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**Discussion Papers**

**556**

**Michael Grimm  
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**Longer Life, Higher Welfare?**

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# Longer life, higher welfare?

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**Abstract** Whereas life expectancy continues to increase in most industrialized countries many developing and transition countries are today confronted with decreases in life expectancy. Usual measures employed to compare welfare over time and space fail to deal with such demographic change and may lead to the so-called ‘repugnant’ conclusion that lower life expectancy involves higher welfare per capita. We illustrate this type of transmission channel using various welfare criteria and reference populations. We also consider feed-back effects from the demography on the economy using a neo-classical growth model. We show that the ‘repugnant’ conclusion can be avoided if we choose a lifetime welfare measure instead of a period (or snapshot) welfare measure. All concepts are illustrated empirically using a small sample of developed and developing countries.

**JEL Classification:** D63, I31, J11.

**Key words:** Life expectancy, repugnant conclusion, welfare comparisons.

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# 1 Introduction

Whereas life expectancy continues to increase in most industrialized countries, many developing and transition countries are today confronted with decreases in life expectancy, among other things caused by the AIDS epidemic and worsening health conditions especially in transition countries (see e.g. UNAIDS, 2004). Usual welfare comparisons over time and space face the problem that they fail to deal with such demographic changes. Aggregate welfare indicators, as GDP per capita, do neither reflect differences in life expectancy nor do they account for the number of preventable deaths. More precisely, standard welfare measures usually disregard non-material sources of personal well-being and have a strong focus on annual income flows, at least in the empirical literature. Under these assumptions, cross country welfare comparisons are not affected by differences in life expectancy. Likewise, we usually sidestep the issue of variations in population size, by undertaking welfare comparisons in per capita terms. Then the implicit ethical judgment is that we are ‘neutral’ to the population and indifferent to the unborn. As discussed by Kanbur and Mukherjee (2003), Becker, Philipson and Soares (2005) and recently empirically illustrated by Ravallion (2005) a similar problem is also inherent in standard poverty measures and inequality measures. If the poor face higher mortality rates than the rich, the poverty headcount index decreases over time. Or, to put it bluntly, higher mortality among the poor is ‘good’ for poverty reduction. The current AIDS epidemic in developing countries, the 1918 influenza epidemic and the black plague centuries ago might have reduced poverty by increasing the capital-labor ratio, but also simply by killing the poor harder hit by the diseases.<sup>1</sup> Most people will agree that this kind of ‘repugnant conclusion’ (Parfit, 1984) is incompatible with value judgements one may like to postulate when undertaking welfare comparisons over time and space.<sup>2</sup>

The ethical and axiomatic issues related to welfare rankings of alternatives with different populations are discussed in detail in a recent and excellent monograph by Blackorby, Bossert and Donaldson (2005). Our objective is not to contribute to the theoretical literature on population principles, but instead to suggest and illustrate welfare measures which take into account demographic change and which can help to avoid the ‘repugnant conclusion’. In a first step we incorporate the dynamics of demographic change in aggregate welfare comparisons. To do this, we use the methodology of

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<sup>1</sup>For instance, Brainerd and Siegler (2003) find empirical evidence that the 1918 influenza epidemic had a significant positive effect on per capita income growth across the US states in the 1920s.

<sup>2</sup>From a theoretical point of view, a welfare criteria implies the ‘repugnant conclusion’ if and only if any alternative in which each member of the population has a positive utility level, no matter how high, is ranked as worse than some alternative in which a larger population has a utility level that is above neutrality but arbitrarily close to it (see Blackorby, Bossert and Donaldson, 2005).

