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Spielauer, M.

IIASA Interim Report
July 2001

Spielauer, M. (2001) Microsimulation Modeling of Population, Economic Growth, and Social Security Systems. IIASA Interim Report. IR-01-026 Copyright © 2001 by the author(s). http://pure.iiasa.ac.at/6494/

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Interim Report **IR-01-026/July**

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July 2001

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Abstract

This paper is a first step in trying to develop a modeling and simulation framework that allows to incorporate the strengths of microsimulation in economic growth modeling in the context of demographic change. This is mainly done by restating and programming an existing neoclassical macroeconomic growth model in terms of microsimulation, which allows to explore and demonstrate some of the features microsimulation techniques can possibly "add" to this kind of modeling. The starting point of the analysis is the IIASA "Social Security Forecasting and Simulation Model", developed by the IIASA Social Security Reform (SSR) Project as described in MacKellar et al. (2000). This model was developed to study the influence of pension systems on the economy mainly by investigating long-run capital accumulation and economic growth as functions of the evolving age distribution of the population and the nature of pension schemes. Differently to most economic growth models, the IIASA macro-model explicitly introduces "realistic demography" by disaggregating the household sector (and all model outputs) by age cohorts. This kind of economic modeling is incorporated in a dynamic microsimulation framework by further disaggregation of the cohorts to the individual micro-level. Allowing for heterogeneous individual agents, economic and demographic behavior can be modeled taking into account a wide set of individual and household characteristics. As part of this research a “microSSR “ software is developed, both as a tool for the testing of different behavioral theories and as a projection and forecasting tool.

Acknowledgments

A draft of this paper was presented at the Agent Based Computational Demography (ABCD) Workshop at the Max Planck Institute for Demographic Research in Rostock, Germany, 21-23 February 2001.

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Microsimulation Modeling of Population, Economic Growth, and Social Security Systems

Martin Spielauer

Introduction

This paper is a first step in trying to develop a modeling and simulation framework that incorporates the strengths of microsimulation in economic growth modeling in the context of demographic change. This is mainly done by restating and programming an existing neoclassical macroeconomic growth model in terms of microsimulation, which allows us to explore and demonstrate some of the features microsimulation techniques can add to this kind of modeling. The starting point of the analysis is the IIASA "Social Security Forecasting and Simulation Model", developed by the IIASA Social Security Reform (SSR) Project as described in MacKellar et al. (2000). This model was developed to study the influence of pension systems on the economy mainly by investigating long-run capital accumulation and economic growth as functions of the evolving age distribution of the population and the nature of pension schemes. In contrast to most economic growth models, the IIASA macro-model explicitly introduces realistic demography by disaggregating the household sector (and all model outputs) by age cohorts. In this paper, this logic is carried further by further disaggregation of the cohorts to the individual micro-level. Allowing for heterogeneous individual agents, economic and demographic behavior can be modeled taking into account a wide set of individual and household characteristics. As part of this research, a “microSSR“ software is developed, both as a tool for the testing of different behavioral theories and as a projection and forecasting tool.

Microsimulation models can be particularly powerful in this kind of research, as will be discussed in the first part of the paper, where a short overview of microsimulation models and techniques will be given and some strengths and weaknesses in comparison to other models will be discussed.

The second part describes how the existing IIASA model can be restated in terms of microsimulation. Necessary extensions are the explicit modeling of demographic scenarios within the model and – among others – the extension of scope regarding distributional aspects within cohorts.

The third part describes the "microSSR" software-prototype as so far developed and focuses on technical questions regarding this kind of simulation modeling.

Microsimulation Approaches, Traditions and Models

Microsimulation is an inexact term for the type of models it usually addresses, and, in addition, it has the unfortunate characteristic of confusing the model as such with the way in which the model is solved. In the context of this paper a broad definition of both, simulation and microsimulation, is chosen, though most of the microsimulation framework developed here follows a dynamic data-driven approach as is usually used in dynamic tax-benefit models. In general, microsimulation addresses a broad range of models, from static tax benefit models to dynamic data-based microsimulation and context-driven agent-based simulation resting in the artificial intelligence approach. Following this broad view, simulation cannot be exclusively regarded as a technique to solve models or equations which cannot be solved analytically – a technique that, in principle, does not add anything to the models. While this view is dominant, especially in economics and in data-driven microsimulation that clearly distinguishes the model itself from the technique used to solve the model, this distinction cannot be made in rule-based and context-driven agent-based simulation, where (computer) simulation serves not only as a technique to solve a model, but also as a method of theory development.

The common element of all 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 according to probability laws in the field of fluid or thermodynamics, where microsimulation was first introduced, or they might represent artificial species of "artificial societies" as in most agent-based simulations, or represent individuals, families or households of empirical populations as in data-based microsimulation.

Data-based microsimulations are based on micro-databases storing detailed individual, household and (regional) environmental attributes. In modeling the welfare impact of alternative economic policies, the incidence of taxes and benefits can be more accurately modeled on the basis of these micro-data than by means of aggregate functions.

Reduced to its bare essentials, a data-based microsimulation model suitable for this type of policy evaluations 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 work of Pechman and Okner (1974) to analyze the redistributive effects of the US tax system represents the most celebrated example of this type of research. Generally, these models can be characterized as static, as they simply re-weighting the dataset at each time step to reflect the composition of the population. In addition, some microsimulation models incorporate a third component - 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; and
- behavior producing feedback reactions of individuals and/or families to changes in external circumstances, notably to changes in public policies.

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, with or without simultaneously accounting for behavioral response. 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).

Microsimulation allows for simulation of the feedback between individual characteristics and characteristics on the population level. This is explicitly done in multilevel models, which handle the micro-scale of people and the macro-scale of contexts simultaneously within one model. In the multilevel modeling technique each individual evaluates his or her environment as a whole and reacts to it, thus changing the environment by his or her behavior. In practice, detailed micro-models and macro-outcomes are not always produced in a single model, but micro-macro links are established in order to connect micro- with macro-models. An example of this approach is the "Darmstädter Mikro-Makro-Simulator (DMMS)" (Heike et al., 1994) that links a micro-model of the household and enterprise sector with a macro-model of the whole economy. Another method widely used (and not without its critics) is aligning techniques that “force” micro-models to fit externally determined macro-scenarios.

To escape the limitations of static models, a second important development led to the construction of dynamic models, which can be used to compare the effects of alternative policies many years into the future. The study of the evolution of retirement systems, and the evaluation of alternative arrangements to finance public and private pension systems, are typical applications of dynamic microsimulation models of this type. Again, the use of micro-data is of central importance in this kind of detailed analysis, which is especially true for the calculation of retirement income, where the required attributes frequently do not only include the full individual's contribution history, but also the spouse's history. Examples of existing models of this type explicitly designed to study policy options in the field of social security and pension systems are DESTINIE developed in France and the Canadian DYNACAN model.

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. In this type of microsimulation, individual characteristics are changed by a dynamic process generated by a combination of deterministic and stochastic elements. The behavior of individuals is a function of individual, household or socioeconomic characteristics, usually included as independent variables in discrete choice models or simply as categories used to estimate transition matrices that describe the probability of moving from one state to another. This kind of dynamic modeling was first introduced in 1956 by Guy Orcutt's DYNASIM model for the US (Orcutt, 1957) and has since advanced steadily with the increase of computer power, growing availability of longitudinal micro-data, and development of improved statistical methods, especially in the field of longitudinal research and event history analysis.

A clear distinction needs to be maintained between the data representing the population, the model that determines the behavior, the Monte-Carlo simulation usually 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. For an extensive comparison of associated statistical models, data requirements, necessary assumptions, advantages and drawbacks, see Galler (1997).

Agent-based microsimulation, based on the distributed artificial intelligence approach, represents a very different modeling tradition. 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 act simultaneously;
- agents can learn.

Agent-based microsimulation differs from data-based microsimulation in two major ways: Firstly, the "rules of motion" or the behavioral model are not based on statistical modeling relying on empirical data, but on synthetic rules and "intelligent" behavior. Secondly, the aim is context-driven microsimulation, which is not primarily intended to help forecast of the behavior of actual populations, but to study dynamics and patterns of artificial societies that result from the interactions of artificial species following a given set of rules. 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.

While both described traditions or approaches evolved in almost total ignorance of each other (Troitzsch, 1996), each increasingly uses concepts grounded in the other, and a synthesis might be approached by combining or allowing various "rules of motion" and population types according to the research questions and goals. This is increasingly true for economic modeling and simulation, where economic principles such as utility maximization or rational behavior (rules) might be combined with heterogeneous agents representing "true" empirical populations. In this way microsimulation can be used both for theory testing as well as for forecasting, having the potential to improve the accuracy of economic forecasting and to provide new insights into underlying economic principles.

