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

Žamac, Jovan; Hallberg, Daniel; Lindh, Thomas

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, Economic growth

Basse fécondité et croissance à long terme dans une économie à secteur public très développé

Il a été suggéré récemment que les pays à basse fécondité pourraient être victimes d'un piège dont ils auraient du mal à se dégager. Un mécanisme essentiel dans ce piège serait l'interaction sociale et son effet sur la taille idéale de famille. Des mécanismes de ce type sont difficiles à représenter dans un modèle formel, et c'est pourquoi nous avons eu recours à un modèle de simulation multi-agents pour explorer le processus. Dans notre dispositif expérimental, un modèle de croissance et de population stable est calibré aux données suédoises, en utilisant la configuration suédoise de politique sociale. Le modèle est entraîné dans un piège de fécondité en élevant les coûts relatifs de l'enfant en lien avec la croissance positive. Dans ce cas, même des augmentations importantes des prestations familiales sont insuffisantes pour sortir du piège. Toutefois, le petit nombre d'enfants permet temporairement à l'économie de croître plus rapidement pendant quelques décennies. L'arrêt de l'adaptation aux normes sociales conduit à une neutralisation du piège.

Mots-clés : Piège de basse fécondité, Normes sociales, Revenu relatif, Croissance économique

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 which takes account of the changing economic impact of age distribution as longevity increases. 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 new, but provides confirmation, for example, of the shift-share analysis of Krueger (1968) who makes 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 fraction will appear as value-added in the national accounts. As emphasized by Bloom et al. (2003), the demographic dividend from falling fertility appears as the working population starts to grow faster than the dependent population. Mason and Lee (2007) stress 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 for rising elderly dependency ratios by decreasing fertility. Indeed we observe that several developed countries both in Europe and Asia are experiencing very low fertility which is accelerating their aging. While only China has a deliberate one-child policy, fertility involuntarily seems to be lower than in China in both South Korea and Japan. Since below-replacement fertility will speed up population aging, this is ultimately not a sustainable equilibrium. Sooner or later the current financial support for the elderly provided by 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 there are fewer people of reproductive age. The second feedback is hypothesized to work through social norms which make fewer children more 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

[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.

feedback reinforcing low fertility standards. Thirdly, Lutz et al. add the socio-economic relative income effect of Easterlin (1961), where the aspired standard 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 elements in an agent-based simulation model are 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 offers 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 of 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 to 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.

For reasons of brevity, this paper does not go into detail about the model, and 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. This is followed by a short account of the model structure and the crucial mechanisms in the modeling context. In the third section, we analyze the results of alternative scenarios

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

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 is still higher than actual total fertility rates (TFR) in Europe, there are some countries, e.g. Austria and Germany, where ideal family size is now 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 the next generation will fare worse than their parents. All this seems to coincide with downward trends in cohort fertility and definitely with postponement of childbearing. But will these factors combine into a mutually reinforcing feedback circle as the LFTH suggests? There are three apparent escape routes 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 frameworks differ substantially across the countries that are now 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 less pronounced in these countries (Ferrarini 2003). The Swedish case is thus very relevant to study as a potential model that refutes the inevitability of the LFTH. Sweden has had a very stable cohort fertility rate (CFR), at around 2 for all cohorts born in the 20th century where we can observe 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 make up for the lag in their CFR, and indeed birth rates have been picking up and may be headed for a new baby boom. It nonetheless seems to be a fact that the relative income of young adults in Sweden has been falling over the same period. Norms regarding the desired family size have been very stable, at around 2 children, as measured in attitude surveys. At the same time the average age of the mother at first birth has risen steadily (24 years in 1970, 29 years in 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 designed to conform to social norms). However, as the South Korean and Japanese examples show, the design of pro-natalist social policies may be hard to implement efficiently in order to actually achieve any results.[3]

[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 have limited effects on fertility.

There is so far little consensus on whether the demographic transition will end up maintaining world population at approximately stable levels or will 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 difficulties, however, since we cannot in general observe these feedbacks 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 become intractable when the population structure is non-stationary. This has led to numerous 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 increasingly non-transparent 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 reached 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 do too much, to keep too many options open, to start playing a Sims computer 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, mating and the fertility decision 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. What Is Agent-Based Modeling?

ABM starts from the premise that the "real world" is hardly the work of a central planner, built to 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 and habits, and where the local relational context also contributes to those agents' strategies and behaviors.

There is a growing interest among economists in modeling 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 feedbacks, which therefore have to be assumed as exogenous.

