World
Demographic
Association

University of St.Gallen

The WDA – HSG
Discussion Paper Series
on Demographic Issues

Low Fertility and Long Run Growth in an Economy with a Large Public Sector

by Jovan Zamac, Daniel Hallberg and Thomas Lindh

No. 2009/2

Low Fertility and Long Run Growth in an Economy with a Large Public Sector

by Jovan Zamac, Daniel Hallberg
and Thomas Lindh

The WDA-HSG Discussion Paper Series
on Demographic Issues

No. 2009/2

MANAGING EDITORS:

Monika BÜTLER	Professor, University of St.Gallen, Switzerland
Ilona KICKBUSCH	Professor, The Graduate Institute of International And Development Studies, Geneva, Switzerland
Alfonso SOUSA-POZA	Delegate of the Board, World Demographic Association, Switzerland Professor, University of Hohenheim-Stuttgart, Germany

ADVISORY BOARD OF THE WORLD DEMOGRAPHIC ASSOCIATION:

Marcel F. BISCHOF	Founder of WDA, Spain
Richard BLEWITT	CEO, HelpAge International, UK
David E. BLOOM	Clarence James Gamble Professor of Economics and Demography, Harvard University, USA
Robert BUTLER	CEO and President, ILC, USA
Joseph COUGHLIN	Professor and Director AgeLab, Massachusetts Institute of Technology (MIT), USA
Monica FERREIRA	Director, International Longevity Centre-South Africa, University of Cape Town, South Africa
Oliver GASSMANN	Professor of Technology Management, University of St. Gallen, Switzerland
Peter GOMEZ	Chairman of the Board, Swiss Exchange (SWX), Switzerland
Melinda HANISCH	Director, Policy and Alliances, Corporate Responsibility and Global Policy Support, Merck & Co., Inc., USA
Werner HAUG	Director, Technical Division, United Nations Population Fund, New York
Dalmer HOSKINS	Director, Office of Policy Development and Liaison for Public Trustees, US Social Security Administration, USA
Alexandre KALACHE	Head, International Centre for Policies on Ageing, Rio de Janeiro, Brazil
Ursula LEHR	Former German Minister of Health and Family, and founding Director of the German Centre for Research on Ageing, Germany
John P. MARTIN	OECD Director for Employment, Labour & Social Affairs, Paris
Jean-Pierre MICHEL	Professor and Director, Department of Geriatrics of the University Hospitals of Geneva, Switzerland
Rainer MÜNZ	Head of Research and Development, Erste Bank der Oesterreichischen Sparkassen AG, Austria
Hiroyuki MURATA	President, Social Development Research Centre, Japan
Alexandre SIDORENKO	Head, UN Focal Point on Ageing, New York
Alan WALKER	Professor, Director New Dynamics of Ageing Programme and Director of the European Research Area in Ageing ERA-AGE, UK
Erich WALSER	Chairman of the Board of the Helvetia Group, Switzerland

Main partners of the World Demographic Association are:

Helvetia Group
Merck & Co., Inc.
University of St.Gallen

This discussion paper series is kindly supported by the Ecoscientia Foundation

The opinions expressed in this article do not represent those of WDA.

Low fertility and long run growth in an economy with a large public sector

Jovan Zamac, Daniel Hallberg and Thomas Lindh
Institute for Futures Studies, Box 591, 101 31 Stockholm
Corr: thomas.lindh@framtidssstudier.se, office +46-8-401216, fax +46-8-245014

Abstract

Recently it has been suggested that low fertility countries may be caught in a trap that is hard to get out of. One important mechanism in such a trap would be social interaction and its effect on the ideal family size. Such social interaction mechanisms are hard to capture in formal models, therefore we use an agent based simulation model to investigate the issue. In our experimental setup a stable growth and population path is calibrated to Swedish data and using the Swedish social policy setup. The model is provoked into a fertility trap by increasing relative child costs linked to positive growth. Even rather large increases in child benefits are then insufficient to get out of the trap. However, the small number of children temporarily enables the economy to grow faster for several decades. Removing the adaptation of social norms turns out to disarm the trap.

Keywords: low fertility trap, social norms, relative income hypothesis, economic growth

1. Introduction

There is by now plenty of evidence that gross domestic product (GDP) growth across countries has a negative relation to fertility rates and dependency ratios. Kelley and Schmidt (2005) summarize much of the evidence concerning the importance of demographic factors for growth in both developing and developed countries. Lindh and Malmberg (2007) estimate a demographically based forecasting model allowing for changing economic impact of the age distribution with rising longevity. The negative impact of large cohorts of children is a robust feature. In Barro-type cross-country growth regressions high fertility has also been established as a substantial negative factor. This is not really news but confirmation of for example the shift-share analysis of Krueger (1968) making the point that a very large part of the difference in production levels between developing and developed countries can be explained by demography and education.[1]

It is intuitively rather obvious that an economy where almost half of the population is below 15, as is the case in many African countries, has to carry a large burden of supporting and educating the young, a burden of which only a tiny piece will appear as value-added in the national accounts. As Bloom et al. (2003) emphasize the demographic dividend from falling fertility appears as the working population starts to grow faster than the dependent population. Mason and Lee (2007) stresses the possibility of a second demographic dividend as middle aged people start saving for retirement and thereby contribute to increasing capital resources.

Because growth can be accelerated by lowering fertility it becomes theoretically possible to compensate rising elderly dependency rates with decreasing fertility. Indeed we observe that several developed countries both in Europe and Asia are experiencing very low fertility accelerating their aging. While only China has a deliberate one-child policy, fertility inadvertently seems to be lower than in China in both South Korea and Japan. Since fertility lower than replacement rates will speed up aging in the population this is ultimately not a sustainable equilibrium. Sooner or later the current financial support for the elderly in the economically active population will become insufficient. That may well take a long time though and in the meantime resources can be shifted from reproduction to support for the elderly.

Recently it has been put forward, e.g. Lutz et al. (2006), that countries with very low fertility (below say 1.5) may be caught in a low fertility trap (the Low Fertility Trap Hypothesis, LFTH). This builds on the observation by inter alia McDonald (2005) that a recovery towards replacement levels seems to become increasingly difficult to achieve in countries with very low fertility. The mechanism suggested by Lutz et al. builds on three different feedbacks. One is the demographic inertia of a baby bust where the small cohorts will have fewer babies simply because they are fewer in fertile ages. The second feed-back is hypothesized to work through social norms making fewer children more

---

[1] Myrskylä et al. (2008) find a U-shaped relation between a Human Development Index and fertility. While an HDI weighs in GDP per capita as one factor this is not the same as GDP growth.

desirable as the prevalence of children in society becomes rarer. This social interaction and its effect on the ideal family size work as a negative feedback reinforcing low fertility standards. Thirdly Lutz et al. adds the socio-economic relative income effect of Easterlin (1961), where the aspired level of living is determined by consumption standards in the parental home acting as a constraint on the number of desired children when it becomes harder to achieve these aspirations (also cf Macunovich 1998). Such social interaction mechanisms are hard to capture in a standard economic model framework. For this reason we propose to use an agent based simulation model (ABM) to investigate the economic consequences of low fertility and its feedback on the fertility decision.

We use a simple agent-based framework model as an experimental tool to investigate under what circumstances a low-fertility trap may be likely to appear. The model is built around the tension between a long education interfering with the prime fertility period of females and the need for such education in order to satisfy consumption aspirations arising from the relative income effect.

The crucial element in an agent based simulation model is the rules of thumb that agents use for making decisions. These rules can incorporate both an economic dimension and a social interaction dimension both of which are important for the low fertility trap. Individual micro behavior results in a macro outcome which in turns feeds back into individual decisions, and hence a micro-macro interdependence is obtained which cannot be modeled in more traditional microsimulation models.

By calibration to Swedish micro and macro data[2] the simulation model offer an experimental laboratory to test different theoretical mechanisms and their implications for the balance between current benefits from low cohort fertility and the losses in terms of future shrinkage of the tax base and the growth potential. Thus our base scenario in this paper approximately reproduces the natural reproduction features of the Swedish population during the 20th century.

We then experiment with alternative scenarios focused on the relative income mechanism in order to spring a low-fertility trap. It turns out that introducing a mechanism that increases the relative cost of children versus consumption has the potential to set off a low-fertility trap. The growth rate in GDP per capita increases substantially and for a long time before the elderly dependency burden makes the system fiscally unsustainable. It takes a very large benefit that is permanently increased to counteract this and even delay the low fertility trap. The crucial element of the fertility trap turns out to be the social norms system. When the social norm mechanism is disabled the increase in relative costs of children does decrease fertility somewhat but does not provoke a fertility trap.

The disposition of the paper has to be parsimonious with details about the model, a more comprehensive description is available in Žamac et al. (2008). In the next section we first discuss the background and theoretical starting point more completely. Thereafter a short

---

[2] We have also used some data from the Swedish National Transfer Accounts. See Lee and Mason (2004) about National Transfer Accounts that tracks intergenerational flows in an economy.

account of the model structure and the crucial mechanisms in this context follows. In the third section, we analyze the results of alternative scenarios and discuss the potential implications. Finally we conclude our argument by discussing how the results can be used to focus further work around growth and fertility.