Strengths and Advantages of Microsimulation Models

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. This stands in contrast to existing macro-level projections of future population trends, which, apart from the analyses of population by age and sex, can only add a very limited number of variables to the analyses. Going beyond the traditional analyses, useful projections for the analysis of different population-related social and economic research need to consider additional dimensions. Some examples are educational composition, rural/urban differentials, household structures, labor force status and family networks, which become increasingly important in the context of rapid demographic change.

Based on micro-units, microsimulation avoids bias caused by aggregation, because it allows construction of the appropriate 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.

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.

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.

Based on multivariate methods such as history event analysis or rule-based behavioral models, microsimulation permits study of the interaction between variables and the life course interactions between various parallel carriers and roles, such as education, work, partnership and parenthood within a changing socio-economic context.

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, p. 4) 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.

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.

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.

The Use of Microsimulation in Social Security Research and Economic Modeling

Demand for microsimulation models in social security research does not only result from the special advantages of these kinds of models compared to others, but also from the fact that there is no alternative modeling strategy to address a series of related critical policy and research issues. Caldwell and Morrison (2000) give the following examples:

- analysis of projected winners and losers on 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.

In response to the demands associated with prospective social security reform in the context of demographic change, decision makers of various countries - including the US, Canada and France – have begun to use dynamic microsimulation models to supply key policy inputs. Prominent examples of microsimulation models used in the field of social security research and pension systems are CORSIM in the US, DYNACAN in Canada and DESTINIE in France.

CORSIM, based at Cornell University, was begun in 1987 building on the first dynamic microsimulation model DYNASIM and is now in its third generation. Built 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 DYNACAN and the Swedish SVERIGE model. Based on a representative data sample of the US population, CORSIM simulates in one of its central applications the US Old Age Security and Disability Insurance (OASDI) contributions paid by each person during their working years and the resulting benefits received during retirement. Contributions and benefits are calculated in close approximation to actual rules, fully taking into account all family links to determine survivors' benefits. 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. 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.

Further models applicable for social security research not yet mentioned include MOSART from Statistics Norway (Fredriksen 1998) and the closely related Dutch NEDYMAS model (Nelissen, 1995), furthermore the German Sfb3 (Sonderforschungsbereich 3) model, the first major application of dynamic microsimulation in Europe (Galler, 1994), and the Australian DYNAMOD model.

Though it has long been considered important to incorporate economic optimization behavior into microsimulation models, theory is often sacrificed to get a very detailed model with a good fit to the data. In data-based models, behavior is mostly modeled implicitly, and so are corresponding assumptions, which can make models difficult to understand. Additionally, these kinds of microsimulation models often define only individual and not market behavior; in fact, behavior is often only partially modeled, not taking into account the extent to which different decisions affect each other. In contrast, context-driven agent-based microsimulation incorporates behavior explicitly. 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).

In the field of economic macro-models, the same contrast can be found between OLG models that incorporate behavior as fully as possible at the expense of a simple highly-stylized structure and accounting models such as, for example, the IIASA SSR model with its fine-grained accounting for age-specific stocks and flows. While a reconciliation of accounting and behavioral approaches might be desirable both in micro- and in macro-modeling, it is conceptually easier on the micro-level, being the appropriate level for modeling the economic behavior of the household sector. In the following it is argued that the use of microsimulation can not only be beneficial where no other modeling strategies exists, but it might also improve and add flexibility to models usually expressed on the macro-level.

In the case of the IIASA SSR model, the flexibility gained might be of different dimensions and applications:

- the possibility to either use stylized data of representative households or to base the model on empirical populations;
- the possibility to model social security systems and other tax-benefit systems at any level of detail;
- the possibility to model and account for changing household structures;
- the possibility to extend the scope of research to distributional issues;
- the possibility to extend the number of individual and household characteristics, i.e., by kinship information or individual risk factors necessary to assess health and elderly care costs, etc.;
- a more consistent representation of the model that allows for more efficient object-oriented programming.

The IIASA SSR Model Restated as Microsimulation Model

This section explores ways to restate the IIASA SSR model in terms of microsimulation. For this purpose a very simple dynamic microsimulation model will be developed which, with some extensions, could serve as a micro-version of the IIASA SSR model, but also demonstrates some strengths of the microsimulation modeling strategy. A dynamic microsimulation approach is chosen that handles both demographic and other life-course events, and economic stocks and flows, mostly in the form of individual accounts representing claims on different types of capital assets. While this gives a consistent representation of the household sector, additional decision-making agents have to be modeled, namely financial institutions (including private pension funds) which are allocating savings across alternative investment projects, the enterprise sector which allocates earnings between corporate retentions and dividends, and the government which is setting net taxes and running a public pension system.

As in the macro-model, behavior is mostly expressed implicitly by transition matrices and exogenously assumed age- and time-specific rates such as saving rates. Following the terminology of object-oriented programming, these matrices are methods of determining transition probabilities and rates. This representation can serve as a starting point for more advanced behavioral modeling, with these exogenously assumed rates being subsequently replaced by expressions based on more advanced statistical models for better empirical foundation (such as event history analyses) or derived from theoretical models of utility maximization. While the endogenization of economic behavior such as consumption and labor supply is beyond the scope of this paper, the framework developed does serve as a logical starting point of this exercise. The microsimulation approach supports this goal, both by providing all necessary information usually used for individual decision-making on the individual and household-level, and by a representation of the model where behavioral modeling can be introduced on a level on which individual and household decisions are made: the micro-level. The object-oriented software-design of the "microSSR" software platform explicitly supports the definition of alternative methods determining behavior for two purposes: to (1) allow the model builder to test various (combinations of) behavioral models, as well as to (2) allow for the introduction of agent-based modeling approaches, where heterogeneous agents themselves can choose their behavioral rules according to different goals.

This section is organized in three main parts, which can be interpreted as an anatomy of dynamic microsimulation models: (1) the micro-population, (2) the "rules of motion" that might be subdivided into demographic behavior and education, human capital and economic behavior such as labor supply, income and saving. The third part (3) regards ways of accounting for and aggregation of all model output.

The Micro-Population

The most obvious difference between the IIASA macro-model and its representation as a microsimulation model is the representation of the population. In the macro-framework, this is done by an age-period population matrix for each sex (if distinguished) that might be imported from another source or be produced by the cohort-component method within the model. In the micro-representation, a micro-population has to be imported, e.g. from empirical micro-data containing all characteristics used, or it may also be generated within the model according to specific assumptions. As micro-units are, unlike the “representative individual” macro-framework, distinguished per definition in microsimulation models, births can be explicitly linked to parents and the model can keep track of kinship networks as well as account for different family sizes and types – information that might be valuable in modeling various socio-economic behaviors such as labor supply or savings, etc.

Switching from a representative behavior to the linked lives of individual agents allows for and implies the necessity to model a multitude of aspects of human life-course interactions: how do people select their partners, what determines the stability of partnerships, how do education, professional and partnership careers interact, what determines fertility, etc. While considerable effort is made in most microsimulation projects to model these behaviors – and microsimulation can be seen as the best tool to study the resulting dynamics – it has to be noted that any population dynamics produced by the cohort-component method can be produced by microsimulation just by interpreting the underlying transition rates as transition probabilities (ignoring some Monte-Carlo variability depending on population size). Of course, the justification of microsimulation in population projections, which are, at present, almost exclusively produced with the cohort-component method, lies in its ability to handle larger state spaces. It can handle more population categories on which information is desired (usually limited to age and sex in cohort-component models), as well as non-demographic variables that are considered to be important covariates of demographic behavior. In this way, together with its ability to project kinship patterns, microsimulation can serve as powerful demographic projection tool. On the other hand, all microsimulation models of human societies contain a demographic "module", where population comes more or less as a by-product of a much more comprehensive model, and not as the ultimate output (Imhoff, 1998). A distinction can be made between models where the interdependencies of demographic with other variables are modeled explicitly, and models that use predetermined demographic scenarios.

For the purpose of this pilot study, a closed synthetic micro-population with all demographic characteristics is produced first, on which all later simulations will be based. All individuals enter the simulation at birth, which implies that the model has to be "run" for 100 years – the assumed maximum age a person can reach – to build up the population. Age-specific death rates by period, sex and education level as defined below are applied; the survival of each person for each one-year period is determined by Monte-Carlo simulation. The resulting individual life span can be determined at birth. From the point in time, when the first female age cohort reaches the end of her fertile period, all population dynamics (births, deaths) are produced within the simulation. For the initial period, the number of births has to be exogenously set in order to account as well for births by women outside the simulated population.

