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Optimal Fertility

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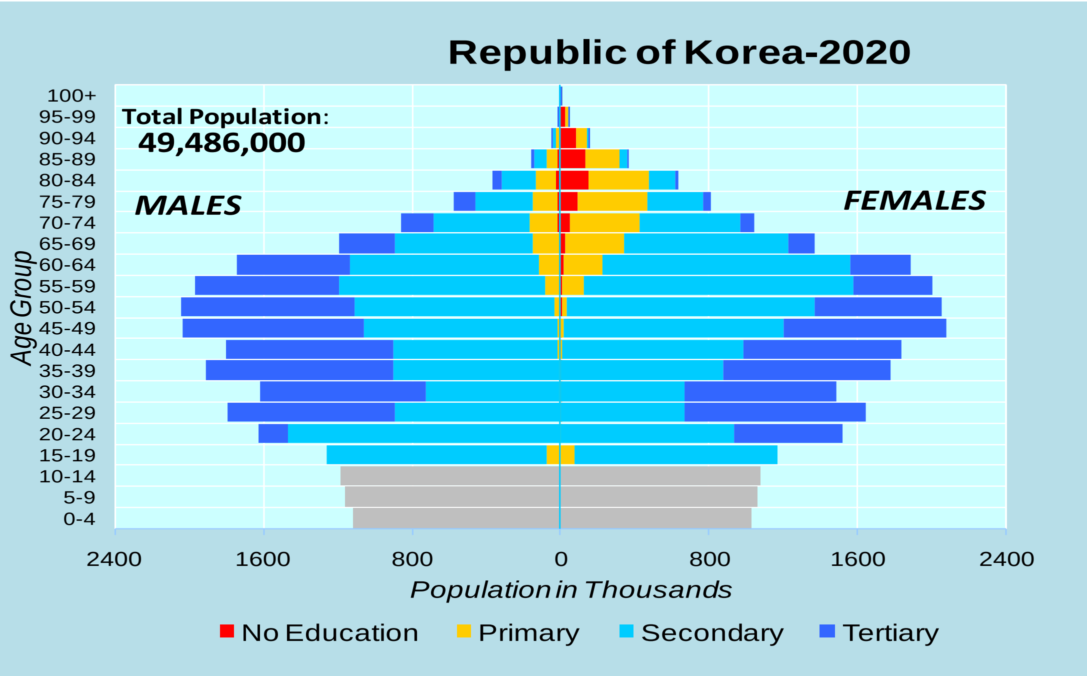
Abstract

In this paper we challenge the wide-spread view that replacement level fertility is the most desirable level of fertility both for countries currently above and below this level. We first discuss different possible criteria for choosing one fertility level over another. Dismissing for the time being purely nationalistic criteria related to increasing national strength relative to other national populations, in this paper we focus primarily on age dependency and also experiment with the consideration of environmental effects of alternative fertility levels as measured by CO_2 emissions. In doing so, we relax the conventional strong assumption that all individuals of a given age are equal in terms of their contribution to society and the economy and introduce education as a most relevant observable source of population heterogeneity with education presenting a cost to society at young age but a benefit in terms of higher productivity and better health at adult age. Our criterion variables for assessing the long term implications of alternative fertility levels then are the education-weighted total dependency ratios, as well as CO_2-emissions and different mixes of the two criteria. We study the sensitivity of optimality with respect to the time horizon and choose to focus on the actual populations of Europe and China over the course of the 21st century. We perform thousands of alternative simulations for different fertility levels (assumed to be constant over time) starting from empirically given population structures. The results show that when education is assumed to present a cost at young age and results in higher productivity during adult age, then for most countries the optimal long term TFR turns out to lie well below replacement fertility. Internalizing the environmental cost of different levels of fertility, the model gives an optimal level of fertility that lies even lower.

1. Introduction

The interest in this topic of what is the socially most desirable level of fertility under different conditions arose in the context of comparing alternative scenarios in IIASA's population projections by age, sex and level of educational attainment [1]. Given the strong association between the level of women's education and their level of fertility, the question arose whether in low-fertility countries the smaller number of young people can be compensated in terms of aggregate economic wellbeing by their better education. A rather extreme case is the projection for 2020 by age, sex and level of education for South Korea as shown in Figure 1 where colour indicates the men and women by highest level of educational attainment.

Figure 1. Population by age, sex and education. Republic of Korea, 2020. Source: Lutz 2011.



As shown in the figure, the age pyramid of Korea is getting extremely narrow at the bottom. In 2020 the age group 0-4 will be less than half of the size of the age group 45-49. This is the result of the fact that South Korea already for some time has had one of the world's lowest fertility rates around a TFR of 1.2. On the other hand, Korea has experienced one of the fastest expansions of the educational composition of its population in human history. While as recently as in 1960 the vast majority of reproductive age women has never been to school and only very few had had at least junior secondary education (the consequences of this can still be seen among elderly women in Figure 1), today young Korean women are among the best educated in the world with already more than half of the young cohorts having completed college education. There is little doubt that this most impressive educational expansion has been one of the key factors behind the astonishing economic growth which followed soon thereafter [2]. Actually, the study of education levels by 5-year age cohorts allows us to identify much more closely the strong association between economic growth and the better educated young cohorts entering the working ages.

But in discussions, this picture as shown in Figure 1 has given rise to very different conclusions concerning the future socioeconomic prospects of South Korea. Some point at the tremendous aging and the associated increase in the conventional old-age dependency ratio which is taken to imply doom, if not economic collapse, for the future. Others point at the stunning increases in education and assume that in a likely future of high tech industries fewer and much better educated young people is just what the Korean labour market needs. Who is right? These differing views also result in opposing policy recommendations. Given that highly educated Korean women have difficulty finding an equally or better educated male partner and often reject the traditional role as a housewife, some of the people primarily concerned about the low fertility, in part blame higher female education for this trend.

In scientific terms the question refers to the trade-offs between age structure and education structure in terms of their contributions to current and future wellbeing. This is the main topic of this paper. It is complemented by the second question about how different fertility levels affect the future wellbeing through their impacts on climate change, which can be seen as another criterion for determining the level of "optimal fertility" in the sense of socially desirable fertility.

Let us assume for the moment that fertility is a policy variable and we could choose among different hypothetical future pathways. Which average level of fertility should we see as the most desirable in terms of being in the best longer-term interest of society? (Long-term here is understood to refer to the coming decades up to the end of this century.) One argument often mentioned in favour of replacement lever fertility is that in the very very long run (over several centuries or millennia), any other level would result in either population explosion or eradication. But it seems to make little sense to argue with possible consequences many centuries down the road when the task is to assess the implications of fertility levels in the near term future. Looking at the consequences that go well beyond the current century we can leave to our great grand children who should then figure out what they see as the optimal fertility in the 22nd century given the still unknown technologies and socioeconomic conditions of those future days.

It is surprising that this highly relevant question of the criteria for the desirability of different fertility levels among low-fertility societies has been hardly asked by demographers so far. There is abundant literature on the century old discussion around optimal population size which has been thoroughly inconclusive up to the present date. Joel Cohen's impressive book entitled "How many people can the world support?" [3] presents and discusses a wealth of different estimates and criteria for optimality of population size but also fails to be able to give a clear answer to the question posed in the title, mostly because of the uncertainty about the technologies to be assumed for the longer term future. But the question asked in this paper about optimal fertility is less a question about population size – which enters only indirectly – and more one about the optimal population structure.

The goal of our paper therefore is to first define possible criteria for preferring one level of fertility over others. These criteria are then operationalized in a quantitative model in the following sections. Section 3 introduces the age-dependency model and the basic assumptions with the results presented in Section 4. Section 5 presents a detailed sensitivity analysis with some of the key model parameters. Section 6 then tries to add the environment dimension to the model in terms of long term greenhouse gas emissions associated with alternative fertility trajectories and gives results for different weights assigned to the dependency burden versus environmental impact. The paper concludes with a discussion.

2. **Criteria of Optimality**

When asked about what a desirable fertility level for populations might be, most politicians, journalists and even demographers would spontaneously answer that it is slightly above two children per woman – a level we use to call ‘replacement level fertility’. The reasons stated in support of this level of fertility (which in most European countries is higher than the one currently reported) usually refer to some vague notions of maintaining the size of the labour force and stabilizing the dependency ratio. But a closer look at the demographic models that underlie this reasoning reveals that this supposedly precise level of 2.1 (actually more like 2.06 under low mortality conditions) is only derived from a highly stylized theoretical model of stationary population. It has little to do with actually maintaining the size of the labour force in contemporary *real* societies. These have an age structure which is often quite irregular and the size of the working age population is influenced by migration and mortality changes in addition to fertility.

However, even in the hypothetical absence of migration and under constant mortality conditions, in countries with a high share of young people (positive momentum of population growth) fertility should be well below replacement level if the goal is to keep the absolute size of the working age population constant. Conversely, in countries with relatively few younger people (i.e. that have already entered a phase of negative momentum) fertility should be significantly above replacement level if again, the goal is to maintain the working age population. Lutz et al. [4] showed that Europe’s population entered the phase of negative momentum around the year 2000. Hence in this context of real European populations and their empirically given age structures, a reference to replacement level fertility makes little sense in terms of the stated goal of maintaining the labour force in its current size. On top of this, all real populations in Europe and elsewhere do experience mortality change and migration and hence render the 2.1 goal even less relevant as a way to achieve a supposedly desirable constant working age population.

