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IFSIM Handbook

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Summary: IFSIM Handbook
This handbook explains the simulation model IFSIM. IFSIM is an agent based simulation model written in JAVA. The model is constructed for analyzing demographic and economic issues. The aim of the model is to include the main consumption and production patterns over the life-cycle and thus being able to test demo-economic interactions.

Sammanfattning: Handbok för ISIM
Det här är en handbok för simuleringsmodellen IFSIM. IFSIM är en agentbaserad simuleringsmodell som är skriven i JAVA. Modellen är ämnad att analysera demografiska och ekonomiska frågeställningar. Dess syfte är att undersöka interaktionseffekter mellan demografi och ekonomi genom att inkludera de huvudsakliga konsumtions- och produktionsfaktorerna över livscykeln.

Contents

Introduction

Populations are aging throughout the world. Over the century decreasing fertility and increasing mortality has changed the demographic structure of essentially every country. These changes are predicted to continue implying that population aging will reach unprecedented levels. Concerns are raised about many publicly financed intergenerational transfer programs, such as pension and old age health care. At the same time we know that other intergenerational transfer programs, such as child care provision and education systems, affect people's desire to acquire children. Demography affects the economy but the economy shapes future demographic outcomes as well. There is a non-trivial interdependence between these two which has been hard to capture ever since the Malthusian law broke down.

IFSIM is developed as a tool to study intergenerational transfers and the interdependence between demography and the economy. How public transfer system will be affected by future demographic changes and how these systems may intervene and shape the future demographic structure is one central question. For this reason IFSIM includes main public intergenerational transfers programs such as pensions, education, child care benefits and study allowances.

IFSIM is an Agent Based Model (ABM). ABM allows us to account for individual heterogeneity as done in standard micro simulation models. We can model the whole distribution of many variables, for instance education. IFSIM can thus be used to study how different socio economic groups are affected by changing demographic structure or by different policy changes. Although similar to standard micro simulations when it comes to modeling individual heterogeneity, ABM also allows us to study the micro-macro linkages between individual behaviors and economic outcomes.

ABM starts from the premise that the real world is hardly the work of a central planner, making it conform to rational rules. Rather, the real world is characterized by decentralized, simultaneous interactions between a very large number of different agents, whose decision making is often the expression of imperfect information, past personal experiences, and where the local relational context also contributes to those agents' strategies and behaviors. For tractability reasons, traditional economics model tend to overlook such complexity. If instead rationality becomes "bounded" by e.g. social or other contextual contingencies, modeling agents' decision-making will require somehow modeling also such contingencies: it is these very contingencies which will make otherwise identical agents adopt different decisions, thus generating diverse (and possibly unexpected) societal outcomes.

Indeed, it has become rather common among economists to want to model "micro-macro linkages" between individual and aggregate level variables. However, existing modeling tools often fall short of quantifying interactions and feedbacks in any way close to their actual complexity. Most recent attempts have consisted of combining economy-wide Computable General Equilibrium Models (CGE), with microsimulation models see Davies (2004), for a review). On the one hand, the former (CGE) model the behavior of key economic agents (households, firms, government) to provide the micro foundations of overall production, consumption, price and trade levels, and to simulate the consequences of economic shocks. They rely on the classical assumptions (e.g. rationality, perfect foresight, competitive markets, perfect information, market clearing etc.), in order to find an equilibrium for aggregate level variables such as total output. In other words, by relying on the principles of optimization, CGE impose a functional structure on the way the economy is meant to behave as a whole, i.e. they provide a "top-down" approach governing agents' behaviors. It follows that, for model solubility, CGE often cannot account for many functional differences among agents of the same class, e.g. for heterogeneity between various household types, preferences or technologies; they just limit themselves to specify few types of representative agents and assign to all of them the same production or utility functions. This is clearly a simplification which overlooks important variations at the micro level, and more generally makes distributional analysis unfeasible.

Microsimulation models on the other hand, are mostly used to study distributional effects e.g. of tax and benefit systems, at the micro level, including (in the case of dynamic microsimulation models) projections over the individual agent's entire life cycle (including behavioral responses e.g. labor supply, fertility choice, education etc). Usually built on household survey data (or other micro-level data), they allow access to detailed information e.g. about individuals' income sources, areas of residence, past employment history etc., but they cannot deal with modeling the monetary side of the economy or with the inclusion of structural macro features, which therefore have to be assumed as exogenous. Traditionally they often (although not always) tend to be non-structural i.e. agents' choices are based on reduced form estimations that do not reveal the underlying preference structure or the rational "rule" guiding them (i.e. predicted behaviors are not necessarily derived from optimization). Therefore they can be interpreted to be more ad hoc or less generalizable than CGEs.

Fortunately, over the past decade the distinction between these types of models is increasingly breaking down, for instance through layered or integrated CGE, and microsimulation models, which essentially can combine the study of endogenous price changes with distributional changes at the household level, e.g. Cogneau and Robilliard (2000). For example, household level micro-data are used to estimate heterogenous households' preference functions parameters to derive an income distribution (i.e. choice of labor market status and income generated at given wages); a standard CGE model, which includes all the key sectors of the economy (i.e. both its supply and demand structure), is then used to produce equilibrium prices and wages, which are then fed into the micro model to derive behavioral responses. Overall, these integrated models allow us to capture effects of external shocks not only on aggregate level variables such as total output and prices, but also on labor statuses, inequality and on the income distribution (as the access to real micro data allows to predict household specific responses). Convergence between micro and macro results can sometime be a problem in these models; iterative loops between the two models can be generated until convergence is reached.

In practice, integrated macro-micro models suffer from difficult implementation, mostly due to a trade off between adding model complexity and finding solutions which can be handled by standard computational tools. Given such difficulties, ABMs represent a further step in the development of dynamic macro-microsimulation modeling, as they avail themselves of modern computing developments (e.g. object-oriented programming languages) to simulate complex interactions simultaneously, and how these interactions evolve in time through the accumulation of new information, with no need to have two separate converging models (e.g. one micro and one macro), nor to have convergence to an equilibrium solution at all.

Remaining part of the paper is organized as follows. First we explain in more detail what Agent Based Modeling is. Then we present the simulation model. The final section discusses which issues we have analyzed so far and how we plan to extend the model. The appendix contains two sections. The first section collects all the modules of the model with brief comments about them.

What is Agent Based Modeling?

Agent-based Models (ABM) are computer generated micro-simulation models suited to study not only how individuals behave, but also how the micro interaction of many individuals together can lead to large-scale societal outcomes. So, as they aim to explain micro - macro linkages, ABMs are becoming increasingly popular among the social sciences, not least economics.

Quoting L. Tesfatsion[1], one of the most prominent scholars in the field of ABM: "ABM [..] is a method for studying systems exhibiting the following two properties: (1) the system is composed of interacting agents; and (2) the system exhibits emergent properties, that is, properties arising from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents. When the interaction of the agents is contingent on past experience, and especially when the agents continually adapt to that experience, mathematical analysis is typically very limited in its ability to derive the dynamic consequences. In this case, ABM might be the only practical method of analysis".

In summary, the principle behind ABMs is that of multiple interacting agents who are goal directed (e.g. preserving a certain consumption level in old age), and who try to control their environment, in a decentralized system. ABMs, unlike other models, do not assume rationality nor contemplate the existence of a pre-defined equilibrium outcome. Agents might behave in sub-optimal ways, but they can gradually learn from their experiences and adjust their behavior to the neighboring environment.

The first attempt to apply ABM to the social sciences is considered to be T. Shelling's "Models of segregation" (1969). It is however only in the last decade that computer advances have seen the real development of ABMs. Often using JAVA or similar object-oriented programming languages, ABM agents are usually implemented in software as objects i.e. computational entities that have initial states (e.g. sex, age), are able to perform some pre-specified action or method, can communicate or share information with others, pass on or even inherit characteristics or behavioral rules.

Running an ABM simply means instantiating an agent population, and let it run forward in time - executing it, rather than solving it. The outcomes of agents' interactions can be observed at any given time by the modeler who only needs to specify some initial behavioral algorithms (the equivalent of classical preferences) and initial conditions for his agents and their environment. These agents can represent people (say consumers, sellers, or voters), but they can also represent social groupings such as families, firms, communities, government agencies and nations.

There are several advantages to ABM. For a start, ABM provides a way to understand empirically observed large scale regularities which emerge and

[1] Tesfatsion manages an on-line resource on ABM, see: http://econ.iastate.edu/tesfatsi/abmread.htm.

persist from micro-processes without an apparent top-down control system or in any case with limited rationality. Given assumptions about autonomous heterogeneous agents, ABMs simply rely on powerful computer simulation platforms to generate histories that can reveal the long term macro consequences of these assumptions.

ABM can also fulfill a second aim of normative understanding, i.e. they can be used as simulation laboratories where alternative socio-economic structures can be studied and tested, for instance with regard to their effects on family welfare. Axtell (2000) identifies three key motives for using ABMs against more traditional approaches to modeling macro regularities (such as dynamic general equilibrium models in economics). The first motive is when fully soluble stochastic equations can be formulated to describe a social process. In this case, as the solution corresponds to a distribution of possible outcomes (e.g. requiring a Monte Carlo experiment), ABMs can be used to provide numerical simulations. The second motive is when a mathematical model of social processes can be written down but cannot be completely solved analytically, and so its properties become hard to assess. In these cases ABM can shed light on the dynamical properties of the model (e.g. non-equilibrium phenomena), and on its parameter dependence, without actually having to solve it. Finally, ABMs are most useful when it becomes impossible to devise a full mathematical model of equations and solutions, with a closed form solution, as it is the case in so called intractable models. Often in these cases numerical solutions are attempted, but often these are not very useful (e.g. in cases where governing equations are highly non linear). In all these cases, ABM can become a useful alternative. Following assumptions already developed e.g. by experimental or evolutionary economics, ABMs thus relax the dependency on the rational agent and on equation-based models involving optimizing behaviors (as it is the case in the classical economic approach). ABMs instead introduce a less able but more realistic agent with “bounded rationality”, i.e. whose behavior is not dictated by forward looking optimization. The individuals rather act by adopting a set of decision rules, given their initial states, current information, and surrounding opportunities. This effectively simplifies the computational work compared to optimization-driven models.

The advantages of ABMs over more traditional mathematical models are exactly to limit the agent rationality, as well as to introduce more agents’ heterogeneity (in initial states, preferences etc.) in such a way that classical models could not handle, by discarding the idea of a representative agent. By developing an initial heterogeneous population and a set of rules of thumb guiding the behavior of this population, the researcher can observe the evolution of the macro system without worrying about its equilibrium properties, but rather focusing on the system's entire behavior at any point in time. By varying initial conditions, and randomizing the order of agent activation, the researcher can then check the robustness of the emerging results, e.g. how sensitive social outcomes are to changes to the underlying system parameters, again at any point in time (rather than at the equilibrium point). There is therefore no fixed solution to an ABM; rather there are many possible evolutions or "histories" which can be simulated by changing some initial parameters.

The disadvantages of ABM models vis-a-vis mathematical modeling can be mostly explained in terms of their alleged methodological weaknesses, in particular their inability to produce robust theory about emerging regularities from just a simple model run. Indeed, in ABMs, final outcomes depend entirely on the initial distribution of the state variables pertaining to the artificial agents, but in the absence of a general law from which their evolution can be derived a priori, it becomes difficult to defend their scientific validity. Richiardi and Leombruni (2005) however provides an interesting methodological defense of ABMs, arguing that outputs from ABM runs can ultimately be used to infer a functional representation of the systemic behavior i.e. a general law linking the macro outcome, Y, to all the agents' exogenous initial states. A meta-model can thus be estimated, i.e. a fitted function approximating the general function, obtained by estimating the functional parameters on the simulated data. The "fitness" of this meta-model can be furthermore validated against real data.

