The location in time and place or the cultural background constitutes the first key element. It determines the individual life course and closely corresponds the demographic concept of period effects as a dominant concept especially in historical demography. Using archival parish registers, births, deaths and marriages are reconstructed and the economic and political factors that shaped the key demographic events of everyday life are determined. Key topics and insights of this kind of historical research - which concentrates on 'ordinary people' rather than leaders and battles - regard the changing roles and functions of families, and in particular women. In addition, institutional changes caused by demographic changes (e.g. changes in inheritance laws) are investigated.

The second key element is social integration or the concept of 'linked lives'. It closely corresponds to cohort effects as used in demography. Important insights were gained by comparing and identifying 'typical' life patterns of different cohorts, a method widely used in sociology. Rich, new empirical studies of variations in life patterns among different birth cohorts helped to elaborate the multidimensional model of the human life course.

Individual age is of key importance both in demography (as third concept beside period and cohort effects) as in all in all life-cycle models, especially in the psychology of developmental stages. Various scholars have tried to describe the typical life cycle that begins with birth and moves through adolescence, young adulthood, and the middle years to old age and death. By moving to a multidimensional model, the study of the life course has perceivably moved from a tendency to divide the study of development into discrete stages to the firm recognition that any point in the life span must be viewed dynamically. It must be seen as the consequence of past experience and future expectation, as integration of individual motives and external constraints. In this way, human agency and individual goal orientation are added to the explanatory framework..

The fourth component of the life course framework was mainly brought in by longitudinal surveys and associated methods: strategic adaptation or the timing of lives. Timing of live events can be understood as both passive and active adaptation for reaching individual or collective goals. By using duration-dependent rates of changes for

characterizing different persons in a population, and by differentiating between endogenous, exogenous and reciprocal effects we can distinguish the impact of biological change (age grade) from the impact of socialization and experience (event grade) or cultural and institutional change (history grade). Individuals adapt to the challenges confronting them by timing the events of their lives so as to make the most of opportunity and suffer the least frustration and failure. Whatever a person's social and cultural heritage, friendships and networks, or personal motivation, all come together and are experienced through the individual's adaptation to concrete situations and events. (Giele 1998; 10) In demographic research, the life course framework links the concepts of time, age and cohort by the fourth component of timing of lives.

The life course paradigm moved research from single-factor explanations to multidimensional models flexible enough and capable to encompass many different types of cultural, social and individual variation. While human lives can be described in various ways and terminologies, one approach increasingly gains importance and dominates life descriptions from a live course perspective: the description of lives as event histories. An event is defined as qualitative change that occurs at a specific point in time and that places an individual in a new status. Events are transitions between states such as marriage and divorce that change the marital status of a person. Individuals experience events and organize their lives around these events. As Willekens (1999: 2) states, most people spend a considerable part of their life either preparing for life events or coping with life events.

States and events typically belong to different domains or careers, like partnership, job and educational careers that interact and influence each other. As a result, people may experience problems of synchronization and compatibility of careers. Many of the resulting problems—e.g. the reconciliation of job and family life—are central in explaining demographic phenomena. A typical strategy to cope with incompatibilities is rescheduling activities and events. An example of this strategic adaptation is to postpone births.

The collection of all possible states for each career to be considered in a specific analysis creates a state space that determines all possible trajectories and outcomes of individual live histories along with all possible transitions. Once defined, the description of individual lives consists of 'event history data', i.e. all events are recorded together with the time they occurred or alternatively, all states are recorded by precisely noting when they began and when they ended. This approach of describing individuals is popular in dynamic microsimulation and allows to overcome the limitations of other approaches as it

allows for the inclusion of duration-dependencies in behavioral models and thereby does not restrict modeling to Marcov processes. This can clearly be seen when comparing dynamic microsimulation (following a state-space approach) to cell based approaches (that put individuals into a grid of cells representing all possible combinations of states). While both approaches use a state-space approach (note that microsimulation is not restricted to do so), no information how individuals organized their lives until entering a cell can be recorded in latter. A comparison of microsimulation and cell based approaches are given below.

1.5 Microsimulation versus cell based approaches

Regarding projection models microsimulation and cell-based macrosimulation are often two alternative methods for making similar statements about future population characteristics. (Imhoff 1998) While population projections in the narrow sense (by age, sex and some few other characteristics like education) are almost exclusively produced by the cell-based cohort-component method, for more detailed projections – i.e. in the field of health care need and finance – the choice becomes one according to priorities that has to be based on a detailed evaluation of strengths and weaknesses of both methods according to the research goal. While health care models are a typical example where both approaches can be found in parallel there is a broad range of applications, where no alternative exists to microsimulation. Good examples are tax-benefit and social security models that include detailed policies and/or require individual accounts over time. Caldwell and Morrison (2000) give the following examples:

- analysis of projected winners and losers of alternative policies on a period-specific or lifetime basis;

- analysis focused on families and individuals simultaneously;

- exploration at the micro-level of the operation of social security programs in the context of the broader tax/transfer system;

- quantifications of incentives to work, to save, or to retire at particular life course or period junctures;

- cross-subsidies across population segments or cohorts;

- feedback effects of government programs on population demographics; and

- longer-term consequences of social trends in marriage, divorce and fertility.

This chapter compares the micro- and cell-based macrosimulation approach and highlights their strengths, weaknesses and relevance in family studies. It is organized according to the following headings:

- The representation of populations

- The modeling of population dynamics

- The strengths of microsimulation compared to cell-based macrosimulation

The representation of populations

One of the first and most obvious differences between micro-and macro models lie in the description of the population itself. In microsimulation all individuals are represented by an individual record containing all individual characteristics that also might include links to other individuals/records (i.e. to keep track of kinship networks) or any other variables. In contrast, in cell-based models population is represented by an aggregated cross-classification table, in that the cells represent all possible combinations of the considered characteristics.

A first trade-off can be found regarding the storage space required by both methods determined by the number of attributes and the population size. While this space is independent of population size in cell-based models, the number of cells – the state space consisting of all possible combinations of attribute values - "explodes" with the number of possible population attributes. In contrast, the number of records is determined by the population (or sample) size in microsimulation, and storage space will increase only linear with the number of variables[2] (independent of their possible values). Note, that for this reason cell-based models are limited to categorical variables, leaving microsimulation

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[2] Example: For a population of size N with A attributes and Ci categories for attribute i = 1..A, the state-space would consist of C1*C2*..*CA cells in the macro model representation while the population would be represented by a matrix of dimension N*A in the micro model. While the population representation would be more storage-efficient in a common age-sex state-space (of typically 101*2 = 202 cells) for any population (sample) bigger than 100 persons (N*A = 100*2 = 200), this picture would change dramatically considering more population characteristics. Consider for example a model that additionally includes nationality, occupation, education level, income class, parity and health status, then even if allowing for only 6 categories each, the state space would increase to 6*6*6*6*6*101*2 = 9.424.512 cells. In this case, a micro-population of the same storage size could already consist of 9.428.512/8 = 1.178.064 individuals. Doubling the possible categories of only one attribute i.e. increasing the income categories to 12, would double the whole state-space, while this would be of no effect in the case of the micro-representation.

being the only practical way when the projection model were to contain continuous covariates.

The importance of population size in microsimulation leads to another distinction between the approaches: microsimulation models are usually based on a population sample rather than the total population. An exception to that is the Swedish SVERIEGE model, that is based on individual data of the whole Swedish population. The reasons why microsimulation is (usually) based on samples not only lie in practicability issues, but also in the usually large number of covariates microsimulation models usually contain. The joint distribution of all state variables and covariates is generally unknown at the population level and necessary data are typically only available from sample surveys. (Imhoff 1998)

The modeling of population dynamics

In cell-based macro models, for a given state-space and cell occupation the projection model has to evaluate how the number each individual cell contains changes over time. Limited to categorical variables, dynamics can always be described by a limited set of events describing all possible changes of attribute values – or transitions from one cell to another. Given the importance of event history analysis in microsimulation models, this concept is also often applied to microsimulation whether microsimulation is not limited to this approach. Events are random variables that occur with a certain probability. At the population-level one can speak of the 'average' occurrence of a certain event, but this average remains to be ultimately based on the individual occurrences. Imhoff notes that '[..] when making a statement about a certain future number of events, we are in fact making a statement about the expected value of a random variable. In doing so, both the microsimulation and the macrosimulation approach rely upon the Law of Large Numbers. However, they do so in different ways. A macro model assumes that the size of the population is so large that the projected number of events may be set equal to its expected value. A micro model assumes that the number of repetitions of the random experiment in the sample is so large that the resulting projected number of events will approximately equal its expected value.' (Imhoff 1998)

The processes that can be simulated by cell-based models are restricted to first order Markov-processes, that is, processes without memory. The number a cell contains does not

give any information of how long the individuals it represents have bee in this cell and from "where" (which cell) they came.

In microsimulation models, for each individual, the attribute vector is updated according to a behavioral model formulated at the individual micro-level. If needed, all past information can be stored allowing to retrieve the whole event history or biography of individual agents that might enter the behavioral model. This allows to include variables of duration spent since the previous event, which is seen as a significant source of demographic heterogeneity.

As there are no restrictions according variable types microsimulation models can handle, behavioral models can be of various forms. Regarding the implementation of the state-space approach in microsimulation, whether an event occurs or not for an individual is typically determined by Monte-Carlo simulation. This leads to a major difference between the modeling approaches even when modeling the same processes: dynamic microsimulation models do not only produce the expected value. As individual simulation experiments are subject to random variation, repeated simulation experiments can produce information on the distribution of target variables. As will be seen below, this is not always a "convenient" strengths of the microsimulation approach.