Another line of argumentation in favour of two surviving children per woman follows the bottom-up approach. It refers to individual preferences and a supposedly “natural” desire for a man and a woman to have two children together in order to replace themselves and hence continue living in their children. Recently, Lutz and Scherbov argued that it is worth distinguishing between population-level replacement and individual-level replacement [5]. They stress that at the individual level it is sufficient to have one child (under low child mortality conditions) if the primary goal is to pass on your genes and continue to live on in the next generation. In the absence of cloning it takes a partner of the opposite sex to produce this one offspring. As such, the child is made up of only half each parent's genes. Yet, having two or three children does not make the offspring more similar to you. It would of course spread your genes more widely, but this is a very different goal from replacement and if this were the goal then, of course, you should have as many children as possible. There would be no reason to stop at two. There may clearly be other individual-level reasons for having a second child, such as providing your first child with a sibling. But again, this is not related to the question of replacement. We only mention this important distinction between societal- and individual-level replacement here in order to make sure that the following discussion of optimal fertility at the societal level is not confounded with that of personal optimal fertility at the level of individuals and couples. Seen from the individual perspective, it may be optimal to minimize the difference between desired and actual family size, however, the resulting aggregate level of fertility may not be 'optimal' for society.

Any discussion of optimality must be very clear and explicit with respect to the optimality criteria used. In the context of current low-fertility populations (which is the main focus of this paper), most of the concern in the discussion of demographic trends relates to the economic and social consequences of population ageing. Following this particular line of thought, any criterion for optimality has to focus on the goal of minimizing the projected increases in the age-dependency burden which is often seen equivalent to, more generally, maximize the economic wellbeing of the average citizen in the population studied. But in times of major concerns about global climate change, the possible impacts of different demographic trajectories on future paths of greenhouse gas emissions and on future generation's ability to cope with the expected negative consequences of climate change also should be taken into consideration as relevant factors contributing to future societal wellbeing. With respect to this environmental dimension, there is generally little doubt that fewer people are considered to be better for the planet. But as will be discussed later, there are major challenges in trying to quantify this effect and in weighing it against the costs and benefits of population ageing.

However, especially in the political debate there still is a third, quite powerful criterion for judging the desirability of alternative longer-term fertility trends and levels. When Russian president Putin states that fertility must increase and the Russian population must change its trajectory from shrinking to growing again, he presumably has neither climate change, nor age-structural concerns on his mind. Rather, he is guided by a nationalistic perspective associated with population being a relevant security factor. In a similar vein, the origins of the still ongoing French pro-natalist policies lie in concerns that after the relatively low fertility over the course of the 19th century France lost the war against Germany in 1870/71 presumably (at least in the analysis of scholars of that time) due to a smaller number of soldiers. While such nationalistic criteria can never be operationalized in terms of internationally applicable criteria for optimal fertility (because they are based on the very idea that one nation gains at the expense of others that lose), one might still be able to define some more reasonable criteria in terms of national identity, or the survival of certain languages which requires a critical minimum population size in order to sustain e.g. a living language. While we will not make any attempt here to operationalize such ethnic criteria, it is worth noting that they also apply to intra-national rivalries. For example, the prevalence of exceptionally high fertility rates among both Palestinians and Jews in Israel despite their high levels of education has been attributed to such factors [6].

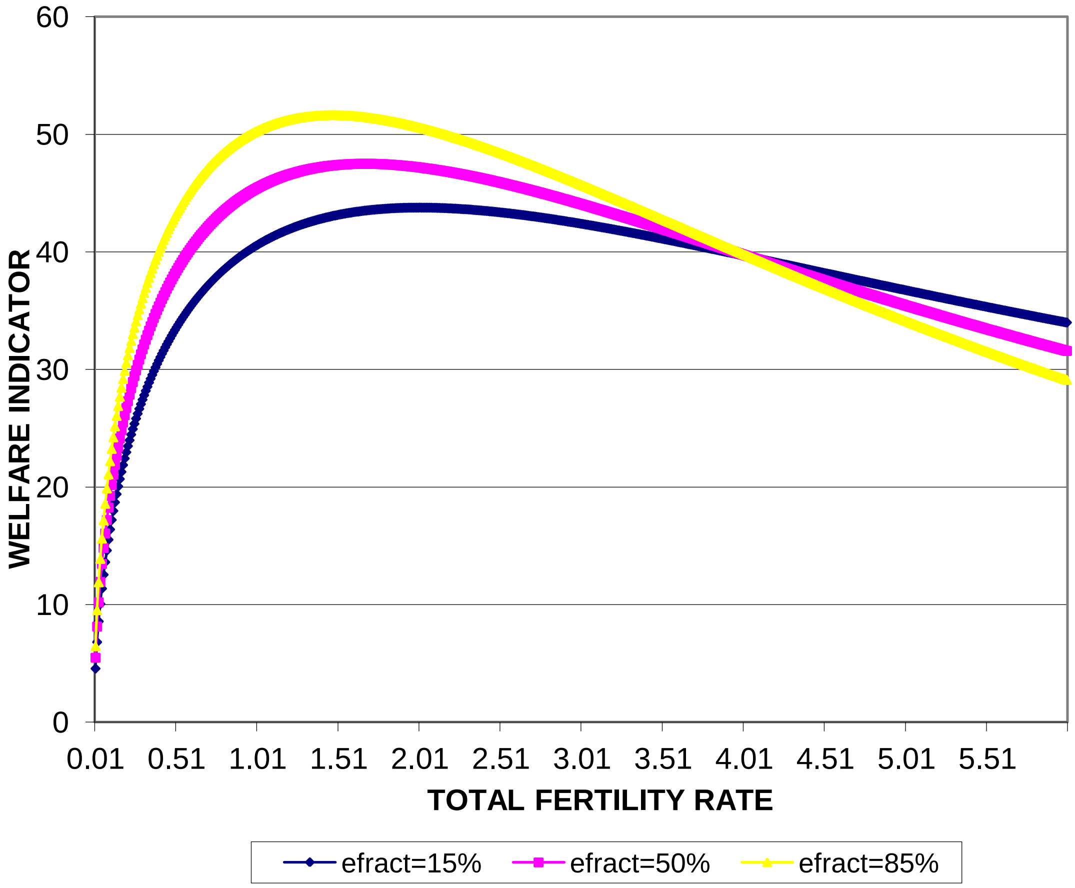
In the following, we focus on the economic and environmental aspects associated with the changing size and age-structure of the population while explicitly taking education into account. The specific optimality criteria used will be described more precisely in the context of the description of the model that will be used.

3. The Model

In 2004, Lutz, Sanderson and O'Neill published a model called "Population Balance" which directly addressed the question of optimal fertility [7]. The welfare indicator that was used to assess "optimality" was sensitive to assumed age- and education-specific productivity, cost of pension and cost of education. The question they were asking was whether the per capita welfare decline caused by rising dependency ratios could be counterbalanced by the improved education of the smaller young cohorts. This might increase their productivity, offsetting the costs of rising dependency ratios. At the same time, smaller young cohorts cost less at a given level of education expenditure per child.

The effects of alternative levels of education on welfare were evaluated in the context of different fertility scenarios. Their welfare indicator is directly derived from education-weighted support ratios. Each steady-state level of fertility produces a distinct age structure which becomes stable in the long run. The results are shown in Figure 2 below. They clearly indicate that in the case of low education the optimum is very broad – meaning that the welfare indicator is not very responsive to changes in fertility – and peaks around two children. In the context of higher education levels, however, the optimum moves to the left (around 1.4 – 1.7 children per woman) and the overall level of welfare increases. This clearly illustrates that under hypothetical stable conditions, sub-replacement fertility can be optimal if society is willing to spend more on each child's education.

Figure 2: Welfare Indictor for Stable Populations by Fraction Educated and Total Fertility Rate, Baseline Parameters.



We will now further expand this analysis, conduct sensitivity studies and, most importantly, apply the model to the actual age and education structures of real populations over the 21st century rather than steady states. Here we use the example of the EU-27 and China, partly because for these countries model-based calculations of the effects of alternative fertility levels on greenhouse gas emissions are available [8]. In order to assess the welfare impact of different long-term levels of fertility, we use a simple population projection model that enables us to calculate education-weighted dependency ratios, based on observed initial (2010) population structures and survival probabilities as reported by the UN in the 2008 revision of the World Population Prospects [9]. Using the IIASA/VID data and projections on educational attainment [10] the population is first divided into four education categories (none, primary, secondary and tertiary – where for Europe the first category is irrelevant). We then apply different weights to these categories, both with regard to the dependency burden due to the cost of education and to differential support (considering education-specific productivity) that people in working age can supply for those not in working age. This is simply an extension of the conventional total dependency ratio in which the strong and unrealistic assumption is made that every person of working age will make the same contribution to the support of the dependent population.

$$Dependency\ Ratio = \frac{Children + Retired}{Working}$$

$$Working = pop_{prim}^{16-57} * ed1weight + pop_{sec}^{19-61} * ed2weight + pop_{tert}^{26-65} * ed3weight$$

$$Children = pop_{preschool}^{0-5} * ed0cost + pop_{prim}^{6-10} * ed1cost + pop_{sec}^{11-18} * ed2cost + pop_{tert}^{19-25} * ed3cost$$

$$Retired = pop_{prim}^{58+} * pencost + pop_{sec}^{62+} * pencost + pop_{tert}^{66+} * pencost$$

Since there is overwhelming evidence that in virtually every society the more educated are more productive in economic terms and hence contribute more, this effect is captured here in terms of giving them higher weights when calculating the denominator of the dependency ratio.[1] In the equation above, $ed1weight$ refers to the weight given to working age people with only primary education (this is usually set to 1.0), $ed2weight$ refers to those with at least junior secondary and $ed3weight$ to those who have at least a completed first-level tertiary education. In the figures below, the specific assumptions made are listed in the box on the upper left. In all other respects this analysis makes the same simplifying assumption as the usual dependency ratios (that everybody of working age who no longer goes to school is in the labour force, there is no unemployment, etc).