IFSIM structure

IFSIM is modeled in JAVA using the JAS platform (see the appendix concerning programming technicalities). Every variable (object) is updated in sequence and the time interval represents one year. The starting year is 1996 when a population is initiated from the Swedish micro data set HUS, which contains variables related to household market and nonmarket activities. Every individual included in the initial sample (3000 individuals) is then duplicated to obtain the wanted number of individuals in the simulation. Every individual goes through a large number of events representing real life phenomena like network formation, education, marriage, having children, working, retirement, etc. For each year the individual is assigned a status depending on his current characteristics such as work, number of children, education level, and so forth.

The sequential updating procedure is presented in Figure 1. The first part consists of allocating each individual to a network. After this a sequence of demographic events follows (aging, mortality, matching, etc.). Then there is a sequence of educational events: elementary school, high school, and university. Beside an educational level, here we assign also a corresponding ability level, or human capital. Next the individuals go through the labor market module where their status concerning work, retirement, parental leave and possibility of becoming a teacher is determined. Currently every adult individual who is neither in the education system nor on parental leave works up to the age of 65 and retires after that. A planned extension of the model is to include the possibility of unemployment and sick leave, and to allow for endogenous retirement age. Depending how the year has passed their human capital will be updated (for instance it will depreciate during periods spent on parental leave). When all the individual characteristics have been determined the aggregate outcomes are collected. First the pensions are set and then other state programs collect contributions and allocate benefits.

The sequential updating process is similar to a microsimulation model. The difference consists of how individuals move between states. Looking at the education module, for instance, the first part with assigning individuals to elementary schooling is identical to what would have been used in a standard microsimulation. Here there is no individual choice. Every individual between the ages of 7 up to 15 attends elementary school. The choice to continue to the second level of schooling, namely high school, is however based on thumb rules as done in agent based modeling. If an individual enters high school is determined on how many in ones network that are in high school, what the expected economic payoff is, and a baseline probability. A standard micro simulation model would essentially only estimate the baseline probability and use this estimate as the transition probability.

Macro outcomes result from individuals actions during the year. Wages for high skilled versus low skilled depends on the share of population that has a university degree. Likewise the taxes collected by the government will depend on the share of contributors in the working population. These macro variables will then affect individual choices in the next period. For instance, the economic payoff of a university degree falls when high skill wages fall (due to a large share of highly educated) which will result in fewer attending university in the next period. In turns this will affect fertility, since people's decision to have a child depends, among others, on their projected future income. How the public transfer systems evolve due to economic growth and labor force growth will also affect people's fertility choice.

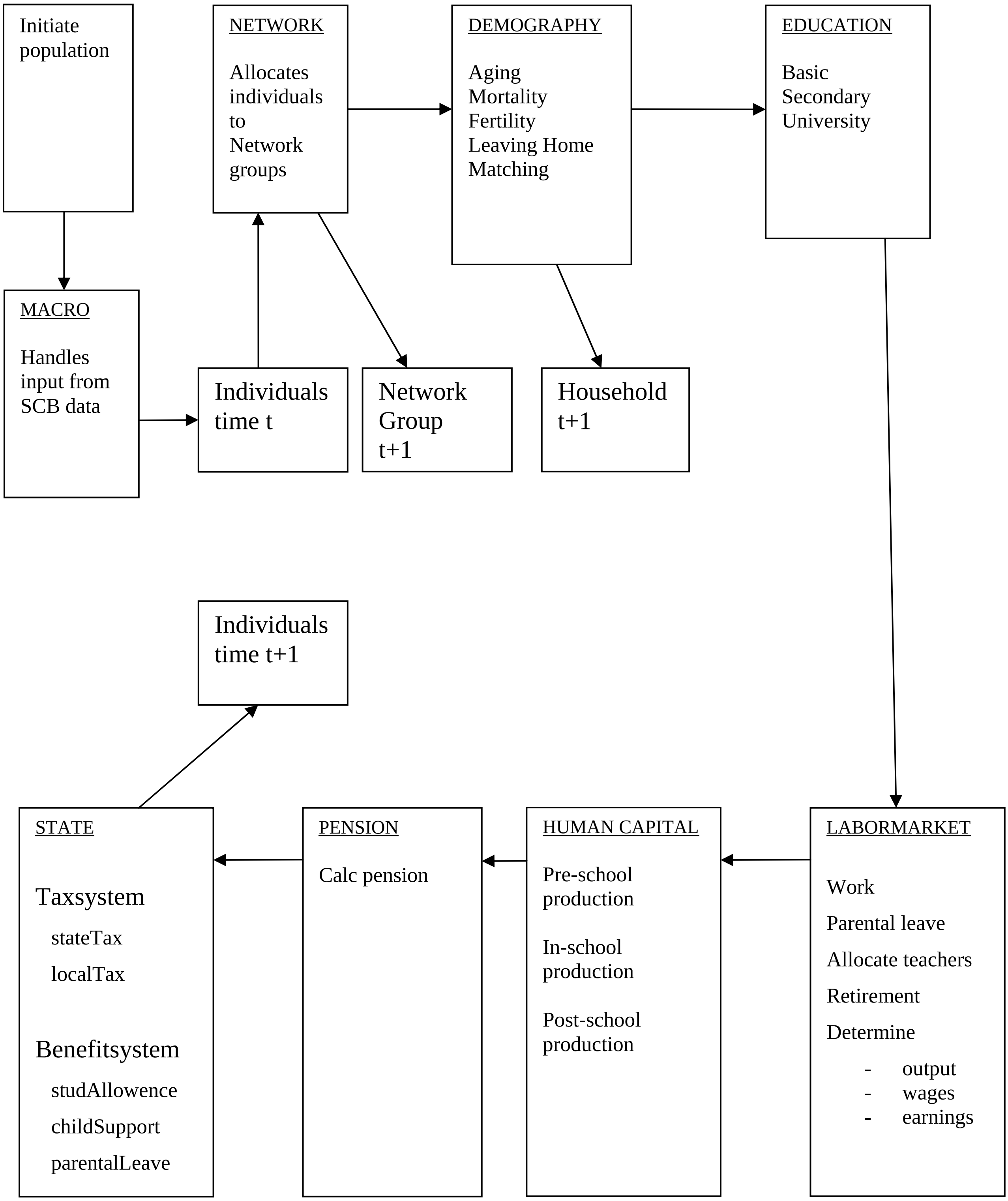

Figure 1: Flow chart for IFSIM

Model overview

The model has three agents: **Individual, Household,** and **NetworkGroup**. During the simulation new agents are created and old disappear. There is also a **State** that can be viewed as an agent that is only created once, i.e. at the beginning. The State, however, is no agent in a technical aspect. The individual agent goes sequentially through the different modules, according to the flow chart, and when doing so the Household and the NetwokGroup composition might change.

The modules that are used are the following: Demography, Education, Labor market, Human capital, Pension, and State. When individuals sequentially go through these modules their characteristics will change and so will the characteristics of the Household and NetworkGroup to which the Individual belongs to.

Model agents

By agents here we mean java objects belonging to a specific agent class to which certain actions and characteristics are ascribed. As mentioned above the agents are **Individuals, Household** and **NetworkGroup**.

Individuals

Individuals are the main agent type being simulated; they are uniquely identified, they can be born, die, procreate, leave home, study, work or retire. There are multiple variables associated to each individual. These variables indicate the current status for different individual characteristics. There is no life-time history saved. Some collective history variables exist, such as `lifetimeIncome`, `histsocialcontribution`, etc. We also store the income of an individual at age 10 since this is used for implementing decision thumb rules when e.g. having children. There is, more generally, a possibility to specify and save the life-time history of an individual.

Individuals can be born either outside or inside the model. Individuals born outside the model are those who come directly from the initial data set (discussed in appendix). At time zero, they will have an age greater than zero and a history that we import from the original data. On the contrary, individuals born inside the models are produced from the model's fertility modules, and start their life at age zero within the model; they are thus "artificial" agents. Each new individual will have a mother and a father and will inherit some of its parent's characteristics.

Households
These are separate agents that have characteristics of their own: a separate ID, a given size, number of children, household income, a history and special links between household members such as inheritability of certain personal features (e.g. initial skills are inherited as the average of both parents). Households will change as the individuals goes through the different modules.

NetworkGroups
Networks are lists of individuals grouped by age and subgroups determined by inheritance and randomness. Networks are programmed so as to be able to perform certain actions for instance retrieve network characteristics such as mean participation or education rates which can be used by the agents to make forward looking decisions.

State
State is the only single agent in the model i.e. the single class being instantiated only once. The State performs the tax and redistribution functions, including setting a local tax rate to keep the budget in balance, calculating and collecting income tax rate, paying teachers' salaries, student allowances, parental leaves and pensions, as well as setting some policy targets through which it can affect micro behaviors and macro outcomes.

Network
A distinguishing feature of ABMs is their ability to capture agents social interactions as these are supposed to influence individual decision making. The role of these social interactions is mostly to provide individuals with incomplete (as opposed to perfect) information which individuals in turn use to make decisions. This exchange is a process often described as social learning, or even as social or peer pressure (Billary et. al., 2006). For instance, the share of people married among one's friends might contribute positively to that individual's desire to get married, representing a pressure to conform. The crucial idea behind modeling social interactions more generally is that this might indeed work together with economic incentives in explaining human behaviors, possibly affecting the size or even the direction that economic incentives might have otherwise. Our assumption therefore is that missing out social interaction from an analytical framework might bias the final results. In other parts of the model we use the decision of whether to go to gymnasium as an example of how to integrate social pressure into the more standard forward looking economic

calculation of individuals when they decide whether to continue investing in their education or rather going into the labor market.

Every individual in our model is, from birth, member of a "social network" containing all those individuals to whom he or she is "close". We follow Billary et. al. (2006) in defining social "closeness" as a spatial area representing the individual's scope of interaction, by age group. Most specifically, agents are arranged along the surface of an imaginary cylinder, whose vertical length is broken into as many segments as there are age groups in the model (at present they are 8, from age 0 to Age_{Max}). Each age group therefore is allocated to an imaginary sub-cylinder whose height is the age interval for that group, and whose circumference is in turn sliced into a different number of networks (i.e. different age groups have different numbers of networks belonging to them). Each network is constructed as a segment on the circumference delimited by a corresponding angle. The model develops a procedure to then allocate each individual to a given network group within his or her own network space, by age group, and also to update his or her network in time, as the individual ages and moves between age groups and networks. A graphical representation of the network group organization is presented in Figure 2 below.

This means that the individuals will migrate between network groups as they age, and two individuals that belongs to the same network group at one age, may belong to different groups at later ages. Furthermore, this implementation will allow for "spatial" migration as well as individuals could be allowed to change their "spatial" location, here measured as the angle on the circumference, over time.