The strengths of microsimulation compared to cell-based macrosimulation

Due to the inclusion of stochastic elements - i.e. Monte-Carlo simulation - resulting in different outcomes of each single simulation experiment, microsimulation allows for the exploration of the distribution of events rather than its point-estimates, thus leading to more adequate representation of uncertainty and risk. As mentioned above, this is not always a "convenient" strength, as it implies that simulations have to be run various times and results have to be stored for all simulation runs in order to allow for further exploration of the distributional properties of the variables. Since this is burdensome and computer power still is one of the main bottlenecks of microsimulation, this is not always done. The stochastic nature of single simulation experiments is not always wanted, and quite frequently simulations are rather forced to reproduce externally set scenarios regarding aggregate characteristics.

One of the central strengths of microsimulation lies in the fact that it permits inclusion of more variables than other methods, which is especially important in projection and

planning applications, as this allows for more detailed research. For example, when trying to estimate future demand for health care facilities, etc. based on population projections, a large set of household characteristics, such as household size, family composition, age and income can be used. Microsimulation does not impose limits to variable types, allowing also continuous variables or links to other records. As a result, there exists often a very close link between microsimulation models and its underlying data. Data availability can be seen as second bottleneck of microsimulation.

Microsimulation allows for a broad range of behavioral models of any detail or complexity. This flexibility supports the study of the interaction between variables and therefore the life course interactions between various parallel carriers and roles, such as education, work, partnership and parenthood within a changing socio-economic context. This flexibility adds responsibility to the model builder, as the model parameters should be estimated in such a way that the interaction effects are properly taken into account. Imhoff states, that this might lead to a false sense of security, since it might be very tempting to disregard interaction effects in the estimation phase.

Linking Microsimulation and cell-based macrosimulation models

In various fields of projection modeling, microsimulation and cell-based macrosimulation are often seen as two alternative methods for making similar statements about the future. With both methods having their strengths and limitations, the modelers choice is not necessarily one between these two alternative methods but can also be one of how to combine both approaches. A common practice is to align microsimulation projections to projections obtained from macro models or scenarios (like variants of "official" demographic projections). This approach allows to produce or reproduce given scenarios regarding aggregated target variables while including distributional information into the projection.

Various approaches have been made in linking micro models (i.e. of a household population) to macro models (i.e. of the economy), the German DMMS Darmstadt Micro Macro Simulator (Heike et. al. 1994) being one example. In this approach, models interchange data via a defined interface (micro-macro link). This link can be of various nature, from models where the simulation results of one model feed into the other model without producing feedback reactions, to highly dynamic models, like of an economy,

where behaviors simulated at the micro level will influence prices determined in a macro model that will again feed back into micro behavior.

Another approach might be of interest in cases, where data availability limits possible modeling approaches to macro-models (resp. in cases, in that microsimulation would not add anything, as transition rates are only known at aggregated level) but some additional information can be obtained from separate microsimulation models and incorporated into the macrosimulation model. An example are the attempts to link the PSSRU (Personal Social Services Research Unit, University of Kent) cell-based macro model and the NCCSU (Nuffield Community Care Studies Unit) microsimulation model for projections of long-term care finance in the UK. (Hancock et. al. 2002) In this approach, the means test of long-term care policies is simulated in a microsimulation model and results fed into the macro model of future care demands and costs, that way including the issues of cost incidence into the analysis.

1.6 Strengths and limitations of microsimulation

Four of the main strengths of dynamic microsimulation have already been listed above where the approach was compared to cell-based models. These were (1) the exploration of the distribution of events rather than its point-estimates, (2) the possibility to include more variables into the model and (3) the possibility to study the interaction between variables and therefore the life course interactions between various parallel carriers and roles. It was also noted, that (4) microsimulation allows a wider set of processes (not restricted to first order Marcov processes like in cell-based models)

From the view of policy-makers the main strength of microsimulation lies in its ability to test new policies in a virtual world before they are introduced into practice. In comparison to more traditional policy evaluation modeling exercises, microsimulation is especially powerful in addressing distributional issues, both in a "static" cross-sectional way and over time.

Microsimulation allows the construction of behavioral models at the level on which the relevant decisions are made, i.e. on the micro-level. There is no need to translate behavioral relations from the micro-level to the macro level. This also implies that no information is lost through aggregation.

Based on micro-data, microsimulation allows flexible aggregation as the information may be cross-tabulated in any form, while in aggregate approaches the aggregation scheme is determined a priori. Simulation results can be displayed and accounted for simultaneously in various ways - in aggregate time series, cross-sectional joint distributions, and individual- and family life paths.

Flexible aggregation helps to determine "winners and losers" of policy changes by various characteristics. An example is the possibility to study and compare contribution and benefit histories over a whole individual lifespan, permitting the calculation of return.

Microsimulation allows to study the interaction between individuals. While modeling takes place on the individual level, simulation is used to study the resulting dynamics and patterns of change on the macro-level. This is the key element of most agent-based simulation, where societies are "grown" by "putting together" micro units defined by their behavior in order to study the resulting dynamics. The use of models to compose complex processes from simple processes has been termed theoretical modeling (Burch, 1999) as opposed to empirical modeling. In the empirical "data-based" tradition of microsimulation, the possibility to study the interaction between individuals is mainly used to study changes in family and kinship networks. Direct applications can be found in the field of elderly care and other aspects of aging societies, where knowledge of the detailed household and family characteristics is valuable information when designing policies. The knowledge of kinship patterns additionally allows for detailed study of intergenerational transfers and bequests.

The potential to handle large state spaces in projections implies the possibility to handle not only a wider set of individual characteristics and categories, but also spatial and other environmental characteristics that allow for detailed modeling and studying of the interaction between individuals and the environment. The study of these interactions is of central importance to most agent-based and multilevel microsimulation models.

The advantages described certainly come at a price, fortunately a price that decreases over time, at least with regard to two of the most frequently listed drawbacks of microsimulation: (1) the usually large investments with respect to both manpower and hardware required might be considerably reduced over time as hardware prices fall and more powerful and efficient object-oriented computer languages become available; and (2) data problems are reduced over time, as more and better data, especially longitudinal data

become available – and this increasingly in standardized and internationally comparable form.

A main problem in microsimulation (using Monte Carlo methods) is its 'randomness'. As these dynamic microsimulation models are of stochastic nature, its outcome is subject to random variation. In microsimulation, various sources of randomness can be distinguished, these are

- imperfection randomness: this randomness is not specific to microsimulation but also applies to macro models. Sources are both wrong hypothesis on the values of exogenous variables and the fact, that parameters are usually estimated from empirical data.

- Monte Carlo variability is an inherent randomness in microsimulation that does not produce the expected value but a random variable having the expected value.

- Randomness coming from the initial population database the simulation is starting on. Usually based on a population sample, this starting population randomness can only be reduced by increasing the sample size.

While imperfection randomness is unavoidable in all models, its scope is especially large in microsimulation becoming a mayor problem of microsimulation.. This is especially true for what is also called specification randomness (Pudney and Sutherland, 1994, quoted from Imhoff 1998) basically caused/increased by the usually detailed information / large number of variables introduced in most microsimulation models. With the number of explanatory variables, measurement errors in the sample accumulate. Additionally, because a microsimulation model generates its own explanatory variables, each additional explanatory variable requires an extra set of Monte Carlo experiments, with a corresponding increase in Monte Carlo randomness. There exists a trade-off between specification randomness ("many variables") and misspecification errors (too few variables / too simple models).

2   Review of dynamic microsimulation models and some conclusions for the development of the FAMSIM+ family microsimulation model for Austria

There have been a number of surveys and reviews of microsimulation models (Merz 1991; Mot 1992; Sutherland 1995; Klevmarken 1996; O'Donoghue 2001; Zaidi 2001) having different scopes and following different purposes. The purpose of this survey is to capitalize on the expertise acquired by what is now more than 40 years of dynamic microsimulation model development regarding modeling of demographic behavior. Based on literature research, 32 dynamic microsimulation projects were identified, for that documentation is available. While a short description and classification of these projects is given in the appendix of this chapter, 12 projects are reviewed in more detail. This selection should cover most approaches made towards dynamic (data based) microsimulation regarding structure and modeling options.

The review focuses on the modeling of demographic and family behaviors and how these models are integrated into the whole model structure. After giving a brief description of each of the selected models, the modeling approaches are summarized and commented with four criteria distinguished. These are the use of alignment techniques, the models' complexity and range of variables used, the theoretical foundation of the model and the type of starting population used.

Conclusions are then summarized in a series of "lessons" that can be learned from existing projects. A similar approach can be found in Zaidi (2001) who focuses on the simulation of social policies in an aging society and draws 12 lessons based on a review of seven dynamic microsimulation projects. These lessons were used as template for the organization of the conclusions regarding FAMSIM+.

2.1 DYNASIM

Overview

The DYNASIM "Dynamic Simulation of Income Model" was the first large scale dynamic microsimulation model in the social sciences. It was developed under direction of Guy Orcutt at the Urban Institute between 1969 and 1976. It was Orcutt, who first

proposed conceptually the development of dynamic microsimulation in the social sciences in 1957. It was intended as social science research tool able to mimic natural experiments in economics and as a framework for integrating economic and sociological research. The early model was used to analyze Aid to Families with Dependent children (AFDC) and Unemployment Insurance issues and to develop long range projections of earnings histories for analysis of social security issues. (Anderson 2001)

A second version - DYNASIM2 – was developed between 1979 and 1983. The base year database was generated by matching the March 1973 Current Population Survey (CPS, n=60.000 persons) with Social Security earning records for 1951-1972. Selected later data were incorporated until 1993. The simulation horizon is from 1973 to 2030. DYNASIM has various successors using more up to date data and methods (or being applied in other countries then the US), but being the first model of this type that served as "template" for various models, its structure is explored in more detail here.