2. Background and theoretical starting point

Negative momentum from low birth rates that decreases the future fertile population is an obvious demographic feedback from low fertility. Ideal family size as measured in attitude surveys shows a downward trend in many countries. Whereas ideal family size still is higher than actual total fertility rates (TFR) in Europe, there are some countries e.g. Austria and Germany where ideal family size now is well below replacement rates. There seems to be a downward trend of relative income in many industrialized countries (as far as it can be correctly measured) where it is claimed that he next generation will fare worse than their parents. All this seems to coincide with downward trends in cohort fertility and definitely with postponement of child bearing. But will these factors combine into a mutually reinforcing feedback circle as the LFTH suggests? There are three apparent routes of escape to consider. First, extensive immigration may increase the fertile population and reverse the negative momentum. Second, ideological pressure could be mobilized to favor ideals of replacement fertility. Third, social policies can be implemented to relieve the relative income pressure. Our focus is on the third escape route although it turns out that the second is more crucial for creating a trap. The first with immigration cannot be implemented in the current version of the model.

The social policy framework differs quite a lot across the countries that now are experiencing negative fertility trends. It has been argued that the Scandinavian emphasis on policies favoring dual-earner families explains why the downward fertility trend is much more damped in these countries (Ferrarini 2003). The Swedish case is then very relevant to study as a potential model that refutes the necessity of the LFTH. Sweden has had a very stable cohort fertility rate (CFR) around 2 for all cohorts born in the 20th century where we can observe the completed fertility, i.e. up to the early 1960s. The TFR, however, has fluctuated between 2.1 and 1.5 in the postwar period. Björklund (2006) thinks younger cohorts in Sweden will catch up in their lagging CFR, and indeed birth rates have been picking up and may be headed for a new baby boom. Still it seems to be a fact that the relative income of young adults in Sweden have been falling over the same period. Norms regarding the desired family size have been very stable around 2 as measured in attitude surveys. At the same time the average age of the mother at first birth has risen steadily (24 years 1970, 29 years 2005) substantially increasing the probability of not achieving desired fertility.

Thus, one may hypothesize that family policy is a crucial factor interfering with the mechanisms of the LFTH both by relieving or amplifying economic pressures and maybe also by a strong influence on social norms (or family policy being designed to conform to social norms). However, as the South Korean and Japanese example shows, the design of pro-natalist social policies may be hard to implement efficiently in order to actually achieve any results.[3]

There is so far little consensus on whether the demographic transition will end up maintaining world population at approximately stable levels or result in a future shrinking population. A generally accepted theory to generate predictions on fertility is missing today. The LFTH suggested by Lutz et al. (2006) offers a framework to structure further research around the micro-macro feedbacks. There are, however, difficulties since we cannot in general observe these feed-backs in isolation. We are dealing with very long-range processes taking place in a quickly changing social environment. Although OLG models following Allais (1947), Samuelson (1958) and Diamond (1965) have become a standard tool for economists analyzing intergenerational issues as well as general macroeconomics it is still the case that these models quickly turn intractable when the population structure is non-stationary. This has led to a great number of attempts to use simulation in order to investigate their properties under more realistic assumptions (e.g. Kotlikoff et al. 2001). Increased realism, however, comes at the price of evermore intransparent calibration and assumptions that are not readily verifiable.

Agent based modeling offers an alternative where we can observe the aggregate effects of decentralized decision making without very strong assumptions on individual behavior and still maintain a degree of transparency and the opportunity to experiment with different mechanisms. Traditional microsimulation models building on estimated micro relations (Klevmarken 2002) have pretty much come to a point where severe problems have arisen concerning their ability to actually improve our understanding of behavioral mechanisms and their repercussions on the economy at large. Agent based simulation modeling has recently been increasingly explored as a more flexible alternative focusing on actual behavior rather than the optimal behavior of individuals in recognition of the fact that even if agents do behave rationally under their respective information sets, statistical methods will not allow us to evaluate the full heterogeneity of individual behavior (Richiardi et al. 2006).

While the flexibility of ABM allows us to use the model as a laboratory to experiment over a wide range of issues its drawback is that it easily tempts the researcher to try to do too much, to keep too many options open, to start playing a Sims game instead of investigating real issues. It is therefore of paramount importance to define the focus of each study rather narrowly. The basic model that we use has been developed at the Institute for Futures Studies using JAVA programming. The variant used in this paper is adapted to the specific issue of fertility and the mechanisms of the LFTH.

In brief it exploits the interaction of education choice, matching to marry and the fertility decision in order to generate a self-propagating population embedded in an endogenous growth model. This base version of the model is adapted here to the low-fertility issue by introducing a relative income mechanism.

---

[3] The efficiency of social policies in increasing fertility is still an open issue. While Feyrer et al. (2008), Björklund (2006) and others have estimated large effects there are other studies like OECD (2003) and Grant et al. (2004) which find that income related policies do not affect fertility much.

3. What Is Agent Based Modeling?

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 based on limited rationality, imperfect information, habits and where the local relational context also contributes to those agents' strategies and behaviors.

It has become rather common among economists to want to model micro-macro linkages between individual and aggregate level variables. Most recent attempts have consisted of combining economy-wide Computable General Equilibrium Models (CGE), with microsimulation models (see Davies 2004, for a review). They rely on the classical assumptions (e.g. rationality, perfect foresight, competitive markets, perfect information, market clearing etc.), in order to find an optimal solution or "equilibrium" for aggregate level variables such as total output. CGE cannot account for heterogeneity across households, preferences or technologies; only a few types of representative agents are assigned 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 (i.e. how total output and consumption are actually distributed between different agents and what drives these differences).

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 and aggregate feed-backs, which therefore have to be assumed as exogenous.

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. 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.

The principle behind ABMs is that of multiple interacting agents who are *goal directed* (e.g. preserving a certain aspired consumption level in our case), and who *try to control their environment*, in a decentralized (i.e. non-coordinated, non-centrally planned) system. ABMs do not assume rationality or 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. Schelling's "Models of segregation" (Schelling 1969). 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 or objects can represent people (say consumers, sellers, or voters), but they can also represent social groupings such as families, firms, communities, government agencies and nations.

In our application we view the model as an experimental laboratory for testing mechanisms in a more complex setting than analytical modeling allows yet more transparent and subject to experimental control. This makes inference possible regarding causal mechanisms that cannot be gleaned from econometric estimation on real world data. This does not replace other modes of analysis but is a complement for testing the logic of economic mechanisms in a more complex setting that can to some extent be validated against real world data.

4. The IFSIM model

The IFSIM model, as we call it, consists of a small number of interacting modules. Due to space considerations we only give a brief overview of some features that are important for this paper (see appendix for more detail).

4.1. *Demographic module*

The starting population comes directly from the initial data set.[4] There is no migration in the model thus population evolves according to the fertility and mortality rates. Since we focus on the fertility decision the mortality rates are exogenously set in line with the Swedish rates in 2006. The maximum age an individual can reach is 110.

Before a woman can give birth she needs to find a partner and move out of her parental home. Starting from age 18, individuals living with their parents may start to leave the

---

[4] The data comes from the Swedish micro data set HUS (See Klevmarken and Olovsson 1993 and Flood et al. 1996), which is a representative sample with about 3000 individuals which we scale to obtain our desired number of individuals in the initial year of simulation. In the first period of the model we also introduce some initial aggregate variables (like, e.g., mortality rates) from Statistics Sweden.

parental household and set up a household of their own. The decision to leave home is modeled as an exponential probability function depending on age and on the share of youngsters living with their mother within the network. We check that leaving home and matching occurs at relatively early ages so that it does not impose a restriction for the fertility. By the age of 21 every individual has left the parental household.

The matching process is assortative such that pairs with similar human capital and belonging to the same network are more likely to create a new married household.

4.1.1. Fertility

There are several variables that affect the fertility outcome. First we have fecundity which is beyond individual control. We roughly capture this biological restriction by calibrating the probability of conceiving to medical studies which yields a fast declining probability from 30 years onward. The upper limit for conceiving is set to age 40 since only few births are recorded in Swedish data after that. We also have a lower starting age set to 20 under which it is not possible to give birth. There are few teen-age pregnancies in Sweden today.

Second, we model a fertility function that allows us to capture the main elements of the LFTH. The LFTH has a social dimension and an economic dimension. The social dimension refers 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 desired number of children. Every individual has a *desired number of children* that is determined by the number of siblings that he/she has. For the couple we use the average number of the male's and female's desired number of children to construct the couple's desired number of children, weighted with a random number. The couple strives to reach its desired number, but, due to their economic outcome and the social influence from their network group, it is not sure that they will reach this number. Given that the female is in fertile age and that the number of desired children is not reached than the actual number, she will give birth if the two following conditions hold:

$$\frac{DISP}{\sqrt{n+r}} \geq median\ income,$$

$$SocialFactor * PROJC^{10} > ASPC,$$

where *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 *r* to 1. However, in the alternative scenarios when we simulate that the cost of having a new child increases we model this by increasing *r*. The square root captures the economics of scale of large families. The first 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 condition says that the social factor in combination with expected future income, $PROJC^{10}$ must exceed the aspired consumption level, denoted *ASPC*. We define the social factor according to:

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

where N_{Kids} is the number of children belonging to the $N_{Members}$ members in the network group. Here 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. As postulated by Easterlin this aspired consumption level is a norm that is formed during youth and which has the consumption level of the home of origin as the reference point. We model this aspired consumption, *ASPC*, according to:

$$ASPC = \theta \overline{C},$$

where $\overline{C} = \left(\overline{DISP / \sqrt{n}}\right)$ is the average equivalent disposable income today 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 an individual in the household. The subscript *at10* indicates that it is when the individual was 10 years old that the aspirations were set. 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 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 than what they had when young adjusted for economic growth. We also apply a weighting factor, $\gamma \in (0,1)$, currently set at 0.5, for the two different reference points for the aspired consumption. Since the reference point was set when the parents were 10 years old 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:

$$PROJC^{10} = \frac{DISP^{10}}{\sqrt{n + r}},$$

Where $DISP^{10}$ is the disposable income ten years from today *if they choose to have one additional child.* The household's disposable income ten years into the future is estimated from the sample of individuals in the model that today have ten more years of labor market experience. As mentioned earlier, in the base scenario, *r* is equal to unity, but varies between 1 and 3 in alternative scenarios, depending on economic growth in society.