Compared to the use of an empirical micro-population, this approach has the main advantage that it can generate otherwise (usually) unavailable information on kinship patterns, which is the logical approach when studying related questions. Good examples are the work of Wachter (1995; 1998), who, for that purpose, generated the present American population with detailed kinship information "solving backward" for the whole 20th century.

In the context of economic modeling, synthetic populations are not only useful to generate missing data, but might even be preferred in highly stylized model designs. In this way relationships between different processes and their individual contributions to the resulting aggregates can be studied free from "unwanted irregularities" of empirical populations, or the influence of shocks can be isolated or assessed directly by comparing shock scenarios to regular ones.

Generating the present population in this way additionally opens ways of extensive model validation, as the resulting synthetic population can be compared with available empirical micro-data. Again, a good example of this kind of study can be found in the work of Wachter et al. (1998).

Creating a population "from the scratch" obviously limits the simulation of accumulation processes to those that can be directly linked to simulated individuals. This implies the necessity of additional assumptions regarding initial endowments or inheritances and other related issues, both with regard to initial stocks and distributional issues. Regarding the production of a synthetic micro-population for the purpose of this paper, a two-step approach was chosen. First, all demographic variables as well as human capital and labor market participation characteristics are generated by running the simulation for an initial period of 100 years. This is done by applying the same dynamics and behavioral assumptions as used later to run the model "into the future" as will be described in the next section. While this allows to calculate total (and individual) effective labor input from the year 0 onward, total capital at this initial year has to be set exogenously. In a second step not realized in this prototype version, the initial capital stock has to be distributed among cohorts and within cohorts according to external information or assumptions.

Rules of Motion

1. Demographic behavior and education

While the cohort-component method is restricted to very few additional variables beside age and sex, behavioral modeling on the individual level allows to process data on past life histories, current states, as well as other individual risk factors. Compared to the component-component method underlying the demographic macro-scenario, two extensions are made, one by introducing education and the other by applying parity-dependent fertility measures instead of overall measures.

In contrast to the "representative individual" approach in the macro-framework, educational levels are introduced as a main discriminator for most behaviors. Education is of central importance in demography as well as in social security forecasting for various reasons:

- Research regarding population projections has identified education as the single most important variable beside age and sex in determining fertility and mortality (Lutz et al., 1999).
- While education to a considerable extent sums up the social class, the socio-professional group and the qualification, it is a key determinant of human capital and therefore of income and job careers.
- Household formation, marriage and parenting careers are usually started after finishing school.
- As education is attained to a high extent before entering the labor force, educational careers typically correspond with the age when entering the labor force - and therefore the age starting to contribute to the social security system.

Education careers are modeled very differently in various microsimulation models. Models vary from a detailed reproduction of a national school system, thereby allowing to model all possible careers in detail (realized, e.g., by the SVERIGE model additionally including regional characteristic), to much simpler models summing up education by few characteristics such as the school leaving age. This is done, for example, in the DESTINIE model developed to study the dynamics of the French social security system. DESTINIE does not model school careers at all, but determines the school-leaving age as soon as a person is born in a two-step process. First it determines the average school leaving age of the cohort and then the individual deviation from that number, with parental school-leaving ages entering the calculation. In the following, this age enters the equations of the labor market and the income module as well as all demographic modules.

The base model developed here distinguishes three education levels. For simplicity, education level and school leaving age are determined at birth, with probabilities of the education level depending on the own birth cohort and – in its simplest female-dominant version – the education level of the mother. Once the education level is determined, the school leaving age is also determined by Monte-Carlo simulation for given age-specific probabilities by education level and birth cohort.

Regarding fertility, in order to produce a reasonable assignment of children to mothers and reasonable parity patterns, parity-specific fertility probabilities have to be applied. Various modeling approaches were developed in different microsimulation projects that can address timing and spacing of births dependent on various characteristics. The study of fertility patterns is one of the key applications where microsimulation can be used not only for predictions but also to test theories. Timing and variance effects can bias available period measures such as the TFR, making it difficult to directly assess policy and environmental effects or changes in cohort fertility. Improved behavioral modeling of fertility based on event history analysis can address strategic adaptation to changes in policy and environmental contexts and therefore can potentially create new insights into these topics.

For the purpose of this study, fertility is modeled by applying cohort rather than period measures in a two-step process. First the parity of a woman is determined at birth (assuming survival) for given parity progression rates by age cohort and education level. In a second step, where applicable the age at first birth (again depending on the women's year of birth and education) and the spacing between births is determined. Resulting dates are checked for survival of the mother and the simulated "babies" are immediately simulated in a recursive process. Sex is determined by random for a given sex ratio.

In the current female-dominant version, only female persons "know" their children, and children only know their mother. When consumption, labor supply and other socio-economic behaviors are modeled, depending on detailed family and household characteristics, partnership formation (including matching) and dissolution have to be explicitly modeled. This is also true for the modeling of bequests and other transfers within the family. Various partner search-and-matching algorithms have been developed and tested in different microsimulation projects. Characteristics normally used in matching algorithms are income, age, education level as well as spatial and cultural characteristics. Modeling the matching process is a key task as it entails a reasonable household income distribution along with other characteristics on the household level, which might also affect the behavior of the children.

Another area of possible improvements is the micro-modeling of mortality risks dependent on individual and household characteristics, rather than applying a set of mortality tables by sex and education as done so far. Good assessment of mortality (as well as morbidity and disability) on the individual level is especially important when studying kinship networks of elderly people and (related) topics such as elderly care (Wolf, 1999).

2. Human capital, labor force participation and wage differentials

In the macro-model, age-specific labor force participation rates are exogenous assumptions, as are unemployment rates, currently assumed to be 0. These aggregated numbers have to be disaggregated in a meaningful micro-framework, as labor market participation will highly depend on observable characteristics of the micro-units, namely sex, school enrolment, education level, living arrangement, parity and age of children as well as income or opportunity costs of not working. The macro-model does not introduce human capital, therefore labor input is simply calculated in person-years that, together with total capital, enter a Cobb-Douglas production function determining output and returns for labor (wages) and capital (profits). Total factor productivity is assumed to grow at a fixed exogenously given rate. In its current version, the macro-model assumes that wages follow a logarithmic age-wage path. Age-specific wage rates are directly calculated as a function of the average wage and then re-scaled to ensure that they sum up to total wages as determined in the production function. This procedure does not model different wages as a result of different human capital, and an aging labor force or increased education would not have any effect on the average wage.

By contrast, in the microsimulation framework developed here, human capital proxies are introduced as a function of personal characteristics such as education and work experience. These proxies are used as individual multipliers of hours worked to calculate the “effective labor input” that enters the production function. Wages per “effective labor” unit are determined by a (Cobb-Douglas) production function for total effective labor input and total capital. Microsimulation lends itself to modeling individual human capital growth paths according to individual characteristics and random effects. While average human capital units might be adjusted in the initial year to be unity for the average person-year labor input (or any other meaningful reference labor-input), the average human capital units per person-year will typically rise over time, not only reflecting the increasing average age of the labor force in an aging society, but also increasing average education levels. While this design allows introduction of different education levels and other characteristics as determinants of income, it still implies the strong assumption that equal human capital earns equal wages independent of all other attributes.

For the purpose of this study, i.e. in order to allow for flexible parameterization and the production of both deterministic and stochastic scenarios, the individual human capital evolvement can be specified as a fixed or random process. The human capital evolution is assumed to depend only on education level and years worked and depreciation is assumed to be 0. For each education level, a central scenario of (1) a starting value of the human capital proxy for the year entering the labor force, and (2) yearly growth rates subject to total time worked can be specified. To generate a stochastic process, two alternative starting values and vectors of growth rates can be specified. In this way, for given probabilities, the starting values and for each period the yearly growth rate are determined by Monte-Carlo simulation.