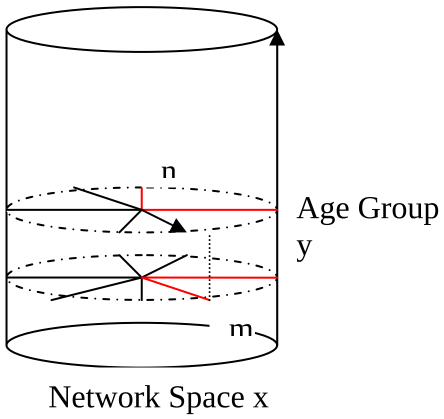

Figure 2: Representation of network groups

Any newborn inherits a “network angle” which is the average of her parents’ plus a random term. A network angle is a technical construct which allows the individual to be placed, given his age, on a specific segment of the circumference throughout her life. In each period the individuals angle is compared against the angle determining where each network begins and ends (within each age group), and placed within the network segment corresponding to his or her angle. In the same network the individual will therefore meet a sub-sample of other people in the same age group who happen to have a similar angle. In time, as the individual ages and jumps between age groups, the composition of his or her network will change since different age groups are characterized by different network angles, hence individuals are shifted not only vertically but also horizontally depending on their own angle relative to the new age-group network angle.

To sum it up, the individual’s location within the cylinder space is determined by 2 coordinates: (i) their age group. This defines the location within the vertical Y space (ii) the angle of the circumference within which the individual’s network falls (corresponding to the interval on the circumference occupied by that network). This defines the horizontal x-coordinate.

By looping over all age groups and angle groups, networks are thus populated. The size of networks will vary in time while the characteristics will remain relatively stable at least in terms of age composition. Each network group is modeled as a Java object capable to iterate over its members and extract a number of summary statistics such as averages by group.

Demographic module

The demography module handles the following main events: Ageing, Mortality, Leaving Home, Matching (marriage) and Fertility.

Ageing and mortality

The most basic life process simulated in the model is the process of aging: at any period, the age of individuals is increased by one year. After the individual has aged one year it is determined if he will die or not. The maximum age an individual can reach is given by the variable Age_{Max} currently set at 110 years. If the individual has not died before, the model will automatically “kill” him at this age. In any given year, the individual has a certain probability of dying which at present is exogenously given according to mortality rates from SCB (Statistics Sweden) data for 2006.

For each individual a uniform draw is compared to the relevant age-specific probability of dying, if his uniform draw is below he will die.

Overall, the age-composition in the population is very stable over time, see Figure 3 below, which shows the shares of young (0-20), prime-aged (20-64), retired (65+) and oldest old (80+) by model year. There is an oscillatory pattern (suggesting a saw-toothed age distribution) that reflects influential baby boom cohorts which, to some extent, actually resembles quite well the Swedish demography over the 20th century.

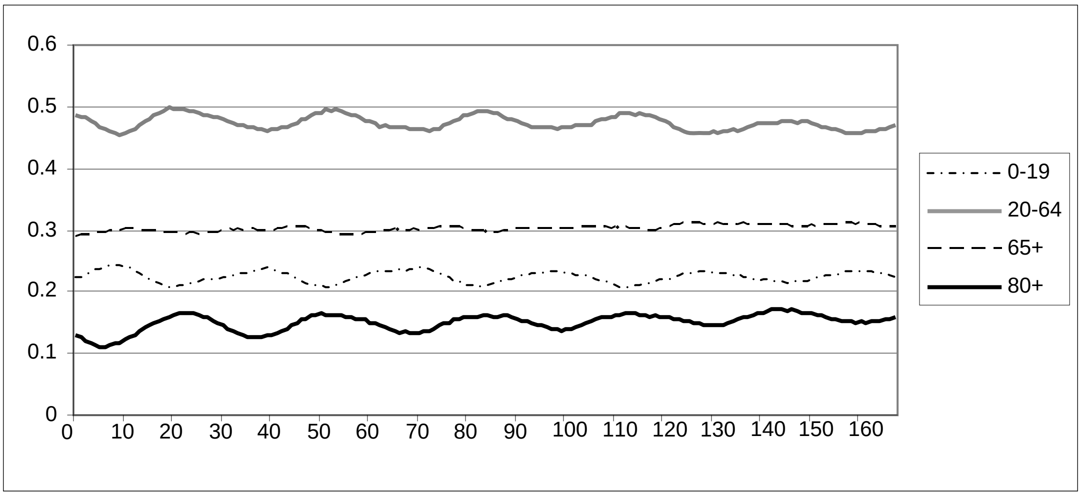

Figure 3. Simulated Age Structure in the base scenario

Leaving Home

Starting from age 18, individuals living with their parents may start to leave the parental household and set up a household of their own. The decision to leave home is modeled as an exponential probability function depending positively on age, and adjusted on the basis of social pressure effects (i.e. how many people of similar age in that individual network have left home). Those whose final probability is high enough (against a random draw), are made to leave and their new household is given the status of single household. The baseline probability of leaving home (i.e. without social interaction effects) p is given by the following expression:

(1) $$\text{Prob(LeavingHome|age)} = p = \frac{e^{(age-\partial)/\eta}}{1+e^{(age-\partial)/\eta}}.$$

This baseline probability *p* is a number between 0 and 1 which increases with the age of the individual, in particular with the difference from the parameter δ, currently set at 20 and η currently set to 2.

This probability is then corrected by an adjustment factor *k* representing the social pressure and reflecting the proportion of individuals aged 15-20 and 20-30 not living with their parents (specifically, with their mothers) across the individual's network. We calculate the proportion of individuals not living in their parents' household within each network group and compute the relative difference between this share and the leaving home rate. This relative difference is then transformed into a variable that varies between 0.8 and 1.8 using an exponential transformation. The main reason for keeping within this interval is so that it should not be a factor that lowers the fertility in the model to a great extent. The final variable is multiplied by the baseline probability of leaving home producing the final probability of leaving home. Hence if the proportion of individuals not living with their parents is higher, the probability that this individual will leave home increases, and vice versa. The final probability is this:

$$(2) \qquad \text{Pr (leaving home)} = p * \left(0.8 + \frac{\exp\left(\left(mean_g - p\right)/p\right)}{1 + \exp\left(\left(mean_g - p\right)/p\right)} \right),$$

where *p* is the baseline probability as in (1), and the expression in brackets is the social pressure *k*; within that, *mean* denotes the network group specific proportion of (young) individuals not living in their parents' household. According to this formula, for a given network mean someone older relative to the minimum age for leaving home will have a softer social pressure than someone younger; at the same time for a given age a higher mean will imply a stronger social effect.

Those individuals who are selected to move out are placed in a new household of their own, assigned both adult and single marital status, and are removed from the member list of their original household. Individuals who leave school at 16 and enter the labor force then are still regarded to live in the parental household. Their earnings add to the household's income.

Matching

The matching process consists of making single people meet in order to create a new married household. First, the model looks for all non-students, single households of age 18 or above.[2] Hence, individuals still living with their parents and students are not allowed to match. Non-student single households are divided between male and females households, and individuals of opposite sex are picked randomly from these singles lists. The matching probability depends linearly on the age difference between the potential partners only, rather than on more complex criteria (e.g. education, income etc.) with a maximum of a 15 year difference between the male and female age if the man is older than the female and 5 year difference otherwise. A candidate couple's matching rate is determined by how far their age difference is relative to the optimal age difference, currently set at 0, and this rate is then compared to a randomly drawn number in order to determine the actual matching outcome for that couple. When a couple is formed, the man moves into the female's household.

Although this matching procedure appears primitive, it does allow for assortative matching as university degree individual match later in life and are thus more likely to match another unmarried university degree individual of the same age.

Fertility

There are several variables that affect the fertility outcome. First we have fecundity which is more or less beyond individual control. We roughly capture this biological restriction by putting an upper limit at which females in our model can give birth. This upper limit is set to age 40, above which no female can give birth. We also have a lower starting age set to 20 under which it is not possible to give birth. This lower limit has not that much to do with fecundity but we have chosen it since few give birth earlier.

Beside the biological restriction to giving birth we model a fertility function that allows us to capture the main elements of the low fertility hypothesis. The Low Fertility Trap Hypothesis (LFTH) has a social dimension and an economic dimension. By the social dimension we refer to how our desire to acquire children is influenced by the number of children around us. We first start by assuming that the norm of how many children one wants to acquire is set during youth. We call this the wanted number of

[2] Note that we do not allow someone still living in the parental home to find a match. This assumption seems realistic in Sweden where most people move out rather early in life and so are likely to already be living alone when meeting a partner with whom they will build a future family.

children. Every individual has a wanted number of children that is determined by the number of siblings that he/she had when young. For a couple we use both the males and females wanted number of children to construct the couples wanted number of children. This is the average number of the couple weighted with a random number. The wanted number is something that the couple strives to obtain but it is not sure that they will reach this number due to their economic outcome and the social influence from their network group. Given that the female is in fertile age and that the number of wanted children is higher than the actual number she will give birth if the two following conditions hold:

$$(3)\frac{DISP}{\sqrt{n+r}} \geq \textit{median income},$$

$$(4) SocialFactor * PROJC^{10} > ASPC.$$

Looking at (3) first, *DISP* is the disposable household income, *n* is the number of individuals in the household and *r* is the cost of a new child. In the baseline scenario we fix this cost to 1. However the model is set up to handle alternative scenarios where the cost of having a new child can vary over time, e.g. in relation to the growth in GDP per capita. We show the alternative formulation in equation (5), where $\gamma = 0.8$. Since the expression in parenthesis has a logistic form, ranging between 0 and 1, the final value of *r* will range between 1 and 3.

$$(5)\quad r = \gamma\left(\frac{e^{\Delta GDPpc*10}}{1+e^{\Delta GDPpc*10}}\right)*\frac{1}{0.2}-1.$$

Overall, in (3), we use the square root to capture the economics of scale of large families. This condition says that the household's equivalent income (adjusted to include one extra child) must exceed the median individual income, which implies that today's economic conditions are very important in the fertility choice. The median income is considered a sort of minimum income for affording a child.

The second restriction we have, as expressed in (4), is that the social norm in combination with expected future income, $PROJC^{10}$ must exceed the aspired consumption level, *ASPC*. We define the social factor according to:

(6) $$Socialfactor = \left(\frac{e^{N_{Kids} / N_{Members}}}{1 + e^{N_{Kids} / N_{Members}}} \right)^{\varphi},$$

where N_{kids} is the number of kids belonging to the $N_{members}$ members in the network group. φ is a parameter that controls the strength of the social pressure currently set to 0.92. If many individuals within ones network have children this would positively affect the fertility decision of a couple.

The economic dimension consists of determining if the couple can afford a new child or not in the future given their living standards aspirations. We follow the LFTH and state that a couple aspires to a certain consumption level based on their previous experience. They will not acquire a child unless they can reach this aspired consumption level (once they deduct that child's cost). What remains is to define this aspired consumption level. As postulated by Easterlin this aspired consumption level is a norm that is formed during youth and which has the consumption level of ones home of origin as the reference point. We model this aspired consumption, *ASPC*, according to:

(7) $$ASPC = \theta \overline{C},$$

where $\overline{C} = \overline{\left(\frac{DISP}{\sqrt{n}} \right)}$ is the average equivalent disposable income today and

and $\theta = \gamma \left(C_{at10} / \overline{C}_{at10} \right) + (1 - \gamma) \left(C_{at10} / PROJC^{10} \right)$.