In practice, integrated macro-micro models are difficult to implement, mostly due to a tradeoff 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. They can incorporate modern computing developments (e.g. object-oriented programming languages) to simulate complex interactions simultaneously, and to simulate 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 letting it run forward in time, i.e. 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, allowing yet more transparency, 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.

4.1. *Demographic module*

The starting population comes directly from the initial dataset.[4] There is no migration in the model so the population evolves according to 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 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 mating occurs at relatively early ages so that it does not impose a restriction on fertility. By the age of 21 every individual has left the parental household.

The mating 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] 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 of 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.

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. This yields a fast declining probability from age 30 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 below which it is not possible to give birth. There are few teenage 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 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 of the man's and the woman'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 of their network group, it is not sure that they will reach this target. Given that the woman is of fertile age and that the number of desired children is higher than the actual number, she will give birth if the two following conditions hold:

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

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

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 an increase in the cost of having a new child, we model this by increasing *r*. The square root captures the economies 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 as 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:

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

where N_{Kids} is the number of children belonging to the $N_{Members}$ members in the network group. Here $\wp$ is a parameter that controls the strength of social pressure, currently set to 0.92. If many individuals within a couple's network have children this will positively affect the couple's fertility decision.

The economic dimension consists of determining if the couple can afford a new child or not in the future given their consumption 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 $\overline{C} = \overline{DISP/\sqrt{n}}$ is the average equivalent disposable income today and $\theta = \left[\gamma C_{at10} / \overline{C}_{at10}\right] + (1-\gamma)\left[C_{at10} / PROJC^{10}\right]$. C is the equivalent disposable income for an individual in the household. The subscript *at10* indicates that the aspirations were set when the individual was 10 years old. 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 a lower consumption level than they themselves 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 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 it is 13 months at maximum), 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 old and the right to paid leave to care for sick children up to age 12. Doing a sensitivity analysis with parental leave reduced to just one year results in only a minor tendency for higher fertility but the dynamic behavior of the model remains very close to what we present below.

4.2. *Social networks*

Newborn individuals inherit some of their parents' characteristics. From birth they will belong to a network group, the first one being determined by their parents' characteristics. The networks are segmented first by age groups and second, 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 enrolled in basic schooling until the age of 16, corresponding to 9 years of compulsory education. If they enter high school, they will stay in school another 3 years. The choice to apply to university is determined by individuals' prospective earnings compared to their aspired consumption level, and 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 individuals estimate that they can reach their aspired consumption level given their preferred number of children without having to invest in education, then they 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 production of consumption goods*

We postulate a production technology that only depends on human capital (i.e. there are no savings into other types of productive assets). Production depends on 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 $H_{H,t}$ are the aggregate 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 production output going to each worker. Allocation of the produced goods 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. As a result, the education premium also increases. This will be observed by young individuals who will be more likely to choose university and thus increase the future supply of university degree individuals.

As human capital is of paramount importance in the model, we will describe in detail how it is modeled. There are four main inputs that determine the human capital of each individual: (i) innate 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 innate human capital h_{i0}. The discrete time evolution of the human capital in the pre-school phase is modeled as

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

where Δ indicates first differences and h_{it} is the human capital of individual i in period t. $h_{i_m t}$, $h_{i_f t}$ 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 so we account for the number of students. To formalize, the human capital production during school periods is defined as:

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

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^{teach}_{t} 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 setup, 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 to age 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 dependent on the level of education: basic, secondary, and university. The rate of increase accelerates as level of education rises, 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 tax 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-rate tax 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 mechanisms are included. The relative income mechanism has been implemented by defining an aspired consumption level based on the household income in the parental

[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.

home at 10 years of age. See Žamac et al. (2008) for 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, and if future income expectations allow a new child, then 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 of 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 with respect to the aspired income make potential parents postpone childbearing, in hope of better economic conditions in the future. As the returns of education increase with education level, highly educated parents increase their chance of getting 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.