Regarding labor market participation, aggregated rates have to be disaggregated in a meaningful micro-framework, as labor market participation will highly depend on various personal and household characteristics. Therefore, even for a given labor market participation rate of e.g. 70% for a given age group, individual participation rates might vary considerable, with the extreme cases that 70% of the members of the age cohort work the whole period, or all members work 70% of the time period. In economic modeling, labor supply is usually assumed to result from some kind of inter-temporal utility maximization of consumption-leisure choices linked with saving decisions and the choice of the retiring age. While the explicit behavioral modeling of labor supply is a central goal of the future model development, at this first stage labor market participation rates are modeled as the outcome of a set of very simple behavioral assumptions, which follow stylized "traditional" patterns of gender roles:

- Male individuals are assumed to enter the labor force when leaving school and leave the labor force when retiring, with given probabilities to retire at a specific age distinguished by education level and age cohort.
- Female individuals are simulated accordingly while childless, and are assumed to stay outside of the labor force for a given fraction of the year giving birth. For the following years probabilities are given to re-enter the labor force, depending on education, parity and birth cohort. The maximum time a women stays outside the labor-force after giving birth is assumed to be 20 years. The retiring age is determined as for males, using given probabilities for females to retire at a specific age distinguished by education level and age cohort.

In spite of their rather demonstrative nature, the assumptions and the model specifications as stated in this and the previous section already allow to create a starting population "from the scratch", containing all basic demographic characteristics such as age, sex and parity, as well as some economic characteristics such as human capital and labor market participation. Note that, though behavioral assumptions are rather preliminary, the model itself can be parameterized in a way that closely reproduces any demographic and labor supply scenario as currently used in the macro-framework of the IIASA SSR model. It can therefore serve as a starting point for more theory-based modeling as well as for more detailed analyses including distributional aspects and dynamics induced by a changing education composition of the population.

3. Saving and pension systems

For a given labor supply, saving behavior has still to be modeled that determines capital accumulation over time and therefore - together with labor - the economic output. Saving is of central importance in this kind of analysis, as savings are the "crucial link between decisions today and living standards tomorrow" (Kohl and O'Brien, 1998). Social security systems interact with private saving decisions and put additional complexity into the analysis, as individual contributions to unfunded public pension schemes are transformed into later benefits via an intergenerational contract. With social security contributions usually not accounted for as savings and pension benefits even in funded systems accounted for as income rather than running down assets, measurement problems arise that make it difficult to link micro- and macro-evidence of measured saving rates and therefore to assess life-cycle saving behaviors (Miles 1999). With its fine-grained accounting of age-specific stocks and flows, the

IIASA SSR model links household behavior to aggregated numbers following the standard OECD System of National Accounts (SNA). This accounting method can be transformed into the microsimulation framework by further disaggregating the various cohort accounts to individual accounts. Regarding the parameterization of the model this implies that capital stocks of all different types have to be distributed not only between cohorts, but also within cohorts. In the macro-model, four types of capital are distinguished:

- residential capital;
- capital operated by private unincorporated enterprises;
- capital operated by incorporated enterprises and held on behalf of households by private pension systems; and
- capital operated by incorporated enterprises and held on behalf of households by other financial institutions.

As all capital types enter the same production function, they produce the same gross – and after netting out indirect taxes and depreciation – the same net returns. Apart from a public defined benefit (DB) pension system, two private pension systems are modeled, one of a defined contribution (DC) type, the other of a DB type run by firms. All economically active persons contribute to the public system according to by exogenously given rates of contribution out of wage and entrepreneurial income. These rates can be set in order to balance the system in a way resulting in a pay as you go (PAYG) system or, on the other side, lead to government savings or debts. Regarding private pension systems, age-specific fractions of the population are assumed to contribute with age-specific rates of wage and entrepreneurial income with all rates set exogenously.

Personal income sources are wages, imputed rents from residential capital – all housing is assumed owner-occupied –, profits and dividends, as well as private and public pension benefits. All income is subject to direct taxation except for dividends and private pension benefits that have already been taxed at the firm level.

Saving is determined by exogenously assumed age-specific saving rates on the different income types and distributed over asset classes also using exogenously assumed rates. While all investments produce the same return, pay-out and reinvestment differs considerably as does accounting, following the SNA.

Net return on residential capital is assumed to be consumed in its entirety.

A given fraction of the return produced by incorporated enterprises is reinvested, with the rest paid out in the form of dividends. In the case of capital held on households' behalf by the private pension system, dividends are reinvested and capital stays untouched until converted into a pension stream at the age of retirement.

The macro-model does not use any explicit decision procedures based on maximizing multi-period objective functions regarding working, consumption and saving decisions or decisions on the distribution of savings to different economic sectors that – in a framework without relative prices – serve a purely accounting purpose. As presently constructed, the IIASA model uses a fixed age-specific coefficient approach to private consumption and labor supply. While it mimics life-cycle models, this is simply because elderly persons, who consume out of annuity income as well as current income, have a lower age-specific saving rate (current income minus consumption relative to current income) than working-age persons. Similarly, the lower labor force participation of older persons due to retirement represents an exogenous assumption, and not the result of an endogenous labor-leisure tradeoff.

Microsimulation modeling might simultaneously maintain the strengths (the accounting treatment, especially the conformity with the SNA), and contribute to overcome the obvious weakness of this model (the mechanical treatment of saving, investment allocation and labor supply decisions). Individual saving rates can be modeled as functions that might take into account different saving motives according to individual and household characteristics. By doing so, the effect of changes of public pension systems on private savings might be assessed both in a consistent theoretical framework and based on empirical evidence, with individual decisions being transformed into macro-outcomes by appropriate aggregation.

At the current state of the pilot microsimulation model developed here, none of these potential strengths have been realized so far, as capital stocks are not tracked individually and only one pension system – a PAYG system in which contribution rates are set every year in order to finance the benefits – is modeled. This imposes further restrictions on saving rates, as only one global saving rate from interest on capital can be set and accumulated capital assets can not be “run down” but have to be implicitly inherited.

The MicroSSR Software and Illustrative Results

As part of this pilot study, the prototype of a social security reform microsimulation software microSSR was programmed in C++ that up to now contains a (mostly) demographic module able to generate a synthetic starting population and project its dynamics in a 100+100 years horizon (the first 100 years are used to generate a synthetic population with all individuals born within the simulation). Births, death, education levels, age of leaving school, labor market participation, human capital formation, parental leave and retiring age are determined as outlined in the previous section. As in the macro-model, total output, wages and interest rates are determined by a production function and individuals save part of their wages and interests received, while the government runs a PAYG pension system, collecting contributions and paying benefits according to individual contribution histories. In this way, individual wages and pension benefits as well as individual consumption from these wages and pensions are calculated, while accumulated wealth and consumption from interest can only be calculated for the total population.

Parameters are read in from currently over 30 tables, with all model input and output kept in one EXCEL-file containing various sheets. Graphical output is produced in the form of 3 types of age pyramids, showing total population by sex, total population by occupation, and female population by occupation. Age pyramids can be displayed for any year of the simulation with navigation buttons provided to “browse” through time (see screenshot below). Using standard-Excel format, data can be easily exchanged with various software applications, and the embedded Excel-workbook provides flexible graphical facilities.

In a first stylized scenario, a stationary population of around 200,000 individuals is produced and simulated, resulting in around 2,500 births and deaths per year. The economic simulation and accounting process is simplified, as fixed saving rates from wage income (8%) and of interest income (20%) are assumed. Pension benefits are assumed to be at 60% of the last gross wages – thus, depending on social security contribution rates necessary to balance the PAYG system, replacing around 70% of the last net wage. Pension income is assumed to be fully consumed. No direct or indirect taxes are levied in this simple model, and an initial capital stock of 250,000 “units” is assumed, not further distributed to households. Regarding the production function, a Cobb-Douglas function with a labor coefficient of 0.667 and constant total factor productivity growth of 1% is assumed. Note that the current model specification and the parameterization given below serve purely demonstrative purposes.

Model Parameterization and Baseline Scenario

Mortality rates are read from mortality tables by sex and education level.
Baseline scenario: time-invariant mortality patterns by sex, according an Austrian life-table for 1992.