general multitype branching processes (Mode, 1971) allowing to compute long-term welfare indicators for levels and distributions for the steady state population resulting from currently observed demographic developments. In other words, the steady-state or stable population constitutes the reference population incorporating the long-term effects of currently observed demographic change which is not reflected in usual welfare comparisons. We illustrate how welfare comparisons using such type of reference population are affected by changes in life expectancy. In a second step, we consider also economic feed-back effects from a standard Solow-type growth model, but in which we incorporate more realistic demographic assumptions. This exercise will highlight the economic transmission channels between changes in life expectancy and per capita income by considering the joint development of the mean age at consumption, the mean age at activity and the equilibrium per capita capital stock. Such an analysis nicely shows which mechanisms drive the ‘repugnant conclusion’. In a third step, we show that a switch from period welfare measures to lifetime welfare measures can avoid that conclusion. All three steps are illustrated empirically using a small sample of countries some of them strongly affected by the AIDS epidemic and all at very different stage of development.

The rest of the paper is organized as follows. Section 2 presents our theoretical framework and our methodology. Section 3 describes the sample of countries and the data sources used for illustrative purposes. In Section 4, first the steady state welfare properties for the different countries are analyzed. Welfare rankings using the population at the steady state are compared with standard welfaristic rankings. The transition paths to the steady states are analyzed and welfare comparisons for alternative assumptions on life expectancy are undertaken. Second, the impact of economic feed-back effects is considered. Third, the previous analysis is extended by considering a lifetime income instead of a period income measure. Section 5 concludes.

## 2 Theoretical foundation and methodology

### 2.1 Welfare changes without economic feed-back effects

In a first step we make the assumption that personal well-being—for simplicity ‘income’ in what follows—in period  $t$  of individual  $i$ ,  $y_{it}$  is solely determined by the age of individual  $i$  in  $t$ ,  $a_{it}$ , that is:

$$y_{it} = f(a_{it}). \tag{1}$$

In consequence, we omit all other factors which might influence  $y_{it}$ , at the level of the individual as well as at the level of the whole economy. In such an economy all changes in mean income  $\bar{y}_t$ , the distribution of income  $F_t(y_t)$

or in any welfare index like  $W(F_t) = \int_{y_t=0}^{y_t^{\max}} w(y_t) dF_t(y_t) dy_t$  ( $w$  being a non-decreasing function of  $y_t$ ) are then driven by changes in the population age structure. For instance, mean income  $\bar{y}_t$  is simply the age income schedule  $f(y|a)$  integrated over the population density function observed in  $t$ :

$$\bar{y}_t = \int_{a=0}^{a^{\max}} f(y|a) dF_t(a) da. \quad (2)$$

If age is measured in discrete terms, e.g. in years, we can write equivalently:  $\bar{y}_t = \sum_{a=0}^{a^{\max}} y(a) g_{t,a}$ , where  $g_{t,a}$  is the population share at age  $a$  in  $t$ . Again, the income schedule  $f(y|a)$  is assumed completely exogenous, i.e. without considering any feed-back effects of changes in the population age structure on  $f(y|a)$ .

Obviously if this framework is used welfare comparisons over space depend not only on differences in the income schedule  $f(y|a)$ , but also on differences in the population age structure  $dF_t(a)$ . Usual welfare comparisons neglect this issue, i.e. comparisons in  $t$  do not take into account the effects on  $W(F_t)$  of changes in the population age structure resulting from current mortality and fertility conditions in the medium and long term.<sup>3</sup> Hence, a more adequate comparison would be one using a consistent reference population.

Such a reference population can be constructed by assuming that the currently observed mortality and fertility conditions prevail. It can easily be shown that such a population will converge when  $t \rightarrow \infty$  to a stable population, i.e. a population with a constant age structure and a constant population growth rate. To derive this equilibrium population and its ergodic properties, one can use the methodology of multitype branching processes. The idea of multitype branching processes is that each individual in the population produces a random number of offspring of various types (Mode, 1971). The verb ‘produce’ can refer to very different phenomenon, i.e. females reproducing children or simply to a certain mobility process between different population types. Specifically, an individual of type  $i$  at period  $t$  could ‘move’ to type  $j$  at period  $t + 1$ . In this case between period  $t$  and period  $t + 1$ , individual  $i$  ‘produces’ one unit of himself in the type- $j$  group. In what follows the only type differentiation we consider is by age.