DYNASIM is organized in three sub models that follow different approaches and simulate events of different domains. These are

- The Family and Earnings History (FEH) model

- The Jobs and Benefits History (JBH) Model, and

- The Cross-Sectional Imputation Model (CSIM)

The Family and Earnings History (FEH) model is a dynamic microsimulation model of demographic and labor market behavior consisting of 14 modules corresponding with events or characteristics that are simulated. It is a discrete time model with annual updates. The following table summarizes the events and variables that determine them. Note that the probabilities for events might be estimated separately for specific population groups with not all variables used for each group.

	age	race	marital status	education	parity	sex	previous marital status	income	region	weeks worked	hourly wage	asset income	receipt of welfare	unemployment compensation	age at marriage	presence of young children	marriage cohort	years at current school level	parents education	years married	family size	age of head	sex of head	education of head	size of metropolitan statistical area	disability	student	spouse earnings	transfer income	expected wage	children in household
Death	X	X	X	X	X	X																									
Birth	X	X	X	X	X																										
Marriage	X	X		X			X	X	X	X	X	X	X	X	X																
Mate matching	X			X																											
Divorce			X				X				X	X			X	X	X														
Leaving home (beside marriage, giving birth, divorce and death)	X	X				X																									
Education	X	X				X												X	X												
Mobility/Location		X							X											X	X	X	X	X	X						
Disability Onset	X	X	X			X																									
Disability Recovery	X	X	X	X		X																									
Labor Force Participation	X	X	X	X		X			X																	X		X	X		X
Hours in the Labor Force	X	X																								X			X	X	X
Wage Rate	X	X	X	X		X			X																			X	X		
Unemployment	X	X	X	X		X			X																	X					X

Table: The Family and Earnings History Model; Source: Anderson 2001

The output of the FEH model consists of a file that contains the demographic and labor force histories for each person and cross-sectional files for every (selected) year of the simulation. The FEH output serves as input for the Jobs and Benefits History model (JBH)

Regarding the simulation approach, the Jobs and Benefits History model (JBH) follows a different order: for each individual it simulates the whole life careers at once. It contains six sub models for (1) job characteristics and pension plans, (2) pension eligibility and benefits, (3) social security eligibility and benefits, (4) individual retirement accounts and (5) retirement and (6) Supplemental Security Income.

	age	sex	tenure on current job	industry	education	previous industry	program administrative data	earnings level	fulltime/parttime status	years of service	type of pension coverage	benefit formula type	covered earnings	calendar year	earnings history	program rules	earnings test rules	current earnings	disability status	benefit history head	parent's eligibility	school status	private pension model	Primary Insurance Amount	account balance	marital status	pension eligibility & amount	social security eligibility & amount	wage	social security wealth	pension wealth	imputed wage
Job change	X	X	X	X																												
Industry of first job		X			X																											
Industry off job changers		X				X																										
Social security coverage				X					X																							
Pension coverage on new job		X		X					X																							
Pension plan participation	X	X	X							X																						
Type of pension coverage				X																												
Retirement eligibility	X			X						X																						
Vesting				X																												
Benefit formula type				X								X																				
Benefit plan parameters				X								X	X																			
Reirement benefit eligibility	X										X																					
Primary Insurance Amount (PIA)	X													X	X	X																
Benefit																		X	X									X				
Disability benefit											X					X		X	X													
Spouse benefit	X										X					X				X												
Children's benefits	X																				X	X										
Retirement plan participation		X																					X									
Retirement contribution																X							X									
Retirement benefit distribution																								X	X							
Probability of retiring from job	X	X															X	X									X	X	X	X	X	
Probability of taking new job	X																	X									X	X	X	X	X	X

Table: The Jobs and Benefits History Model; Source: Anderson 2001

The JBH model produces both events, like job changes, and detailed histories of retirement-, disability-, spouse- and child benefits. The used tax-benefit models are highly parameterized in order to allow for the simulation of various alternative policy scenarios. Taxes and social security contributions calculated in the last module are only determined for the last simulated year.

The CSIM Cross-Section Imputation model is a static model used to impute additional information into a single cross-sectional file for a given year generated by the other two models. Imputed variables include

- health status

- institutionalization for persons 60+

- financial assets including home ownership, and

- Supplemental Security Income

Health status is measured by ADLs – the number of limitations on activities of daily life – and IADLs, limitations on instrumental activities of daily living.

Demographic and family behavior

Demographic and family behaviors are modeled in the "model of family and earnings histories" (FEH) and beside the three key demographic events births, death and migration (mobility) they also include mate matching, marriage, divorce and leaving home. While the model is therefore able to produce demographic projections based on these demographic modules, it also includes a large array of time series adjustment factors that allow the user to align the models aggregate projections to external forecasts – usually by age, race and sex. In the context of aligned outputs, the "internal" behavioral equations are therefore used to depict the social-structural effects and distributions of events across demographic groups, while the aggregate results are aligned to external forecasts. Given the heavy use of alignment techniques usually applied in simulation studies, demographic projections per se are not a central model application.

The model includes institutionalization as well as disability onset and recovery as events as well as disability benefits, however, a detailed health and disability status can only be imputed for a given year and is not dynamically modeled. The model does not include health care finance issues, neither of public or private sector health care finance plans

Main applications

Regarding social security modeling, the main focus lies in pension modeling including both public and (seven representative) private pension plans. In 1979 the private pension model PENSIM developed by Prof. James Schulz at Brandeis University was completed, but due it's complexity it was never fully integrated into DYNASIM as initially intended.

Applications include (Anderson 2001)

- Effects of mandatory retirement through 2000; US Dept. of Labor, 1981

- Effects of teenage childbearing on welfare costs; NICHD, 1982

- Forecasts of private pension systems through 2020 under different scenarios, US Dept. of HHS, Brookings Institution

- Long range effects of 1983 Social Security Amendments; 1983, consortium of foundations

- Earnings sharing alternatives in Social Security System; 1984, women's advocacy group, private foundations

- Long range effects of private pension rule changes in Tax Act of 1986; 1988, Rockefeller Foundation and National Senior Citizens Law Center

- Need for elderly in 21st century; 1989, Administration of Aging.

2.2 CORSIM

Overview

CORSIM, based at Cornell University and developed under direction of Steven Caldwell, was begun in 1987 building on the first dynamic microsimulation model DYNASIM. (Caldwell was part of the team that developed DYNASIM at the Urban Institute.) The project is now in its fourth generation (Corsim 4.0) and probably also the most "researched" model itself, as this University-based model is not only built to (1) simultaneously support basic research into fundamental socioeconomic processes and as (2) a platform for a broad range of policy analysis, but also (3) as a study object itself serving as platform and framework for research regarding microsimulation modeling. The core CORSIM modules were also widely adapted by other models, namely the Canadian DYNACAN and the Swedish SVERIGE model.

The base year database is the 1960 US Census Public Use Microdata Sample (PUMS) containing 180.000 person records. Regarding the behavioral modules, CORSIM aims to synthesize the empirical strengths of numerous, diverse data files of various types including longitudinal microdata – i.e. the Longitudinal Mortality Survey – aggregate totals, cross-section microdata, vital statistics as well as administrative statistics. CORSIM makes extensive use of grouping of the population into subgroups for that the behavioral equations are estimated separately. Regarding data sources and number of equations CORSIM is among the largest microsimulation models. Individual and family behavior is represented by approximately 1100 equations and 7000 parameters as well as dozens of algorithms. Individual behaviors include schooling, labor supply, demographic characteristics and risk factors such as smoking, alcohol or diabetes. Family behaviors and attributes include wealth represented by 11 asset types and 3 debt types, different taxes and benefits, demographic attributes such as family links and economic behavior such as consumption and savings.

Differently to DYNASIM, CORSIM is a fully dynamic single integrated simulation model. It is organized in approximately 26 of behavioral modules and several rule-based accounting routines. Three modules are separable from the main model as their results do not feed back into the model: a voting module, the consumption expenditure module and the dental module (the second "generation" or version of the model developed 1990-1993 was funded by the National Institute of Dental Research)

One of the characteristics of the model is the use of a more than 40 year old starting population that contributes to its usability as study tool, both regarding the study of underlining socioeconomic processes as regarding the model accuracy itself. CORSIM makes heavy use of alignment techniques to align its projections to data that become available over the decades. For future projections, time series data of historic alignment factors are used in order to develop alignment factors for future years. This approach makes projections into the future difficult to interpret, or as Anderson (2001) states: without realigning or debasing the data for a recent historic year, projections of future years may begin from a base that already is subject to errors accumulated over a 35 year simulation period. Even if many group and aggregate outcomes can be aligned to recent data exactly, there is no way to assure that the joint distributions based on the 1960 data remain accurate after 35 years.

Demographic and family behavior

Compared to DYNASIM, demographic behavior is modeled in far more detail both regarding variables used – i.e. the inclusion of income and wealth in the modeling of fertility and mortality – and the number of population groups built. First marriage is distinguished from remarriage, mate matching is based on a series of additional characteristics compared to the age/education framework in DYNASIM and the custody of children at death or divorce of parents are modeled in detail. CORSIM keeps track of kinship networks among parents and children, among spouses and ex-spouses as well as among siblings including half- and step siblings. CORSIM includes both modules for geographic mobility (migration out and into a new state of residence) and immigration.

Schooling is modeled in detail following the main school transition paths which characterize the US education system.

CORSIM includes the modeling of four main risk factors for health, namely smoking, alcohol consumption, sugar consumption and diabetes. It keeps track of disability status, and models institutionalization. Regarding health care finance, private systems are only covered regarding dental care including modules for dental insurance coverage, dental condition/health and dental services and expenditures. While private pension plans are currently implemented, the public OASDI Old Age, Survivors and Disability Insurance system is modeled in detail including cumulative (i.e. life course) outcomes like internal rates of return, lifetime transfers and taxes, ratio of benefits to contributions, replacement rates and rate of adults and retired in post-OASDI poverty. Regarding health care finance, the model this way covers the disability insurance.