Fertility: parity-progression rates and distributions of first births and birth intervals by education and birth cohort are read in from 9 tables.
Baseline scenario: time- and education-invariant parity distributions as given below:

No children 15%

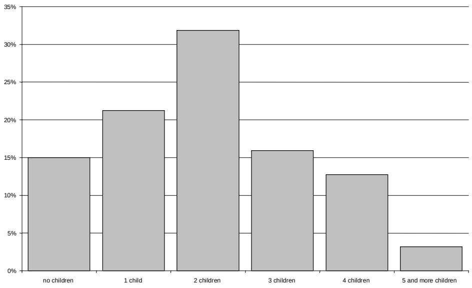
one child 21%

two children 32%

three children 16%

four children 13%

five and more children 3%



Timing of first birth is determined in years since leaving school, and the same distribution of the time intervals is chosen for the spacing between births:

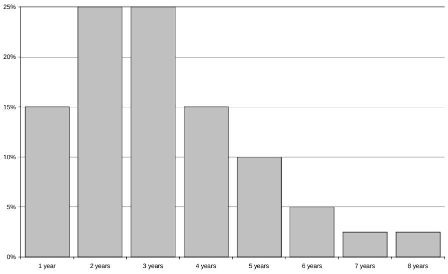
1 or 4 years: 15% (each)

2 or 3 years: 30% (each)

5 years: 10%

6 years: 5%

7 or 8 years: 2,5% (each)



Leaving school: time-variant distributions can be given by education level (3 tables).
Baseline scenario: last year in school

for education level 0: 15 years

for education level 1: 18 years

for education level 2: 23 years

Education level: distributions can be given dependent on mothers' education and birth cohort; currently no distinction is made by sex (3 tables).
Baseline scenario: distribution invariant from mothers' education and time:

60% education level 0

30% education level 1

10% education level 2

Labor market participation: individuals are assumed to work from the year after leaving school until retiring if not caring for children (see below). Retiring age distributions can be specified by sex, education and time (6 tables).

Baseline scenario:

90% of males retire at 65, 25% of the male population remaining in the labor force retires each following year, all remaining workers retire at 70 years.

90% of females retire at 60, 25% of the female population remaining in the labor force retires each following year, all remaining workers retire at 70 years.

Parental leave and staying home with children: time-variant distributions of durations staying outside of the labor force after giving birth can be specified by education level (3 tables). Maximum period staying outside of the labor force is assumed to be 20 years.

Baseline scenario:

education level 0: 10% of mothers currently staying home re-enter the labor force per year.

education level 1: 10% of mothers return in the first, 10% of the remaining mothers in the second, and 50% of the remaining mothers return in the third year after birth. Thereafter, 10% of remaining mothers re-enter the labor force per year.

education level 2: as education level 1, but 75% of women who have not already re-entered the labor force in the first 2 years re-enter in the third year.

Human capital: separate random walks for human capital proxies by education level can be specified by giving three possible starting values per education group (and attached probabilities) and three alternative growth rates for each year worked (3 tables).

Baseline scenario: Central starting value and growth rates (random draw per period).

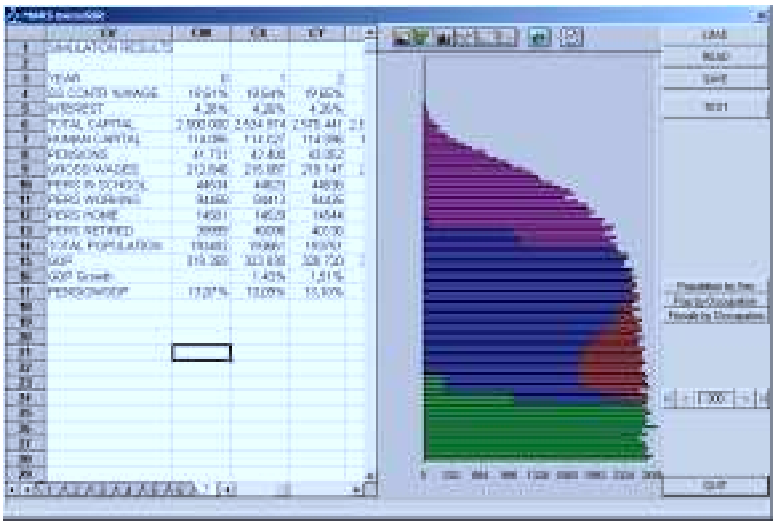
Education 0 :				
starting values:	0,6 (25%)	0,8 (50%)	1 (25%)	
growth rates:	0% (25%)	1% (50%)	2% (25%)	years 2 to 20
	-0,5% (25%)	0% (50%)	1% (25%)	afterwards
Education 1 :				
starting values:	0,8 (25%)	1 (50%)	1,5 (25%)	
growth rates:	0% (25%)	1% (50%)	3% (25%)	years 2 to 25
	0% (25%)	0,5% (50%)	1% (25%)	afterwards
Education 2 :				
Starting values:	1,25 (25%)	2 (50%)	2,5 (25%)	
growth rates:	1% (25%)	2% (50%)	3% (25%)	years 2 to 25
	0% (25%)	0,5% (50%)	1% (25%)	afterwards

The baseline scenario

In the following the baseline scenario will be compared to two alternative scenarios, mainly differing in fertility and education patterns.

- The baseline scenario is one of a stationary population, with initial capital set in a way that puts the economy on a stable growth path with no changes in return to capital and contribution rates.
- The first alternative scenario is a low fertility scenario with all other parameters unchanged.
- The second alternative scenario is based on the low fertility scenario, but with higher rates of people attaining higher education.

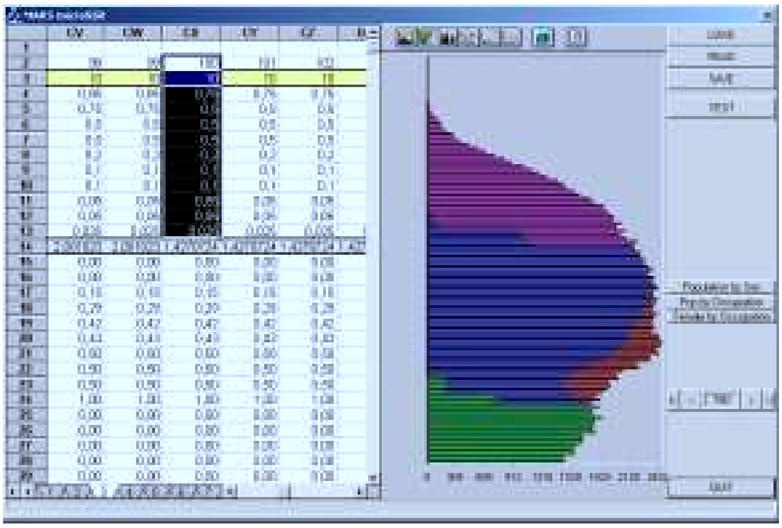
In the baseline scenario, around 20% of gross wages have to be contributed to the social security system in order to balance the PAYG system, with pensions being 13% of total GDP. The GDP growth is around 1.5% and the interest rate is around 4.3%. From the total population of around 193,500 persons, 23% are children and/or persons enrolled in schools, 49% work, 7.5% stay home as “housewives”, and 20.7% are retired. The age-pyramid in the figure below displays the groups disaggregated by age in the year 200, or 100 years after the “setup period” of the population.



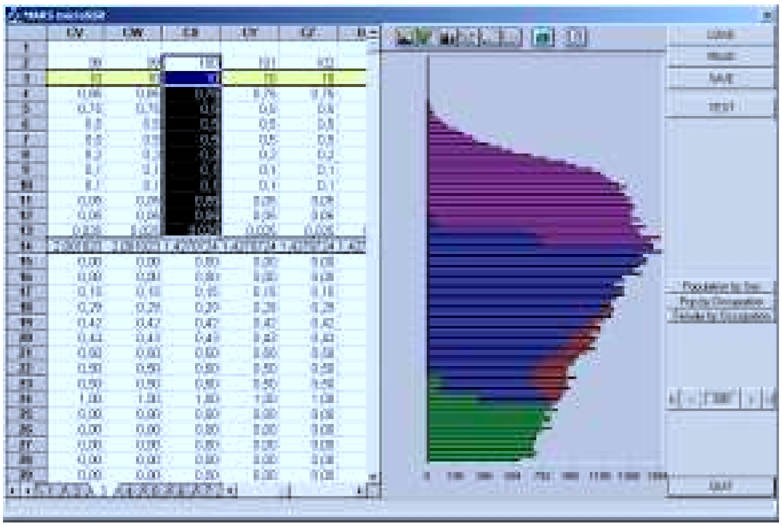
Stationary age pyramid of the baseline scenario. The table displays simulation results for the initial years.

Alternative scenario 1

In a first alternative scenario, cohort fertility is lowered from the 100th cohort on to 1.42 children. Starting from the same stationary age distribution as in the baseline scenario, the age pyramid changes for the next 100 years reaching a new stable distribution. The following two screenshots show the resulting age pyramids for the year 150 and the last simulated year 200.