When age is counted in discrete units, the projection matrix of our branching process becomes the so-called  $n \times n$  Leslie matrix (Chu, 1998):

$$Q = \begin{pmatrix} 0 & 0 & \cdots & 0 & F_\alpha & \cdots & F_\beta & \cdots & 0 & 0 \\ p_1 & 0 & \cdots & 0 & 0 & \cdots & 0 & \cdots & 0 & 0 \\ 0 & p_2 & \cdots & 0 & 0 & \cdots & 0 & \cdots & 0 & 0 \\ \vdots & & & & & \ddots & & & & \vdots \\ 0 & 0 & \cdots & 0 & 0 & \cdots & 0 & \cdots & p_{a^{\max}-1} & 0 \end{pmatrix}, \quad (3)$$

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<sup>3</sup>In what follows we neglect the contribution of migration to changes in the population age structure.

where  $F_a$  is the probability that a person aged  $a$  will bear a child,  $\alpha$  and  $\beta$  refer to the youngest and the oldest ages of possible female reproduction,  $p_a$  refers to the probability that a person aged  $a$  can survive to age  $a + 1$ , and  $a^{\max}$  is assumed to be the upper bound of human age.

The Leslie matrix can be decomposed into the following four blocks:

$$Q = \begin{pmatrix} A & 0 \\ D & C \end{pmatrix}, \quad (4)$$

where  $0$  is an  $(n - \beta) \times (n - \beta)$  zero matrix,  $A$  is  $\beta \times \beta$ ,  $D$  is  $(n - \beta) \times \beta$ , and  $C$  is  $\beta \times (n - \beta)$ . Such a block decomposition implies that females older than  $\beta$  can never produce any offspring of type (age)  $\alpha \leq \beta$  in the future. As shown in Chu (1998), all the relevant information regarding the dynamics of the population is contained in  $A$ . The age group beyond the upper bound of reproduction,  $\beta$ , does not contribute to the intrinsic growth rate of the whole population. More precisely, Parlett (1970) proved the following theorem:

**THEOREM 1:** *Parlett 1970, p. 194*

(i) *The eigenvalues of  $A$  and the eigenvalues of  $C$  constitute the eigenvalues of  $Q$ . (ii) No eigenvalue of  $A$  is zero, and all eigenvalues of  $C$  are zeros. (iii) For any eigenvalue  $\lambda$  of  $A$ , let  $v$  and  $u$  be the right and left eigenvectors; that is,  $Av = \lambda v, uA = \lambda u$ . The right and left eigenvectors of  $Q$  are determined by*

$$Q \begin{pmatrix} v \\ \tilde{v} \end{pmatrix} = \begin{pmatrix} v \\ \tilde{v} \end{pmatrix} \lambda, \quad (5)$$

$$(u, \tilde{u})Q = \lambda(u, \tilde{u}),$$

where  $\tilde{v}_1 = D_{1,\beta}v_\beta/\lambda$ , and  $\tilde{v}_j = C_{jj-1}\tilde{v}_{j-1}/\lambda, j = 2, \dots, n - \beta; \tilde{u}_k = 0, k = 1, \dots, n - \beta$ .