Main applications

The life course projection of contributions paid by each person during their working years and the benefits received from the US Old Age Security and Disability Insurance System is one of the main applications of the model. Contributions and benefits are calculated in close approximation to actual rules, fully taking into account all family links to determine survivors' benefits. Typical applications include the estimation of welfare costs and the distribution of benefits of welfare reform proposals by Nixon, Carter, Reagan and Clinton, and a detailed assessment of Reagan's tax and federal benefit policies over the 1981-83 period.

Another core application is the study of asset accumulation regarding a variety of asset types distinguished. This also involves the transfer of assets due to inheritance, asset transfers at divorce as well as the tax treatment of assets.

2.3 DYNACAN

Overview

DYNACAN was developed in the Office of the Chief Actuary (OCA) of the Canadian Pension Plan. Accordingly, the model's main aim lies in the projection and evaluation of the financial impacts on individuals and families of alternative policy proposals for the Canadian Pension Plan (CPP). As of January 1999, the team moved to the Strategic Policy Branch of HRDC (Human Resources Development Canada).

Plans of HRDC to build this model go back to 1990 and following a feasibility study in 1994, the project was approved and decided to be based on CORSIM, that was acquired to serve as template in 1995. A significant characteristic is its capacity to be closely aligned and used with the aggregate results of the CPP Actuarial Valuation Model, ACTUCAN, as maintained by the Chief Actuary (OCA). DYNACAN achieved full operational status in 1998 after demonstrating its capacity to replicate ACTUCAN results for the existing CPP system. Since then it has been used to analyze a variety of CPP policy options for the federal government. (Anderson 2001)

Other recent and ongoing applications have included mortality impact analyses for Health Canada and analyses of non-CPP portions of Canada's retirement income system. Now that the model has achieved operational status in simulating the CPP in isolation, further development is scheduled to enable it to analyze the impacts of CPP changes in the context of the broader retirement income system, including taxes, employer pensions, private savings and income-tested benefit programs.

The starting population is the one-percent (213.000 person), public use, sample of the population from the 1971 Canadian Census. Those data have been considerably augmented with survey and administrative data. The database is aged annually through 2100.

The model can produce both, simulated cross-section data for every simulated year and individual event and income/employment/contribution histories.

DYNACAN is organized in three components corresponding with data preparation, simulation of events and accounting:

- DYNACAN-A: prepares the initial input database for the simulation, i.e. by imputing earning histories and disability status to the 1971 cross-section data.

- DYNACAN-B: simulates the longitudinal histories of demographic and labor market events and earnings (that feed into DYNACAN-C in order to calculate contributions and benefits). DYNACAN-B is organized in some 17 behavioral and rule-based or bookkeeping modules with most equations adapted from CORSIM. Most events are simulated stochastically in a two-step process, with probabilities being aligned to exogenous alignment values in the second step. As DYNACAN was developed to mirror the aggregated outputs from the CPP Actuarial Valuation Model (extended by extensive distributional detail), alignment is a central feature of its operation.

- DYNACAN-C: calculates pension contributions and benefits and produces aggregated data output.

DYNASIM reached complete "independence" from the CORSIM microsimulation project and with the release of CORSIM v4.0 in 2000, DYNACAN and CORSIM no longer share a common source tree as the changes to CORSIM were too great to be incorporated into DYNACAN.

Demographic and family behavior

The modules for demographic behavior are mostly adaptations of the CORSIM equations to Canadian data. Given the heavy use of alignment techniques, the "internal" behavioral equations are therefore used to depict the social-structural effects and distributions of events across demographic groups, while the aggregate results are aligned to external forecasts. Therefore, demographic projections per se are not a central model application.

DYNACAN models disability histories. Disability status, including rehabilitation and the increased mortality associated with the disabled population, is simulated using probabilities drawn from CPP administrative data. DYNACAN does not model health conditions or any health insurance or finance issues, this partly due to Canada's universal (tax-financed) health care coverage. Future applications might include more detailed health care finance models, recent applications like the mortality impact analyses for Health Canada point in this direction.

Main applications

The model's main aim lies in the projection and evaluation of the financial impacts on individuals and families of alternative policy proposals for the Canadian Pension Plan (CPP). Having achieved "operational status" in simulating the CPP, further development and applications in broader/additional fields can be expected.

2.4 DYNAMOD

Overview

DYNAMOD-2 model - a dynamic microsimulation model of the Australian population which is designed to project characteristics of the population over a period of up to 50 years. Major elements of the model include demographics, international migration, education, the labor market and earnings.

The DYNAMOD-2 model can be seen as the population simulation module of what was initially thought as a two-part model, with an separate analysis module being the second part – a design following the DYNASIM2 approach to reduce computing demands. The first analysis tool corresponds with the models first specialized application as a model for the analysis of student loans.

DYNAMOD-2 uses a "pseudocontinuous" time framework operating in monthly steps for most demographic and labor market processes and in annual steps for education and earnings. Regarding the statistical modeling approaches used, it makes maximum use of survival functions. This design was chosen in order to brake the trade-off between time interval and computing demands: while it is one of the first comparable models using months as time units, the survival functions only have to be re-evaluated if changes occurred in the characteristics incorporated in these functions. For example, the month of death is determined at birth and stored in what was called the 'crystal ball' (King et. al. 1999). This month is only re-evaluated, if a change in the health status occurs, as beside the birth year, age, sex and disability status no other variable enters the survival function used.

DYNAMOD-2 concentrates on four broad groups of processes, namely demographics, education, labor markets and earnings.

Demographic and family behavior

Fertility is modeled using survival functions derived from a 1986 national survey (n=2547 women aged 20-59) undertaken by the Australian Family Project at the National University and containing detailed biographic information. The fertility processes are aligned by scaling the outcomes of the survival functions so that simulated fertility matches exogenously specified age-specific fertility rates.

Mortality is modeled applying rates by single-year age, sex and disability status being based on observed mortality rates and assumptions on future changes. Disability is an important variable that beside the mortality function also enters educational functions. According its importance in the Australian context, migration is modeled in detail distinguishing five categories of movement and also taking into account the migrant eligibility category. The modeling of immigration involves the simulation of five 'pools of potential immigrants' created from LSIA (Longitudinal Study of Immigrants) data. The actual numbers of immigrants from each 'pool' is exogenously set for every year. As LSIA data do not cover immigrants from New Zealand, these are produced by cloning of matching individuals already in the dataset. To change the characteristics of the 'pools', reweighing procedures are used.

Couple formation and dissolution are also modeled female dominant using survival functions estimated from the same data as for fertility. Matching is based on age, education and employment status.

Education is modeled in annual time steps for the whole following year using observed transition probabilities between school types and levels.

DYNAMOD-2 models the monthly transitions between labor force states, fulltime- vs. part-time as well as sector of industry and wages. Employment of fulltime students is treated separately. Details are given in King (1999).

2.5 LifePaths and POHEM

Overview

LifePaths is a dynamic microsimulation model developed at the Canadian Statistical Office that differs considerable from other existing models for four reasons:

- it operates in continuous time what (amongst other things) allows for a more accurate representation of causation and behavior.

- it is an open model in which new individuals are created in case of partnership formation using a concept of "dominant individuals".

- it uses a synthetic initial database: LifePaths uses a variety of historical micro-data sources in order to create representative synthetic life histories from birth to death for all birth cohorts since 1872.

- it runs on a generic simulation language (ModGen) also developed at Statistics Canada which is freely available and can be used to produce new "variants" and applications of the model.

LifePaths is structured with an explicit event orientation. Behavioral equations together with their stochastic components determine the distribution of waiting times to events. A LifePaths simulation consists of a set of mutually independent cases. Each case contains exactly one dominant individual in the first generation. The spouse and children of the dominant individual are simulated as part of the case and are created to satisfy the marriage and fertility equations. (Statistics Canada 2002) This approach also determines the order of the simulation: LifePaths simulates the completion of one case, before going on to another.

Demographic and family behavior

The simulation of demographic behavior is the central focus of LifePaths and the continuous time framework allows for a variety of behavioral models that might be used. In order to reproduce the current Canadian population, the modeling of immigration is of comparatively high importance, and "it is a special challenge to model the Canadian population without at the same time modeling the rest of the world". (Statistics Canada 2002) Independent of place of birth, all individuals are simulated from birth, and entering/leaving Canada as well as moves between provinces are treated as events. Mortality (remaining life time) is re-assessed at each birthday; recently mortality has been modeled in much more detail in the development of the sister model POHEM (see below).

Education is modeled in detail including 30 possible post-secondary education fates as well as 100 possible fields of study.

Births are simulated as a sequence of fertility decisions. Each decision is modeled in two parts: first a decision whether having a child is made and in this case a waiting time is generated. Partnerships are modeled in a series of possible marriage and common-law transitions. Partners are either created "when needed" by generating individuals of appropriate age and sex until a match regarding education is found or are taken from a "spouse market" created prior to the simulation of the cases. Two further ways of changing household composition modeled are children leaving home and the institutionalization of elderly.

Statistics Canada used the ModGen modeling environment to generate several daughter models of LifePaths, most prominently POHEM – a Population Health and Disease Model, which uses the demographic module of LifePaths but replaces the mortality equations with a highly detailed model of morbidity and mortality. POHEM is used to empirically evaluate competing heath care scenarios. (Zaidi and Rake 2001) POHEM simulates representative populations and allows the rational comparison of competing health intervention alternatives, in a framework that captures the effects of disease interactions.

Beside the core demographic behaviors, the employment status is modeled distinguished for three phases or circumstances: employment of fulltime students, that is partly determined by the academic year, career employment and maternity leave. Possible employment states are paid employee, self-employed and not employed.