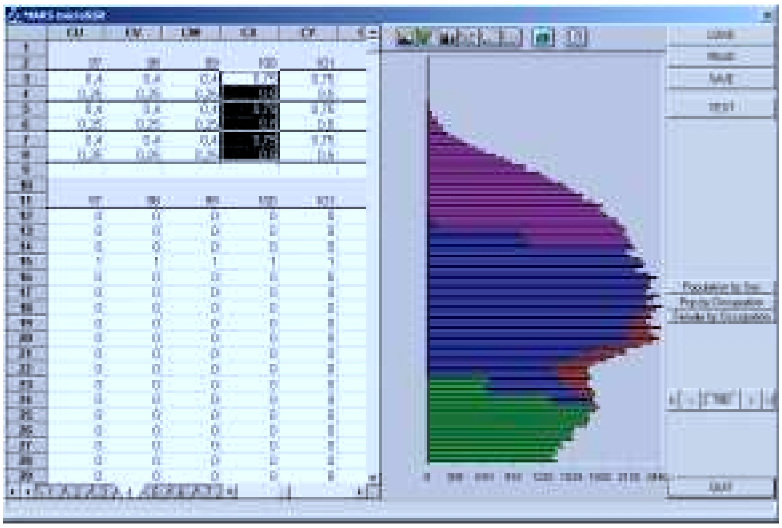
Age pyramid 50 years after change of fertility patterns from replacement to low fertility.



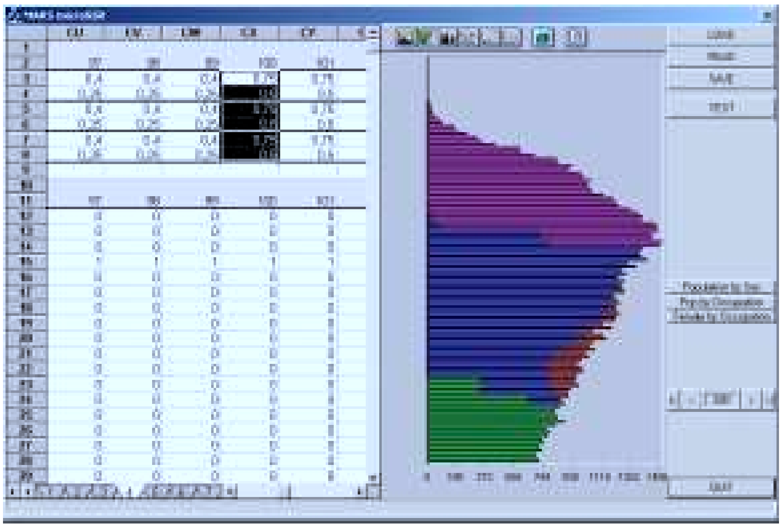
New stable age distribution 100 years after change of fertility patterns from replacement to low fertility.

Alternative scenario 2

In the second alternative scenario, cohort fertility is also lowered from the 100th cohort to 1.42 children. Beginning from the same cohort, education levels are changed, with only 25% staying at level 0 and all others moving to level 1 and 2 with same probabilities. As higher educated women, according to the model, have their children later, this effect can be seen in the shape of the age pyramid. The following two screenshots show the resulting age pyramids for the starting year 150 and the last simulated year 200.



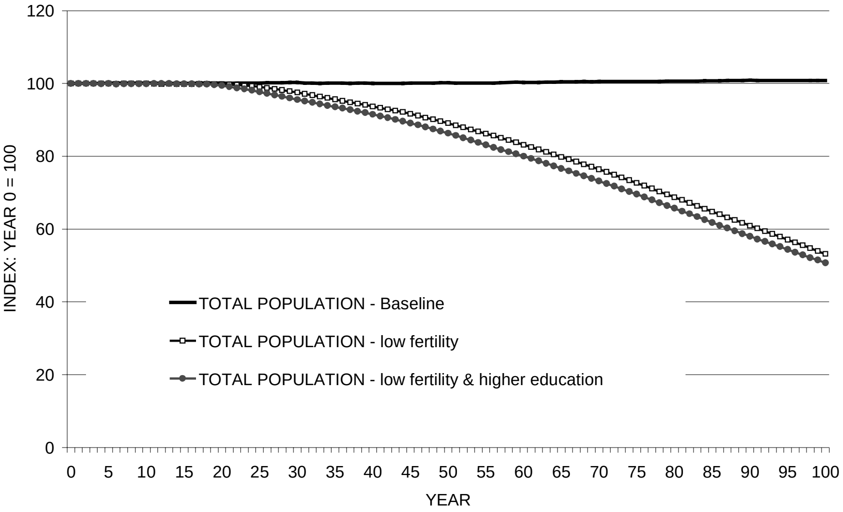
Age pyramid 50 years after change of fertility and education patterns.



New stable age distribution 100 years after change of fertility and education patterns.

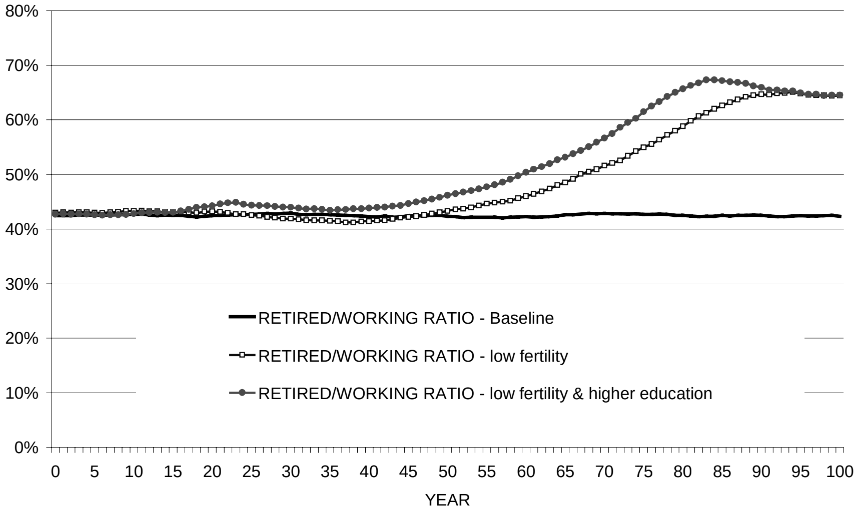
Comparison of scenarios

(1) Demographic changes



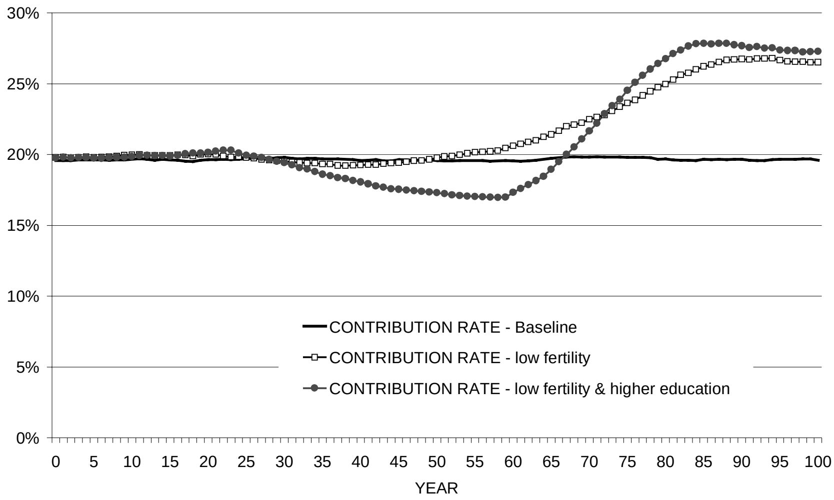
Total population

In both alternative scenarios, the population declines to around half of its initial number 100 years after the drop of fertility from the replacement level to a cohort fertility of 1.42. As women attaining higher education have their children later, the drop in population is more pronounced in the second alternative scenario. As people attaining higher education enter the labor market later in their life course, also the ratio of retired to economically active people departs earlier from the baseline rate in this scenario and - until stabilizing at the same rate in the long run - reaches higher levels due to later births.