C is the equivalent disposable income for every individual in the household. The subscript *at10* indicates that it is when the individual was at the age of 10, which captures that aspirations are set during youth. We also apply a weighting factor, $\gamma \in (0,1)$, currently set at 0.5, for two different reference points for the aspired consumption. The first term states that the position in the consumption distribution at the age of 10 affects the aspired consumption level. The idea is that ones children should not obtain a worse position in the consumption distribution. The second factor captures the idea that parents do not want their children to have less consumption then what they had when young adjusted for economic growth. Since the reference point was set when the parents where of age 10 it is natural to compare the new child's consumption level at the age of 10. For this reason they project expected future income according to:

(8) $$PROJC^{10} = \frac{DISP^{10}}{\sqrt{n+r}}.$$

Where $DISP^{10}$ is the disposable income ten years from today *if they choose to have one additional child*. The household's disposable income in ten years is estimated from the sample of individuals whom today have ten more years of labor market experience. We correct for the fact that these individuals live in households with different age composition of the children (since they will, for instance, be on average 10 years older and thus not receive the same amount in child benefits which changes the household's disposable income). Let $Y(X,E)$ be the net labor income after taxes for an adult, who has X years of experience after diploma year from education level E (=basic, high school, university). This is net of taxes, and does not include the child benefit b. The child benefit is introduced in some of the alternative scenarios. It is given to all households with children 0-17 years of age. So at each year all household receives $n_{0-17}b$, where n_{0-17} is the number of kids 0-17 in the household today.

Thus, for each model year and education level E, we estimate (by ordinary least square, OLS) $Y(X,E)$ as a quadratic function in X, for each of the (potential) parents. Then the predicted value of someone with 10 more years of experience with the relevant education level is $\hat{Y}(X+10,E) = \hat{\alpha} + \hat{\beta}_1(X+10) + \hat{\beta}_2(X+10)^2$, where $\hat{\alpha}$, $\hat{\beta}_1$, and $\hat{\beta}_2$ are OLS estimates.[3]

The projected disposable income is the household's disposable income in ten years with one additional child. This is then: $DISP^{10} = \hat{Y}_m(X_m+10,E_m) + \hat{Y}_f(X_f+10,E_f) + (n_{0-7}+1)b$, where m=mother, f=father, and n_{0-7} is the number of children 0-7 in the household today.

This fertility algorithm, as any other module, could be replaced with a different decision rule. Up to now we have also elaborated with a different algorithm which is explained in the appendix. There is an opportunity to choose the thumb rule for fertility depending on the issue analyzed. The thumb rule presented above is suited for analyzing the low fertility hypothesis. Overall, our baseline simulation yields a rather stable Completed fertility rate (CFR) over time, i.e. the average number of children per woman (Figure 4).

[3] Those who are enrolled in education and will reach the education level E within 10 years will have a negative value of X corresponding to years until graduation.

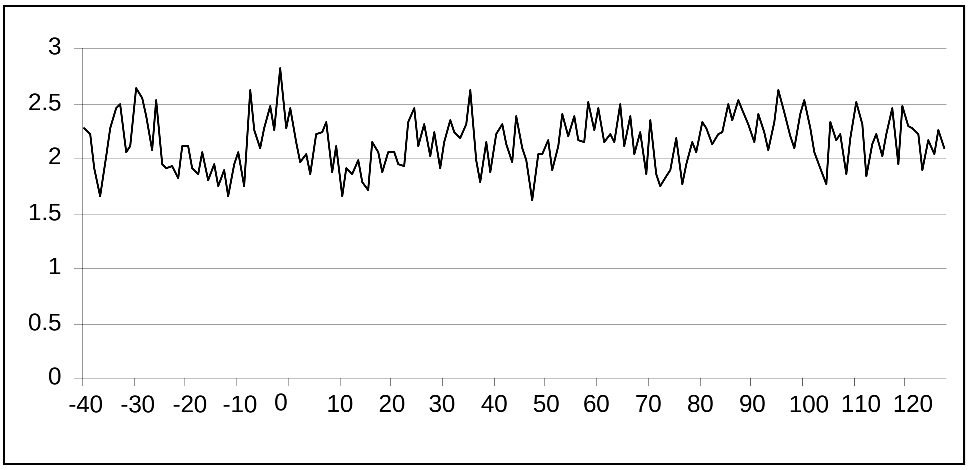

Figure 4. Completed fertility, by birth cohort (with 0 being the birth cohort of someone born in the first year of simulation)

Education Module

There are three levels of education: primary (basic/elementary), secondary (gymnasium/high school), and tertiary (university). When reaching the age of 7, all individuals are in basic schooling up until the age of 16, corresponding to 9 years of compulsory education. After completing basic schooling the individuals have the choice to enter secondary schooling

Gymnasium

The choice of gymnasium education follows the idea of calculating both a social and an economic "pressure" which balance the baseline (in this case exogenous) probability of going to Gymnasium. The final individually adjusted probability is then compared to a random number for determining the actual stock of Gymnasium students in any given year.

If entering secondary school, the individual will stay in school until graduation in a predetermined number of years (3 years in the standard version). The individual can however postpone entry into secondary school until she reaches 18. The baseline probability to enter secondary school p is exogenous and age dependent with probabilities currently set at 0.9 at age 16, 0.6 at age 17, and 0.6 at age 18.

The economic incentive is calculated by the individual as his or her expected economic return from going to gymnasium rather than going to work. There is no aspired consumption level affecting the economic reasoning at this stage since we assume that the individual is too young. We do however assume that each individual is forward looking and able to predict the difference in wages over the next ten years stemming from each choice, based on the wages of those whom have gone to college versus those who have not. The individual's probability of going to gymnasium should therefore incorporate the rational preference of going to gymnasium if the predicted future income is higher under this choice than otherwise. In particular, if the wage difference gymnasium-versus-basic, ΔY is positive, then the probability to enter gymnasium increases otherwise it decreases:

$$\text{(9)} \qquad Economic\,\mathrm{Pr}\,essure_{gymnasium} = \alpha + \beta \frac{e^{\Delta y}}{1 + e^{\Delta y}} ,$$

where $\alpha = 0.8$ and $\beta=0.4$.

The social incentive is calculated similarly. The average participation rate (i.e. proportion of youngsters in gymnasium) is first calculated at the individual's network level. Subsequently, the model calculates the relative deviation of the network's specific participation rate from the baseline probability *p*. This deviation is then fed into the same exponential function, returning a value between 0.8 (if the pressure is negative) and 1.2 (if the pressure is positive):

$$\text{(10)} \qquad Social\,\mathrm{Pr}\,essure_{gymnasium} = \alpha + \beta \frac{e((mean_g - p)/p)}{1 + e((mean_g - p)/p)} .$$

At this point, this baseline probability *p* is multiplied by a factor obtained in turn by multiplying the economic and social pressure factors together, thus introducing individual heterogeneity. The final participation stock is determined by random selection.

Those who are selected to go into gymnasium will have their student status changed accordingly for the next three year, after which they are made to graduate. After graduation from secondary school, the individual face the option to continue to tertiary school.

University

The choice to enter university is determined by the individual's prospective earnings compared to their parent's earnings. If secondary education will be enough for giving them the same equivalent income as their parent's given that they have the same number of children there is a 90% possibility that they will not apply for university.

The applicants are then ranked according to accumulated human capital (production of human capital is discussed below) such that the ones with the highest human capital are actually accepted by the university. The number of available positions at the university is set to a proportion of the current number of individuals aged 19 to 30. The number of university positions available for new-entrants is determined by the number of current students in the system. Furthermore, if attending university, the student will be entitled to a student allowance for the duration of the course (max 5 years), amounting to a fixed proportion of average earnings. The actual time between entering the university and exiting with a degree will of course be longer if the agent has been on parental leave during the period. The educational choice does not depend on fertility choices.

The choice of going to university is made upon the assumption by the agent that it will have the same number of children as its parents. Given that number of children, it estimates how it can reach the same equivalent income (adjusted for the growth in the medium equivalent income). It does so by first checking if the average wage for university educated people times an adjustment factor (that is meant to adjust for their years spent in college which reduce work experience) is higher than the average wage for people with a gymnasium degree as their highest level of education.

$$adjustmentfactor * avg.WUniversity > avg.Wgymnasium \tag{11}$$

The adjustment factor is currently set to 0.95 but could also be a function of an individual discount factor. If the expression above holds true then the university income is deemed to be higher by the agent. At this point, another required criterion for applying to university is if the university education is needed to reach the desired equivalent income. Rephrased, that is if the average wage of those with a gymnasium degree as their highest level of education is lower then the aspired equivalent income times the before mentioned adjustment factor:

$$adjustmentfactor * incomeaspiration > avg.Wgymnasium \tag{12}$$

In (12) the aspired income is calculated as a weighted average of aspired income and child cost. Here neither child cost nor aspired income are however exactly the same as they are in the fertility decision. Indeed, child cost is not the same as r in equation (4): there it was an indirect cost affecting the way equivalent household income is calculated. Here instead it is actually a direct cost amounting to a proportion of GDP per capita. As for aspired income, it is not as ASPC in equation (7). In this case it refers simply to equivalent income at ten adjusted by a growth factor.

If both conditions (11) and (12) are met the individual will apply for university. If these conditions are not met there is still a 10 percent chance that the agent will apply for university. Once accepted the university education lasts for 5 years if it is not interrupted by periods of parental leave. Each year the human capital of the agent is increased at a specified rate that is dependant on for example the teachers' human capital.

As for the fertility rule, we also have an alternative rule for tertiary education that is presented in the appendix.

Labor Market Module

Individuals that are not in school, above 16 years of age, enter the labor market. The labor market module determines in every period the individual's labor market status - whether employed, on parental leave, or retired. This module also determines the total output level in the economy, the wages and earnings.

All between the ages of 16 and 65 that are not students, and not on parental leave are employed. If someone is in work, we assume that they are in full time work for the whole year. All females that give birth are on parental leave for 3 years and receive parental leave benefits. The model is currently being developed also to include female labor supply, in particular the choice of part time, full time work or voluntary unemployment as a function of projected household income, aspired consumption levels and childcare costs.

Among those who are in work, we also randomly assign the work status of teachers, following a policy set parameter which fixes the desired number of teachers per student. Those who become teachers do not participate to the production of consumption goods but rather to that of human capital. The number of teachers fluctuates with the number of students (so that the ratio is constant). However, at any given time, the total human capital of teachers will depend on the human capital of those randomly selected to become teachers; in turn, the total human capital level of teachers is an input into the total human capital production of the population, hence it will influence the future total output level which will be produced.

In the current version, retirement is deterministic. At age 65, individuals are automatically removed from the labor force and included into the list of "retirees". From this point onward, individuals are entitled to a retirement pension (the level of pension benefit is discussed below).

Output Production

There is a single sector in this economy producing a single consumption good. The amount of consumption good produced depends entirely on the total human capital level of the labor force (excluding teachers). The production function follows a Cobb-Douglas shape with a time-dependent productivity factor. Modeling the output production function this way is meant to capture the idea that returns to human capital investment are increasing, in line with endogenous growth theory, but after a certain level the situation might be actually reversed, if, e.g. there is an excess supply of skills in the economy. There are two input factors in the model; the total human capital of the non-university degree (primary or secondary degree) individuals, and the total human capital of the university (tertiary) degree individuals. The output function looks as follows

(13) $$Q_t = A_t H_{1+2}^{\alpha_{1+2}} H_{t3}^{\alpha_3},$$

where $\alpha_{1+2} + \alpha_3 = 1$, and $H_{t,1+2}$ and H_{t3} is the aggregated human capital in the non-university and university degree groups, respectively. In this version, the productivity factor A is set equal to 1.

Earnings

There are no monetary values in the model at present so earnings for now are represented by the share of total output produced going to each worker. The allocation of the produced good to workers is separated into two steps. First, the total produced goods are allocated to the two production factors (non-university and university degree individuals) proportional to each group's marginal product. Then, within each group, the consumption good units are allocated proportionally to the human capital of the individual. This implies for example that, if the supply of university degree individuals is reduced, their marginal product will increase and thereby increase their share of the produced goods.[4] This will be observed by young individuals who will be more prone to choose university and thus increase the future supply of university degree individuals.