2.6 MOSART

Overview

MOSART is a dynamic microsimulation model for Norway developed by Statistics Norway to investigate policy options regarding the financing of public expenditure (Fredriksen 1998). In its first version developed between 1988 and 1990 it focused on demographic behavior, education and labor force participation in order to study the impact of demographic change on labor force and education attainment. The second version extend the model allowing for pension modeling. Currently MOSART exists is in its third version that includes more detailed behavioral modules regarding household formation and disability. MOSART is mostly based on administrative and register data, representing 12% of the Norwegian population.

This database is in fact equivalent to a longitudinal database that contains rich retrospective information on many variables dating back to 1985 resp. 1967 in the case of labor income and pension entitlement.

Most events are represented by time-invariant transition matrices and logit relationships assuming constant behavior over time. The only exception are currently the mortality rates, that are assumed to further decrease over time.

Demographic and family behavior

Time-invariant transition tables are used for leaving home, institutionalization, marriage and cohabitation, matching couples and couple dissolution. Fertility is modeled applying a TFR of 1.86 using a model based on age of mother, age of youngest child and parity. Net immigration is exogenously imposed, education activities are based on observed rates for 1987. Disability and rehabilitation as well as labor market participation are modeled using multinomial logit functions.

2.7 LIFEMOD and HARDING

Overview

LIFEMOD and HARDING are two dynamic cohort microsimulation models developed in parallel for Australia (HARDING) and Great Britain (LIFEMOD). (Falkingham, Harding 1996) The models share a similar modular structure and common core code for the initial modules, but diverge in the form, labor force participation and earnings are modeled..

The models simulate complete life histories for a pseudocohort of 2000 individuals of each sex each. Both models assume a steady state world: the HARDIG cohort is 'born' into and lives in a world that looks like Australia in 1986; the LIFEMOD cohort lives in a world that looks like Britain in 1985. This are typical assumptions in this type of cohort models, thought to provide a useful benchmark against which policies can be evaluated.

The main use of both models are the study of inter- and intra-personal distribution effects of different policies, i.e. comparisons of poverty alleviation vs. social insurance systems; a comparative study using both models for the regarding countries can be found in (Falkingham, Harding 1996)

2.8 NCCSO Long-Term Care Model

Overview

The NCCSU microsimulation model of long-term care charging is developed at the Nuffield Community Care Studies Unit at the University of Leicester. It is based on data on older participants in the Family Resources Survey 1997 (FRS), a representative sample

of British households (n=6.400 individuals 65+). It contains detailed information on incomes, wealth and housing but as it excludes people living in care homes it only represents the population from which future entrants to care homes will come. As a model of long-time care charging, it simulates alternative policies including means-tests and policies taking into account housing wealth. The model simulates the incomes and assets of future cohorts of older people and their ability to contribute towards care home fees, should they need to be cared for in such settings. As a dynamic model, this includes the "running down" of assets associated with care needs.

In order to project future health care costs, transitions regarding health care needs have to be modeled. Currently the model concentrates on the cost incidence – the simulation of means tests etc. – and uses exogenous scenarios from macro projections in the modeling of future demands. This is done by linking the microsimulation model with the PSSRU (Personal Social Services Research Unit, University of Kent) cell-based macro model. In this approach, the means test of long-term care policies is simulated in the microsimulation model and results are fed into the macro model of future care demands and costs, that way including the issues of cost incidence into the analysis. (Hancock 2002)

2.9 DESTINIE

Overview

The first version of DESTINIE developed by INSEE calculates social security contributions, benefits and taxes since 1945, and simulates the socioeconomic evolution of a micro population till 2040 on existing demographic and economic projections. For this interval, DESTINIE allows to compute the rate of return of public pensions for different age cohorts born between 1920 and 1974. DESTINIE simulates the evolution of pensions in the long run allowing for heterogeneous careers and changes in the demographic structure. The current 2nd version of the model is based on individual data derived from the 1998 Financial Assets Survey (about 50,000 individuals) The population is followed year by year from 1998 to 2040. DESTINIE models 3 kinds of stochastic events: demographic events, labor market transitions and income. It simulates the effect of alternative pension designs on the participation rates and the amount of pension of successive cohorts.

Demographic and family behavior

The modeling of demographic behavior is based on logistic regression models including variables of duration spent since the previous event, which is seen as a significant source of demographic heterogeneity. (Robert-Bobee 2001) The age at leaving school, which is a major covariate in Destinie, is the only economic covariate taken into account to model demographic transition probabilities. School leaving age is modeled as deviation from the birth cohort mean, and is dependent on parent's education. For birth cohorts born 1975+ the mean age is assumed to remain fixed at 21 years. DESTINIE models first partnership, union disruption and start of other partnerships and births. The modeling of death accounts for the social inequalities that are summed up in age at leaving school. Leaving home is modeled as an irreversible event, again dependent on school leaving age and is additionally generally assumed when starting a partnership. DESTINIE is a closed model regarding partner matching but allows for immigration, with numbers and age distributions of immigrants assumed exogenously.

The behavioral models underlying the demographic events and their underlying assumptions are kept reasonable simple, taking only a very small list of covariates in account what makes results interpretable. DESTINIE closely reproduces "official" population projections done by other methods without additional alignment. As a result, DESTINIE may become a useful tool to study not only retirement issues but also demographic topics. A recent example of such a study using DESTINIE is the analysis of future change in completed fertility. (Robert-Bobee 2001)

2.10   FAMSIM

The FAMSIM model

FAMSIM – an acronym for dynamic 'Family Microsimulation' - was developed as a prototype of a demographic module for a microsimulation model destined for projecting and evaluating the effects of family policies. (Lutz 1997) FAMSIM is based on female biographies collected in the Family and Fertility Survey (FFS). What makes this project unique is the fact that the FFS retrospective event history data are available for more than 20 countries in a standardized way. So far, the model was estimated for five countries, namely Austria, Belgium, Italy, Sweden and Spain. (Neuwirth, Spielauer 2001)

Being based on the female event histories, the simulated micro units are exclusively women. All other persons in the family along with relevant household characteristics are attached to the female data-records as attributes.

FAMSIM is a discrete time model using months as time units. The history events that are considered are the start and the end of different kinds of partnerships, school enrolment, labour force participation and the beginning of pregnancy resulting in birth.

The behavioural models of FAMSIM are derived from 13 logistic regressions for the following transitions:

Transitions with binary outcomes (yes/no):

- beginning of pregnancy followed by birth (transition probabilities for first, second, third and further births are estimated separately)

- beginning of school enrolment

- end of school enrolment

- beginning of paid work

- end of paid work

- end of marriage

Transitions with 3-category outcomes (a/b/none):

- exiting single status: (a) single to cohabitation   (b)   single   to marriage

- exiting cohabitation status: (a) cohabitation to marriage (b)   cohabitation to single

The FAMSIM-prototype is based on a set of 11 variables containing information about actual states and durations. A summary of estimation results – the logits of the 13 equations – for Austria, Belgium, Italy, Sweden and Spain – is contained in the appendix; for full statistical output see Spielauer (2000). The following table briefly describes the variables.

VARIABLES	
INTERCEPT	intercept
PARITY1	one child (dummy)
PARITY2	two children (dummy)
PARITY2P	two and more children (dummy)
PARITY3P	three and more children (dummy)
PARITY4	four children
PARITY5P	five and more children
AGE	age in months / 12
AGESQU	age * age
BINT1324	13-24 months after last birth (dummy)
BINT2536	23-36 months after last birth (dummy)
BINT37P	37 and more months after last birth (dummy)
COHAB	living in cohabitation (dummy)
MARRY	married (dummy)
TOTCOHAB	number of non-married months in current partnership / 12
TOTMARRY	number of married months in current partnership / 12
SCHOOL	enroled in school (dummy)
TOTSCHOOL	total months of school education since 15th birthday / 12
WORK	paid work (dummy)
TOTWORK	total months working / 12
LTREND	logarithm of time in months / 12 since 1940
PGDUR13	in first three months of pregnancy (dummy)
PGDUR46	in fourth to sixth month of pregnancy (dummy)
PGDUR79	in seventh to 9th month of pregnancy (dummy)
PGDUR49	in fourth to 9th month of pregnancy (dummy)

The starting population is generated from FFS data, a process that includes the simulation of the life histories of teenage girls from 15–19, as this age group is not covered in the survey. A simulation run typically comprises 50 years. Major weighting problems in the dataset for Austria were detected, which for example created an over-representation of women with children. This seriously affected the fertility rates in the simulations. Reweighing the data set with respect to age and parity restored the representativity in most dimensions Since this careful preparation of the datasets was not done for the other countries, actual projections so far were only performed for Austria and estimation results for the other 4 countries for that the model was estimated so far were only investigated in a comparative way regarding individual risk pattern in different life course situations. The results for Austria are consistent with other macro population projections. The FAMSIM prototype model includes a time-trend variable in the form of the logarithm of calendar time. The base scenario assumes that this trend continues into the future. An alternative scenario was simulated for Austria, keeping time constant from the start of the simulation in 1995. In many population forecasts unchanged behaviour is assumed. This equivalent to the simulation results without the time trend.

The FAMSIM prototype model described in this section was developed within the framework of a feasibility study for a dynamic microsimulation model of family dynamics. In its current version it focuses on the life course interactions between education, work, partnership formation and birth. This investigation has shown that the behavioural models are very useful for comparing risk patterns for life course events such as partnership formation and fertility for women in the five countries. Furthermore, the simulation runs

showed that the forecasts are stable and correspond fairly well to macro measures from independent sources.

2.11   A comparison of approaches regarding the modeling of demographic and family behavior: lessons for FAMSIM+

As dynamic microsimulation models simulate the socio-economic development of a sample of individuals through time, as part of that exercise, they also create their own demographic projections. By doing so, the models differ considerable in four aspects that can be distinguished.