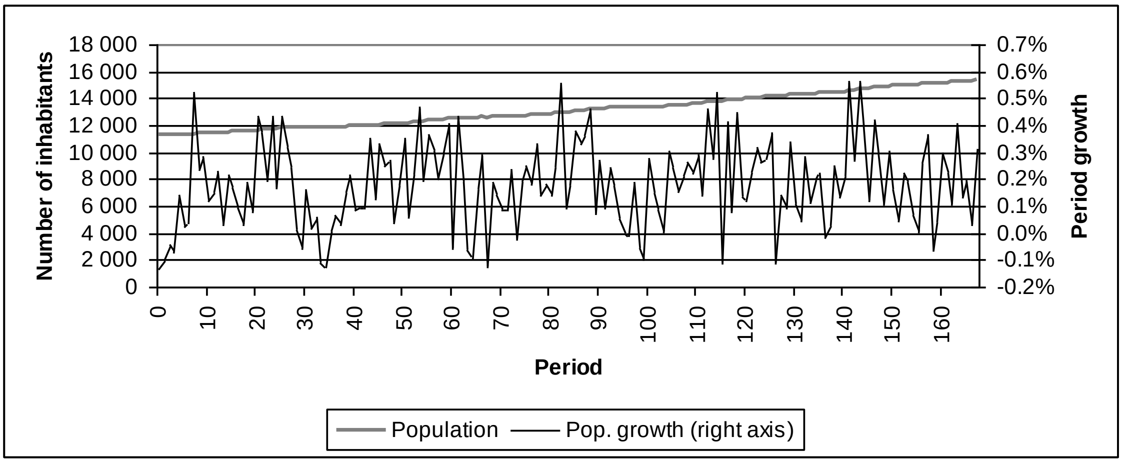

Figure 1 Population development in base scenario

The age composition of 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 and which, to some extent, actually resembles the Swedish demography over the 20th century. In the 65+ group these oscillations cancel out.

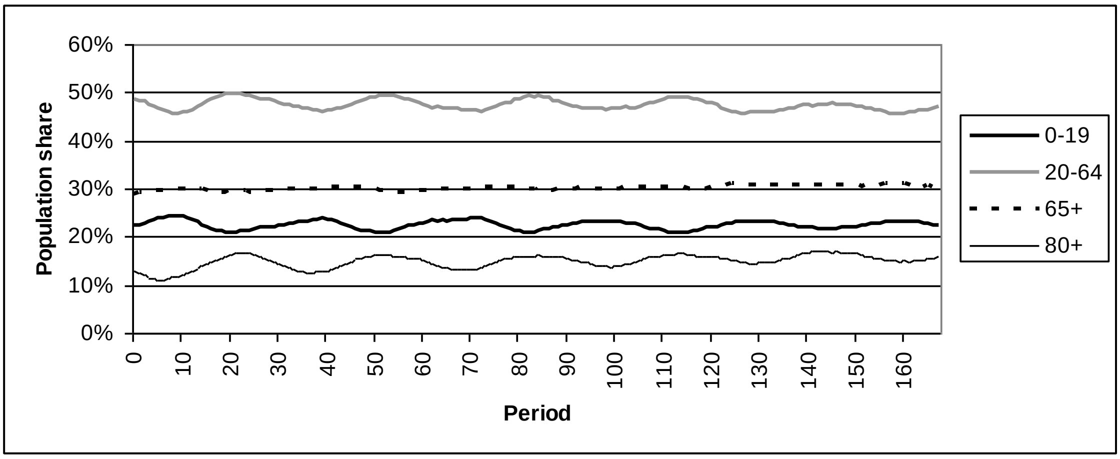

Figure 2 Age structure in the base scenario

There is variation in the CFR over time that explains this pattern. For the whole period CFR is on average above replacement level at 2.15 children per woman. We observe a rather steady pattern but there are some temporary swings in CFR, as shown in Figure 3. We do not have any mechanism that leads to intensified efforts to procreate as fecundity declines. 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.