For individuals not born inside the model, we also need to impute past consumption good earnings, in order to track their earnings history (comparably with other individuals born inside the model), and thus

[4] The net effect could be either positive or negative as the total amount of consumption good produced will decrease.

establish their eligibility e.g. for certain income related benefits such as pensions.

Human Capital Production Module

In the current version of our model, we postulate a production technology only dependent on human capital i.e. there is no savings into other types of productive assets. Human capital pertains to the quality of labor embodied in each worker, for a given amount of schooling, training, work experience, as well as innate abilities. As such, the individual human capital level can be accumulated and measured as the output from a human capital production function which should capture, e.g. the quality of educational institutions and the ability of the system to transfer knowledge between individuals, as well as parental attitudes and native endowments.

The difference between human and physical capital can be explained by the presence of social externalities embodied in the private accumulation of human capital. When someone is increasing their human capital, e.g. through an additional year of schooling or on-the-job training, their action has two distinct effects: (i) he or she is increasing their marginal productivity, hence, according to the basic principle of competitive markets, they will increase their returns or wages. This is empirically supported (people with higher education tend to have higher wages) (ii) he or she is contributing to raising the quality of the total human capital stock, which also enters the "human capital production" functions of current students, determining the rate at which another individual will in turn be able to accumulate their own human capital, hence increase their own productivity and wages. This spillover effect is essentially the key "externality" distinguishing human from physical capital. We want to incorporate this linkage into our model through the incorporation of the teachers' human capital in the function governing production of human capital in school.

At first, upon birth, an individual is immediately assigned a native human capital stock which captures the average native human capital stock of the parents (i.e. a purely genetically inherited feature) plus a random number. Subsequently, from the first year of life, human capital evolves every year depending on events during the year. We allow for three different functions for human capital updating depending on which life phase the individual is in. We believe that there are three main inputs into the production of human capital: (i) ability acquired from parental influence and parental own human capital levels (ii) ability acquired through formal education (iii) skills and expertise acquired through training on the job. The model aims to separate these three phases of human capital accumulation through the definition of three distinct production functions (i.e. depending on age and labor market status, the individual is run through each function in subsequent steps). In each phase the human capital increase (or decrease in the event of parental leave) of individual i at year t+1 denoted h_{it} is computed using the production function for that phase.

Each production function has its own set of covariates such as parents human capital stock, the quality of education in school (i.e. the teachers aggregated human capital per student), and the employment status when in the labor market. For example, for a given amount of schooling years, higher parental human capital implies a larger production (growth) of the individual's human capital. Reflecting the impact of better educational facilities, the number and the sum of teachers' human capital also increase the growth rate of human capital when in school. Further, when in the labor market a year of parental leave deteriorates the stock.

Pre-school

Consider an individual with natal human capital h_{i0}. This natal human capital is derived from the natal human capitals of both parents (cf. genetic and inheritable ability), and a random factor. The discrete time evolution of the natal human capital in the pre-school periods is modeled as

(14) $$\Delta h_{it+1} = A h_{it}^{\alpha_{own}} \left(h_{i_m t} + h_{i_f t} \right)^{\alpha_{parents}},$$

where Δ indicates first differences and h_{i_m}, h_{i_f} denote the human capital of individual i's mother and father (in that given year). Hence, the human capital production function is a Cobb-Douglas type with the sum of parents' human capital and the child's own capital as input factors, and their respective elasticities α_{own} and $\alpha_{parents}$ are specific to the pre-school period and set exogenously.

In-school

During schooling not only the parents' human capital enters the individual's human capital production function. During these periods, also the human capital of the "teachers" enters the function. The argument is that training by highly educated teachers should imply a steeper learning curve for the current students. This creates an additional link between current aggregate human capital and the production of "new" human capital through schooling.

We assume that the *aggregate level* of human capital among the teachers, scaled by the number of students, enters the human capital production function along with the parents' human capital. The rationale behind this assumption is that the policy makers should be able to influence the output of the educational sector by allocating more teachers. If teachers are assumed to be randomly drawn from the population of the labor force, then using the average would not enable policy decision in this respect as the "quality" of education would be more or less independent of the number of teachers. However, using the (scaled) sum of human capital enables such policies.

To formalize, the human capital production during school periods is defined as

$$(15) \qquad \Delta h_{it+1} = A_t^s \left(h_{i_m t} + h_{i_f t} \right)^{\alpha_p^s} \left(H_t^{teach} / \#students \right)^{\alpha_t^s} h_{it}^{\alpha_{own}^s},$$

where the superscript s indicates that the parameter values depends on the level of education (primary, secondary, and tertiary). For example teacher human capital has level specific impact on human capital production. The time index on the productivity factor A indicates that the overall productivity of human capital production can be time dependent.[5] Here, the human capital production function can be influenced directly by the policy makers by allocating more resources to the educational sector (employing more teachers) or indirectly by lagged effects when the average human capital in the labor force increases.

It is important to add that, for those university students who are temporarily on parental leave, the accumulation of human capital is temporarily stopped. The total number of teachers in the educational sector is as stated above determined by a policy parameter which gives the target share of teachers per student. Currently, the ratio of teachers per student is fixed at 0.1.

Post-school

In standard wage equations, labor market experience approximates human capital production at work. In our set up, we can use a pure "at-work" human capital production function similar to the in-school production function. The human capital while in work will increase for every year in work proportionately less the older the individual gets, up until the age of

[5]This could be used to formalize a Becker-Murphy-Tamura approach with convexities in the human capital production function.

55. We extend the production function to incorporate a deterioration of human capital in unemployment spells or periods of parental leave. Formally, the human capital production at work is a percentage increase, decreasing in age, which turns negative after age 55 such that

(16) $$\Delta h_{it+1} = \frac{55 - age_{it}}{10} * edu_k * h_{it} ,$$

where edu_k is a factor that is dependant on the level of education. Currently it takes the value 0.01 for a person with a basic education, 0.015 for a person with a gymnasium education and 0.025 for a person with a university education. During periods out of the labor market, notably on parental leave, the human capital is set to depreciate at a yearly rate of 0.015. However, this is not assumed to be the case for students on parental leave (i.e. we assume that they will not depreciate their skills while looking after a child, only workers will).

The Pension System

The pension system is modeled according to the Swedish system (2003), with some simplifications related e.g. to the fact that the model does not yet have capital markets. Every retiree is assigned a state pension which is comprised of three elements: a premium pension, an income pension and a guarantee pension. The premium and income pension are related primarily to the amount of notional contributions paid by each individual during their working life into their personal account (as well as other factors such as e.g. the income index or automatic balancing). The guarantee pension is instead a minimum universal pension for all.

During working life, each individual pays an amount of contributions *C* equivalent to 16 percent of her earnings into a personal fund *PF* which accumulates over time and grows at the rate of earnings. Every year, we assume that the fund grows at a rate R, which varies depending on the so called balance ratio (i.e. the ratio of total assets and liabilities in the PAYG system) between the income index (i.e. the growth rate in average pensionable incomes, if the balance ratio is over 1) and the automatic balancing ratio (if the balance ratio is less than 1, in which case the pension will be growing by less than incomes growth) .

At the time of retirement (age 65), the individual will therefore have accumulated a certain lump sum which is converted into a yearly pension income, IP. The pension annuity is calculated on the basis of a unisex life expectancy of 20 years at age 65 through a so called annuitization divisor. [6] Each year in retirement the benefit is furthermore adjusted by the rate of R. The pension benefit is eventually adjusted also so as to keep the (PAYG) in balance.

The general algorithm for the total value of the individual pension fund is given by:

(17) $$PF_{t+1} = (PF_t + C_t) * (R_t - b) .$$

Where PF_{t+1} is the value of the accumulated fund at time t+1, PF_t is the value of the fund at time t, C is the amount contributed into the fund at time t, R is the income growth rate and b is the balancing index. If b is greater than 1, in (17) it will be ignored i.e. b=0, so that the pension fund grows at rate R. If b is less than one, we reduce R by the same amount.

An issue which is inherent to simulating a pension model is to back simulate historical earnings and contributions for those people who either have already retired or are in the middle of their working life in the first year of model simulation (in our case, e.g., 1996). For those who have already retired then, we simply assume that their pension will be entirely based on the old system, i.e. they would not be eligible for an income pension hence would not have a pension fund, but only the maximum amount of guaranteed pension. For each individual who is already in work at this time, we need to make some assumptions about the pension fund that they will have probably accumulated up to the point when we start simulating. Since we lack historical data for these individuals, we currently opt for making the simplifying assumption that, for each year of declared work experience, they would have contributed 16 percent of their current discounted earnings. We assume that the discount rate would offset the fund's growth rate R.

The system's overall balance at any given time period is given by the amount of total social insurance contributions *CW* (paid into each individual account by the current generation of workers, W) and the amount of total income pension benefits I*PN* (paid out to eligible current retirees, N):

(18) $$\sum_t CW = b \sum_t IPN .$$

[6] This is the life expectancy at 65 for the 1990 birth cohort. We assume this also for subsequent cohorts. In 2006 life expectancy at 65 was 17.6 for males and 20.7 for females.

Where $b = \Sigma\ (CL)\ /\ \Sigma\ (IPN)$ is the inter-temporal balancing index required to keep the income pension bill financially sustainable. As we are modeling the Swedish Notional Defined Contribution system here, we develop *b* into a simplified equivalent of the real Swedish automatic balancing mechanism, which entails a proportional reduction in the amount of pension *IP* any time the ratio CL/IPN goes below 1 (i.e. when the income pension liability exceeds or falls short of the assets of the system). Finally, the income pension benefit at time t becomes:

$$(19) \qquad IP_t = \frac{PF_t}{L_{65}} \text{*}(\mathrm{R}\text{-}b).$$

Where the subscript *t* is any time after retirement, *L* is the life expectancy for the individual at 65 (by gender), *R* is the growth rate of the fund and *b* is the balancing index. If *b* is greater than 1, in (19) it will be ignored i.e. *b*=0, so that the pension grows at rate R. If *b* is less than one, we reduce R by the same amount.

Once the income pension is calculated, the individual will be checked to see whether additionally she will be eligible for a guaranteed pension. A guarantee pension will be awarded to all individuals, regardless of their social insurance contributions, who have an income pension amounting between 0 and 3.7 (for singles) or 2.72 (for couples) basic amounts (this threshold has been set on the basis of the 2008 system).

Given 2008 values for Sweden, those who have an income pension equal to zero (i.e. no income pension at all), will be entitled to the maximum amount of guarantee pension, currently fixed at 1.9 basic amounts (for singles) and 2.13 basic amounts (for couples). [7] For those with an income pension above zero, yet below the maximum pension income threshold, more precisely up to 1.26 basic amounts (1.12 for couples), the income pension amount is withdrawn from the maximum guarantee pension amount by 100% (so in practice the total pension income of these people will be equal to the maximum guarantee pension, albeit the composition will be split between income and guarantee pension). For those with an income pension between 1.26 and 2.7 basic amounts (1.12 and 2.72 for couples), the maximum amount of guarantee pension will be tapered away at a rate of 48% for every additional unit of income pension. In other words the guarantee pension benefit is calculated as follows:

[7] In 2008, one Basic Amount corresponded to SEK 48,000.

(20) $$GP = MaxGP - \alpha(IP) \quad > 0.$$

Where α is set equal to 1 for IP < 1.26 BA per worker, and to 0.48 above that.