-   The first point regards the extent to that the model is used to produce demographic projections resp. the degree of alignment to other (macro) projections.

-   Models differ in the degree, in which socioeconomic variables are included into the modeling of demographic behavior.

-   Models differ in the degree of (explicit) behavioral modeling: that is, to which extent the models are based on theory versus statistical "black-box" models.

-   Models differ in the way the base population is created. It can be derived from a cross-sectional sample or by creating a synthetic population from other sources of information.

Alignment to other models

The first point regards the extent, internally produced projections are used (and trusted) regarding the projected aggregates. Many models, like DYNASIM, CORSIM and its various successors make heavy use of alignment methods in order to align the models aggregate projections to external forecasts or to historic numbers if simulation starts in the past. The latter is the case for example in COSRSIM that still uses a 40 year old population sample as its starting population. Over the years, time series of adjustment factors arose and in order to use the model for forecasts, research rather concentrates on the prediction of alignment factors from this time series data than on changing the model. In the context of aligned outputs, the "internal" behavioral equations are therefore used to depict the socio-structural effects and distributions of events across socio-demographic groups, while the aggregate results are aligned to external forecasts. There are various reasons, why this

approach is followed. The first is randomness. As all (surveyed) microsimulation models are of stochastic nature, its outcome is subject to random variation that increases with the number of variables included (specification randomness). Additionally, the Monte-Carlo method, used in order to determine if an event happens for a given probability, creates its own "Monte-Carlo"-variation, that is, every simulation experiments produces a different outcome. This would imply, that simulation runs have to be repeated several times in order to investigate the distribution of outcomes, a procedure often not done in reality. While specification randomness reduces the prediction power of a model (in a trade off against misspecification errors due to the omission of important variables), the alignment of detailed micro models to macro-models believed to have a higher predictive power is frequently seen as a way out of this dilemma.

The reason of aligning outputs does not always lie in the lack of trust regarding the model predictions but also results from the demands of policy makers who are interested in "what if studies", the "if" being the aggregate output the model is demanded to reproduce. A typical example are "official central scenario" population forecasts. In this respect, the alignment of fertility outcomes is also needed and used to make model results – i.e. of pension models - comparable to other modeling approaches by using the same population scenario. To meet this need, alignment methods were also incorporated to microsimulation models, that initially were not planned to follow this road – the Australian DYNAMOD being a good example.

Other models like DESTINIE and MOSART are also able to reproduce given population scenarios but do so rather using less complex models of demographic behavior, that is, methods and variables that come close to conventional cohort-component models and therefore can "internally" reproduce given scenarios by according parameterization. MOSART mostly uses time-invariant transition matrices, producing pre-set total fertility rates in a model that is based on age of mother, age of youngest child and parity. Being based on a large administrative data base, this approach can be seen as an alternative to the cohort component methods being able to produce the same projections but adding additional flexibility. DESTINIE clearly crosses the line of what could be done with the cohort-component method by introducing duration dependency in its models of demographic behavior. But as this is done by keeping the number of variables used small and being based on a comparable large population sample, randomness is reduced to the extent that makes the model a useful tool also to study demographic topics. A comparable

small set of (11) variables (containing durations) together with simple behavioral models is also used in FAMSIM. The population projections produced by FAMSIM are very close to "official" projections, but being based on a small sample of 4500 women, Monte Carlo variation has to be smoothed out by averaging over dozens of simulation runs.

LifePaths and POHEM are the only models surveyed in that the simulation of demographic behavior is the central focus of the model. Accordingly alignment is not a topic in the sense that model outputs are aligned to fit another model but it is rather tried to find and fit models in order to reproduce the observed patterns in the past and gain from this experience when projecting into the future. As LifePaths restores the demographic experience for every simulated person from its birth, it creates a synthetic cross-section rather than working with a single sample cross-section as starting population. Being very flexible regarding modeling approaches at the one side – LifePaths is based on a continuous time frame – the modeling of demographic behavior is restricted regarding the modeling of interactions between individuals: LifePaths simulates individuals case-wise in an open population. The cohort models LEFEMOD and HARDING in some respect share characteristics of LifePaths in the sense that they work with synthetic populations – in this case of only one single cohort. Cohort models are therefore very restricted as tools for family studies as most demographic phenomena as population ageing and their socio-economic impact cannot be studied focusing on a single cohort in a steady state world.

Alignment was never regarded as important topic for FAMSIM as the model prototype (1) was developed to study and project demographic and family processes using a "better" model by incorporating state durations and (2) as the aggregated simulation results turned out to be close to macro-projections like the central population scenario of Statistics Austria. So far, the different population scenarios produced by the model differed by the inclusion/exclusion of time trends, that is, by "freezing" behaviors as observed today vs. continuing recent trends. Regarding the future development of FAMSIM+, a modeling strategy that allows to "internally" produce different scenarios will still be preferable. Problems might arise through the planned "double-nature" of FAMSIM+ designed not only to study demographic and family processes but also as a policy tool to calculate costs and distributional effects of (family) policies. To meet this requirements, detailed personal and household characteristics have to be included into the model that might reduce the prediction power of the model. The way out of this dilemma leads directly to alignment – or to less ambitious models regarding the detail included in long-term projections.

Concentrating on demographic processes in the long run and limiting detailed tax-benefit analysis to the short term (while studying tax-benefit and social security policies in rather stylized form in the long run) might be the appropriate way for the first round of the further development of FAMSIM+.

Complexity of the models and number of variables used

As discussed in more detail above, what makes microsimulation especially attractive, namely the large number of variables models can include, comes at the price of specification randomness and the resulting weak prediction power decreasing with the number of variables. While models that are based on rather simple behavioral models like DESTINIE, MOSART and to some extent FAMSIM produce "trusted" demographic projections, this models are not only rather weak regarding explanation (as will be discussed below), but also limit the analysis of behavior to this reduced set of variables. This models i.e. do not allow to include the influence of income and many other socio-economic variables regarded as important in the modeling of demographic behavior. As many socio-economic characteristics therefore have to be assumed independent of demographic behaviors, these models might produce quite biased joint distributions when these additional characteristics are included into the analyses. This is especially a problem in tax-benefit analyses for that microsimulation models have been created. In this models both household structure and the number of other socioeconomic characteristics are needed to simulate policies. This might not be a problem for forecasts in the short term if the base population comes from a recent representative sample, but generates a trade-off between good demographic predictions and a good prediction regarding distributional issues in the long run. This leads back to the heavy use of alignment techniques used in the models mainly built for policy analysis like CORSIM, DYNACAN or DYNAMOD. In this respect, the NCCSO model reaches the "extreme case of specialization" as it entirely concentrates on the projection of income and wealth distribution of pensioners (used for the means-test of care policies) but leaves the modeling of population numbers by age and care need to a cell-based macro model to that the results of the microsimulation model are fed into.

The conclusions for the development of FAMSIM+ are related to that derived above: detail in the short term (as used for policy analysis) and a clear focus on demographic

processes in the long term. In this respect, FAMSIM+ might be rather developed as a microsimulation platform allowing for different types of populations regarding size and detail that can be combined with different behavioral modules.

Theoretical foundation of behavioral models

The weak theoretical foundation of many microsimulation models is a common source of critique regarding many microsimulation models. (Klevemarken 1996) This topic is very related to the intended use of a model – prediction versus explanation – as a good theoretical foundation usually does not go hand in hand with the prediction power of a model. This can also be observed in the separate traditions of how microsimulation (in its wide definition) is applied in demography, ranging from statistical 'black-box' models for predictions on the one side and agent based computational demography (ABCD) as an inductive explanatory method on the other side. Except the LifePaths model, all surveyed models use either transition tables or (usually logistic) regression models including a different range of variables. All these models can be regarded as typical "black-box" models as beside the selection of appropriate variables, little or no theoretical foundation is given. LifePaths deviates from this approach, as it introduces "more behavior" in its modeling of fertility that is modeled as a sequence of fertility decisions distinguished from the statistical modeling of the waiting time until birth after a decision was made. This might be a very useful departure point in order to introduce agent based behavior like goal orientation and explicit models of decision making into microsimulation. (Vencatasawmy 2002) Generally, the inclusion of explicit behavior is supported by time-frameworks that do not restrict the range of models to transition models. The Australian DYNAMOD model give a very interesting example in this respect as with its pseudo-continuous time framework (of monthly steps) and the ability to store future events (in what they call the "crystal ball") whose effective occurrence might be re-assessed as circumstances change, it opens various ways of modeling behavior.

FAMSIM operates with monthly time steps and the computational platform currently under development is designed in order to allow also for duration models.

The starting population

Dynamic microsimulation models usually have a starting population as a cross-sectional database representation of the population simulated. In a cohort model like HARDING and LIFEMOD this population does not origin from an actual sample as simulation of the cohort members starts at birth and the population is created synthetically by simulation of all individual life courses. A synthetic generation of a full population can be found in the LifePaths model. This approach is typically chosen in demographic research, if population characteristics have to be restored that are not contained in survey information. Kinship patterns are a good example, with the work of Wachter (Wachter et. al. 1995, 1998a, 1998b) who restored the kinship patterns of the US population using the SocSim (reference) software being the most prominent example. Other applications using this approach are the simulation of wealth accumulation and distribution including bequests etc.

All other models surveyed do depart from a starting population derived from surveys. Anyhow, the restoration of missing information by simulation can also be found in DESTINIE that restores income histories of the population in order to be able to calculate rates of return of pension contributions. CORSIM at the other side is based on 1960 data and simulates earning and other histories from this year on.

The FAMSIM prototype was entirely "built around" FFS data what opened the possibility for comparative studies as these data are available for around 20 countries. Regarding the starting population, FAMSIM+ will be based on a much larger micro census sample with additional information imputed from various sources including the FFS.