As far as the dependents (numerator of the education-weighted dependency ratio) are concerned, retirees all get the same weight ($pencost$, here assumed to be 1) but the ages of labour market entry and exit are education-specific. In other words, uneducated and primary-educated people are assumed to move from the numerator of the dependency ratio to the denominator after age 15, secondary- educated after age 18, and tertiary- educated follow at the age of 25. We also assume that those getting secondary and tertiary education require a higher education input after the age of 10. Here the assumed values are listed under ed_cost where the cost is 1.0 for everybody up to age 10. It is then increased to $ed2cost$ for those with secondary education up to age 18 and to $ed3cost$ for those going on to study to age 25.

But education has benefits as well as costs. When retiring from the labour market and thus returning to the numerator, the primary-educated – initially – are assumed to make the transition at the age of 57, secondary educated retire at 61, and tertiary educated at 65. These assumptions roughly resemble the current empirical evidence from Europe. However, current trends across the continent strongly suggest these ages will increase over the coming decades. Therefore, as life expectancy goes up in our model, labour market exit is also delayed. For simplicity the retirement ages are assumed to be the same for men and women, but this could easily be changed as could all of the other assumptions on weights and transition ages.

[1] The specific weights at this stage are rather arbitrarily chosen because of only fragmentary empirical evidence, but as sensitivity analysis shows in the following, the optimum does not respond greatly to the choice of these weights. Rather they affect the level of the dependency ratio.

4. Results

In the context of real populations with non-stable age distributions the time dimension becomes extremely important in this exercise. If the time horizon for optimization is only 10 or 20 years, the optimum for minimizing the dependency ratio is very different from that of a longer time horizon. In all the following figures it was assumed that the fertility moves from its current level to the target level (listed on the TFR-axis) by 2030 and then remains constant. The standard assumption used here for all education trends is the global education trend (GET) scenario – defined as a mildly optimistic baseline in the IIASA-VID education projections. It assumes a further improving trend following the countries that are already more advanced in their educational structure with tertiary education assumed to level off at a maximum proportion of 60 percent of a cohort. A three-dimensional representation of our base line results for the EU-27 is given in Figure 3. Different cuts through this "dependency-valley" show the dependency-minimizing levels of fertility in selected years. Figure 4 depicts the same results in two dimensions, highlighting the relationship between the education-weighted dependency ratio and different levels of fertility for the EU-27 and China.

Figure 3: Dependency Ratio for Global Education Trend (GET) – Scenario. Base line for EU-27, 2010-2100.

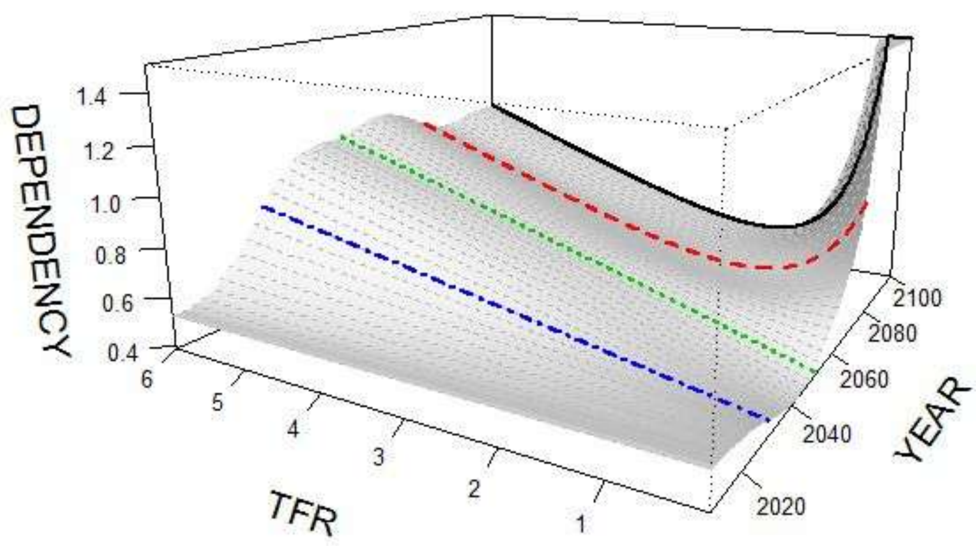
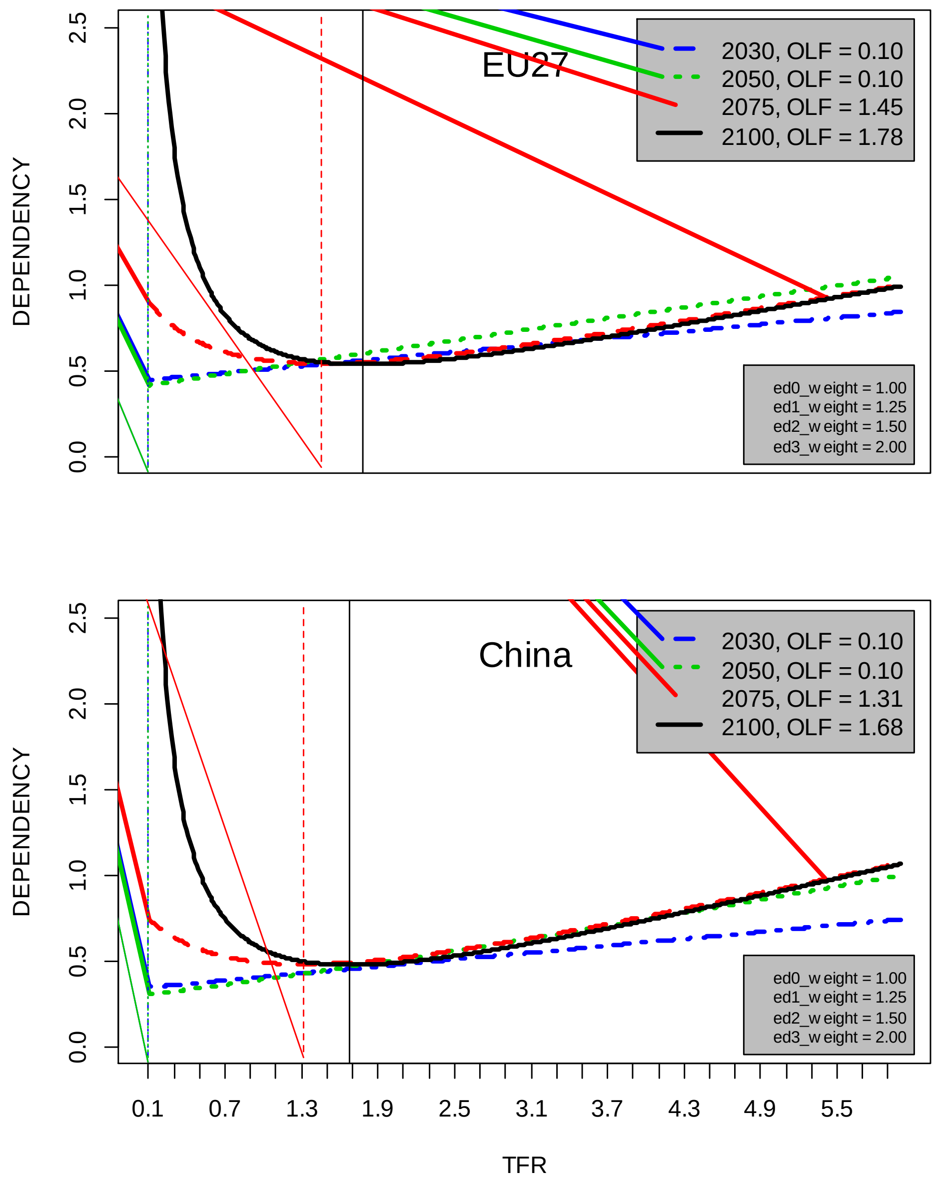