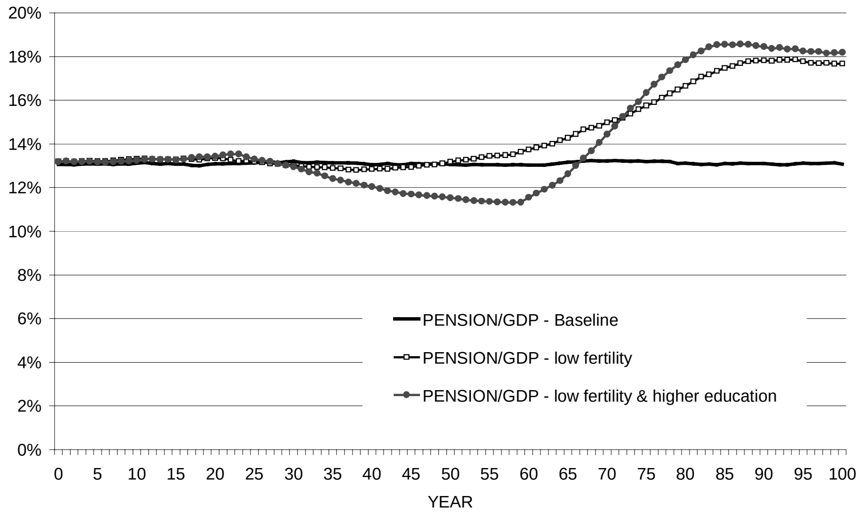
Ratio of retired to economically active people

(2) Pension contributions



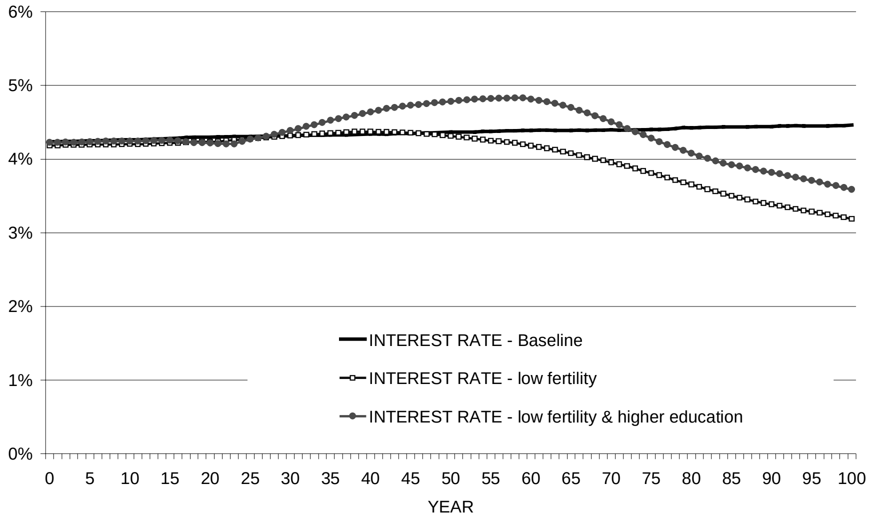
Contribution rates of wages to the pension system

In the baseline scenario of a stationary population, 20% of wage income has to be contributed to the PAYG pension system. The low fertility scenario departs from this rate 50 years after cohort fertility drops from the replacement level to 1.42 and stabilizes again at the higher rate of 27%. In the second alternative scenario, the contribution rate initially falls with the first cohorts of higher education reaching working age. With these cohorts entering retiring age, contribution rates rise fast from a the minimum of 17% to a new stable level of 27.5%. The same pattern is found in pension benefits as percentage of GDP, rising from initially 13% to around 18% in the alternative scenarios.



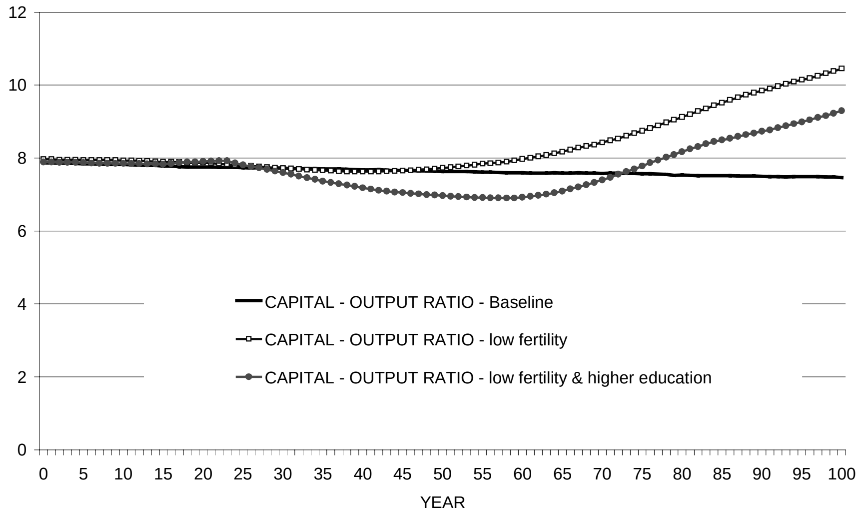
Pension benefits as percentage of GDP

(3) Return to capital and capital-output ratio



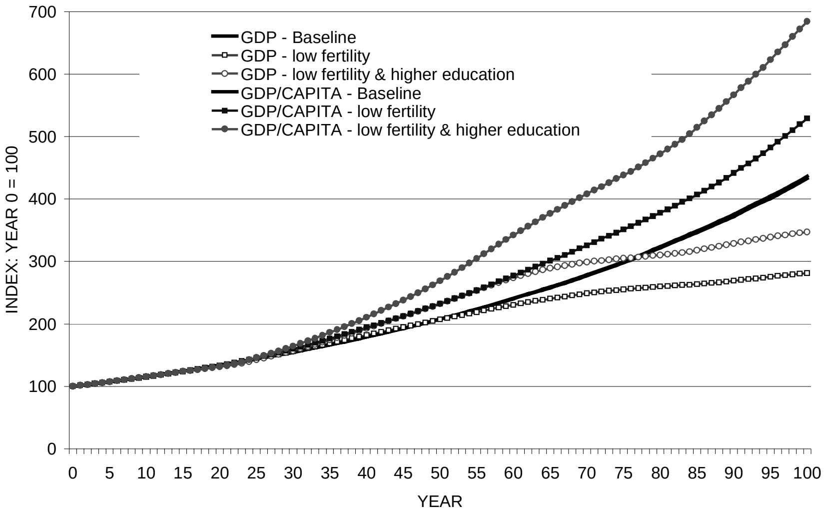
Rate of return to capital

The rate of return to capital falls due to the decreasing labor supply in the low fertility scenario. This effect is temporarily overcompensated in the second alternative scenario, as supply of effective labor initially increases due to higher education. The capital-output ratio in the graph below gives a mirrored picture.



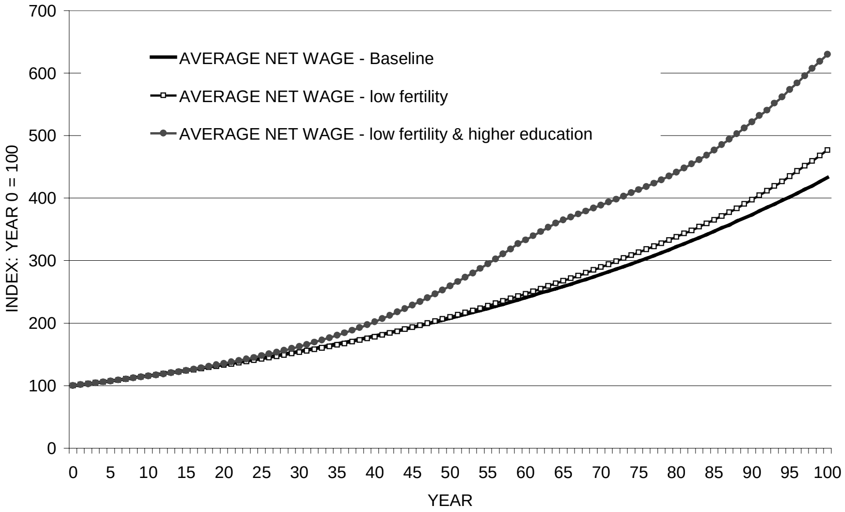
Capital-output ratio

(4) GDP and wages



GDP and GDP/capita

Over the hundred year period, GDP rises about 450% in the baseline scenario of a stationary population. Growth is accelerated in per capita terms in the low fertility scenarios, while total GDP growth will slow down with shrinking population numbers. While lower fertility leads to a per capita GDP around 25% higher at the end of the simulated period, this number will be 55% higher with higher education levels in the alternative scenario. Due to higher contribution rates in order to balance the PAYG system, not all growth in GDP/capita is translated into growth of average net wages and the curves for the low fertility scenarios run closer to the baseline case.



Average net wage

Discussion (by Landis MacKellar)

As was made evident at a recent workshop organized in Helsinki by the IIASA SSR Project and the Center for the Study of the Finnish Economy (ETLA), modelers from a wide range of traditions are focusing their work on population aging and social security. These include modelers coming from the overlapping generations (OLG) school, intergenerational accountants, and traditional macro-modelers (including those who work with linked international macro-models), not to mention actuaries and statisticians interested in projection methods.