Once a child is born, the mother is on parental leave for three years before returning to her previous labor market status. This exaggerates the actual Swedish paid parental leave (today is it maximum 13 months), but is a way to avoid complications in taking into account other benefits, such as the right to part time work until the child is 8 years and the right to take paid leave to take care of sick children up till they are 12 years old. Doing a sensitivity analysis with parental leave cut down to just one year results only in a minor tendency for higher fertility but the dynamic behavior of the model remained very close to what we present below.

4.2. *Social networks*

Newborn individuals inherit some of their parents' characteristics. They will from birth belong to a network group; which network group they belong to is at first determined by their parents' characteristics. The networks are segmented first by age groups and secondly, within each age group, by a spatial dimension. A network group consists of all those individuals to whom the individual is close. We follow Billari et al. (2006) in defining social "closeness" as a spatial area representing the individual's scope of interaction, by age group. Specifically, agents are arranged along the surface of an imaginary cylinder, whose height is subdivided into as many segments as there are age groups in the model (at present there are 8 age groups, from age 0 to 110). Individuals will migrate between network groups as they age, and two individuals that belong to the same network group at one age, may belong to different groups at later ages.

4.3. *Educational module*

When reaching the age of 7, all individuals are universally put into basic schooling up until the age of 16, corresponding to 9 years of compulsory education. If entering secondary school, the individual will stay in school another 3 years. The choice to apply to university is determined by the individual's prospective earnings compared to her aspired consumption level, and her preferred number of children. If secondary education is enough to reach the same per capita equivalent income as their parents' given the preferred number of children, they will not apply for university. Hence, the educational choice does not depend *directly* on fertility choices. However, it does so indirectly since if the individual estimates that she can reach her aspired consumption level given her preferred number of children without having to invest in education, then she will not choose university.

The university applicants are ranked according to accumulated human capital (see 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 fixed proportion of the current number of individuals aged 19 to 30. If attending university, the student will be entitled to a student allowance for the duration of the course (5 years), amounting to a fixed proportion of average earnings.

4.4. *Modules for human capital formation, the labor market and consumption good production*

We postulate a production technology that only depends on human capital (i.e. there is no savings into other types of productive assets). The production depends on the low skilled and high skilled workers according to:

$$Q_t = H_{L,t}^{\alpha_L} H_{H,t}^{\alpha_H}$$

where $\alpha_L + \alpha_H = 1$, and $H_{L,t}$ and $H_{H,t}$ is the aggregated human capital for the non-university and university degree groups, respectively. There are no monetary values in the model so earnings 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) such that the shares reflect each group's marginal product. Then, within each group, the consumption good units are allocated proportionally to the human capital of the individual. If the supply of university degree individuals is reduced, their marginal product will increase and thereby increase their share of the produced goods, and hence also the education premium increases. 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.

Human capital is of paramount importance in the model thus we describe how we model this in detail. There are four main inputs that determine the human capital of each individual: (i) natal individual ability; (ii) ability acquired from parental influence and parental own human capital levels; (iii) ability acquired through formal education; (iv) skills and expertise acquired through training on the job.

At 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. The three phases that we consider are: pre-school, in-school, and post-school.

4.4.1. Pre-school

Consider an individual with natal human capital h_{i0}. The discrete time evolution of the human capital in the pre-school phase is modeled as

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

where Δ indicates first differences and h_{it} is the human capital of individual *i* in period *t*. h_{i_m}, h_{i_f} denote the human capital of individual i's mother and father in period *t*. How the two input factors, the sum of parents' human capital and the child's own capital, are combined is determined by the parameters α_{own} and $\alpha_{parents}$ which are specific to the pre-school period and set exogenously.

4.4.2. In-school

During schooling a third input factor affects the production of human capital, namely the ratio between the *aggregate level* of human capital among the teachers and the number of students. Since teachers are randomly drawn from the labor force there will be a spillover effect when the overall human capital increases. However, the teacher student ratio is also important thus we account for the number of students. To formalize, the human capital production during school periods is defined as:

$$\Delta h_{it+1} = h_{it}^{\alpha^s_{own}} \left(h_{i_m t} + h_{i_f t}\right)^{\alpha^s_{parents}} \left(H_t^{teach} / stud_t\right)^{\alpha^s_{teach}}$$

where the superscript s indicates that the parameter value depends on the level of education (primary, secondary, and tertiary), and α^s_{teach} indicates how the new input factor is combined. H_t^{teach} and $stud_t$ denote aggregate teacher human capital and number of students, respectively. The policy makers can thus directly influence the production of human capital by allocating more resources to the educational sector (employing more teachers). The ratio of teachers per student is fixed at 0.1.

4.4.3. 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 increases for every work year but proportionately less for each additional year up until the age of 55. We extend the production function to incorporate a deterioration of human capital in periods of parental leave. Formally, the human capital production at work is:

$$\Delta h_{it+1} = \frac{55 - age_{it}}{10} edu_k h_{it}$$

where edu_k is a factor that is dependant on the level of education: basic, gymnasium, and university. The rate of increase is higher the higher the level of education, thus generating steeper wage profiles over life for the higher educated. 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.

4.5. *State, tax and benefit systems*

Beside individual agents, the model includes an institutional object acting as an agent that represents "the State" who collects and redistributes resources. First, the State calculates the total expenditure bill, by aggregating the costs of the education, teacher salaries and student allowances, parental leave subsidies, child allowances and pensions.[5] 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). The tax system comprises a state and a local tax. The state tax is paid by the top 20 percent of the income distribution and amounts to 20 percent. The local tax paid by everybody with positive earnings is a flat tax rate on earnings. It is residually derived to cover the part of total expenditure not covered by the state tax. The individual income tax will therefore be a combination of the state tax (if eligible) and the local tax. The individual disposable income is therefore the sum of any earnings, pensions, student or parental allowances, minus the income tax.

5. Model scenarios

Given the basic model setup above both the demographic and the social norm mechanism are included. The relative income mechanism has been implemented by defining an aspired consumption level based on the household income in the parental home at 10 years of age. See Žamac et al. (2008) for some more details. For a fertility decision to take place a match must first have been achieved with a partner in the local network. In the next step a decision is taken whether to have a child. First it is determined whether a child can be afforded at the current income level. If so then if future income expectations allow a new child procreation is initiated. This is the base scenario which we then subject to a cost shock in order to provoke a fertility trap.

5.1. *Base scenario*

In the base scenario the simulation runs for more than 300 years. The influence from initial conditions takes about 100 years to vanish. An initialization period of 150 years is therefore disregarded in the analysis. After this period the model stabilizes and roughly reproduces 20th century demographic behavior in Sweden.

Poor economic circumstances at fertile ages compared to the aspired income make potential parents postpone children, in hope of better economic conditions in the future. As the returns to education increase with education level, high educated parents increase their chance to get their preferred number of children. On the other hand education takes valuable time from their fertile years. Since fecundity decreases with age this increases the risk of not reaching the desired number of children.

Below we briefly present some main features of the base scenario. In Figure 1 we depict the population development in the last 160 years of the simulation (for convenience we label model years starting from the year 0 but note that this is arbitrary). There are short term periods of positive and negative growth, but the long term trend is positive population growth. Over the study period there is an increase from about 11,000 to 15,000 inhabitants.

---

[5] The pension system is modelled according to the new Swedish pension system except that we have a fixed retirement age at 65 and we do not have any funded part. We only model the pay-as-you-go component which in reality comprises about 87 percent of the total public coverage.

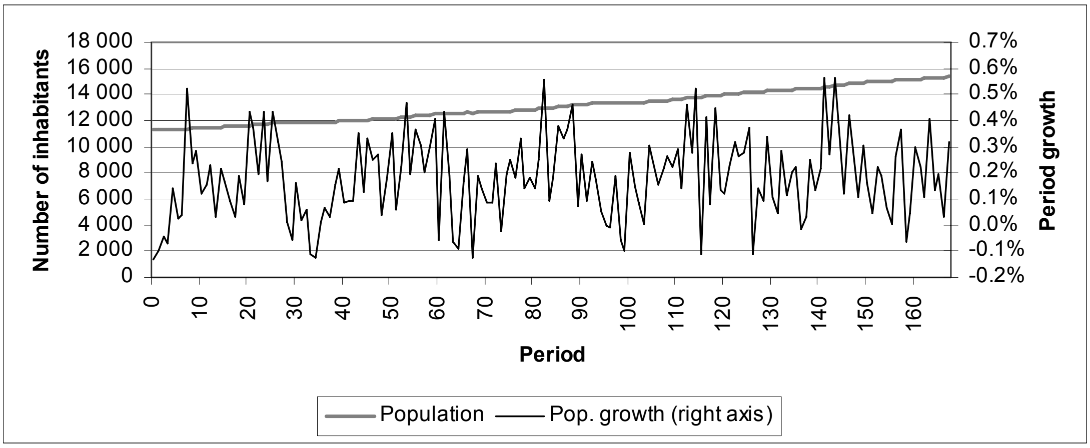

Figure 1 Population development in base scenario

The age composition in the population is very stable over time; see Figure 2 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 the Swedish demography over the 20th century. In the 65+ group these oscillations cancel out.