Theorem 1 says that to understand the ergodic properties of an age-specific branching process, it is sufficient to concentrate upon the block matrix  $A_{\beta \times \beta}$ . Parlett (1970) showed that  $A$  is nonnegative and positively regular and, in consequence, according to Mode (1971),  $A$  has a positive dominant eigenvalue  $\varrho$  of multiplicity one; that is, if  $\lambda$  is any other eigenvalue of  $Q$ , then  $|\lambda| < \varrho$ . Intuitively, people who are still reproductive can produce children of age 1, who in turn have a positive probability to move to any age equal to or younger than  $\beta$ ; so  $A$  is irreducible. As shown by Chu (1998) the dominant eigenvalue of  $A$ ,  $\varrho$ , is the gross population growth coefficient in the steady state. Formally:

$$\varrho \approx \frac{\sum_{a=0}^{a^{\max}} N_{t+1,a}}{\sum_{a=0}^{a^{\max}} N_{t,a}}, \quad (6)$$



where  $N_{t,a}$  is the number of individuals of age  $a$  in  $t$ . When  $\rho$  is greater than 1, population size will expand, whereas when  $\rho$  is less than one, population size will contract.

Moreover, Chu (1998) also showed that the age structure for ages younger than  $\beta$  will be proportional to elements of  $v$  as  $t \rightarrow \infty$ . Then Theorem 1, can be used to calculate  $\tilde{v}$  and Equation (5) to infer the time-invariance of the overall age structure in  $[0, a^{\max}]$ . More precisely, defining  $B_t$  as the total size of births in  $t$ ,  $B_{t-a}$  as the total size of births in  $t - a$ , where  $a$  refers as before to age,  $l_a$  as the probability that a person can survive to age  $a$ , i.e.  $l_a = p_1 \times \dots \times p_a$ , and  $m_a$  as the average number of births per surviving person aged  $a$ , we can write the following accounting identity:

$$B_t \equiv \sum_{a=0}^n B_{t-a} l_a m_a = \sum_{a=0}^n N_{t,a} m_a, \quad (7)$$

which is Lotka's (1939) well-known renewal equation. As shown above  $B_t$  will grow at the rate  $\rho - 1$  in the steady state. Because at period  $t$  there are  $B_{t-a} l_a$  individuals aged  $a$ , the proportion of aged- $a$  people, denoted  $g_{t,a}$ , is:

$$g_{t,a} = \frac{B_{t-a} l_a}{\sum_{a=0}^{a^{\max}} B_{t-a} l_a} \quad (8)$$

substituting  $B_t = B_0 \rho^t$ , we obtain for the steady state population:

$$g_{t,a} \rightarrow g_a = \frac{l_a / \rho^a}{\sum_{a=0}^{a^{\max}} l_a / \rho^a}. \quad (9)$$

Hence, in the steady state the age structure is time-invariant (stable population) and the population grows at the constant rate  $\rho - 1$ .

Using the age structure of the stable population from Equation (9) as weighting scheme, we can compute—given all the assumptions made above—the mean income  $\bar{y}$  as defined in Equation (2) or any other welfare measure conditional on age. By varying, for a given population, the mortality  $l_a$  and/or fertility conditions  $m_a$ , this framework then allows to perform comparative static analysis. Moreover, it allows to undertake welfare comparisons between countries having different mortality and fertility conditions using the country's stable population as reference population. Using Equation (8) it is also possible to compute the population age structure in  $t$  and thus the welfare measure for each period on the transition path to the steady state.

## 2.2 Welfare changes with economic feed-back effects

So far, we made the strong assumption, that the age-income profile  $f(y|a)$  is time invariant and, in particular, that there are no feed-back effects from

changes in the population structure on the economy. This assumption will now be removed. To do this, we use a relatively simple framework based on a neoclassical Solow-type growth model (Arthur and McNicoll, 1978; Chu, 1998).