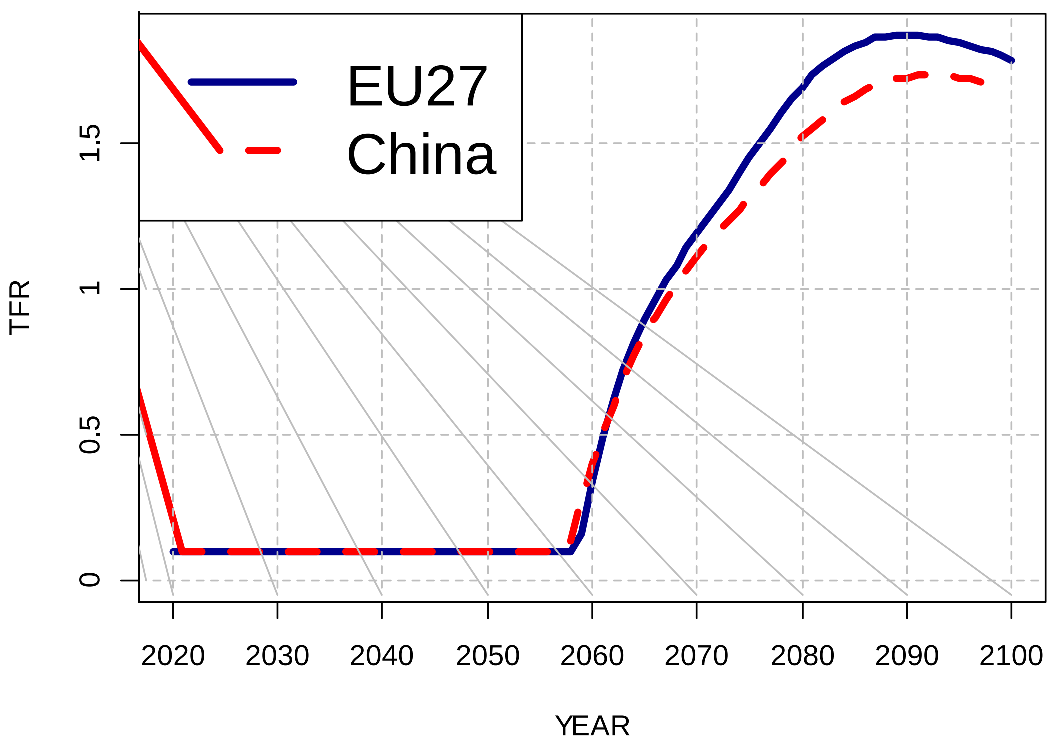
Figure 4: Dependency Ratio for Global Education Trend (GET) – Scenario. Base line for (a) EU-27 and (b) China with lines at 2030 to 2100.



As shown in Figure 4 (a) and (b), extremely low fertility turns out to be optimal for all time horizons in which these fewer children do not yet affect the size of the labour force but only bring down young age dependency. Under such a short time horizon, not to have any children is best. Such a policy decreases the dependency ratio, but is of course very short-sighted because it will begin to starve the economy of workers after 15 years. As can be seen in the second half of the century the pattern of an inverted U-shape appears which characterizes the graphs for the longer run. It is also interesting to note that the curve inclines more steeply to the left for cases of extremely low fertility and somewhat slower to the right for cases of high fertility. The optimal level of fertility (OLF), that is, the TFR which shows the lowest level of education-weighted dependency, is also indicated for different points in time in the box in the upper right corner.

Figure 5 goes further into detail showing the total fertility rates minimizing dependency in every year up until 2100 for the EU-27 and China. And as we shall see, in the GET-scenario for any year these levels of TFR are well below replacement level fertility and within the range that was indicated by the population balance model.

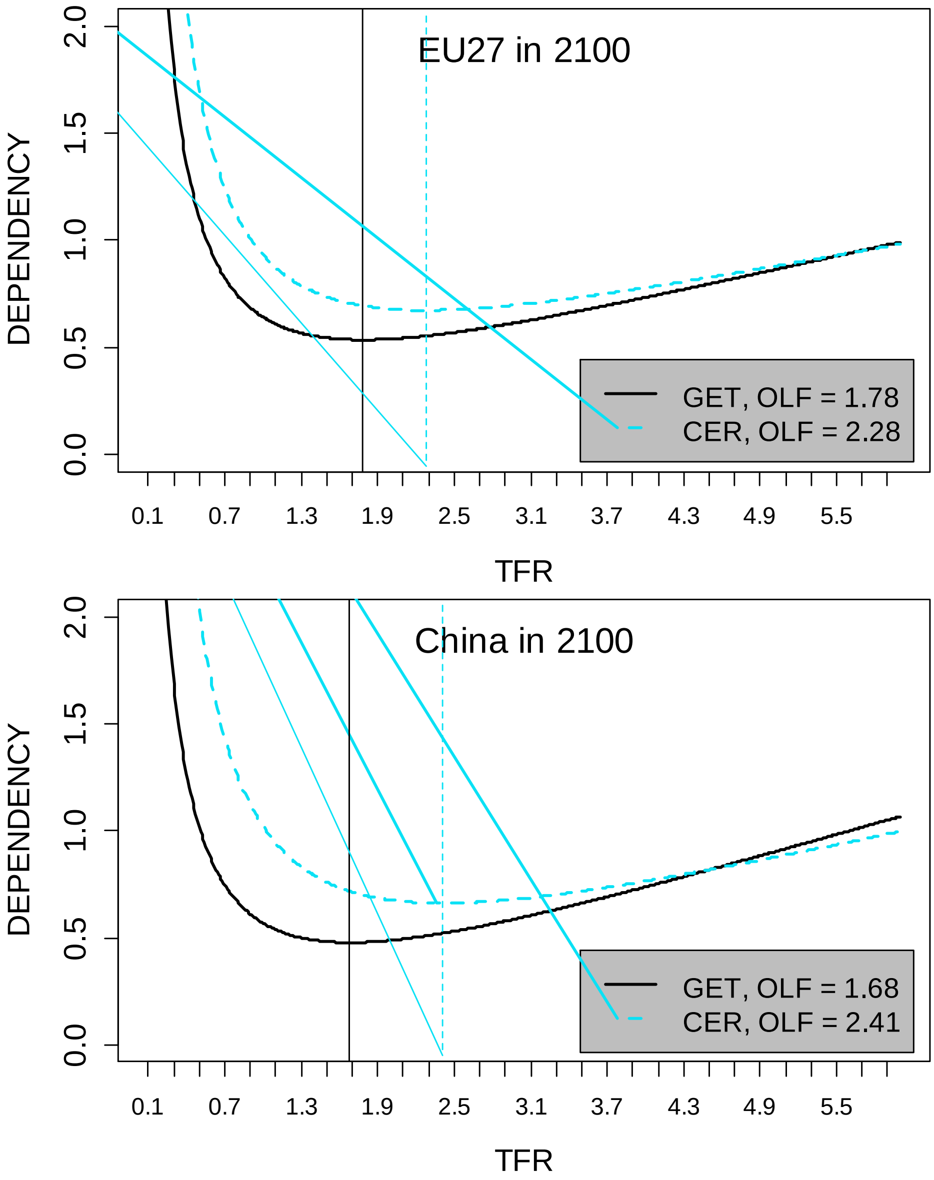
Figure 5: Optimal TFR for the EU-27 and China (GET), individual years 2020-2100.



But what, if the educational system does not, as assumed in the GET-Scenario, continue to expand over the course of the 21st century but rather shows stagnation? In our next step we are looking at the sensitivity of the education-weighted dependency ratio with respect to alternative educational structures of the population. This is illustrated in Figure 6 for the cases of the EU-27 and China where we compare our baseline scenario with the CER (Constant Enrolment Rate) – Scenario. It assumes constant education levels based on current (2010) age-specific school enrolment rates. This implies that future young cohorts will not get a better education than the current one, but still the overall educational composition of the population will improve over several decades as the younger typically better educated cohorts will replace the older less educated ones.

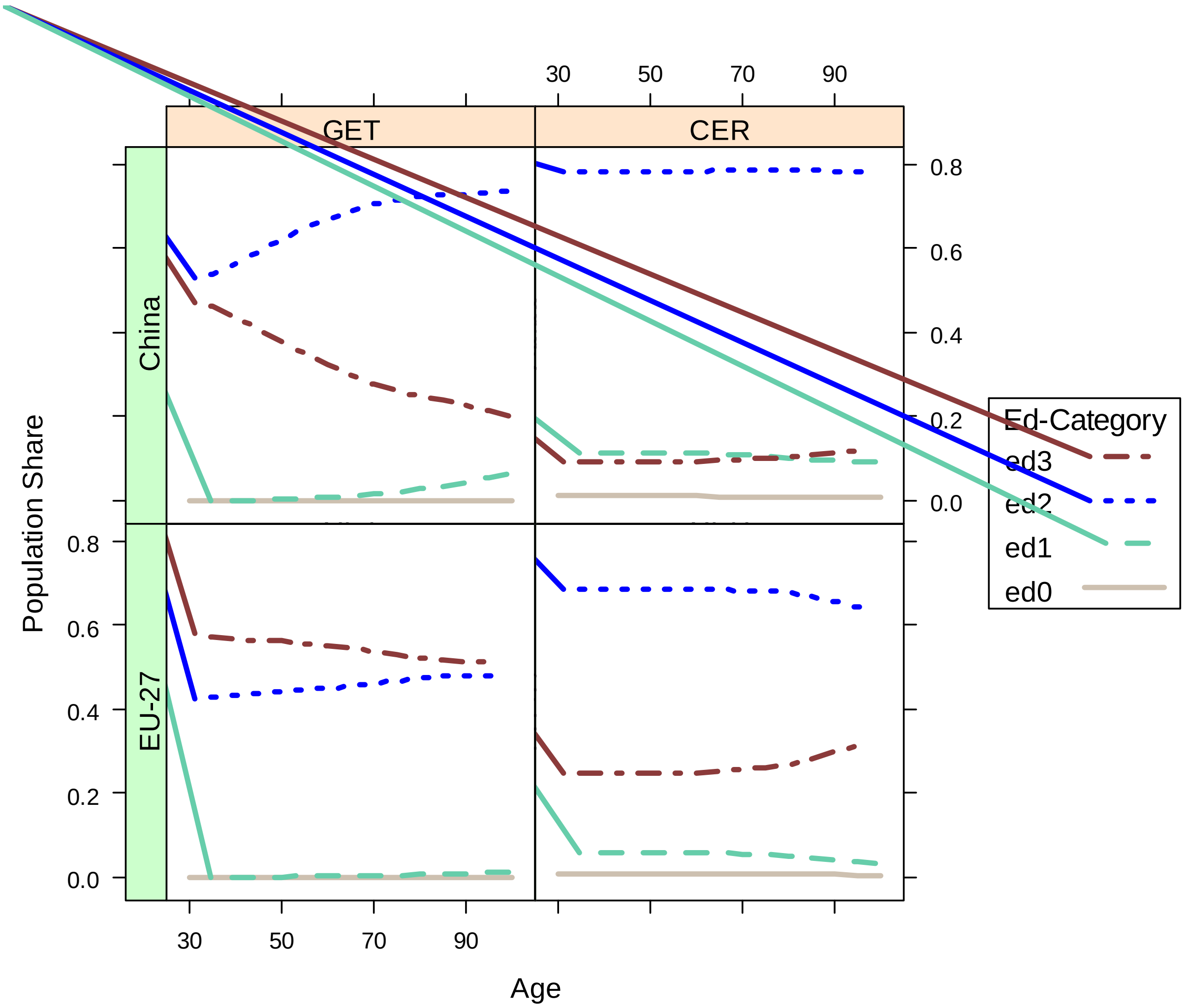
The picture clearly shows that more education not only brings a lower education-weighted dependency ratio (and hence a higher level of per capita material wellbeing) but also that the optimal TFR is lower in a population with higher average education. Whereas in Europe it decreases from an average of 2.28 to 1.78 children, switching from CER to GET in China the OLF (Optimal Level of Fertility) is down from 2.41 to 1.68 children. This reduction is rather insensitive to the choice of the relative productivity weights. It is primarily due to the increased total education cost which makes children more expensive and the increased average age of retirement which in the optimum requires a smaller number of children to pay for a smaller number of future pensioners.