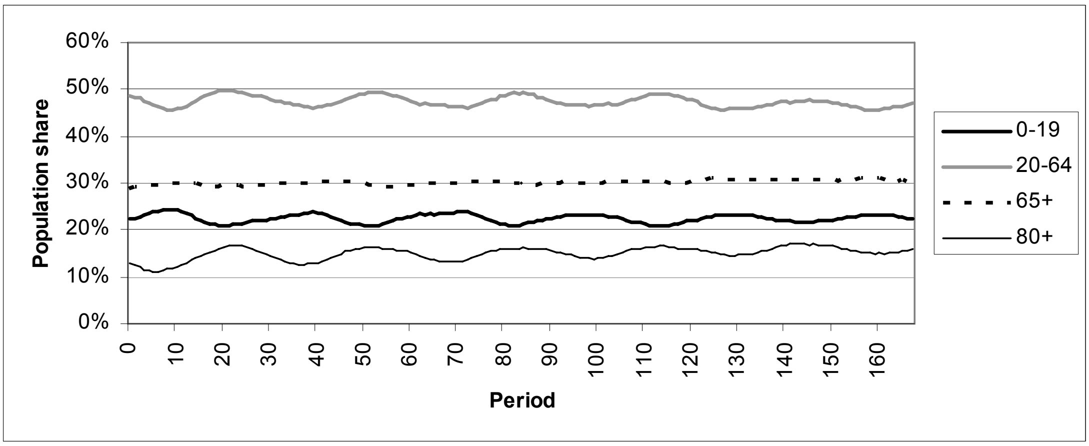

Figure 2 Age structure in the base scenario

There is variation in the CFR over time that explains this pattern. For the whole period CFR is on average above reproduction level 2.15 children per woman. We observe a rather steady pattern but there are some temporary swings in CFR, see Figure 3. We do not have any mechanism that leads to intensified efforts to procreate as fecundity goes down. Intuitively there is no "biological clock" that makes individuals try to catch up in their 30s. Therefore the swings in period fertility due to changing economic conditions mostly carry over to cohort fertility.

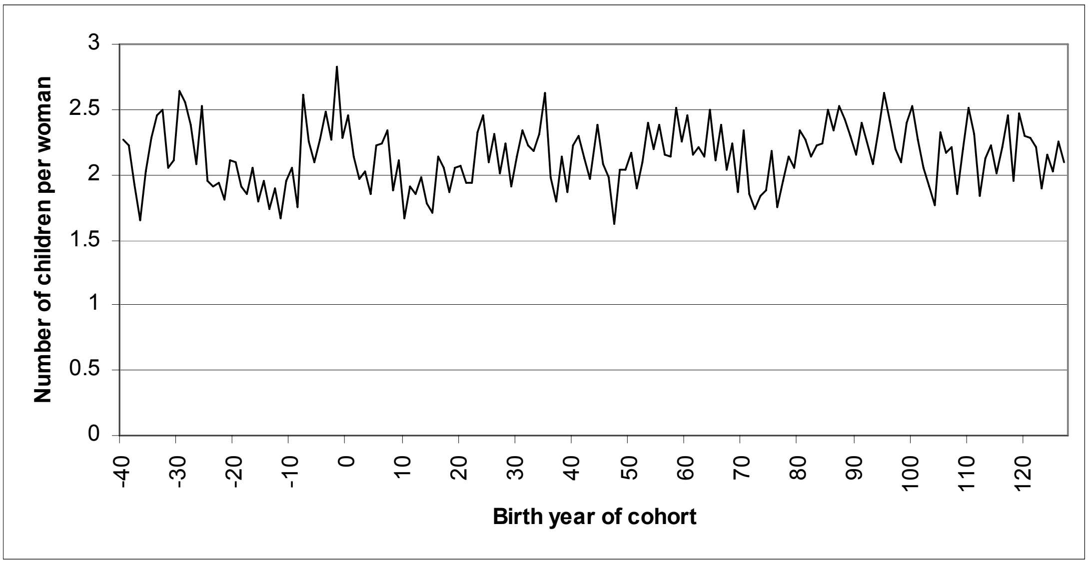

Figure 3 Completed fertility, by birth cohort

As can be seen from Table 1 the age of the mother in general increases with education. Mothers are on average about 27 years old when they get their first child if they have only high school or basic education, while mothers with a university degree are on average about 29 when they have their first child.

Table 1 Average age of mothers when giving birth in the base scenario, by the birth order and education level

Birth order of child	*Basic+High school*	*University*	*Total*
1st	27.4	29.0	28.1
2nd	30.3	31.2	30.7
3rd	33.2	33.9	33.5
4th	34.9	35.5	35.2
5th	36.2	36.6	36.4
6th	36.8	37.4	37.1
Total	30.7	31.7	31.2

One can note that university studies are spread over a rather long period in young adulthood as some actually enter at a late age. The typical age to get a university diploma is age 24 (i.e. the youngest possible diploma age), but the rest, about 17 percent, graduate between 25-40. These delays in achieving a diploma will push child birth later into the fertile period. There is, however, a small chance that students have a baby during education enrolment. Such events will delay university diploma even more for female students (by three years per baby). The larger effect on high educated may reflect the increased difficulty to combine education and children. At the aggregate level the base scenario data shows that rising enrolment rates in higher education are linked with lower birth rates. Once enrolment rates drop, individuals achieve their diploma, and birth rates increase.

The development of earnings over time, presented for the years 60-125 in Figure 4, shows strong period effects. These are due to shortage of one education class relative the other creating a wage drift upwards for the scarce education category. In comparison, most of the period effects are not reflected in the human capital stock, shown in Figure 5 for the same period. The ratio of earnings to human capital hence fluctuates over time.

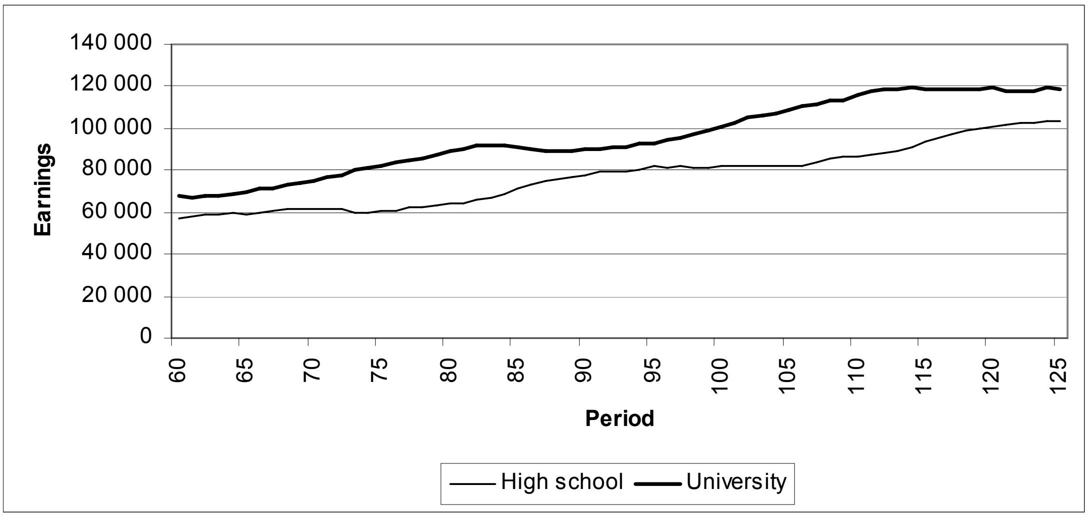

Figure 4 Earnings in model time 60-125 by education, base scenario

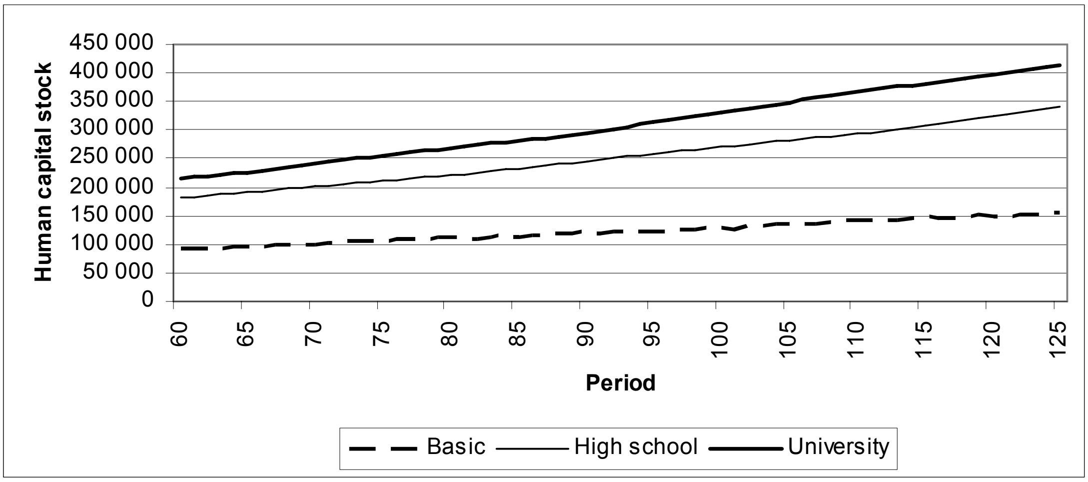

Figure 5 Human capital development, model time 60-125 by education, base scenario

5.2. *Alternative scenarios with a higher cost of child*

In three alternative scenarios we made modifications to the function that determines the cost of children in order to provoke a fertility trap. In the base scenario the expected cost of having a new child is a fixed share of current median income. In the alternative scenarios when the economy grows faster than usual there will be a relative price shift making children costlier in terms of consumption. This will force parents to invest a higher share of their income in the child, if they decide to get one. One rationalization for this upward drift in the relative cost of children is that the opportunity cost of parental time is increasing. Since everybody works full time in our model we cannot implement that mechanism directly through labor supply.