As before, the population structure is assumed to be stable:  $B(t) = B_0 e^{rt}$ , and the population size is given by:

$$N(t) = B(t) \int_0^{a^{\max}} e^{-ra} l(a) da, \quad (10)$$

where  $r$  is the population growth rate. For simplicity, we now classify the age groups continuously. In this case all the insights of the analysis in the previous discussion remain, and we only have to change the notations accordingly. With an age-specific labor-force participation function  $h(a)$ , the total size of the labor force is:

$$L(t) = B(t) \int_0^{a^{\max}} e^{-ra} l(a) h(a) da. \quad (11)$$

Let  $K(t)$  be the size of period- $t$  capital, we assume that total output is determined by a production function  $F : F(K(t), L(t)) = Y(t)$ . Production  $Y(t)$  has to be spent on consumption  $C(t)$  and capital accumulation  $\dot{K}(t)$ :

$$Y(t) = C(t) + \dot{K}(t). \quad (12)$$

The usual assumption in neoclassical growth models is that  $F$  is homogeneous of degree one. Thus, for  $k(t) \equiv K(t)/L(t)$  and  $c(t) \equiv C(t)/L(t)$ , we have:

$$\begin{aligned} \frac{F(K(t), L(t))}{L(t)} &= F\left(\frac{K(t)}{L(t)}, 1\right) \\ &\equiv f(k(t)) = c(t) + \frac{\dot{K}(t)}{L(t)}. \end{aligned} \quad (13)$$

In a Solow-type steady state (Solow, 1956),  $K(t)$ ,  $L(t)$ , and  $C(t)$  all grow at the same rate, which is  $r$ . Thus, dropping the time subscript  $t$  in the steady state, we have  $\dot{K} = rK$ , and hence Equation (13) becomes  $c = f(k) - rk$ , or:

$$cL = [f(k) - rk] L. \quad (14)$$

If the economy follows Samuelson's (1965) 'golden rule' path, then  $f'(k) = r$ , i.e. the economy grows with the growth rate of the stable population ( $r = \rho - 1$ ).

The left-hand side of Equation (14) is the societal total consumption, whereas the right-hand side is the total net output. Substituting in the

formula of  $L(t)$  under a stable population, the societal budget constraint can be rewritten as (Chu, 1998):

$$\int_0^{a^{\max}} e^{-ra} l(a) c(a) da = [f(k) - rk] \int_0^{a^{\max}} e^{-ra} l(a) h(a) da. \quad (15)$$

Differentiating the logarithm of both sides of the above equation with respect to  $r$ , and noting that  $(\partial k / \partial r)(f'(k) - r) = 0$  by the golden-rule assumption, we get:

$$\frac{\int_0^{a^{\max}} e^{-ra} l(a) \frac{\partial c(a)}{\partial r} da}{\int_0^{a^{\max}} e^{-ra} l(a) c(a) da} = (\bar{a} - \bar{a}_l) - \frac{k}{c} + \frac{\int_0^{a^{\max}} e^{-ra} l(a) \frac{\partial h(a)}{\partial r} da}{\int_0^{a^{\max}} e^{-ra} l(a) h(a) da}, \quad (16)$$

where  $\bar{a}_l$  is the mean age of the participation-weighted labor.

If the labor-force participation rate  $h(\cdot)$  is not affected by the change in  $r$ , then the right-hand side of Equation (16) has only two terms. The first term is the difference of mean ages  $\bar{a} - \bar{a}_l$  and the second term is  $-k/c$ , which was called by Arthur and McNicoll (1978) the *capital-widening effect*. There is such a capital widening because an increase in the population growth rate calls for greater investment to maintain the steady-state level of capital per head, and that diverts resources from capital deepening. Lee (1980) summarized this result by the following theorem.

**THEOREM 2:** *Lee 1980, p. 1146*

*Along a neoclassical golden-rule path with an age-specific stable population structure, the proportional change of per capita consumption equals the change in population growth rate times the difference between the mean ages of consumption and earning, minus the capital widening effect, plus the proportional induced change in the labor-force size.*

Using Theorem 2 the economic feed-back effects from changes in the age structure on the age-income profile,  $f(y|a)$ , can be taken into account when making welfare comparisons for a given country, but assuming alternative mortality ( $l_a \rightarrow l'_a$ ) and fertility conditions ( $m_a \rightarrow m'_a$ ). More precisely, changing the population growth rate by  $dr = r - r'$ , changes income at all ages by the factor:

$$(y' - y)/(y) = dr[(\bar{a} - \bar{a}_l) - \frac{k}{c} + H], \quad (17)$$

where  $H$  stands for the induced change in the labor-force participation rate  $h(\cdot)$ , i.e. the third term on the right-hand side of Equation (16). Combining Equation (17) with the new population structure obtained under  $l'_a$  and  $m'_a$ , it is straightforward to compute mean income according to Equation (2) and to compare it with those obtained under  $l_a$  and  $m_a$ .