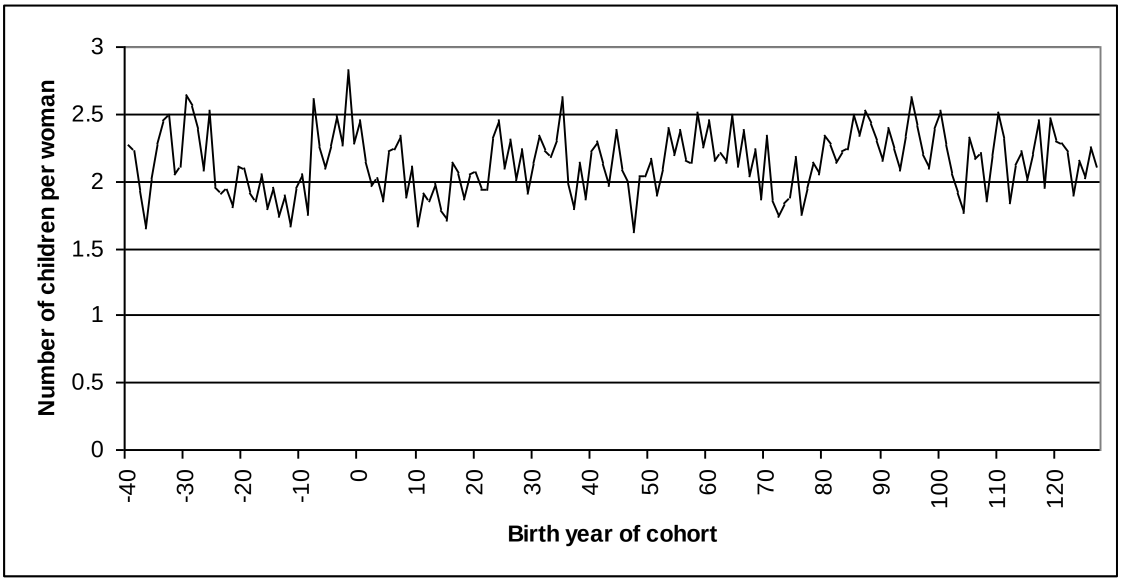

Figure 3 Completed fertility, by birth cohort

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 have 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 birth order of child 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

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 at university graduation is 24 (i.e. the youngest possible graduation age), but the rest, about 17 percent, graduate between ages 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 will have a baby during education enrolment. Such events will delay university graduation even further for female students (by three years per baby). The larger effect on the high educated may reflect the increased difficulty of combining education and children. At the aggregate level, the base scenario data show that rising enrolment rates in higher education are linked to lower birth rates. Once enrolment rates drop, individuals obtain 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 a shortage of one education class relative to 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.