Below we describe the three scenarios.

1. **No policy**: our first alternative scenario, nothing is done to counteract the change in cost of children.
2. **Increasing benefits**: the second alternative scenario, implements a child benefit immediately. In this scenario the benefit is given by $\tilde{b}_t = 0.1\sum_i W_{it-1} / n_{t-1}$ where W_{it-1} is the wage earnings for person *i*, n_{t-1} is the number of children eligible for the benefit in the population, both measured in the period before. 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.
3. **Fixed social norms:** is the "no policy" scenario 1 except that the social norm mechanism for adapting to the local network and siblings is turned off.

In sum, alternative 1 lets the cost shock have full impact on behavior, while alternative 2 implements active policies immediately. Alternative 3 includes no economic policy responses but prevent social norms from adapting and thus cuts out one element of negative feed back.

The relative cost shock mechanism is introduced in the model year 60.[6] This is also the year when the social norm mechanism is turned off in the third scenario. One can clearly see that fertility is affected by the introduction of the changed child cost. In the no policy scenario and with some delay also in the increasing benefits scenario population actually declines at a fast rate (Figure 6) while population in the fixed social norms case still grows but slower. As is obvious in Figure 7 the CFR declines and two decades after the introduction of the relative cost mechanism the CFR only rarely pushes over reproduction level. Increasing benefits are successful in blocking the dive in fertility about 40 years into the future, but this policy cannot turn the tide as fertility rates falls to low levels below 1.5.

---

[6] All alternative scenarios are programmed in such a way 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 components in the model are exactly identical in all scenarios. Thus the alternatives can be interpreted as counter-factual to the base scenario.

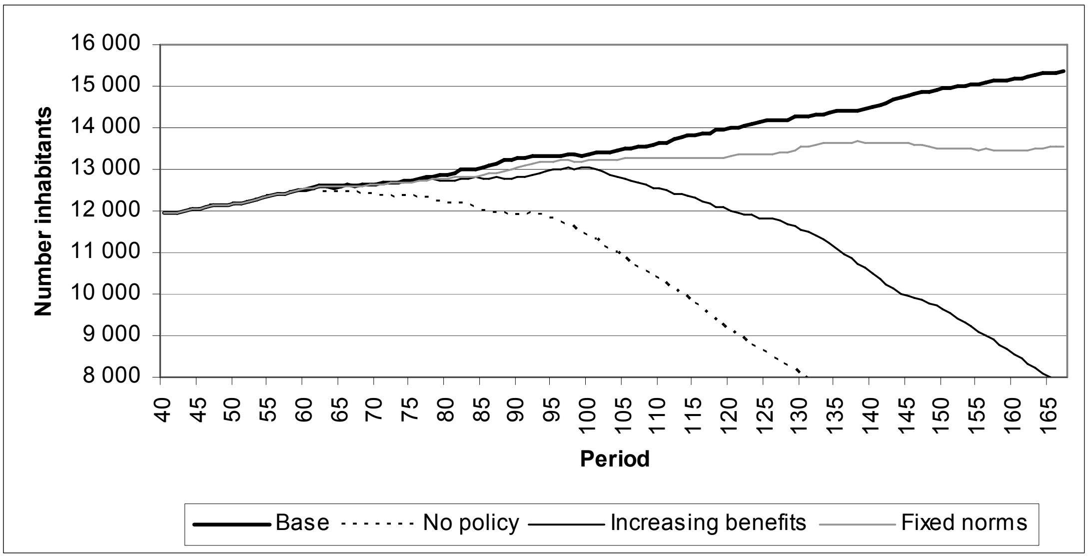

Figure 6 Population in the base and alternative scenarios

The population share in working age 20-64 initially increases in all alternative scenarios (Figure 8). This gives rise to boosted GDP growth and lower taxes since less spending is needed in the educational system. But eventually the really low fertility scenarios enter into a phase with decreasing active population.

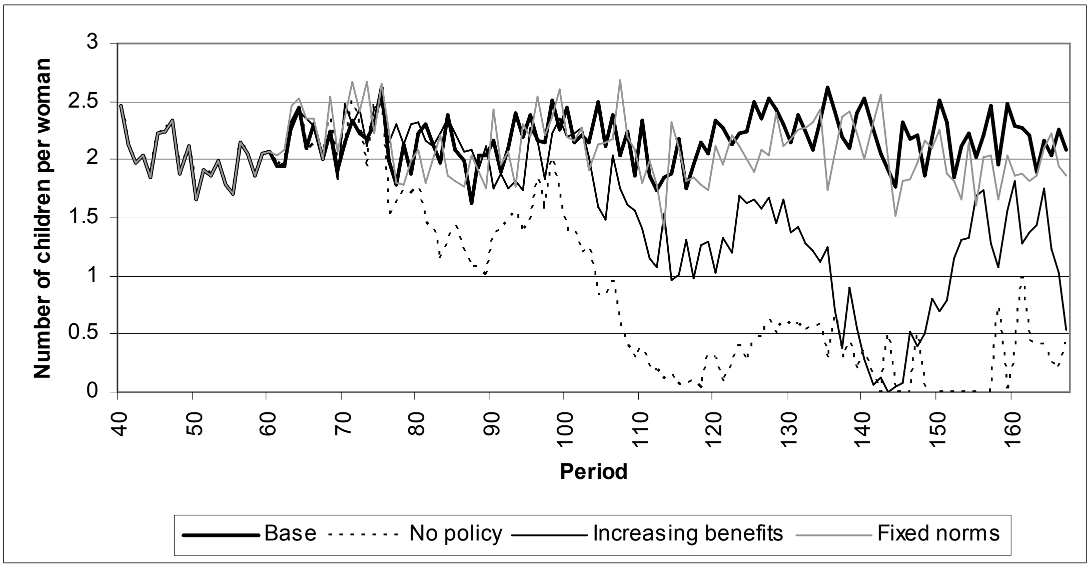

Figure 7 Completed cohort fertility rate (CFR) in base and alternative scenarios, by model time

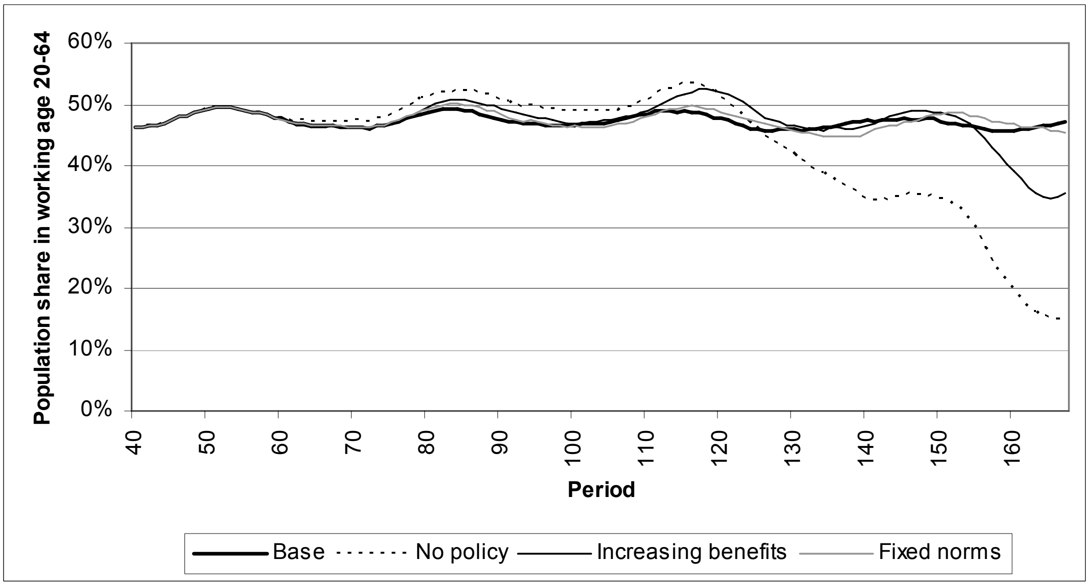

Figure 8 Share of working ages (20-64) relative total population

In the period before the child cost change occurs, mothers are about 28-29 years old when they have their first child, see upper part of Table 2. When the change is introduced in the model births are postponed in all alternative scenarios. As time goes by the fixed norm scenario stabilizes the year at first birth while the other two keep on increasing. This reflects that aspired income is more difficult to reach with the same number of children as before and this makes them postpone births to an extent that finally lowers the desired numbers of children and leads to decreasing fertility in both the no policy and increasing benefit scenario.