State, tax and benefit systems

The function of collecting taxes from individuals is managed through the State, an agent capable of (i) identifying people who are eligible to pay tax, social insurance contributions, and collect them into a tax payer list (ii) calculating an income tax function and a capital tax function for each individual (once savings will be introduced), and summing the total revenues (iii) managing public expenditures including students allowance, teachers' salaries, parental allowances, child benefits, social welfare benefits and pensions.

First, the State calculates the total expenditure bill, by aggregating the costs of the education, teachers' salaries, parental leave subsidies, pensions (including both income and guaranteed pension) social welfare income and child benefits (in the alternative scenario). For instance, the education bill comprises the total costs of paying university student allowances (set to a fixed proportion of average consumption good earnings, e.g. 20 percent), as well as teachers' salaries. The social welfare bill aggregates all the benefits paid to those adults whose disposable income is less than 5% of GDP per capita. The pension bill consists of aggregating the total value of all guaranteed and income pensions paid to retirees, although only the guaranteed pension will affect the revenue side as it will be paid out of taxation, while the income pension will be paid out of a separate "fund" made up of individuals' contributions.

Once total expenditures are calculated, the State will adapt the tax system so as to raise sufficient revenues to balance the budget (no debt is allowed in the current version of the model). The tax system comprises a State and a Local tax. The State tax is a progressive tax payable on all income greater than an endogenous earnings threshold (currently set to include only earnings in the top 20 percent of the income distribution at each time period); the tax rate is set by a changeable policy parameter (e.g. 20 percent rate on all income above the threshold). The local tax is derived also endogenously to cover any revenues' shortfall from the State tax, given total expenditures, and given the current tax base. The individual income tax will therefore be a combination of both the State tax (if eligible) and the Local tax (payable by everybody with positive earnings). The individual disposable income therefore is calculated as the sum of any earnings, pensions, student or parental allowances, minus the income tax.

The Parental Leave Benefit

The parental leave benefit is modeled according to the Swedish system (2007), with some simplifications related to the rules e.g. on number of eligible days for each parent etc. In our model we assume that only the woman gets the benefit within the couple, hence the amount of the benefit is calculated on her eligible income.

The benefit comprises a guaranteed amount, for those who have no previous income history (such as students) and an insurance-related amount, for those who have earnings up to a certain thresholds (i.e. up to 10 times the so called Basic Amount equivalent, which in our model is calculated to reproduce a level comparable with the Basic Amount for 2007 in Sweden, around 40000 SEK per month).

Upon the birth of a child, people with no work history or students would receive therefore a minimum benefit corresponding (in daily terms) to around 0.45 percent of the Basic Amount equivalent. For a parent that is on a full time parental leave this would correspond to a monthly benefit of 13.5 percent of the Basic Amount. Most students that receive a child during their studying period would receive this amount. In our alternative scenario we elaborate to see what happens when this minimum level is raised.

People in work instead first need to have their base income calculated (for the purpose of receiving an income related benefit). This requires the application of a coefficient to their gross earnings which reduces them slightly for the purpose of benefit calculation. The parental leave benefit amount is set to 80 percent of the individual's base income.

The benefit is paid for three years after the birth of the child, after which the individual returns to their previous labor market status. This length of the leave is higher then what is actually possible to take obtain. However, we do not include the right to benefits when taking care of a sick child nor do we include the effect of part time work when raising children. We thus believe that adding a longer initial leave compensates for this.

Being on parental leave does not exclude per se the possibility to have another child, since the model allows women with a child older than one year of age to have another one. In these cases, during the overlapping period when the mother is looking after two children, the parental leave benefit amount is frozen (i.e. it is not doubled).

Simulation applications

Until now the model has mainly been used to study the effects on fertility behavior and the economic implications from different fertility patterns. One application investigated the effects of raising the minimum parental leave benefit. By using thumb rules for the fertility decision that are not based on the individual's age, except for the biological fertility ability, it was possible to match the empirical fertility distribution by age.[8] By using economic and social aspects in the decision rule it is possible to obtain a reasonable fit. The resulting age distribution by age is replicated in figure 5 below.

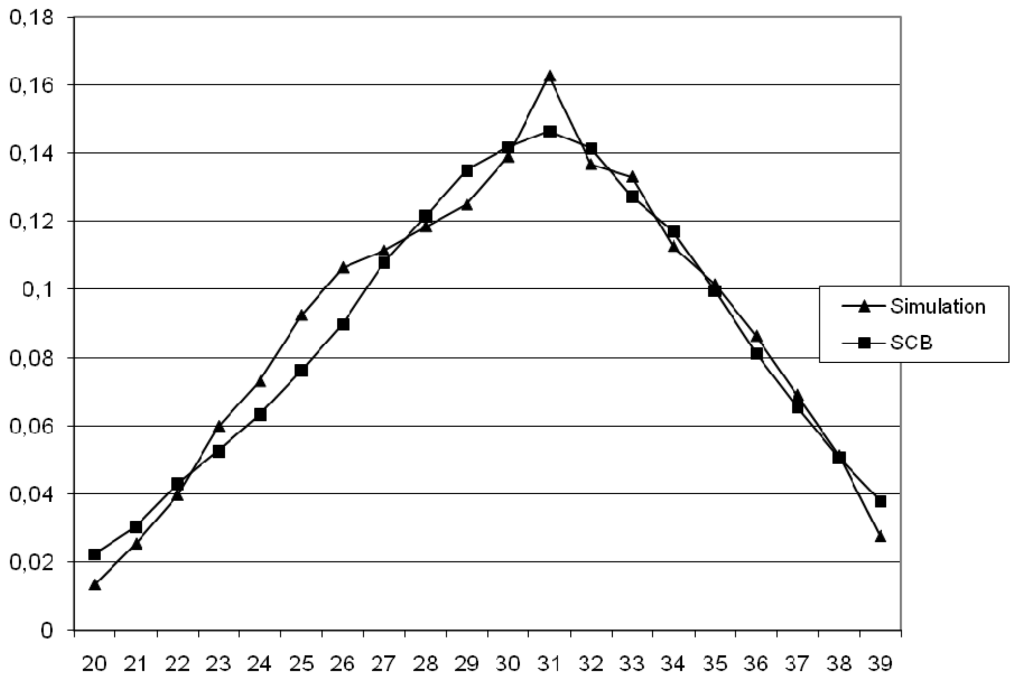

Figure 5: Simulated and actual fertility rates by age. The actual rates are for Sweden 2006 according to Statistics Sweden (SCB).

After showing that the use of thumb rules was able to generate similar age distribution pattern it was tested how raising the minimum parental leave benefit might affect the fertility rates. The result was that minimum parental leave benefit was not able to raise the fertility rates in a significant way. However it was also so that the reform was not associated with any major cost.

[8] They use the alternative thumb rule for fertility which is explained in the appendix of this handbook.

The model was also used to study the low fertility hypothesis. To study the low fertility hypothesis the thumb rule for fertility was adjusted to capture the main elements of the hypothesis. One important factor of the hypothesis is that many aspirations that affect both consumption and wanted number of children are set during youth. By tailoring a thumb rule suited for the hypothesis we investigate under what circumstances a low fertility trap might be provoked and what kind of policy that could avoid the trap. The growth effects of different policies were also investigated. The simulation first starts with a base scenario where the fertility (completed cohort fertility) evolves over time according to figure 4. Then a shock occurs so that the cost of a child increases. This will force parents to invest a higher share of their income in the child, if they decide to get one. One rationalization of this upward drift in the relative cost of children is that the opportunity cost for parental time is increasing. Since everybody works full time in our model we cannot implement that directly through labor supply. We then investigated one base scenario and two different alternative scenarios:

1. In our first alternative scenario, "no policy", no policy is introduced to counteract the change in cost of children.
2. The second alternative scenario, "policy action", implements a strong form of the child benefit immediately. In this scenario the benefit is given by $\tilde{b}_t = 0.1 * \frac{\sum_i W_{it-1}}{n_{t-1}}$ where n_{t-1} is the number of children eligible for the benefit. $\tilde{b}_t$ will in general be higher than b_t. In a situation when few children are born, the benefit $\tilde{b}_t$ will rise to counteract the upward drift in the relative cost of children.

The relative cost mechanism is introduced in the model year 60.[9] One can clearly see that fertility is affected by the introduction of the changed child cost. In the first scenario population declines at a fast rate. We note that in the first alternative scenario the share 65+ in the population passes 50 percent about 65 years into the future after the shock. The child benefits introduced in scenario 2 at first manages in blocking the dive in fertility.

[9] All alternative scenarios are programmed in such a way so that perfect replication of the base scenario is attained, up to a point when a change of arbitrary choice (like the change in child cost) is set into play. This means that the initial random component in the model is exactly identical in all scenarios. Thus the alternatives can be interpreted as counter-factuals to the base scenario.

However, 40 years into the future, not even this policy manage to turn the tide as fertility rates falls to low levels.

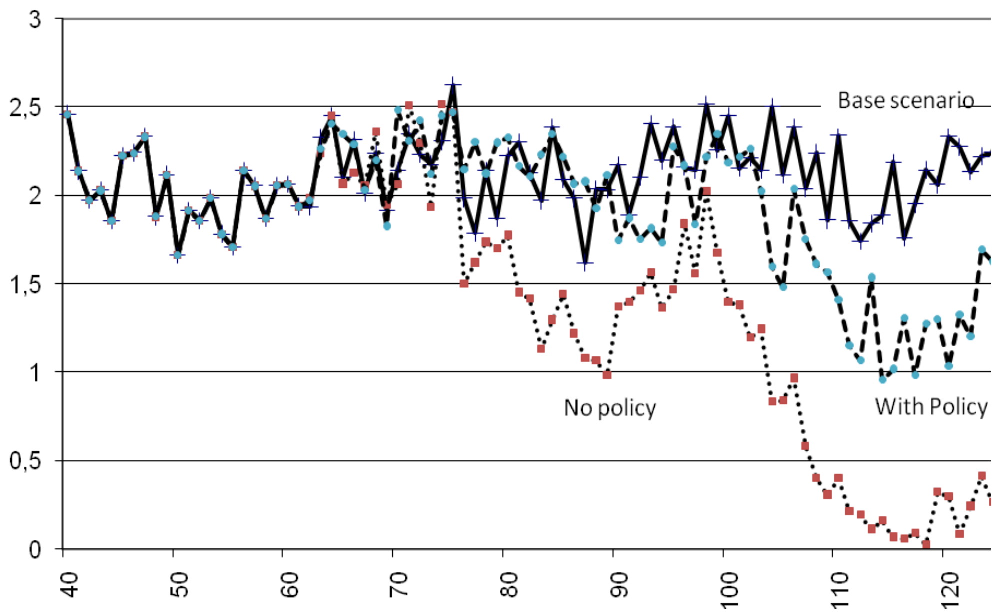

Figure 6: Completed cohort fertility under base scenario and two scenarios when the child cost has increased in period 60.

Concluding discussion

This handbook presented the agent based simulation model, IFSIM. This model has a core on which it is based on but it still maintains the flexibility to be adjusted for specific applications. With fairly modest modification the model could be used to investigate numerous issues. So far it has mainly been used for investigating fertility outcomes under different policy assumptions and to investigate the macro economic consequences of these changes in age composition.

The extension that is under development is to allow for part time labor and migration. One aim is to study how labor market policies, such as parental leave regulation, affects female labor participation rates and thereby also their life time income, including pensions. The observed differences in male and female incomes could perhaps be mitigated with different parental leave policy.

Migration is especially important to analyze when considered that within the unified labor market of the European Union there are autonomous social insurance systems on national basis. Flexible labor markets implies a moving tax base which constitutes new challenges for the national social insurance systems. In the future IFSIM will include a “second country” with its own social insurance systems which will allow us to study the effects of migration.