Figure 6: The effect of alternative education trajectories. Dependency Ratio in 2100 for the EU-27 and China.



In order to better understand the appearing patterns, Figure 7 depicts the trends in the proportions with different levels of education under the two education scenarios. As the educational system in Europe is already quite developed in 2010, the continuation of 2010 enrolment rates leads to quite a high share of people with tertiary education in 2100. China, on the other hand, still has a lot of potential for catching up. As a consequence, switching from a world following the GET-scenario to one that evolves according to the CER-scenario has a stronger effect in China than in the EU-27. Having more people with tertiary education, both in Europe and China, means having less people with secondary education that enter the labour market earlier. But the decrease in the overall level of dependency by 2100 that is due to this effect is much more expressed in China than in the EU-27. This is despite of the additional costs from keeping more children in school for up to ten years longer.

Figure 7: Alternative education trajectories for the EU-27 and China in 2100. Shares of population by age and education category.

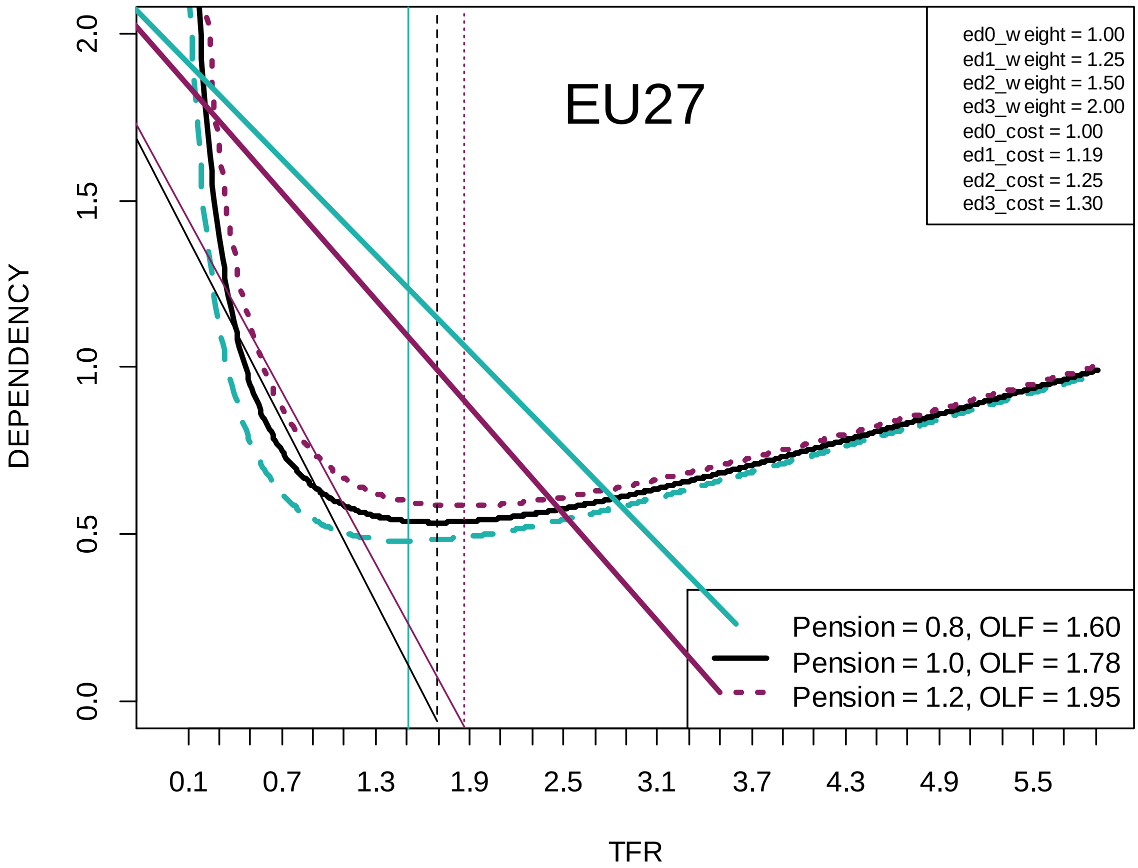


It is worth noting that, if education came at no cost, of course, having ever more children which are ever better educated and therefore more productive can only lead to an ever lower level of overall education weighted dependency. But as will be discussed later, particularly in the context of climate change there are other reasons why an ever growing population might be optimal even with better education. Before entering this discussion, however, we will present some sensitivity analysis of the above described findings with respect to several key model parameters.

5. Sensitivity Analysis

The following graphs will show some sensitivity analysis with respect to the specific weights chosen in the above presented baseline model, as well as the effect of an increase in the pension age for all educational subgroups of the population. While we have performed large numbers of alternative model calculations, Figure 8-11 only summarize the findings with respect to the parameters which the model is most sensitive to. General changes in the education weights for the numerator (ed_weight) and denominator (ed_cost) mostly influence the level of the dependency ratio and have only minor influence on the shape of the curve, i.e. the resulting optimal TFR. But, as might be expected, the shape of the curve is rather sensitive to changes in the pension age, as well as the pension burden ($pencost$) relative to the contribution of working age people. Figure 8 below shows three alternative pension costs (0.8, 1.0 and 1.2 - as compared to workers without education) for the case of the EU-27 for the year 2100. It clearly shows that the higher the level of pension payments relative to the education-specific productivity of active people, the higher the dependency ratio and the higher the optimal level of fertility. In other words, under this scenario more children are required to expand the workforce in order to pay for a higher welfare level of pensioners. As shown in Figure 4, a pension level of 1.0 in the EU-27 results in an optimal fertility of 1.78. If we increase the pension level to 1.2, it would be optimal to have 1.95 children. But one can also read this in a different way and see what pension level would be optimal at a given level of fertility (assuming that fertility cannot be influenced). Then, of course, the result is that the dependency ratio is the lower – and thus more welfare-enhancing – the lower the relative pension cost.

Figure 8: The effect of different pension levels. Dependency Ratio for Global Education Trend (GET)-scenario in 2100 with three lines for pension cost 0.8, 1.0, and 1.2, respectively



An alternative way of decreasing the dependency ratio is to increase the age of exit from the labour market, as shown in Figure 9 below. However, our results suggest that an increase of the average pension age by 2 years (59-63-67) not only raises the general welfare level as measured by our dependency ratio, but it also remarkably decreases optimal fertility. Compared to our baseline results in Figure 4, the level of fertility that minimizes dependency in 2100 is reduced to 1.70 (from 1.78). If again one takes the level of fertility as given, people have to stay in the labour force longer, the smaller the young cohorts to replace them.