Table 2 Average age of mothers at first birth in the base scenario compared to the different alternative scenarios, by model time

Model year	*Base*	*No policy*	*Increasing benefits*	*Fixed norms*
0-9	29.2	29.2	29.2	29.2
10-19	27.9	27.9	27.9	27.9
20-29	27.4	27.4	27.4	27.4
30-39	28.5	28.5	28.5	28.5
40-49	28.2	28.2	28.2	28.2
50-59	28.1	28.1	28.1	28.1
60-69 (decade of change)	28.2	30.2	28.6	29.5
70-79	28.1	30.4	30.4	29.7
80-89	27.7	30.8	31.2	29.7
90-99	28.6	32.4	32.0	31.1
100-109	27.9	32.2	32.6	30.9
110-119	27.5	33.0	32.9	30.6

In Figure 9 the share of high skilled in the working population, suggests that the human capital stock per capita is growing faster in both the no policy and increasing benefits scenarios compared to the base scenario. This is a self-enforcing process. Once education has started to increase; the increase is sustained by a higher level of human capital in the economy making education more efficient. Agents also need more education in order to reach an increasing aspired consumption level. This contributes also to further postponement of births.

Last, the growth of the economy in the scenarios, depicted as per capita GDP and shown in Figure 10, exhibits the expected pattern. The alternatives with lower fertility at first allow a much faster growth. As mentioned the relative cost mechanism is set off by the GDP growth. High GDP growth scenarios therefore create a self-generating process of high child costs, further reducing fertility. The high per capita growth compared to the base scenario lasts in the increasing benefits case almost 100 years (but one should note that GDP is not growing that long in levels, due to shrinking population). This raises the issue of how far into the future the altruism of the current generation will stretch. By abstaining from children they can improve their material well-being but only at the expense of as yet unborn generations in the future.

Figure 11 depicts tax rates that start increasing as per capita growth declines. Tax ratios then in the no policy case quickly increase to a hundred percent of GDP.[7] The increasing benefit scenario, which temporarily stops the drop in fertility, implies a very high cost requiring 10 percent, or more, higher tax rates *in all future periods*. Implementing this

---

[7] This is possible since we have no labor supply choice and people do not die from starvation when they get their income confiscated. Also note that the taxes are redistributed. In practice the 100 percent tax rate should be interpreted as the collapse of the system.

policy would hardly be politically possible unless median voters have a very high degree of altruism towards future generations. In the end, however, high tax increases like these also fail to prevent fiscally unsustainable tax levels and therefore tax hikes to provide high child benefits cannot by themselves reverse the trap. Introducing saving and capital investment might change this conclusion (see Mason and Lee, 2007, about the second demographic dividend) but the implementation of this in the model would imply a very different focus of the study.

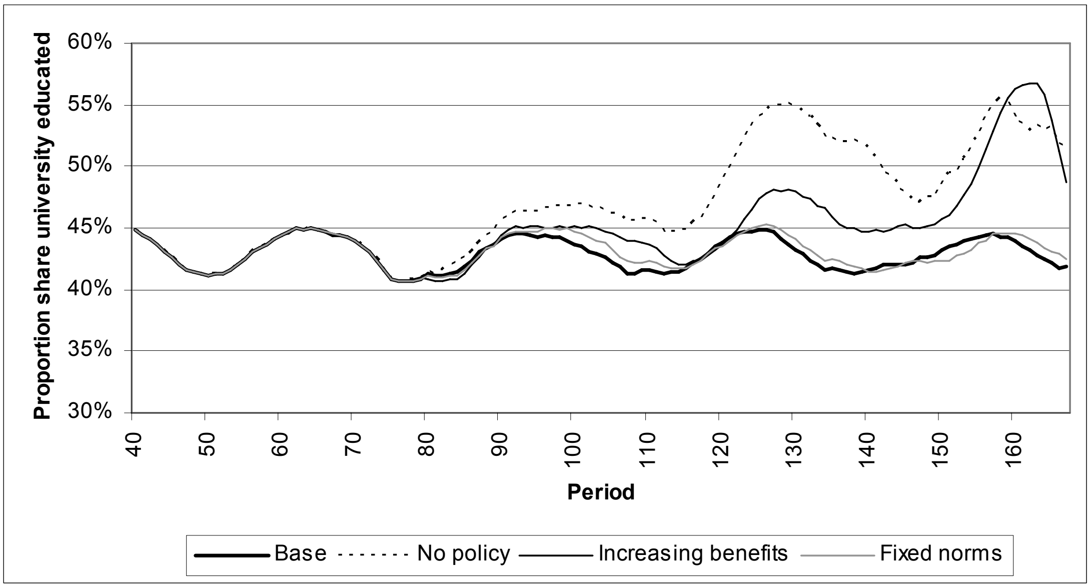

Figure 9 Proportion high skilled (university educated) in the age group 20-64

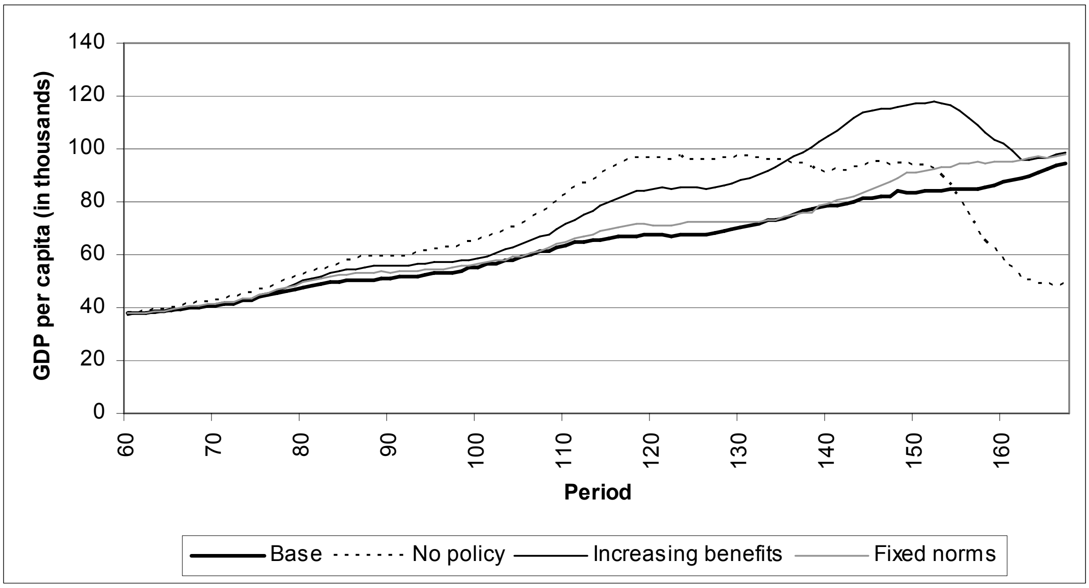

Figure 10 GDP per capita in thousands

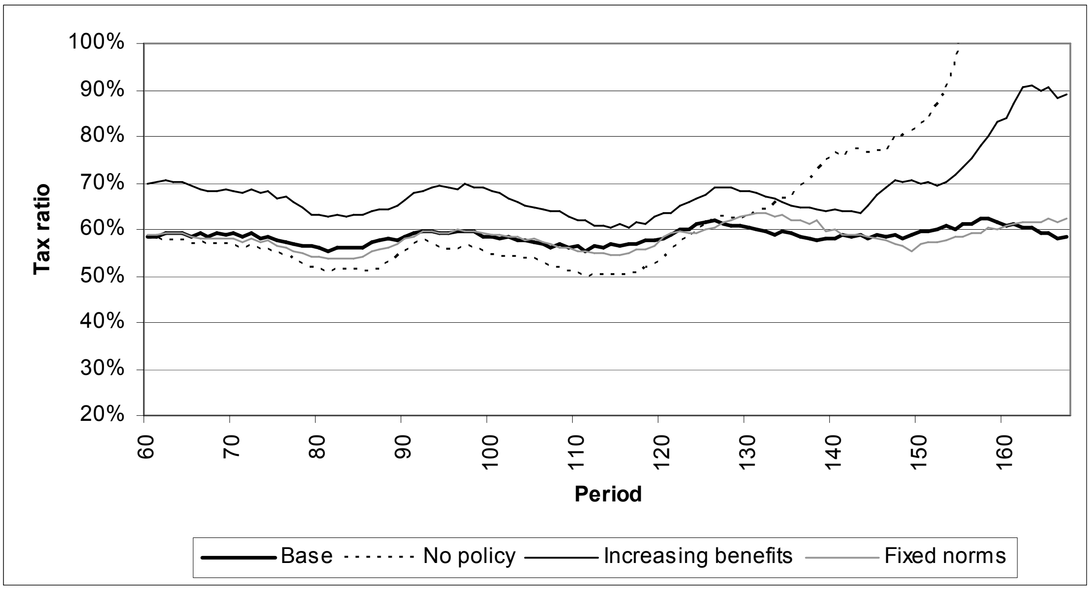

Figure 11 Tax revenues per GDP ("tax-ratio")

5.2.1. Importance of social factors

How much of the fertility trap that we have created is a result of economic feedback from one's parental home while growing up and how much is a result of the gradual formation of social norms? In our model the main part is clearly played by the social norms.

In contrast to the increasing benefit scenario there is no dramatic drop in the population in the fixed norm scenario, but instead a mild increase although smaller than in the base scenario. Cohort fertility is a little lower than the base but still above levels of reproduction. As could be seen from the previous figures this scenario bears a close resemblance to the base scenario also in other dimensions, like age dependency ratios, per capita GDP growth and tax rates. Although a new child will be viewed as more expensive, this affects outcomes more like an idiosyncratic disturbance to adapt to. It seems thus that the social norms as we have modeled them have great impact on the development, reinforcing and forever letting small imbalances spread both through the population and over time. The economic mechanisms, on the other hand, allow adaptation of the agents in order to reach their desired number of children. Thus the adaptation of social norms is the key to create a fertility trap.