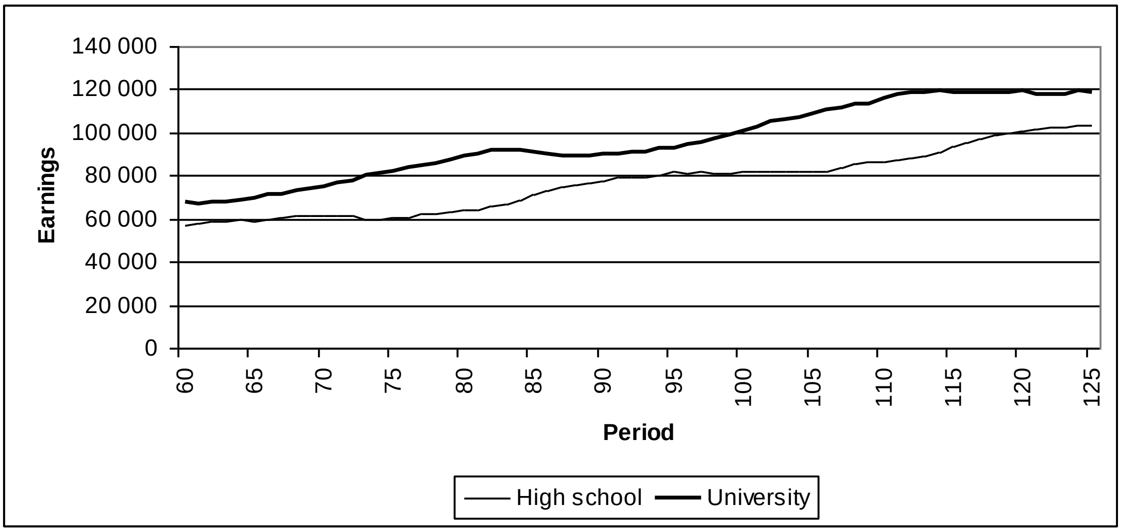

Figure 4 Earnings in model time 60-125 by education, base scenario

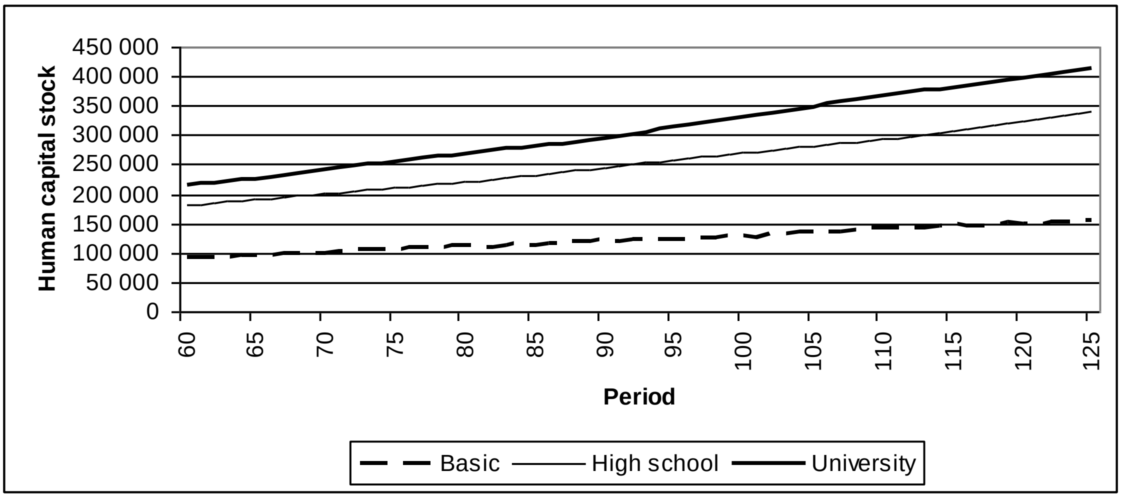

Figure 5 Human capital development, model time 60-125 by education, base scenario

5.2. *Alternative scenarios with a higher child cost*

In three alternative scenarios we modified 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 have 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 previous period. In a situation where 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:** this is the same as 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 feedback.

The relative cost shock mechanism is introduced into 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 more slowly. As is obvious in Figure 7, the CFR declines and two decades after the introduction of the relative cost mechanism the CFR only rarely exceeds replacement level. Increasing benefits are successful in blocking the drop in fertility about 40 years into the future, but this policy cannot turn the tide as fertility rates fall to low levels below 1.5.

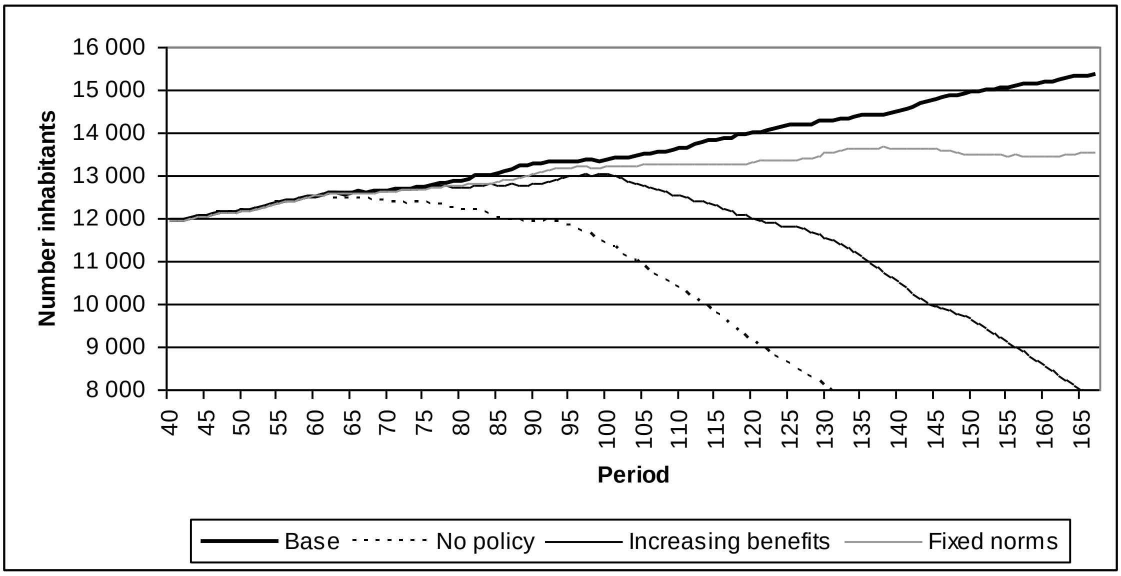

Figure 6 Population in the base and alternative scenarios

The relative size of the working-age population 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 lowest-low fertility scenarios enter into a phase with a decreasing active population.

[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 brought 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.