The 12 SAGE - lessons

The SAGE research group located at the London School of Economics (Zaidi and Rake 2001) have drawn "12 lessons" for microsimulation modelers engaged in the creation of a new microsimulation model. This lessons are based on a review of seven dynamic microsimulation projects. Zaidi and Rake focus on the simulation of social policies in an aging society. In this chapter, their findings are discussed regarding their applicability in family studies.

The surveyed projects differ considerable in the number of processes that have been modeled and therefore in comprehensiveness. Comprehensiveness and complexity comes

at the price of making it difficult to interpret results and to separate out the impact of individual processes. Zaidi and Rake in this context conclude, that the effectiveness and suitability of a dynamic microsimulation model has to be judged in relation to the purpose for which the model was built and summarize this finding in the first of 12 lessons:

> "A successful model requires clear objectives. From this objectives, model builders can identify the processes which are essential to the model and design a developmental strategy for the model, whereby other processes are incorporated over the longer term." (Zaidi and Rake 2001, p. 18)

Dynamic microsimulation in the field of family studies can be seen resp. should be designed as a tool for the investigation of population processes, supporting the conceptualization of this processes and the study of their determinants and consequences. Following, such a model has to include the core demographic processes and should be able to produce its own forecasts regarding aggregated population outputs rather than being aligned to other projections. Family studies are concerned with the broader nature of social and economic change and the impact of demographic change on the family as well as the environment. In order to design a dynamic microsimulation model as appropriate tool in family studies, it has to include additional relevant processes and variables in a way, that makes it either a comprehensive model regarding the objectives followed or a model that produces a detailed and adequate population input for other models. In both cases microsimulation can be the appropriate modeling approach as it adds flexibility regarding the modeling of dynamics and the range of variables included to what is currently dominated by cell-based (cohort-component) models.

Comparing the surveyed projects, a clear trade-off can be observed between the socioeconomic detail included in order to carry out detailed tax-benefit calculations and the prediction power of the models in the long-run. This can also be seen as a trade-off between detail in cross-sectional analysis and the suitability for studies of (population related) processes (and transparency) in the long term. Family studies focus on both, especially regarding family policies, as a detailed calculation of costs and distributional impacts of family policies in the cross-section might be equally of importance as the study of long-term effects. In accordance to this double-nature of the FAMSIM+ model, it will be developed rather as a modeling platform than one single model suitable for all questions.

A problem of all data based microsimulation models is the availability of data. In that respect, the "model builders have to be sensitive to the shortcomings of data [..]" and "the model should be flexible enough to incorporate the most recent and robust data" – what are essentially the lessons 2 and 3 derived by Zaidi and Rake. This concept is extended in the development of FAMSIM+, as we do not only want to allow to incorporate the latest data but also to base the model on different data according to the application. Equally intuitive is the 4th lesson stating, that "Innovation in model building may be desirable, although it involves taking risks, with parts of the model building process having unknown rewards and pitfalls."

A topic related to the comprehensiveness of models as discussed above is, whether models are used and designed to produce input to other models, and if so, whether this combination of models involves feedback reactions. In the wide area of family studies, microsimulation can be useful in all three cases, as "stand alone" tool to study and project population and family dynamics, as method that can produce a more detailed population input to other models as could be done by the cohort-component method, or as one side of an integrated micro-macro model where results of one side feed into the other, and vice versa – i.e. in population-environment studies, where combining the strengths of micro and macro models might be an appropriate modeling option. The design of integrated micro-macro models in reality have turned out expensive both regarding development costs and model transparency. The experience of the DYNAMOD can serve as an example where model builders ultimately preferred to allow for flexibility in specifying external aggregates. Zaidi and Rake conclude in their fifth "lesson" that "[..] Simpler solutions, in the form of taking macroeconomic indicators from external sources and performing sensitivity analysis may be preferable in the short/medium term." This might equally apply for family studies, at least as long as feedback reactions are not the focus of analysis itself.

Regarding the appropriate time frame to use, Zaidi and Rake conclude in their sixth "lesson":

"Limits of data, and the difficulties of modeling 'continuous time' mean that a traditional structure may be preferable. However, it may bring dividends to introduce innovations into a traditional structure. For example, the feasibility of looking at certain events on a shorter timescale (e.g. monthly) should be explored. In addition, hazard rates and survival functions should be examined" (Zaidi and Rake 2001, p. 20)

The latter has been done by various authors including Galler (1997) and in the context with FAMSIM+ Vencatasawmy (2002) Regarding the use of microsimulation in family studies, a pseudocontinuous timeframe of monthly steps might be the most appropriate, as it allows for various modeling approaches also including hazard rates and survival functions. In this respect, the Australian DYNAMOD project can serve as an interesting example, as was already noted above. It has to be noted, that many design choices for a yearly timeframe have not been made regarding data availability or modeling considerations but rather to avoid the high computational demands of shorter time intervals – this might be limitations that have already been lifted. Regarding the surveyed models, the model that focus most on demographic processes – LifePaths – uses a continuous timeframe.

The second time dimension refers to the period over which models operate. Zaidi and Rake conclude in their seventh "lesson":

"Producing output that covers the short and the medium term as well as the longer term is an essential way of ensuring that the model remains credible. In setting the end date of the model attention needs to be paid to known demographic transitions and the life-span of policy reforms in order to show its full impact." (Zaidi and Rake 2001, p. 20)

Most population processes evolve over many decades rather than years and projections of 50 to 100 years are quite common in population projections. As many phenomena that can be observed today are the result of past dynamics, one frequently also has to look back in time. Microsimulation in this respect can also serve as tool to "restore the past". A historical start date as used in CORSIM may be chosen both as a way of validating the model and as (sometimes only) way to impute characteristics of the today's population otherwise not available, like kinship networks or past contribution histories to social security systems etc. In demographic research, microsimulation has also been used to restore historic populations. (Wachter et. al. 1995, 1998a, 1998b)

Lesson eight again is derived from data considerations, stating that the representativeness of the base data is of higher importance than its detail. The same conclusions led to the decision to base FAMSIM+ rather on a large micro-census sample than on the FFS data used so far. The next two lesson regards model validation, rather generally stating that "[..] sensitivity analysis as a way of estimating the impact of specific

parameters on model output and is a first step in validating a model" and that "[..] operating a retrospective microsimulation model is one attractive, although not complete, way of establishing its validity." This is definitely true also for microsimulation applied in family studies, as are the following and last two "lessons", the first highlighting the necessity of thorough and clear documentation and the last the need of a computing strategy "to be developed alongside the microsimulation strategy. Alternative strategies may be tested in the development of a simple prototype model".

Summery

This paper investigated the potential of microsimulation modeling in the context of family studies in general as well as based on a survey of existing models. From this survey some conclusions and lessons for FAMSIM+, the dynamic family microsimulation model currently being developed at the Austrian Institute for Family Studies were derived.

After giving a definition of dynamic microsimulation and a classification of types and approaches, microsimulation modeling was brought into the context of the life course paradigm, the dominant paradigm in demography that can serve as a useful organization principle for the study and projection of population phenomena including their family dimension. Microsimulation was then compared with cell-based approaches and a review of 32 existing dynamic microsimulation projects and applications was given, with 12 of these projects discussed in detail. Based on that, the strengths and limitations of dynamic microsimulation as well as its potential in family studies were explored and some conclusions were drawn for the development of FAMSIM+.

The design decisions to be made in the development of FAMSIM+ have to be based on the focus of the model, and there exists a series of trade-offs that have to be taken into account. Due to the double-nature of the FAMSIM+ model being developed both for the study and projection of demographic processes and as a tool for policy evaluations, we conclude that the project should be rather designed as a modeling platform than one single model. Regarding the timeframe of the model, we found that small time-steps allowing for 'pseudo-continuous' models are more appropriate for the modeling of demographic processes and that the additional flexibility introduced by this framework outweigh the higher computational demand.

Appendix: Summary of Dynamic Microsimulation models

Model	Inst / Country	Uses	Base Data	Sample Size	Base Pop	Time	Open/close	Alignment	Steady State	Behavior
DYNAMOD	NATSEM Australia	DYNAMOD-2 model - a dynamic microsimulation model of the Australian population which is designed to project characteristics of the population over a period of up to 50 years. Major elements of the model include demographics, international migration, education, the labor market and earnings. DYNAMOD-2 uses a "pseudocontinuous" time framework operating in monthly steps for most demographic and labor market processes and in annual steps for education and earnings. Regarding the statistical modeling approaches used, it makes maximum use of survival functions.	1% sample of 1986 census	150000 ind	cross	c/d	c	y	n	n
Harding	Australia	HARDING is a dynamic cohort microsimulation model for Australia developed in parallel with the British LIFEMOD model. The model simulates complete life histories for a pseudocohort of 2000 individuals of each sex each. It assumes a steady state world: the HARDING cohort lives in a world that looks like Australia in 1986. The main use of the model is the study of inter- and intra-personal distribution effects of different policies, i.e. comparisons of poverty alleviation vs. social insurance systems	synthetic cohort age 0	4000 ind	cohort	d	c	n	y	n
Melbourne Cohort Model	Australia	income inequality in a lifetime context	synthetic sample of 20 year olds in 1970	50000 males and families	cohort	d	o		n	n