6. Conclusions

Our simulation model is capable of reproducing a fertility trap without crashing or exhibiting unexpected behavior, such as overly strong reactions to alternative policies, over a secular period of time. The increasing benefit scenario shows that to get out of the trap requires very determined and persistent policy measures with high temporary growth costs, compared to doing nothing. Temporary in this context implies a period longer than the expected remaining life time of the currently active population. Even so our experiments indicate that in the long run benefits will have to increase even further than the policy we implement and once downturns in fertility start the social norm mechanism the system quickly gets into a negative spiral where new policies cannot be financed. Without a fair degree of altruism such measures would not be politically feasible anyway. Selfish individuals without consideration for their offspring far into the future would delay action until recovery is impossible because the tax base has grown too thin to support the necessary transfers.

As we remove the social norm dynamics it turns out that this by itself prevents getting trapped into low fertility; the economic mechanisms can adjust to regain balance in spite of the disturbances. It is the social norm dynamics which entrench new behavior in the population, behavior which is ultimately unsustainable.

Of course, our conclusions are only strictly valid for our virtual world. In the real world there are a lot more margins to adapt on. Our virtual world is, however, reasonably complex and still reproduces features of demographic dynamics in Sweden that we had not expected to model originally. Nor had we expected the results we found. We therefore conclude from this study the following.

1. Within an isolated system of intergenerational transfers where relative costs of children are increasing a low fertility trap can form.
2. When this process has been entrenched in social norms it is very costly and ultimately maybe impossible to reverse the trend.
3. Unless voters are fairly altruistic this will not be politically feasible in a democracy.
4. Dissolution of the social norm mechanism seems the most important policy to pursue.

An obvious question is whether there is a policy that actually can achieve dissolution of strong social norms? Increasing social mobility via increased income redistribution might not be efficient but in our model framework it would be a step on the way. More likely to meet with success is a more proactive policy that prevents fertility rates to fall to levels where the social norms become entrenched. Given failure of a proactive policy information on future consequences for society, immigration and tax policies more directly tailored to compensate for rising relative costs of children might be effective in a real-world setting. Future empirical research should pay more attention to measuring the relative costs of children and whether variation in this variable can be causally tied to actual fertility behavior.

In simulations it is important to test whether a savings mechanism would modify conclusions. There are a number of reasons why capital markets may circumvent the set of vicious circles we have set in motion in our virtual world. First, capital investment may to some extent substitute labor. Second, the “second demographic dividend” of net saving for old age may circumvent the aspired income mechanism by providing sufficient returns to ensure achieving aspired consumption levels without refraining from either education or children. Third, a capital market would allow public borrowing to invest in children without further diminishing the current income disposable for consumption. Other extensions could be to introduce migration and ethnic barriers in the networks.

Acknowledgements

We greatly appreciate comments from two anonymous referees as well as Vegard Skirbekk and other participants in The International Conference on the Economic Consequences of Low Fertility in St Gallen April 2008. We are very grateful to Matias Eklöf, Gustav Öberg and Elisa Baroni who have programmed the simulation model IFSIM and with great patience implemented the experiments this paper builds on. Funding from the Swedish Research Council is gratefully acknowledged.

References

Allais, M. (1947) *Economie et Intérêt*. Paris: Imprimerie Nationale.

Auerbach, A. J., Gokhale, J., & Kotlikoff, L. J. (1992). Generational Accounting: A New Approach to Understanding the Effects of Fiscal Policy on Saving. *Scandinavian Journal of Economics*, 94(2), 303-318.

Billari, F.C.; Prskawetz, A.; Aparicio Diaz, B., & Fent, T. (2007). The "Wedding-Ring": An agent-based marriage model based on social interaction. *Demographic Research*, 17(3), 59-82.

Björklund, A. (2006). Does family policy affect fertility? *Journal of Population Economics*, 19(1), 3-24.

Bloom, D. E., Canning, D., & Sevilla, J. (2003). *The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change*. MR-1274, RAND Population Matters Monograph, Santa Monica.

Davies, J. (2004). Microsimulation, SGE and Macro Modelling for Transition and Developing Economies. United Nations University / WIDER.

Diamond, P. A. (1965). National Debt in a Neo-Classical Growth Model. *American Economic Review*, 55, 1126-1150.

Easterlin, R. A. (1961). The American Baby Boom in Historical Perspective. *American Economic Review*, 51(5), 869-911.

Ferrarini, T. (2003) *Parental Leave Institutions in Eighteen Post War Welfare States*. Swedish Institute for Social Research, Doctoral Dissertation Series no. 58.

Feyrer, J., Sacerdote, B., and Stern, A. D. (2008). Will the stork return to europe and Japan? Understanding fertility within developed nations. *Journal of Economic Perspectives*, 22(3):3-22.

Flood, L., Klevmarken, N. A., & Olovsson, P. (1996). *Household Market and Nonmarket Activities (HUS), Volumes III– VI*. Department of Economics, Uppsala University.

Grant, J., Hoorens, S., Sivadasan, S., van het Loo, M., DaVanzo, J., Hale, L., Gibson, S.,and Butz, W. (2004) *Low Fertility and Population Ageing. Causes, Consequences,and Policy Options*, Rand Corporation, Santa Monica, CA, USA.

Kelley, A. C., & Schmidt, R. M. (2005). Evolution of Recent Economic-Demographic Modeling: A Synthesis. *Journal of Population Economics*, 18, 275-300.

Klevmarken, N. A. (2002). Statistical inference in micro-simulation models: incorporating external information. *Mathematics and Computers in Simulation*, 59(1-3), 255-265.

Klevmarken, N. A., & Olovsson, P. (1993). *Household Market and Nonmarket Activities, Procedures and Codes 1984–1991*. The Industrial Institute for Economic and Social Research, Stockholm.

Krueger, A. O. (1968). Factor endowments and per capita income differences among countries. *Economic Journal*, 78, 641-659.

Kotlikoff, L. J., Smetters, K., & Walliser, J. (2001). The Coming Generational Storm. Computing in Economics and Finance 2001, *Society for Computational Economics* 276.

Lee, R. D., & Mason, A. (2004). *A Research Plan for the Macroeconomic Demography of Intergenerational Transfers*. National Transfer Accounts Working Paper No. 1.

Lindh, T., & Malmberg, B. (2007). Demographically based global income forecasts up to the year 2050. *International Journal of Forecasting*, 23(4), 553-567.

Lutz, W., Skirbekk, V., & Testa, M. R. (2006). The low fertility trap hypothesis: Forces that may lead to further postponement and fewer births in Europe. In *Vienna Yearbook of Population Research 2006*, Austrian Academy of Sciences, Vienna.

Macunovich, D. J. (1998). Fertility and the Easterlin hypothesis: An assessment of the literature. *Journal of Population Economics*, 11, 53-111.

Mason, A., & Lee, R. (2007). Transfers, Capital and Consumption over the Demographic Transition. In Clark, R; Mason, A. & Ogawa, N (Eds) *Population Aging, Intergenerational Transfers and the Macroeconomy*. (pp. 128-162). Cheltenham, UK: Edward Elgar Publishing Ltd.

McDonald, P. (2005). *Low fertility in Singapore: Causes, consequences and policies*. Paper presented at the Forum on Population and Development in East Asia, Beijing, May 16-17, 2005.

Myrskylä, M., Kohler, H.-P. & Billari, F. (2008). *Human development and low fertility*. European Population Conference, Barcelona, Spain.

OECD (2003). *Low fertility rates in OECD countries: Facts and policy responses, Social, Employment and Migration*. Working Papers 15. Paris: Organisation for Economic Co-operation and Development.

Richiardi, M., Leombruni, R., Sonnessa, M., & Saam, N. (2006). A Common Protocol for Agent-Based Social Simulation. *Journal of Artificial Societies and Social Simulation*, 9(1).

Samuelson, P. A. (1958). An Exact Consumption-Loan Model of Interest with or Without the Social Contrivance of Money, *Journal of Political Economy*, 66, 467-482.

Schelling, T. C. (1969). Models of Segregation. *American Economic Review*, 49(2), 488-493.

Žamac, J., Hallberg, D. & Lindh, T. (2008) *Low fertility and long run growth in an economy with a large public sector*. Working Paper 2008:11, Institute for Futures Studies.

Appendix: Model overview

In this section we provide a more detailed description of how we have modeled the network composition, pensions and the state. For a detailed description of the overall model we refer to the IFSIM handbook which is available on request from the authors.

IFSIM is modeled in JAVA using the JAS platform (Java Agent-based Simulation). Every variable (object) is updated in sequence and the time interval represents one year. All individuals go 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. Figure A.1 presents the flow chart with the main elements of the model.

We start by creating an initial population from the Swedish micro data set HUS. This is a representative sample with about 3000 individuals which we scale to obtain out wanted number of individuals in the simulation. In the first period of the model we also introduce some initial aggregate variables from Statistics Sweden, e.g. mortality rates. Then we start the simulation by assigning each individual to a network group (see below for more details). Second we age the individuals by one year and then decide if the will die or not based on actual and predicted mortality rates from Statistics Sweden. A woman then has the possibility to get a child according to the fertility module (which is explained within the paper). Individuals that still live with their parents may leave and create a household of their own, but only if they are above the age 16. The final individual decision within the demographic module is if they will match with a partner. Only single households can match. The matching probability depends linearly on the age difference between the potential partners only 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.