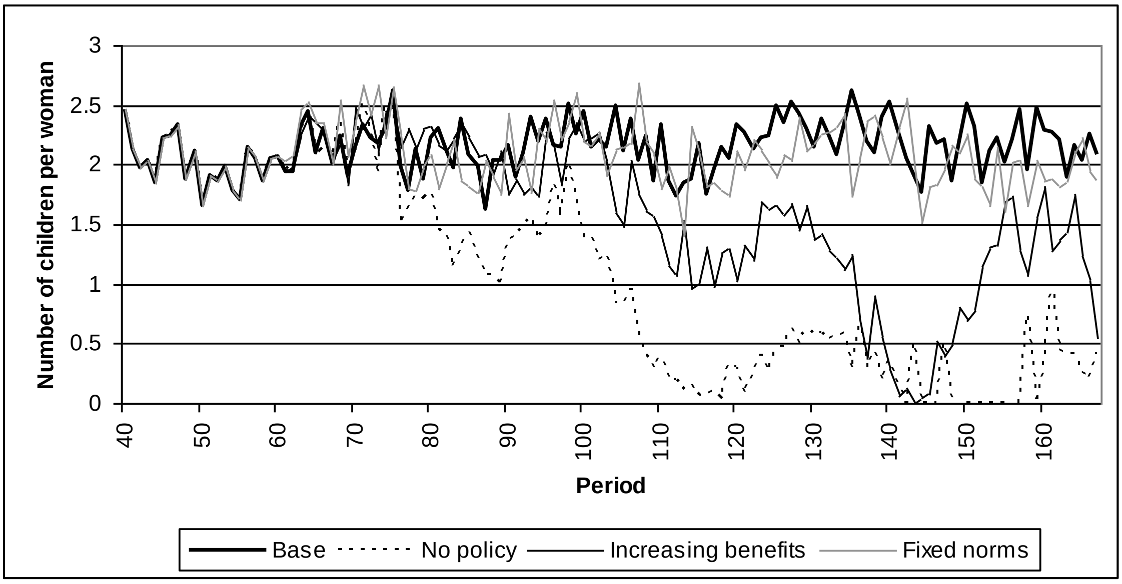

Figure 7 Completed cohort fertility rate (CFR) in base and alternative scenarios, by model time

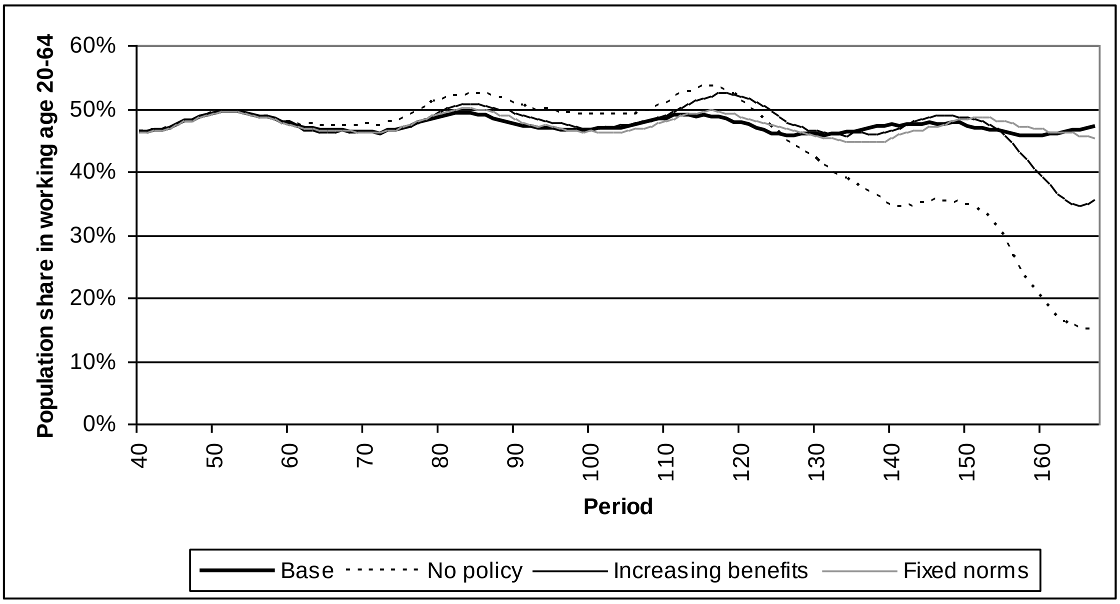

Figure 8 Share of working ages (20-64) relative to total population

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 in the other two it keeps on increasing. This is because aspired income is more difficult to reach with the same number of children as before. As a consequence, women postpone births to an extent that finally lowers the desired number of children and leads to decreasing fertility in both the no policy and increasing benefit scenarios.

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 grows faster in both the no policy and increasing benefits scenarios than in 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 aspired consumption level which is increasing likewise. This also contributes 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 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 for almost 100 years (but note that GDP does not grow for that long in overall terms, due to shrinking population). This raises the issue of how far into the future the altruism of the current generations will persist. By remaining childless they can improve their material well-being but only at the expense of as yet unborn generations in the future.