Figure 9: The effect of higher pension ages. Dependency Ratio for Global Education Trend (GET) – Scenario in 2100

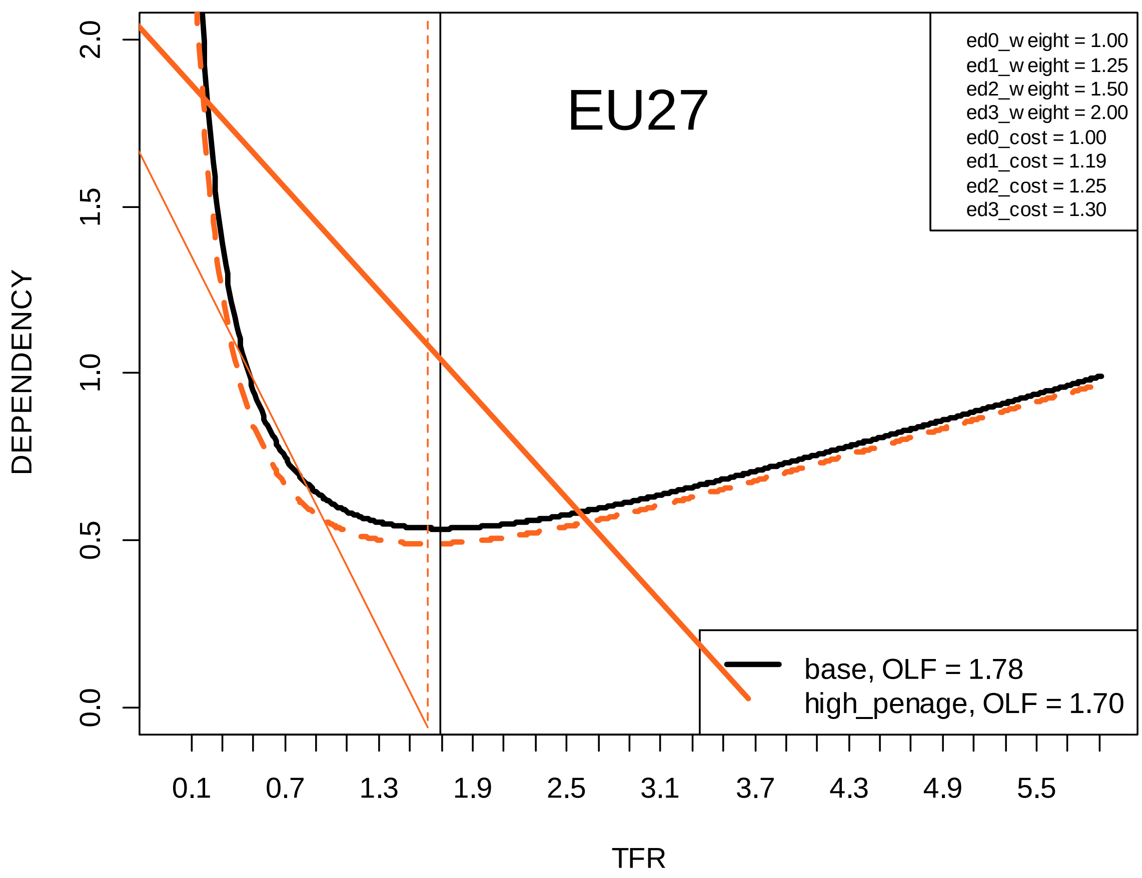


Figure 10 shows what effect an automatic adaptation of the pension-age to gains in life expectancy would have on the optimum. This is shown for three different values of the pension age's "life expectancy elasticity". A value of 0 in the box in the lower right corner means that all life years gained are years spent in retirement, that is, in the numerator of our dependency ratio. As can be seen, this leads both to a higher dependency burden and to a higher optimum TFR compared to the baseline. Likewise, a value of 1 corresponds to all additional life-years spent as part of the labour force. Not only do we observe a lower level of our dependency ratio, also the optimum shifts significantly to the left. It is shown thereby that whether there is more or less of a need for children as a means of supporting our older future population, strongly depends on the extent to which future gains in life expectancy will be translatable into an increased number of years spent as part of the labour force.

Figure 10: The effect of different shares of gained life-years spent in the labour force. Dependency Ratio for Global Education Trend (GET) – Scenario in 2100.

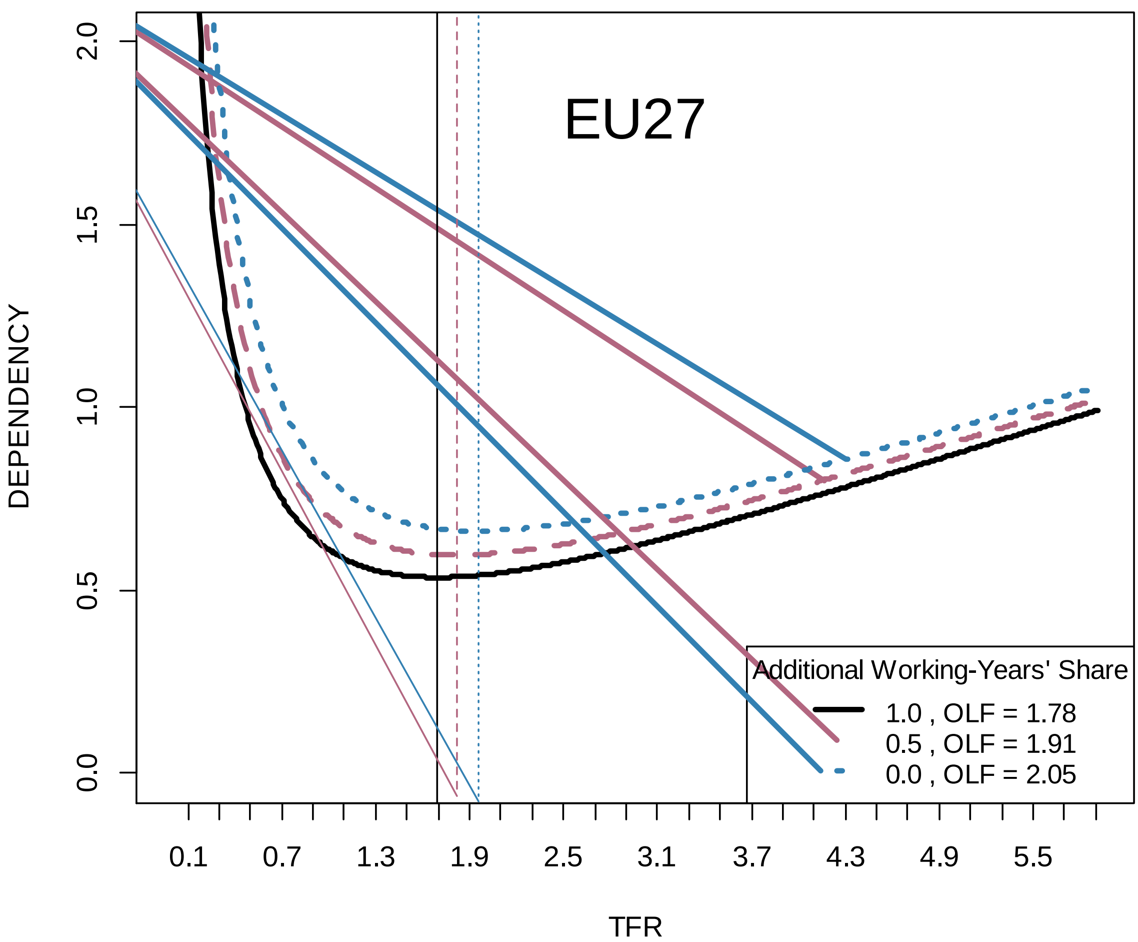
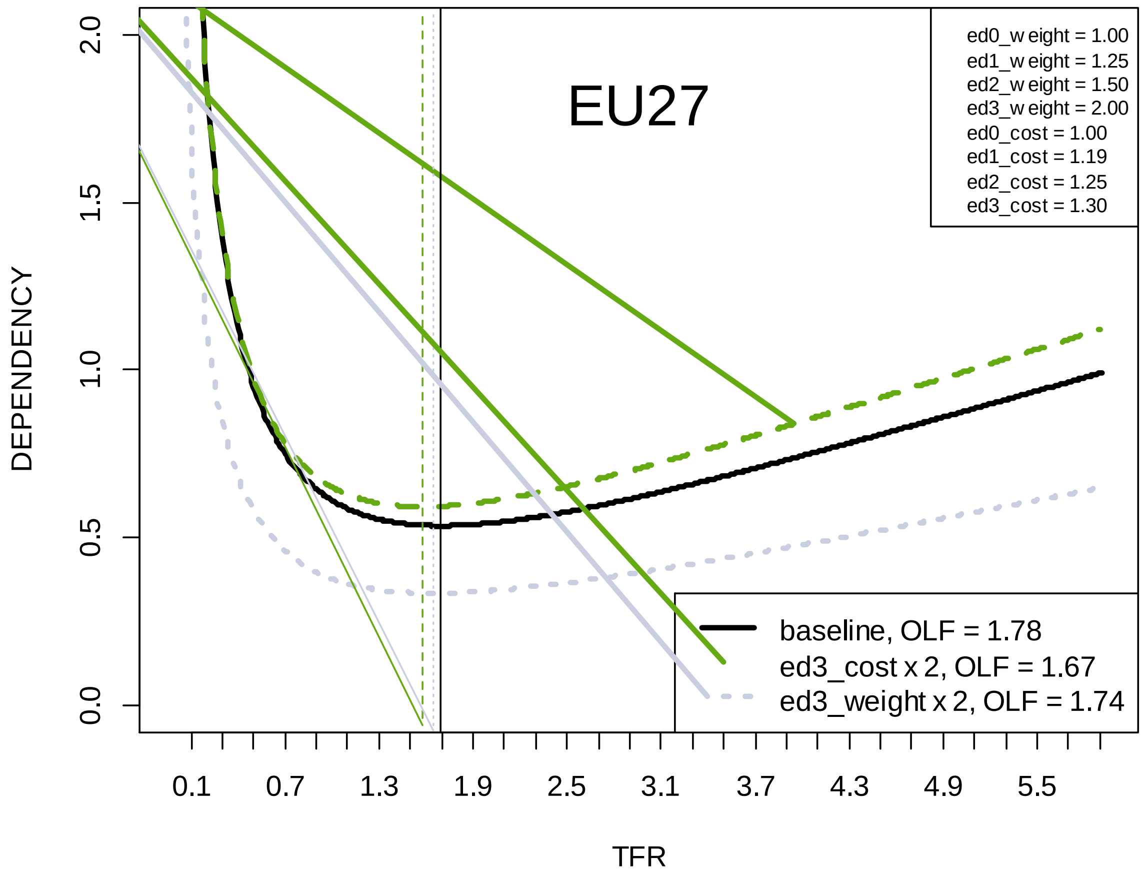


Figure 11 closes our sensitivity analysis looking at the assumed costs as well as the returns to tertiary education. Comparison with our baseline results for EU-27 shown in Figure 4 reveals that if the returns to tertiary education are doubled (all other things being the same) then the overall level of dependency hugely decreases (remember that the baseline GET scenario assumes 60 percent with tertiary education in the long run) while the optimal level of fertility declines from 1.78 to 1.74. When the burden (cost) of tertiary education doubles the support ratio declines by much less. This is because the time people spent in tertiary education is rather short as compared to their working life. The optimal level of fertility also moves to 1.67.