When individual characteristics regarding demographic variables have been established the simulation continues to determine individual status regarding education. We determine if they are enrolled in education, and if they are at which level. The education module also determines if an individual will start a certain education and what their highest completed education level is. Next every agent goes through the labor market module. At this stage this module does not contain any direct choice variable for the individuals. If they are not in education or at parental leave and below the exogenous retirement age they work full time. They are then either employed on the regular labor market receiving earnings based on their human capital level or they will randomly be assigned to become teachers in which case they would be paid a teacher salary. The wages for those with only basic education vis-à-vis those with higher diploma are determined according to their marginal productivity. Depending on the individual's status during the period, education, work, parental leave, etc., his human capital will increase or decrease.

When all the individuals within the system have obtained their characteristics it is possible to for the state to calculate the public cost in term of pensions, education cost, child allowance and parental leave cost. To be able to cover the expenses the state will choose the tax rate endogenously. Note that there is no direct labor supply effect from raising taxes in terms of reduced hours of work or early retirement. There is however a labor supply effect through the education system which affects the start of the working period.

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 (Billari 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 Billari et. al. (2006) in defining social "closeness" as a spatial area representing the individual's scope of interaction, by age group. More 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 110). 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 A2 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.

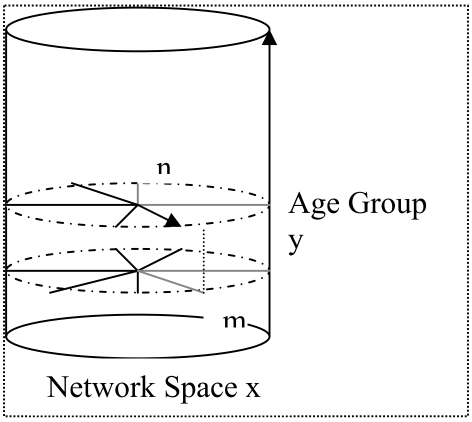

Figure A1: Representation of network groups

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.

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.[8] 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:

(A1) $$PF_{t+1} = (PF_t + (C_t - IP_t)) * R_t$$

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.

---

[8] 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.

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):

(A2) $\sum_t CW = b\sum_t IPN$

Where *b = Σ (CL) / Σ (IPN)* is the 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 (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:

(A3) $IP_t = \frac{PF_t - IP_{t-1}}{L_{65}}$ *(R-*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 (A3) 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).[9] 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:

(A4) $GP = MaxGP - \alpha(IP) \quad > 0$

---

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

Where α is set equal to 1 for IP < 16% of GDP 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).

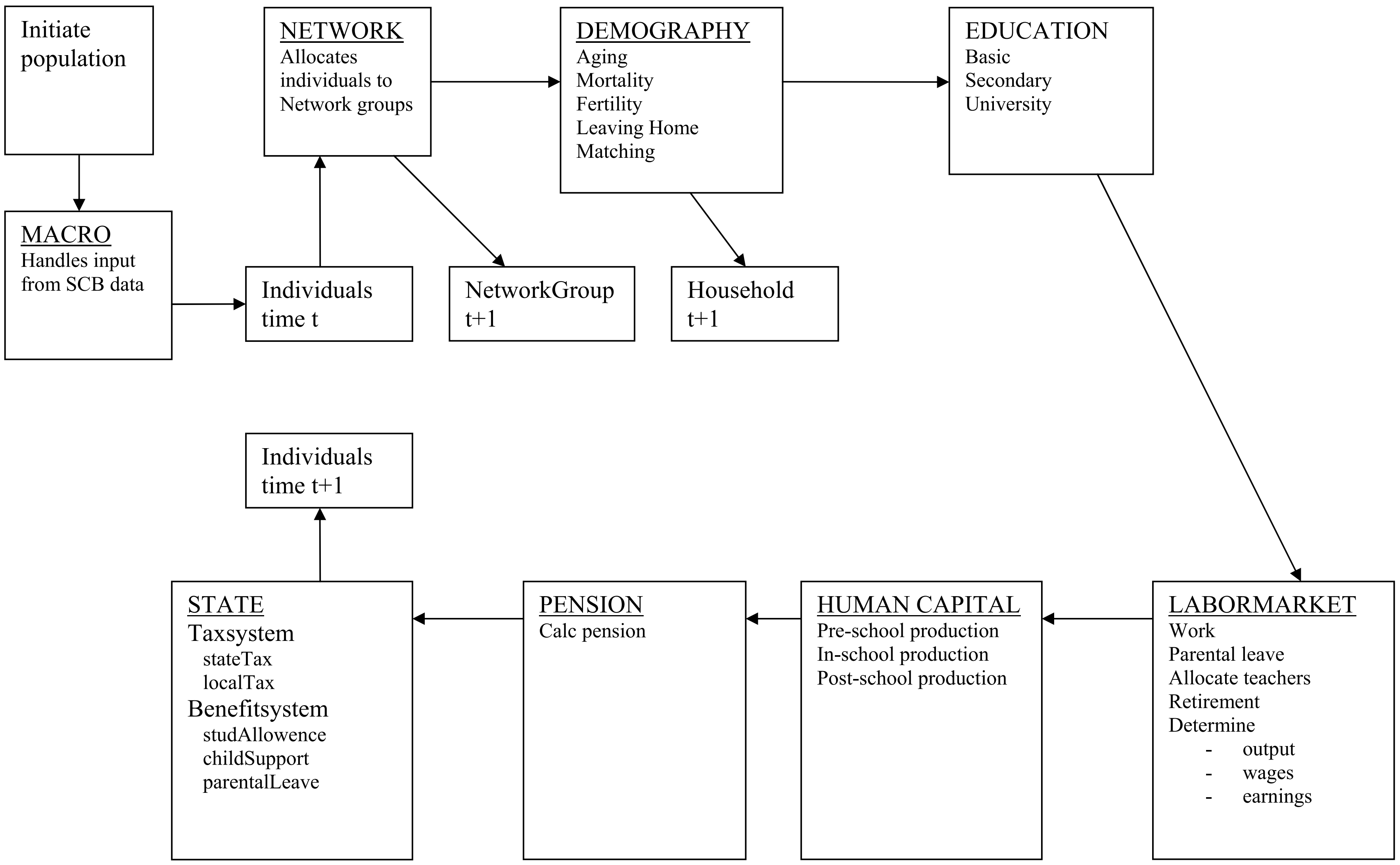

Figure A.1: Flow chart for IFSIM

Previous Discussion Papers:

David E. Bloom and David Canning,
"Global demography: fact, force and future",
No. 2006/ 1

David E. Bloom, David Canning, Michael Moore and Younghwan Song,
"The effect of subjective survival probabilities on retirement and wealth in the United States",
No. 2007/ 1

Glenda Quintini, John P. Martin and Sébastien Martin,
"The changing nature of the school-to-work transition process in OECD countries",
No. 2007/2

David Bell, Alison Bowes and Axel Heitmueller,
"Did the Introduction of Free Personal Care in Scotland Result in a Reduction of Informal Care?",
No. 2007/3

Alexandre Sidorenko,
"International Action on Ageing: Where Do We Stand?",
No. 2007/4

Lord Adair Turner of Ecchinswell,
"Population ageing or population growth: What should we worry about?",
No. 2007/5

Isabella Aboderin and Monica Ferreira,
"Linking Ageing to Development Agendas in sub-Saharan Africa: Challenges and Approaches",
No. 2008/1

United Nations Population Fund (ed.),
"The Madrid International Plan of Action on Ageing: Where Are We Five Years Later?",
No. 2008/2

Svend E. Hougaard Jensen and Ole Hagen Jørgensen,
"Low Fertility, Labour Supply, and Retirement in Europe",
No. 2008/3

Ronald Lee and Andrew Mason,
"Fertility, Human Capital, and Economic Growth over the Demographic Transition",
No. 2008/4

Asghar Zaidi and Alexandre Sidorenko,
"Features and Challenges of Population Ageing using the European Perspective",
No. 2008/5

David E. Bloom, David Canning, Günther Fink and Jocelyn E. Finlay,
"The High Cost of Low Fertility in Europe",
No. 2008/6

Robert L. Clark, Naohiro Ogawa, Makoto Kondo and Rikiya Matsukura,
"Population Decline, Labor Force Stability, and the Future of the Japanese Economy",
No. 2009/1

Previous Letters:

Ariela Lowenstein,
"The Israeli experience of advancing policy and practice in the area of elder abuse and neglect",
No. 2007/1

Jeffrey L. Sturchio & Melinda E. Hanisch,
"Ageing and the challenge of chronic disease: do present policies have a future?"
No. 2007/2

Summary of a Special Session with: Bengt Jonsson (chair), Michaela Diamant, Herta Marie Rack and Tony O'Sullivan,
"Innovative approaches to managing the diabetes epidemic",
No. 2007/3

Baroness Sally Greengross,
"Human Rights Across the Generations in Ageing Societies",
No. 2008/1

Marie F. Smith,
"The Role of Lifelong Learning in Successful Ageing",
No. 2008/2

Aurore Flipo, Hélène Derieux and Janna Miletzki,
"Three Student Essays on Demographic Change and Migration",
No. 2009/1

World Demographic Association

P.O. Box 2239
CH-9001 St.Gallen, Switzerland

phone: +41 (0)71 242 79 79 fax: +41 (0)71 242 79 78
www.wdassociation.org info@wdassociation.org