Figure 11 depicts the increase in tax rates as per capita growth declines. Tax ratios 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 higher tax rates – 10 percent or more – *in all future periods*. Implementing this policy would hardly be politically possible unless median voters had a very high degree of altruism towards future generations. In the end, however, high tax increases

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

like these also fail to prevent fiscally unsustainable tax levels, so tax hikes to provide high child benefits are not sufficient in themselves to reverse the trap. Introducing saving and capital investment might change this conclusion (see Mason and Lee, 2007, about the second demographic dividend) but its implementation in the model would substantially shift the focus of the study.

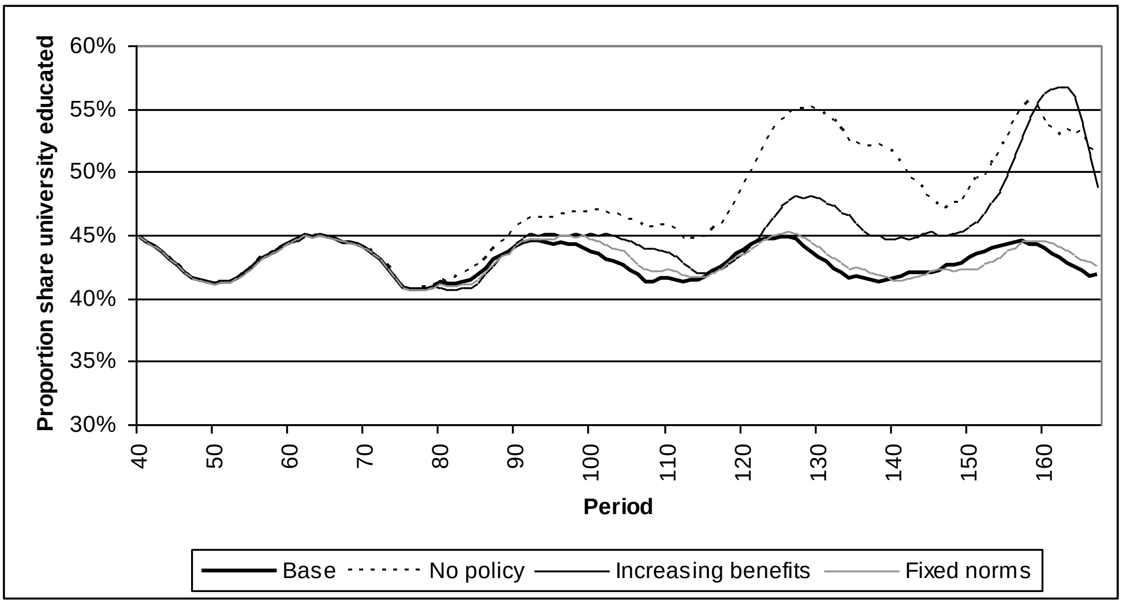

Figure 9 Proportion of high skilled (university educated) in the age group 20-64

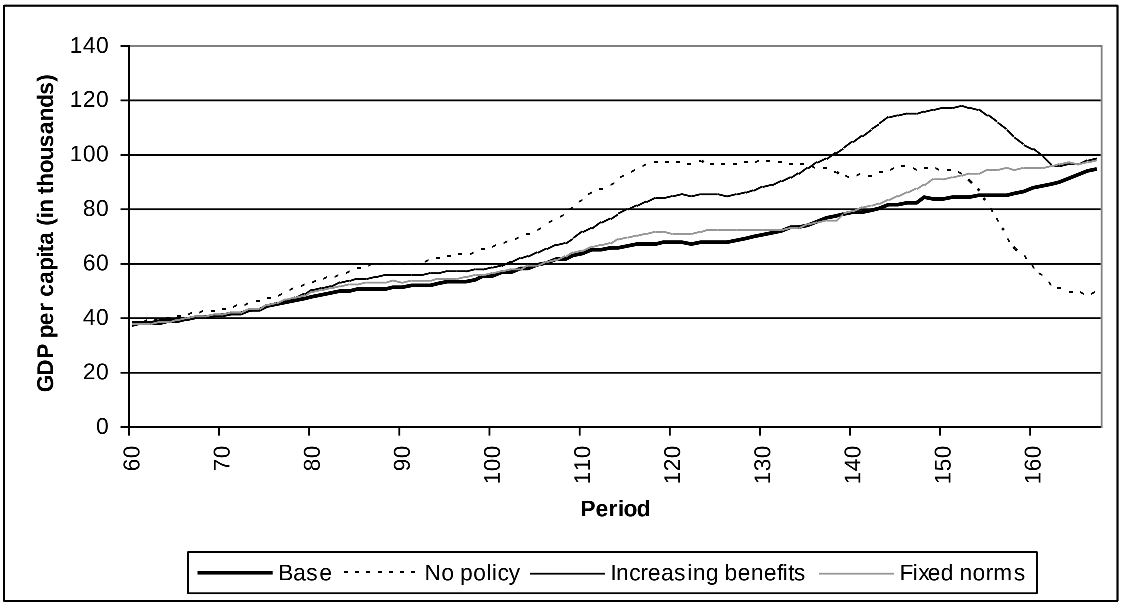

Figure 10 GDP per capita in thousands

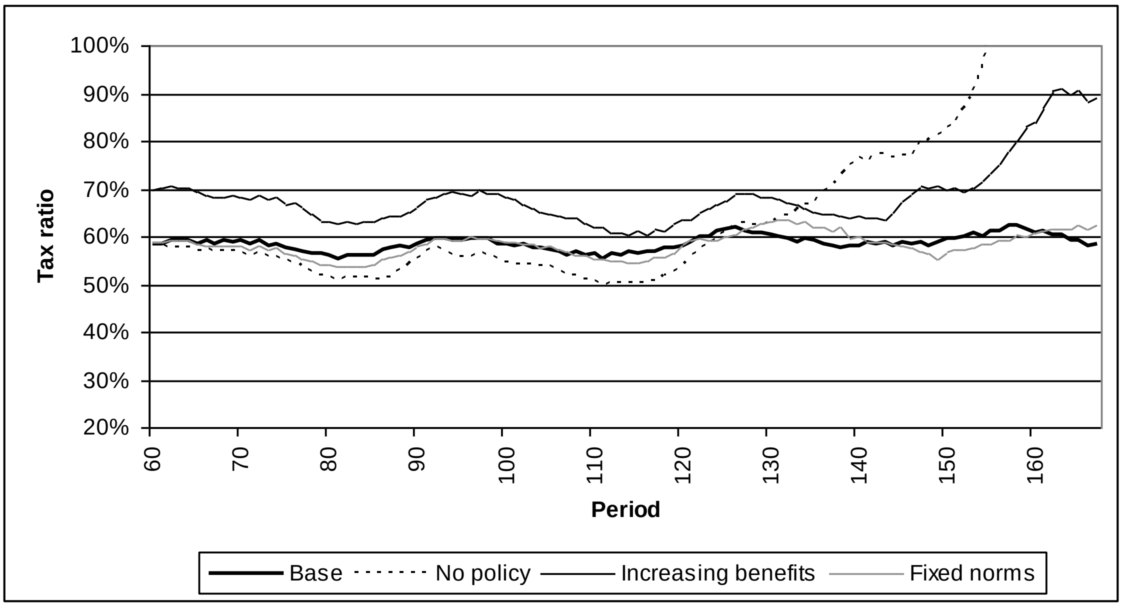

Figure 11 Tax revenues per GDP (“tax-ratio”)

5.2.1. Importance of social factors

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

In contrast to the increasing benefit scenario, there is no dramatic population decline 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 replacement levels. As could be seen from the previous figures, this scenario also bears a close resemblance to the base scenario in its other dimensions, such as 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 that can be adapted to. It seems thus that the social norms as we have modeled them have a major impact on development, reinforcing small imbalances and continually allowing them to spread both through the population and over time. The economic mechanisms, on the other hand, allow the agents to adapt in order to reach their desired number of children. Thus the adaptation of social norms is the key to creating 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, compared to doing nothing, getting out of the trap requires very determined and persistent policy measures with high temporary growth costs. 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. 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 descendants far into the future would delay action until recovery is impossible because the tax base has grown too weak to support the necessary transfers.

Removing the social norm dynamics is, in itself, sufficient to avoid getting trapped into low fertility; the economic mechanisms can adjust to restore balance in spite of the disturbances. It is the social norm dynamics which entrench new, ultimately unsustainable, behavior in the population.

Of course, our conclusions are only strictly valid for our virtual world. In the real world there is a lot more scope for adaptation. 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 may ultimately be 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 can actually 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 in the right direction. More likely to meet with success is a more proactive policy that prevents fertility rates from falling to levels where the social norms become entrenched. Given the failure of proactive policy information on future consequences for society, immigration and tax policies more directly tailored to compensating for the 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 the 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 that aspired consumption levels are achieved without foregoing either education or children. Third, a capital market would allow public borrowing to invest in children without further diminishing the current income available 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.