Figure 11: Baseline with high tertiary education cost and high tertiary returns. Dependency Ratio for Global Education Trend (GET) – Scenario in 2100.



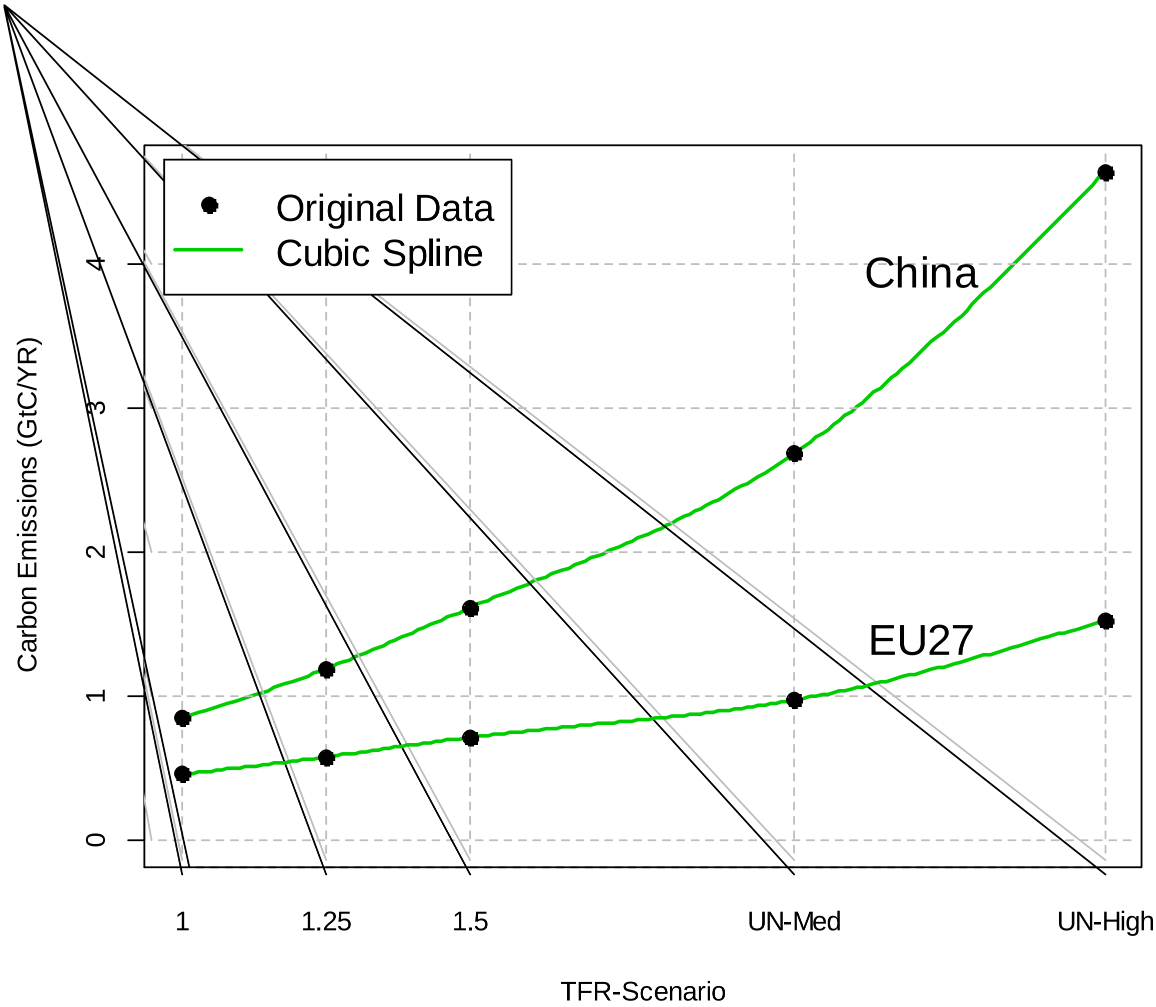
In conclusion, this brief exercise in education specific population dynamics shows that against widespread expectation, it is far from self evident that replacement level fertility should be considered optimal. If education is factored in, a TFR quite clearly below replacement turns out to be optimal. Only very high pension incomes relative to earnings of people in the labour force result in higher optimal fertility but this also comes at the cost of much higher levels of dependency and therefore lower levels of overall well-being.

6. Adding the climate change dimension

In times of major concerns about global climate change, the possible impacts of different demographic trajectories on future paths of greenhouse gas emissions and on future generation's ability to cope with the expected negative consequences of climate change also must be taken into consideration. In order to assess what these different long-term levels of fertility mean in terms of CO_2-emissions but also, to find out, how considering CO_2-emissions affects the optimum level of fertility, we will now combine our results with those from [8]. Using the PET (Population-Environment-Technology) model, O'Neill et al. project global, as well as regional CO_2-emissions based on different fertility assumptions. The PET model is a nine-region dynamic computable general equilibrium model of the global economy with a basic economic structure that is representative of the state of the art in emissions scenario modelling. Their results for the EU-27 and China, fitted with a cubic smoothing spline [11], are shown in Figure 12.[2] As can be seen, CO_2-emissions do not decrease linearly with fertility. This is due to the fact that energy consumption is linked to the number of households as well as to the number of people. As fertility goes down, the number of households declines at a slower rate than population due to population ageing and the fact that many elderly tend to live alone.

[2] While in Figure 12 the data points for UN-Med and UN-High come directly from the O'Neill et al. paper (following the fertility paths over time as assumed by the UN) the results for 1.0, 1.25 and 1.5 for China and the EU come from special model runs by O'Neill and colleagues as presented in the opening plenary of the European Population Conference 2010 in Vienna.

Figure 12: CO_2-emissions for the EU-27 and China in 2100 following from different long-term fertility levels. Source of original data: O'Neill et al..



If we were to care only about this environmental dimension, there would be little doubt that fewer people would be better and the resulting optimal TFR would be zero. In assessing what's optimal in terms of fertility, therefore, the challenge lies in assigning reasonable weights to the environmental consequences of human reproduction on the one hand and the costs and benefits arising from the ageing dimension on the other. Our results presented in Figure 13 assume that emphasizing the environmental dimension with more than 20% would be unrealistic. But even when we do not put a heavy weight on the resulting level of emissions, there is a downward effect on the optimal TFR, both for the EU-27 and China.

Figure 13: Optimal Fertility for the EU-27 and China in 2100 with 5 different weighing schemes.