Appendix

Alternative fertility algorithm

Married females between ages 20 and 40 and who are not on parental leave have the possibility to give birth. Since the fertility event comes before the matching (marriage) event it means that a couple needs at least one year of marriage before acquiring children. Every woman who meets the marital, labor market and age conditions is first assigned a baseline fertility rate, i.e. a probability of having a child in the current year, which is a decreasing probability of age:

$$\Pr(Child \mid Age) = \frac{\alpha - e^{\beta * Age}}{\alpha - 1}$$

We calibrate this function (i.e. the parameters α and β) to 2006 Swedish fertility data, by age (so as to reproduce a similar functional shape); we then compare the individual outcome against a random draw.

Optimally, we would like to model the number as well as the timing of child bearing in the model. At this stage, we endow each individual with a preferred number of children, which depends on the average number of siblings that the couple together has had (so as to capture some kind of social pressure effect), as well as how many children one might have already had. So for a given baseline probability, depending on the number of parents' siblings and the existing number of children in the household, the social pressure will slightly reduce or increase this baseline probability by a number ranging between 0.8 and 1.2.

The baseline fertility is also adjusted to take into account the effects of the so called economic pressure, in other words the expected financial constraints (or incentives) that different women (depending on their marital and labor market status) face if they were to have a child or not. Their expected disposable income will in fact be affected due to temporary exit from the labor market, if in work, or from studying, relative depreciation of human capital, as well as the level of parental benefits relative to earnings. At the moment, we do not base the expected income difference between having a child or not on household income, but rather on the individual's. We are planning to change this in the future.

The economic pressure is a function of the expected relative difference in individual's discounted disposable incomes under the two states (having a child or not); it is an expected difference estimated over a certain number of years ahead, which at present is set to be 6 (but can be easily changed by the user). Clearly, different labor market statuses (i.e. whether one is skilled or unskilled, or whether one is still in University) will affect the expected projected income. So we allow separate calculations of the economic pressure depending on this status; this essentially amounts to a variation in terms of the earnings growth rate applied over the considered timeframe for projection (depending on one's degree, different skill levels are awarded different average earnings growth rates in the market), and also in terms of the parental leave owed if having a child (people with working history are given a benefit equivalent to the 80 percent of last earnings, while people not in work such as students, are just given a minimum fixed amount of 80 percent of average GDP). Parental leave subsidy is made payable only for up to three years (this can be varied by the user). Students considering having a child will assume also different expected earnings over the next six years depending on which academic year they currently are at, and how many years they would need after parental leave in order to finish their degree. Students who are in the final year would be more likely to consider having a child from the economic point of view as they would assume to start working after three years, at an earning rate similar to average earnings for current first year workers with a university degree. Other students would need to resume studying hence after parental leave they would go back to student allowance as their main income source, before joining the labor market.

So, the economic pressure is calculated as an exponential function of the relative individual difference in expected incomes given these two possible states (parenthood or not), and can range between 0.8 and 1.4. It is subsequently multiplied by the social pressure and baseline fertility rate to produce the final individual probability of having a child in that year.

The timing of giving birth is then indirectly determined by the labor market status (discussed below) of the individual. Once a child is born, its mother is on "parental leave" for three years before returning to her previous labor market status, including university if she was a status. Given that the mother satisfies a set of conditions, she faces probability of actually giving birth that is decreasing in age. This probability has the same functional form as the survival function discussed above.

Alternative tertiary education algorithm

The individual's decision to go to higher education, i.e. university (or tertiary) level, is governed by three parts. First we have a base line probability that is assumed to capture the over all probability that any eligible individual enters the university. Next, we have a probability that increases with the perceived economic pay off of higher education, here denoted as the economic pressure. Finally, there is a probability that relates to the average participation rate at university within each given network group, denoted as the social pressure. The path into university is made up by an application step and an acceptance step.

First we construct a set of university applicants based on expected life time incomes, based on contemporary cross-section projections of disposable income on age. This is assumed to correspond to individuals construction of a rough expectation about future pay-offs associated with the educational decision. The mean projections are based on the full sample whereas a specific individual's position in the distribution of disposable incomes will depend on her position in the network group's distribution of human capital. This aims to reflect that individuals with high accumulated human capital should expect to be positioned higher in the distribution of incomes. In other words, individuals with gymnasium degree will have higher probability to apply to University if their expect costs (i.e. 5 years of foregone labor income) will outweigh the future benefits (i.e. higher human capital, higher earnings and higher pensions). Applicants will be able to compare the NPV stream of expected future incomes if they were to go to work immediately or rather go to University, hence they will choose the option the yield the highest expected income.

In order to create expectations of future disposable incomes with respect to various educational decisions, the individual is made to regress disposable income on age and age squared for current workers in the population. The individual's prediction about her future age profile will further reflect the individual's position in the distribution of human capital within her network group. Formally,

$$DI_{ia}^{school} = x'_{ia}\beta^{school} + d_i\sigma_{DI}^{school}$$

where $school = \{college, univ\}$, $d_i = \left(HC_i - \overline{HC}_g\right)/\sigma_{HC,g}$ and σ_{DI} and σ_{HC} refer to the standard deviation in the distribution of disposable income and human capital, respectively. The subscript g indicates that the measure relates to a network group. The vector of independent variables includes a constant, age, and age squared.

Thanks to this regression, the individual can compile for every age and degree an expected life income profile, i.e. the lifetime expected value of income for each educational outcome (i.e. college or university).

The economic pressure is then calculated as follows:

$$EcoPres = 0.5 * \frac{\exp(x)}{1 + \exp(x)}$$

Where *x = (npdUniversity – npvCollege)/npvCollege*, or simply the relative difference in net present value terms of expected life income if going to University versus just having a College degree (i.e. cumulated over the whole life).

List procedure

Some lists are cleared every period some are updated. If the list is cleared or not is stated in the parenthesis. To clear the list is more robust for code errors but it extends the running time.

The following ArrayLists exist:

MAIN

- individualList (updated)
- householdList (updated)

INITMODEL

MACRO

NETWORK

- angleGroupsIntervals (constants)
- networkGroups (cleared)

DEMOGRAPHY

- deceasedList (not used)
- newbornList (cleared)
- age7to15List (cleared)
- leavingHomeList (cleared)
- singleMales (cleared)
- singleFemales (cleared)
- matchedHouseholdList (cleared)
- networkArray (commented out)
- jointnetwork (introduced to make husband and wife share network members)

EDUCATION

- basicList (cleared)

- GymnasiumList (cleared)
- universityList (cleared)

LABORMARKET

- employedList (cleared)
- unemployedList (not used)
- retiredList (cleared)
- laborForceList (cleared)
- parentalLeaveList (cleared)
- teacherList (cleared)

HUMANCAPITALPRODUCATION

PENSION

STATE

TAXSYSTEM

- taxPayers (cleared)

Technical Platform

Initialization

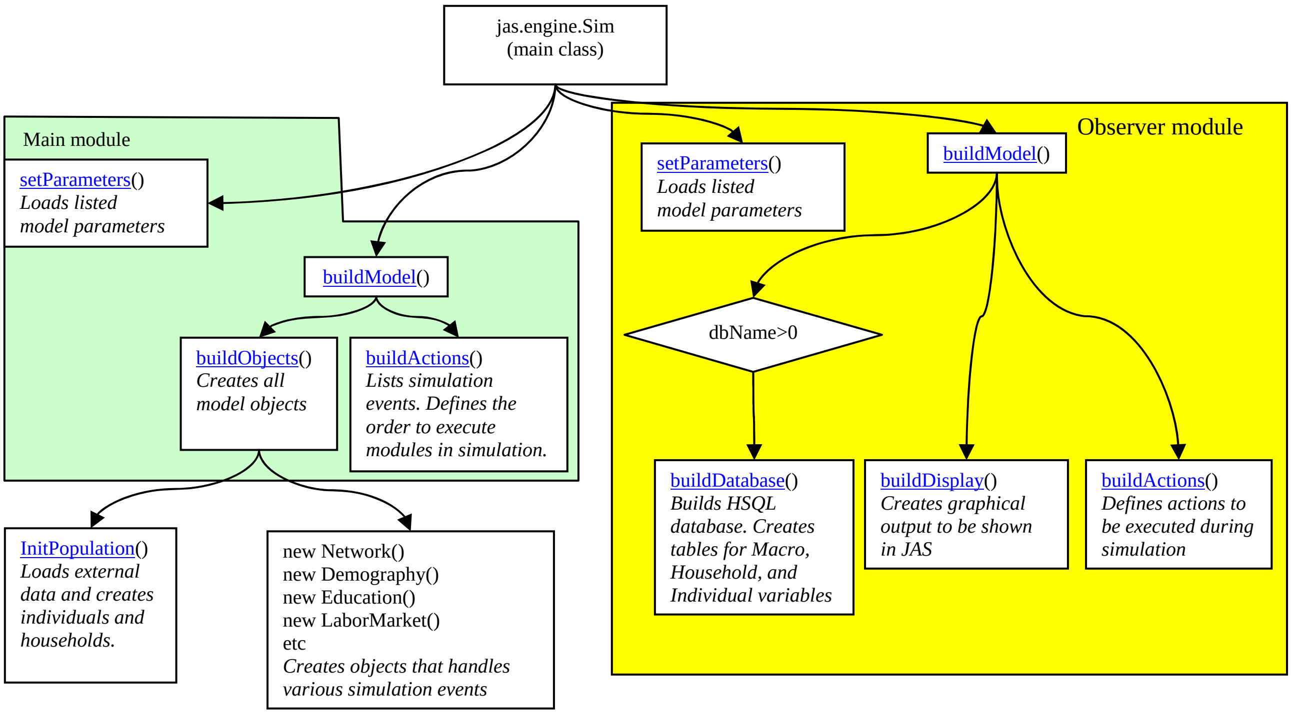

Chart 1 Model initialization overview

As IfSimMod is executed by JAS, JAS calls the BuildModel-methods of the models listed in the JAS project. In this case we have listed two separate models, namely the Main model that holds the actual simulation model, and the Observer model that holds the graphical output and statistics collector. Each of these models can load their own parameter bag and perform different actions as they are executed. These methods are called as the user clicks the [Build model] button in the JAS interface. The primary actions taken by these two models are described below.[10]

Main module actions

In the setParameters() method, the parameters listed in the parameter bag is set. These parameters can be set by the user before the simulation model

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[10] Note that these methods do not execute the actual simulations, they just set of the "playgroup". The actual simulation is started once the user clicks the [Start simulation] button in the JAS interface. This will cause JAS to exectute the events listed in the eventlist defined in buildActions() methods.

is actually built. However, the parameters must be listed in the parameter bag file, which can be edited either via the parameter bag editor in JAS or directly in the parameterBag.pForm.xml file.
The buildModel() method in Main calls the buildObjects() and buildActions().

The buildObjects() method is where all important model objects are created (or instantiated in JAVA programming language). Here we initialize the model in the sense that the data for constructing initial individuals and households are loaded from an external data source and we instantiate the objects that defines the various simulation events such as the demography object etc. As an object is instantiated, the class' construction function is called and all class variables (also denoted class fields) are populated for that instantiation.[11] One of these class variables is a link to the Main model. This means that the constructed objects can "look into" the Main object and consequently look into any other object that are created within the Main object.[12]

The methods involved in the creation of these objects are discussed in the following subsections below.