FAMSIM	Austria	FAMSIM –(an acronym for dynamic 'Family Microsimulation') was developed as a prototype of a demographic module for a microsimulation model destined for projecting and evaluating the effects of family policies. FAMSIM is based on female biographies collected in the Family and Fertility Survey (FFS). What makes this project unique is the fact that the FFS retrospective event history data are available for more than 20 countries in a standardized way. Being based on the female event histories, the simulated micro units are exclusively women. All other persons in the family along with relevant household characteristics are attached to the female data-records as attributes. FAMSIM is a discrete time model using months as time units. The history events that are considered are the start and the end of different kinds of partnerships, school enrolment, labor force participation and the beginning of pregnancy resulting in birth.	1995-96 ffs	4500 women	cross	d	c	n	n	n
Pension Model	Belgium	Pension models	synthetic cross section based on survey data		cross	d	c		n	n
DYNACAN	Canada	The model's main aim lies in the projection and evaluation of the financial impacts on individuals and families of alternative policy proposals for the Canadian Pension Plan (CPP). Plans to build this model go back to 1990 and following a feasibility study in 1994, the project was approved and decided to be based on CORSIM, that was acquired to serve as template in 1995. A significant characteristic is its capacity to be closely aligned and used with the aggregate results of the CPP Actuarial Valuation Model, ACTUCAN, as maintained by the Chief Actuary (OCA). DYNACAN achieved full operational status in 1998 after demonstrating its capacity to replicate ACTUCAN results for the existing CPP system. Since then it has been used to analyze a variety of CPP policy options for the federal government.	1% sample of 1971 census	212000	cross	d	c	y	n	n

Name	Country	Description	Data source	N	type					
LifePaths	Canada	LifePaths is a dynamic longitudinal microsimulation model of individuals and families. Using behavioral equations estimated using a variety of historical micro-data sources, LifePaths creates statistically representative samples consisting of complete lifetimes of individuals. The model's behavioral equations generate, at sub-annual resolution, the discrete events that together constitute an individual's life history. In addition to its longitudinal capabilities, a complete set of overlapping cohorts allow LifePaths to produce accurate and representative cross-sectional results from the year 1971 onwards. LifePaths is used to analyze, develop, and cost government programs that have an essential longitudinal component, in particular those whose nature requires evaluation at the individual or family level. It can also be used to analyze a variety of societal issues of a longitudinal nature such as intergenerational equity or time allocation over entire lifetimes. Health care treatments, student loans, time use, public pensions and generational accounts	Synthetic cross section		cross	c	o		n	n
POHEM	Statistics Canada	POHEM is a longitudinal microsimulation model of health and disease. Using equations and sub-models developed at Statistics Canada as well as drawn from the medical literature, the model simulates representative populations and allows the rational comparison of competing health intervention alternatives, in a framework that captures the effects of disease interactions								
DEMOGEN	Canada	Distributional and financial impact of proposals to include homemakers in the Canadian pension plan	synthetic cohort aged 0	5000	cohort	d	o	n	y	n
DESTINIE	INSEE France	Computes social security contributions, benefits and taxes since 1945, and simulates the socioeconomic evolution of a micro population till 2040 on existing demographic and economic projections. For this interval, DESTINIE allows to compute the rate of return of public pensions for different age cohorts born between 1920 and 1974. DESTINIE simulates the evolution of pensions in the long run allowing for heterogeneous careers and changes in the demographic structure. The current 2nd version of the model is based on individual data derived from the 1998 Financial Assets Survey (about 50,000 individuals) The population is followed year by year from 1998 to 2040. DESTINIE models 3 kinds of stochastic events: demographic events, labor market transitions and income. It simulates the effect of alternative pension designs on the participation rates and the amount of pension of successive cohorts.	1991 financial assets survey 1998 Financial Assets Survey	37000 50000	cross	d	c	y	n	n (Y?)

Name	Country	Description	Data source	Size	Type					
Sfb3	Germany	The SF3 model consists of three versions namely a cross-sectional, a longitudinal and a static model. The cross-sectional model contains demographic events, education, labor supply, income, taxes, transfers, consumption, saving and wealth. Pension Reform, effect of shortening worker hours, distributional effects of educational transfers, distribution of pension system	1969ted micro data file (Pop.), Synthetic cohort aged 0 (Cohort)	69000hh/7300ind	cohort/cross	d	o/c	n/y	n	n
Darmstadt Micro Macro Simulator	TU Darmstadt Germany	The aim of the Darmstadt Mikro-Makro model is the integration of a micro-model of the household sector into a macro model.								
Dynamic Model	Ireland	redistribution effects of tax system	1994 living in Ireland survey (Pop), synthetic cohort aged 0	4500 hh/variable ind.	cohort/cross	d	c	y	y/n	y
DYNAMITE	Italy	household level microeconomic questions; impact of macro changes on distribution of resources	1993 survey of Household Income and Wealth	67000 hh	cross	d	c	y	n	n
ANAC	Italy	Effect of demographic change on saving rate and pension system	1993 survey of Household Income and Wealth	67000 hh	cross	d	c	y	n	n
Italian Cohort Model	Italy	Lifetime income distribution issues	synthetic cohort aged 0	4000 ind	cohort	d	c	n	y	n
Japanese Cohort Model	Japan	Impact of household savings of demographic change	Synthetic multiple cohorts (single representative of each cohort type)	4000 ind	cohort	d	c	y	n	y
NEDYMAS	Netherlands	Pension, redistribution, social security, demographic projections, lifetime income distribution, mortality differences related to socioeconomic status	Synthetic cross-section based on 1947 census	10000 ind	cross	d	c	y	n	y
MIDAS	New Zealand	Wealth accumulation and distribution	Synthetic cross-section based on 1991 census	10000 ind	cross	d	c		n	n

Name	Country/Institution	Description	Data	Size	Type					
MOSART	Statistics Norway	MOSART is a dynamic microsimulation for Norway developed by Statistics Norway to investigate policy options regarding the financing of public expenditure. In its first version developed between 1988 and 1990 it focused on demographic behavior, education and labor force participation in order to study the impact of demographic change on labor force and education attainment. The second version extend the model allowing for pension modeling. Currently MOSART exists is in its third version that includes more detailed behavioral modules regarding household formation and disability. MOSART is mostly based on administrative and register data representing 12% of the Norwegian population.	1989 administrative data (1% sample)	40000	cross	d	c	y	n	n
MICROHUS	Sweden	Dynamic effects of tax-benefit systems on income distributions	1994 HUS income distribution database		cross	c	c	n	n	y
SESIM	Swedish Ministry of Finance	The first mission of SESIM was the evaluation of long term effects of the Swedish national system of study allowances. Beside education finance, it is planned to extend the model to be applied for inter-temporal policy issues such as labor supply, savings and pensions.	1992 HINK survey	30000 ind	cross	d	c	n	n	y
SVERIGE	Sweden	SVERIGE is a spatial microsimulation model used to evaluate human ecodynamics. It is based on a database covering the whole Swedish population.	administrative data in 1985-1995	9 mill	cross	d	c	y	n	n
Swedish cohort model	Sweden	social insurance modeling	synthetic cohort aged 20	1000 ind	cohort	d	c	n	y	n
LIFEMOD	UK	LIFEMOD is a dynamic cohort microsimulation model for Great Britain developed in parallel with the Australian HARDIG model. The model simulates complete life histories for a pseudocohort of 2000 individuals of each sex each. It assumes a steady state world: the LIFEMOD cohort lives in a world that looks like Britain in 1985. The main use of the model is the study of inter- and intra-personal distribution effects of different policies, i.e. comparisons of poverty alleviation vs. social insurance systems	synthetic cohort aged 0	4000 ind	cohort	d	c	n	y	n

Name	Country	Description	Data source	Sample	Type					
NCCSU Long Term Care Model	UK	The NCCSU microsimulation model of long-term care charging is developed at the Nuffield Community Care Studies Unit at the University of Leicester. It is based on data on older participants in the Family Resources Survey 1997 (FRS), a representative sample of British households. It contains detailed information on incomes, wealth and housing but as it excludes people living in care homes it only represents the population from which future entrants to care homes will come. As a model of long-time care charging, it simulates alternative policies including means-tests and policies taking into account housing wealth. The model simulates the incomes and assets of future cohorts of older people and their ability to contribute towards care home fees, should they need to be cared for in such settings. As a dynamic model, this includes the "running down" of assets associated with care needs.	1993-97 Family Expenditure Surveys	6.400 ind 65+	cross	d	c	y	y	n
PENSIM	UK	pension	1988 retirement survey, 1986 social change and economic life initiative survey, 1988 family expenditure survey	5000 benefit units	cross	c	c	y	n	n
CORSIM	Strategic Forecasting USA	CORSIM, based at Cornell University, was started in 1987 building up on the first dynamic microsimulation model DYNASIM and is now in its third generation. Built both to simultaneously support basic research into fundamental socioeconomic processes and as a platform for a broad range of policy analysis, the core CORSIM modules were also widely adapted by other models, including the Canadian DYNACANB and the Swedish SVERIGE model. Individual and family behavior is represented by approximately 1100 equations and 7000 parameters as well as dozens of algorithms. Typical applications include the estimation of welfare costs and the distribution of benefits of welfare reform of various US administrations. Kinship changes, wealth accumulation, social security, wealth accumulation, socioeconomic mobility, health status, migration, tax	1960 census 0.1% sample	180000 ind	cross	d	c	y	n	n

DYNASIM	The Urban Institute USA	The DYNASIM model was the first dynamic microsimulation model. It was developed by Orcutt between 1969 and 1976. Its successor DYNASIM2 includes family formation, geographic mobility, education, disability pensions, labor force participation, earnings, taxes and transfers. Population forecasts, teenage child bearing, policy scenarios, linking with macro model	1973 Current Population Survey (CPS) matched to social security administration (SSA) data		cross	c/d	c	y	n	n
MINT	USA	distribution of income of 1931-1960 birth cohort in retirement	1990-93 survey of income and program participation, matched to SSA data	85000 ind	cross	c/d	o	y	n	n
PENSIM/2	USA	Lifetime coverage and adequacy issues related to employer-sponsored pension plans in the USA	Synthetic cohort aged 0		cohort	c	o	n	y	n
PRISM	USA	Public and private pensions	March 1978, March and May 1979 CPS matched to SSA data	28000 adults	cross	d	c	y	n	y

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