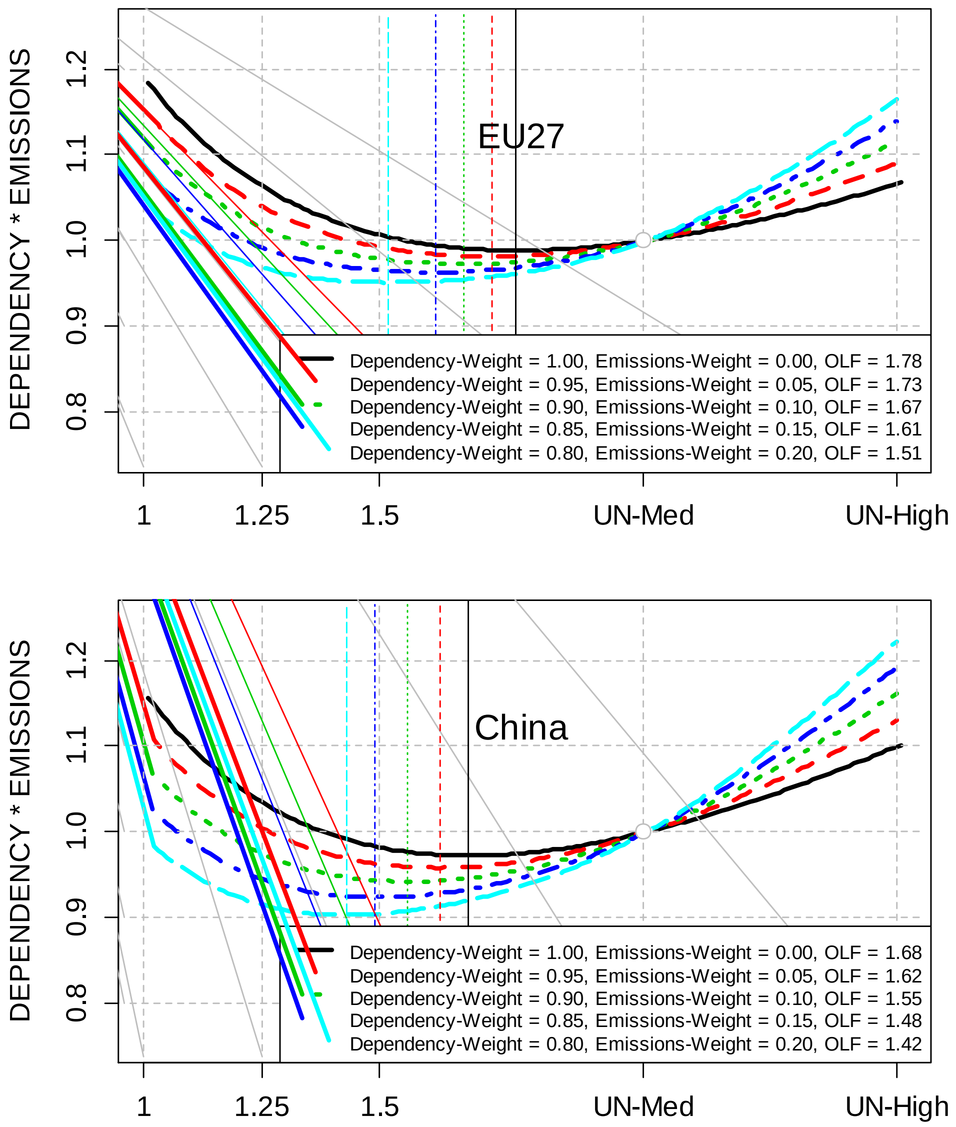


Table 1: Results for Global Education Trend (GET) Scenario, EU-27 and China in 2100.

Country	Dependency Weight	Emissions Weight	OLF	Emissions-Weighted Dependency	Dependency	Carbon Emissions (GtC/Yr)	Population (in 1000)
EU-27	1.00	0.00	1.78	0.99	0.535	0.83	354421
	0.95	0.05	1.73	0.98	0.535	0.81	338758
	0.90	0.10	1.67	0.97	0.536	0.78	320624
	0.85	0.15	1.61	0.96	0.538	0.76	303196
	0.80	0.20	1.51	0.95	0.544	0.72	275671
China	1.00	0.00	1.68	0.97	0.478	1.90	882632
	0.95	0.05	1.62	0.96	0.479	1.81	831036
	0.90	0.10	1.55	0.94	0.480	1.69	773768
	0.85	0.15	1.48	0.92	0.484	1.58	719545
	0.80	0.20	1.42	0.90	0.488	1.47	675408

Table 1 summarizes the results of different weights applied to the combination of the two optimality criteria dependency rate and greenhouse gas emissions. In the case of a weight of zero being applied to emissions, the results are identical to those presented in the front part of the paper. If emissions are given a weight of 0.20 and dependency of 0.80, then the resulting optimal level of fertility by 2100 turns out to be much lower, 1.51 in Europe and 1.42 in China. As the right hand side of the table indicates, due to the rather flat optimum of the dependency rates this fertility level that is about a quarter child (0.26 TFR) lower comes only at the expense of a very small deterioration in the education-weighted dependency ratio while it results in significantly less greenhouse gas emissions and is associated with substantially lower total population sizes by the end of this century.

6. Discussion[3]

Many governments in Europe report in international enquiries that they are dissatisfied with the current levels of fertility in their countries in the sense that fertility is considered as being too low. The further one goes to the east of the continent, the stronger the publicly expressed concern. While the prime minister of Bulgaria calls his country's 'demographic crisis' the number one policy priority, the president of Belarus even speaks of a national 'demographic security crisis', implying that this may require equally drastic action as a security crisis at the military level. Less dramatic in tone but equally urgent in its message, the President of the European Commission repeatedly called Europe's demographic trends one of the three main challenges facing Europe, the other two being globalisation and technological change.

What do these policy makers have in mind when they refer to demographic crises or challenges? In the eastern part of Europe, where most countries (with the notable exception of Russia, which received many Russians from other former Soviet republics) have experienced significant population declines since the political transformation around 1990, the concern seems to be very strongly associated with the fear that the country will lose its population base. Bulgaria, for example, had close to 9 million inhabitants in the late 1980s; now (2008) it has only 7.6 million and is projected by Eurostat (2008) to further shrink to around 6.5 million in 2035 and 5.5 million in 2060. This loss of more than one-third of its entire population, which is also associated with very rapid population ageing, is indeed significant, particularly in the context of traditional thinking, where more population meant more soldiers and more power, but also in view of the fact that throughout human history, population shrinking has always been associated with misery and national decline. But in terms of causality, in the past the disasters (wars or diseases or severe economic crises) came first and resulted in the population declines rather than the other way round. "Voluntary" population decline through very low fertility in times of peace is a new phenomenon and its consequences are still largely conjectural.

Hence, in terms of psychology and inference from the past this reaction in Eastern Europe is understandable but not necessarily correct with respect to the future. In Western Europe the story has been less dramatic because thanks to migration gains, only very few countries are

[3] Part of this section has previously been published by Wolfgang Lutz as a commentary in VYPR 2008

already on a declining trajectory and the public policy concern is mostly with respect to the implications of population ageing.

In the global-level policy debate, for decades the notion of 'population stabilisation' has been the guiding principle and the explicit goal of virtually all population-related policies, both within the United Nations (UN) system and outside. The international political goal of population stabilisation corresponds nicely to the UN population projections which used to assume that in the longer run, all countries of the world converge in their fertility rates to replacement level, resulting (in combination with an assumed levelling-off of life expectancy) in a long-term stabilization, i.e. constant size of the world population as well as of the population of all individual countries. Such a perceived future of population stabilisation is likely to please government officials who do not want to see their population as either disappearing or exploding in the long run. The only problem with this politically attractive concept is that the empirical evidence from the past decades does not seem to support it. With very few exceptions (including France and the US) most countries went well below replacement level, once they had reached this level. This trend is particularly strong in East Asia, affecting a quarter of the world population. As to the future, the trends are highly uncertain and contested.

But what does this political goal of aiming at population stabilisation actually mean at the level of individual countries that experience rapid population shrinking? What does the goal of population stabilisation imply for Bulgaria? Does it call on the government to bring the population back up to the 9 million mark of the late 1980s, or keep it constant at the current 7.6 million, or stop it from declining below 7.0 million? None of these seem to be a realistic goal for Bulgaria. But what would be an appropriate population-related goal for a country like Bulgaria? Since this is not obvious, we see a great need for coming up with a more useful and more comprehensive policy paradigm and goal that includes education as well as the number of people by age and sex.

> BOX – **Human capital**: 'People are the wealth of nations. But it is not only the number of people that counts, it is also the skills, abilities and health status of the people that matter. All these aspects viewed together can be called the human resources base, or human capital in more economic language. This broadened view of population also implies that political goals should not be defined in terms of

population size but rather in terms of human resources available for producing the best possible quality of life for all citizens.' *Wolfgang Lutz, in role as population adviser to Bulgarian Government*

This focus on human capital is not new in the history of demographic thinking. In 1958 Alfred Sauvy wrote in the context of the miracle of Germany's economic rise after total destruction in 1945 and the fact that it had to absorb five million refugees:

> Why this success, contrary to the forecasts of all doctrines…? Because these men without capital came with their knowledge, their qualifications. They worked and they recreated the capital that was lacking, because they included a sufficient number of engineers, mechanics, chemists, doctors, sociologists, etc. If five million manual workers had entered Western Germany instead there would be five million unemployed today [12] (p.169).

Despite the demographic prominence of Sauvy, mainstream demography has not really incorporated this important line of thinking. Instead such "quality dimensions" were considered too difficult to measure and largely left to economists. Only the more advanced demographic tools of multi-state population dynamics, pioneered at and around IIASA in the 1970s, now allow us to fully and quantitatively integrate the educational attainment dimension into formal demography. As the title of an article by Lutz, Goujon and Doblhammer "Adding Education to Age and Sex" suggests, it seems to be time to more systematically apply the human capital approach in standard population analysis and consequently in population policy [13].

This broader view of demography which includes educational attainment as a standard demographic dimension in addition to age and sex has also great relevance when it comes to studying the likely future adaptive capacity of populations to already unavoidable climate change. A recent statement by a prominent group of international scientists published as a letter in Science [14] concludes: "Invest in human capital – people's education and health, including reproductive health – to slow population growth, accelerate the transition to green technologies, and improve people's adaptive capacity to environmental change".

Two other prominent statements about to be released these days in preparation for the Rio+20 Summit on Sustainable Development (one by the Royal Society and one by an Inter-academy Panel) also highlight the view that changes in population have significant impacts on environmental changes which in turn threatens future human wellbeing.

In essence, all these statements with the inputs from hundreds of distinguished scientists stress that less population growth would be better for the environment and for future human wellbeing. But rather curiously much of the focus is on population growth in Africa and countries that (at least currently and in the foreseeable future) contribute very little to global greenhouse gas emissions.

In this paper, we looked at the effect of lower fertility in countries that are big per capita polluters. In those countries, clearly a reduction in population size causes a greater reduction in total emissions and hence has a bigger positive impact on the global climate. Under this view, current fertility in the US and in France is clearly too high (and maybe Germany and Austria have optimal levels of fertility, once the current tempo effect is taken into account).

Much more research is needed on this equally important and complex topic. This paper only wanted to open up a new field of discussion and analysis. The first very tentative results seem to suggest that maybe longer term fertility levels somewhere between 1.5 and 1.8 are the best for our planet and will at the same time result in future higher welfare as long as we invest more in the education of our slowly declining number of children.

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