Finally, in the buildAction() method the order of simulation is defined in the sense that the order in which the various simulation objects will be executed is set. Generally, each simulation object, e.g. Demography(), will have its own method called stepDemography() that defines the order in which the relevant methods in the object should be executed within one simulation step. In the buildAction() method one can define groups of events that are executed every simulation or with any other frequency and with any start date.[13]

Observer module actions

The Observer module is somewhat different from the Main module. The Observer is an object that handles data collection and graphical outputs illustrating what happens inside the Main simulation model. Hence, the

[11] An "object" is an "instantiation" of a "class". Hence, a "class" is something like a blueprint of an object. Several distinct objects can be created from the same class such that each object will have its own copies of the class variables and methods.

[12] In practice this means here that e.g. the Demography object can get information about the class variables in e.g. the LaborMarket object.

[13] In the instantiation of the model (done by JAS), there is an event list associated with each model. One can add elements to this event list using the SimGroupEvent grp = eventList.scheduleGroup(start,loop); method where start indicates the first simulation period at which the elements of the group is executed, and loop indicates the time interval between executions (see Observer.buildActions() for an example).

simulation model could be run without the Observer in the sense that the Observer does not interfere with the actual simulation events.

The setParameters() method in the Observer is empty as there are no parameters to be set. However, this method could be used to define which variables that should be plotted and which variables to write to the data base. This is something that we probably would like to develop soon.

The buildModel() method in the Observer calls the buildDatabase(), buildDisplay() and buildActions() method

The buildDatabase() describes which tables that should be created, and which variables that should be written to these tables. The database format is HSQL (Hypersonic Structured Query Language), which is a very fast, but memory consuming format. We may want to create an alternative format that is less memory consuming in order to avoid run time problems with the memory. The construction of the database and its tables is discussed in detail in Section 0.

The buildDisplay() method creates all graphical output illustrated in the JAS interface which need to be hard coded in the program. The current graphical illustrations are of two different types but there are more types available in the JAS package. The most common one is the time series plotter that plots the evolution of a macro variable over time. The second type is a distribution plot, where the distribution of a variable is plotted each iteration. A more detailed description of how these plots are created can be found in Section 0.

The buildActions() method defines how often the graphs should be updated and how often variables should be written to the database.

buildDatabase()

The output database is a structured database which consists of tables, columns, and records. Each table is two dimensional where each column represent one variable and each cell one record. Hence, in order to create an output database, one need to specify what type of table we want to use, which variables that should be included in the table, and where to get the values to fill the cells in the columns. All the mechanics behind the database handling is solved by JAS.

First we need to create the table. In this example we want to create a table that gets its values from the individuals in each simulation step. As the individuals are collected in an array list, we can use the CollectionTable object as follows

CollectionTable tbI= database.addCollectionTable(

“Individuals”,

Table.PK_SIMULATION_TIME,

model.individualList);

Here we create a new CollectionTable object named tbI and add this object to the database object database (already created). The table is called "Individuals", it is updated every simulation period (PK_SIMULATION_TIME), and the collection used as a source for data is in model.individualList, i.e. the list of Individuals objects which is in the Model object (the instantiation of the Main class). We then add columns to this table using either

tbI.addDoubleColumn("hcProd", Individual.HCPROD);

for double valued individual object variables, or

tbI.addIntColumn("age", Individual.AGE);

For integer valued individual variables. These methods of filling the cells in the table use the methods getIntValue() and getDoubleValue() in the Individual objects.[14] The first argument defines the name of the column and the second gives the integer number to which the variable is associated in the getIntValue() or getDoubleValue() methods. Note that this requires that the collection objects implements the IIntSource or IDoubleSource interface.

Finally, as all tables in the database are constructed, we need to open the database and make sure that the database object is updated every simulation period. The updating is managed via the buildAction() method in the Observer object. See the code for examples.

buildDisplay()

The graphical displays are basically of two kinds, time series or distributional plots. In time series plots we want to illustrate the evolution of a specific variable's evolution over time, whereas the distributional plot is a snapshot in time of a specific variables distribution. Both these types of plots can be generated using JAS capabilities.

Time series plots are created using a new instantiation of the class TimeSeriesPlotter. This object is then populated with specific times series that collect their data from various sources. Each time serie is nevertheless just a scalar valued variable that can be a function of a CrossSection object or a Model macro variable. In the following example we collect data from a

[14] There are other ways of retrieving data from objects using so called "reflexion" where one do not need to use getIntValue() etc. However, the reflexion method is much slower and should be avoided if possible.

method of an object using a reflexion approach. First we create a new instantiation of a TimeSeriesPlotter class

tsPlotter = new TimeSeriesPlotter("Population");

The graphical window will have the title "Population". Next we add two series called "Ind" and "Hh" which get their data from methods called "size()".[15]

tsPlotter.addSeries("Ind", model.individualList, "size", true);
tsPlotter.addSeries("Hh", model.householdList, "size", true);

To have the plot appear in the simulation window we need to add it to the list of plots using

addSimWindow(tsPlotter);

and we also need to tell JAS to update the window each iteration using

grp.addEvent(tsPlotter, Sim.EVENT_UPDATE);

in the buildActions() method.

Note however, that we will have a lot of different time series plotters. We collect them into an arrayList named tsArray. In the buildAction() method we iterate over each element in the tsArray and define that they should be updated in each iteration.

The distribution plots needs a cross section object as a data source. This means that we first need to create a CrossSection object to collect specific data from a collection of objects, e.g. age of individuals. The CrossSection objects can be of various types depending on the type of variables that are collected. Here we specify that the cross section holds integer values, and that we collect the data from the list of individuals and the variable which is associated with the constant Individual.AGE.

csInt = new CrossSection.Integer(model.individualList, Individual.AGE);

(Note that the csInt variable need to be a class variable, i.e. it should be declared outside the methods in the class. We need csInt to be a class variable as it is required in the refreshDistrGraphs() method.) Next we initialize the histogram and add it to the simulation window. Note that the actual construction of the histogram is done in the refreshDistrGraph() method discussed below. Note again that hist is a class variable which is used in refreshDistrGraphs() method.

hist = new Histogram(); addSimWindow(new PlotFrame("CS-distr", hist));

[15] The last argument indicates if the source is a method (true) or a class variable (false).

The actual construction of the histogram is done in a separate method. Here we first clear the drawing area of the hist object and then update the cross section data source. We then collect the data into an integer array called x and iterate over the elements of this array to fill the data points of the hist object.[16]

```
public void refreshDistrGraphs() {
    int[] x;
    hist.clear(false);
    csInt.updateSource();
    x = csInt.getIntArray();
    for (int n = 0; n < x.length; n++)
      hist.addPoint(0, x[n]);
   hist.fillPlot();
}
```

Simulations

As mentioned in the previous section, the order in which various modules are called in a specific iteration is defined in the buildActions() methods in the Main and Observer classes. Generally, the Main class only defines the order in which the separate modules are called whereas each module defines its own sequence of execution in a method called e.g. stepDemography(). In practice we have instantiated an objected (e.g. demography of class Demography) in the buildObjects() in the Main class and then stated in buildActions() that e.g. the method demography.stepDemography() should be executed in each iteration. In the method stepDemography() there is a sequence of other methods that are called to perform all the required actions within the demography object. Once all these methods are executed the Model object takes control and executes the next item in the list of actions, e.g. education.stepEducation().

[16] The hist object is actually an object from the Ptolemy package. For more information on this class, look up the Ptomlemy API on the Internet. There one can also find more features of the package. The Ptomlemy package is included in the JAS package.

Summary of Variables
Below we report a short summary of the principal variables used in the model.

Demographic module

Ageing

Outcome: ages individuals every year and assigns them to an age group
Affected: everyone
Algorithm: deterministic method
Covariates: none

Mortality

Outcome: kills randomly people before or maximum at age 110 according to projections based on SCB mortality statistics for 2007.

Affected: everyone
Algorithm: transition matrix by age
Covariates: age, time (model year)

Fertility
Outcome: having a child
Affected: non-single females between ages 20 and 40
Algorithm: agent based thumb rule
Covariates (factors of influence): age, marital status, age of youngest child, household income, expected equivalized household income (inclusive of potential child benefit), number of children, wanted number of children, social network, parents' equivalized income, average equivalized income at the age of ten, parents' equivalized income at ten, average equivalized income, cost of family member, median income.

LeavingHome
Outcome: leaving the parental household and establishing a single household
Affected: individuals older than 17 living with their parents
Algorithm: logistic function
Covariates: age, network group

Matching
Outcome: creates married households
Affected: single males and females that live by themselves.
Algorithm: matching algorithm based on age difference

Covariates: age of male, age of female, social network, educational status

Social Networks

Networking

Outcome: people are placed in an age-specific social network
Affected: everyone
Algorithm: deterministic by age group and within age groups depending on network angle
Covariates: age, network angle

Education

Basic

Outcome: starting basic schooling
Affected: all individuals of age 7
Algorithm: all individuals at age 7 start basic schooling and all complete it after 9 years of schooling

Covariates: age

Gymnasium

Outcome: starting gymnasium (high school)
Affected: individuals of age 16
Algorithm: all individuals at age 16 start gymnasium for 3 years
Covariates: age, degree, average wage with basic degree, average wage with gymnasium degree, average wage growth with basic degree, average wage growth with gymnasium degree, network group, model year (not calculated but set to one the first year)

University

Outcome: starting university studies

Affected: all above 19 with a gymnasium degree that are not on parental leave.

Algorithm: rule of thumb involving projections of income according to education level and parents' equivalised income

Covariates: average equivalized income, average equivalized income at ten. Number of siblings, alpha parameter for cost of child in university decision (calibration parameter), alpha parameter for weighting the influence of target consumption versus the actual cost of having child (calibration parameter), average wage for a person with a gymnasium and a university degree respectively.

Comment: the share of applicants actually entering university is aligned to external totals and based on the number of available positions

Production of human capital

Pre-school

Outcome: production of human capital

Affected: all individuals younger than 7 years

Algorithm: Cobb Douglas function with father and mother human capital and own human capital as inputs

Covariates: fathers and mothers human capital, and own human capital, alpha parents preschool and alpha own preschool (both calibration parameters)

In-school

Outcome: production of human capital

Affected: individuals in school at all levels, i.e. with student status

Algorithm: Cobb Douglas function, parents' human capital, own human capital, teacher human capital per student.

Covariates: degree, sum of human capital amongst workers at time t= 0 and t = present year respectively, sum of father and mothers human capital, teachers human capital, own human capital, three calibration parameters for the regulating the impact of the three human capital variables respectively, current school level, parental leave.

Post-school

Outcome: production of human capital

Affected: individuals not in school older than 16
Algorithm: Function of own human capital and age.
Covariates: factors of increase dependant on degree, degree, human capital, age, max age for increase (after 55 there is a negative growth), post school adjustment factor (calibration parameter)

Labour Market Module

Output Production

Outcome: produces a fictional single good in the economy

Affected: everyone

Algorithm: Cobb-Douglas production function of high skilled and low skilled human capital

Covariates: aggregate high skill human capital, aggregate low skill human capital

Wages

Outcome: sets the individual wage for workers and teachers
Affected: all workers
Algorithm: it calculates the marginal product of human capital (low and high skilled separately) and then redistribute it to each group of skilled and unskilled workers according to their individual human capital stock.

Covariates: total low skill human capital, total high skill human capital, own human capital, calibration parameters

State

Outcome: manages the tax and benefit system including income and local tax, pensions, parental leave benefits, social insurance contributions, child benefits, teachers salaries.

Affected: everyone

Algorithm: various, given parameters of the Swedish tax and benefit system

Covariates: total GDP, number of benefit recipients and tax payers

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