The reasons for the attraction are obvious. First, even where they are not complex, demographic phenomena are invariably complicated by virtue of the fact that all stocks and flows are age indexed. The fact that the rates which give rise to these stocks and flows are not only age-indexed, but may vary significantly in other dimensions as well (education level, for example) underscores the complicated nature of demography. Complication, in turn, begs the simplifying function of models. The second reason for the deep interest is that social security lies at the core of the modern welfare state, and the need for quantitative policy insights is high. "Demographic stagnation," no less than its Malthusian twin demon (to recall Keynes' metaphor), opens the door for all sorts of political mischief, and model-based analysis can serve as a bulwark against hyperbole and hysteria. Needless to say, it can also feed them, and the need for reflexivity is correspondingly high. Finally, limiting ourselves to economic studies, virtually all of the areas where economists claim to have some special insights – the theory of consumption, the nature of labor markets, the behavior of the firm, the nature of expectations, etc. – are part of the aging problem. It is therefore not surprising that the best minds in the field (Samuelson, Barro, and Feldstein, to name just a few) have all weighed in on this subject.

IIASA is an institution that has a long historical association with model-based approaches, and elaboration of an integrated economic-demographic model has been at the heart of the SSR Project´s activities. In this paper, Martin Spielauer describes a possible avenue for further development of the IIASA SSR model. The essence of the present IIASA model is that it reproduces a not-insignificant sub-set of the standard OECD national accounts while indexing all economic (and, of course demographic) stocks and flows by age. This makes the IIASA model especially relevant to the policy dialogue, including the debate over the intergenerational distribution of income and wealth. The price paid for the fine-grained treatment of demography has been, up to the present, the extreme simplicity with which consumption, labor supply, and asset allocation decisions are treated. All of these are calculated on the basis of exogenously assumed age-specific rates (income-stream specific, as well, in the case of consumption) and shares.

It would be easy to defend this approach by reference to Kaldorian consumption theory, imperfect capital markets, and, ultimately, Marxist approaches to capitalist development. A quarter-century ago, such models, called "structuralist" because they incorporated rigidities arising from history, class, etc., were particularly associated with economists from Latin America. Social accounting matrices, with whose development economists of the World Employment Programme at the International Labour Office in Geneva were a closely associated model class. These ad-hoc modeling approaches have been almost totally supplanted by a more purist neoclassical approach based on Walrasian general equilibrium theory and incorporating forward-looking, model-consistent expectations. The result, for the most part, is that economic modeling has gone roaring down the road to policy irrelevance.

But this is a story, or rather a diatribe, for another day. The truth is that the simple economic structure of the IIASA model has been maintained less for ideological reasons than as part of a “holding pattern” while we developed the accounting framework and demonstrated the basic workability of the modeling approach. Now we are in a position to consider various ways forward.

In this paper, Spielauer makes a strong case that the SSR model should be extended using microsimulation modeling. When microsimulation involves merely the application of fixed rates and proportions at the level of the individual as opposed to the cohort, it at least offers a finer-grained representation of behavior. Nothing, moreover, prevents the microsimulation approach from modeling individual behaviors using the latest developments in economic theory; in fact, the interplay between individual decisions and the overall context resulting from their aggregation is a natural metaphor for representing the real world. Finally, as Spielauer reports, microsimulation is a tried and tested approach in the area of social security analysis.

The fact that microsimulation lends itself well to describing health status, household structure, and residence patterns, areas playing to relative strengths of the SSR model (which models health and disability spending and explicitly accounts for bequests and residential capital formation) strengthens further the appeal of the approach. Finally, the special role of fertility deserves mention. "The aging problem" in industrial countries is, in the main, a problem of persistent sub-replacement fertility (moral hazard in social insurance systems, longevity and technical progress in medicine, etc., are important side issues, but side issues nonetheless). Demographers, sociologists, and even most economists are suspicious of theoretical models of fertility which lend themselves to empirical application. Microsimulation, with its emphasis on population heterogeneity and its ability to follow individual-level event histories and transition probabilities, may be the best -- albeit hardly perfect -- available means of modeling fertility. Parenthetically, the devil of the aging predicatment is that policy cures for low fertility are certain to be worse than the disease, or ineffective, or (most likely) both. If any approach lends itself to demonstrating this, it would appear to be microsimulation, which after all boils down to tracking precisely who does precisely what precisely when.

Spielauer has made a good case for carrying this line of work forward, and I look forward to reading the next installment in the series.

References

Burch, T.K., 1999, Computer Modelling of Theory: Explanation for the 21st Century, London, Ontario: Population Studies Centre - University of Western Ontario.

Caldwell, S., and Morrison, R.J., 2000, Validation of longitudinal dynamic microsimulation models: experience with CORSIM and DYNACAN, in: L. Mitton, H. Sutherland, M. Weeks (eds.), Microsimulation Modelling for Policy Analysis. Cambridge University Press.

Fredriksen, D., 1998, Projections of population, education, labour supply, and public pension benefits: analyses with the dynamic microsimulation model MOSART / Dennis Fredriksen. Oslo: Statistics Norway, 123 p.

Galler, H.P., 1994, Mikrosimulationsmodelle in der Forschungsstrategie des Sonderforschungsbereich 3, in: R. Hauser, N. Ott and G. Wagner (eds.), Mikroanalytischer Grundlagen der Gesellschaftspolitik Volume 2, pp. 369-379. Akademie Verlag, Berlin.

Galler, H.P., 1997, Discrete-Time and Continuous-Time Approaches to Dynamic Microsimulation Reconsidered, Technical Paper 13, National Centre for Social and Economic Modelling (NATSEM). University of Canberra.

Gilbert, N., and Troitzsch K., 1999, Simulation for the social Scientist, Open University Press, Buckingham.

Heike, H.-D, Beckmann, K., Kaufmann, A., Sauerbier, T., 1994, Der Darmstädter Mikro-Makro-Simulator - Modellierung, Software Architektur und Optimierung; in: Faulbaum, Frank (eds.), SoftStat'93 - Advances in Statistical Software 4, Fischer, Stuttgart/New York, pp. 161 – 169.

Imhoff, E.V., and Post, W., 1998, Microsimulation Methods for Population Projection, New Methodological in the Social Sciences, pp. 97-138.

Kohl, R., and O'Brien, P., 1998, The macroeconomics of ageing, pensions and savings: a survey, Ageing Working Paper 1.1, OECD.

Lutz, W., and Sanderson, W.C., 2001, Toward a Concept of "Population Balance" Considering Age-Structure, Human Capital, and Intergenerational Equity, IIASA Interim Report IR-01-003, Laxenburg, Austria.

Lutz, W., Vaupel, J.W., Ahlburg, D.A., Eds., 1999, Frontiers of Population Forecasting, Population an Development Review. New York: Population Council, 24(Supplement).

MacKellar, L., Ermolieva, T., and Westlund, A., 2000, A Social Security Forecasting and Simulation Model," IIASA Interim Report IR-00-055, Laxenburg, Austria.

Martini, A., and Trivellato, U, 1997, The Role of Survey Data in Microsimulation Models for Social Policy Analysis, Labour, 11(1), pp. 83-112.

Miles, D., 1999, Modelling the Impact of Demographic Change Upon the Economy, The Economic Journal, 109(452), pp. 1-36.

Nelissen, J.H.M., 1995, Demographic projections by means of microsimulation. The NEDYMAS model, part A+B, Tilburg University Press, Tilburg.

O'Donoghue, C. and Sutherland, H., 1999, Accounting for the family in European income tax systems, Cambridge Journal of Economics 23: 565-598.

Orcutt, G., 1957, A new type of socio-economic system. Review of Economics and Statistics 58:773-797.

Pechman, J., Okner, B., 1974, Who Bears the Tax Burdon? Washington DC: The Brookings Institution.

Sutherland, H., 1995, The Development of Tax-Benefit Models: A View from the UK, University of Cambridge, Dept. of Applied Economics, Dae Working Paper, No. 9519, pp. 1-19.

Troitzsch, K.G., 1996, Social Science Microsimulation, Berlin, New York: Springer.

Wachter, K.W., 1998, Kinship Resources for the Elderly: An Update, Berkeley: University of California.

Wachter, K.W., 1995, 2030's Seniors: Kin and Step-Kin, Berkeley: University of California.

Wachter, K.W, Blackwell D., and Hammel, E.A., 1998, Testing the Validity of Kinship Microsimulation: An Update, Berkeley: University of California, February.

Wolf, D., 1999, The Family as Provider of Long-Term Care: Efficiency, Equity, and Externalities, Journal of Aging and Health, Vol. 11(3) (August): 360-382.