### 2.3 Welfare changes with a lifetime welfare measure

In a next step, we extend our period welfare measure to a lifetime welfare measure. Whereas above, changes in life expectancy affected the welfare measure only through changes in the population structure, we now introduce life expectancy explicitly. To do this, we take an individual and apply to him the prevailing age-mortality pattern, i.e. we send him through the corresponding life-table. This provides us with the expected share of a year  $L_a$  this individual will live at each age  $a$ . Integrating income over the length of life  $T$  and discounting it by the time preference rate  $i$  yields the following lifetime welfare measure:

$$y^L = \int_{t=0}^T y(a)e^{-it} L_a dt, \quad (18)$$

with  $0 \leq L_a < 1$ . The lifetime income per year expected to live can be computed by:  $\bar{y}^L = y^L / \int_{t=0}^T L_a dt$ . Given that mortality depends in our framework only on age, all individuals in a given population at a given point in time (or in a given steady state) face the same mortality conditions and hence Equation (18) gives also the mean lifetime income in the population.

## 3 Data sources and mortality scenarios

For an empirical illustration of our approach, we use a sample of five developing and developed countries: Burkina Faso and Côte d'Ivoire, which are classified as 'Least Developed Countries' (LDC), Indonesia and South Africa, which are classified as 'Middle Income Countries', and Germany as an example for a developed or industrialized country. Besides economic heterogeneity, this sample presents interesting differences regarding the mortality and fertility patterns as well as the population age structure. For instance, Germany is characterized by a relatively old population structure, by a low fertility rate and by an overall low mortality rate resulting in a high life expectancy of 77.7 years. In contrast the developing countries have a relative young population structure and high fertility and mortality rates. In particular, Côte d'Ivoire and South-Africa are strongly affected by the AIDS epidemic, which means that the mortality rates are particular high for the intermediate age groups and for the newborn (by mother to child transmission). The life expectancy ranges from 46.5 (Burkina Faso) to 63.0 (South-Africa).

All the data sources we used to compute the necessary variables and parameters are listed in Table A1. For the computation of the age-income profiles Equation (1), we use household survey information on household income per capita in the case of Germany and household expenditure per capita in the case of the four other countries. More precisely, we estimate

for each country the following polynomial equation.

$$\log y_i = \beta_0 + \beta_1 a_i + \beta_2 a_i^2 + \beta_3 a_i^3 + u_i, \quad (19)$$

where  $\log y_i$  is the logarithm of household income (expenditure) per capita, and  $a_i$  refers to the age of individual  $i$ . Then we use this equation to compute for each country the conditional mean income for each five-year age group ( $\widehat{\log y_i | a_i}$ ):

$$\widehat{\log y_i | a_i} = \hat{\beta}_0 + \hat{\beta}_1 a_i + \hat{\beta}_2 a_i^2 + \hat{\beta}_3 a_i^3. \quad (20)$$

The resulting age-income profiles are shown in Figure 1. For Germany, we use two different income concepts: First, household net income and, second, household net income minus pensions and retirement payments. Old-age security payments play an important role in Germany, much more than in the other countries in our sample. Hence, it is interesting to analyze the welfare effects with and without this income source. Given that our computations are based on cross-section estimates, it should be noted that they mix age, period and cohort effects. In other words, the ‘true’ age-income profile, can be different from the presented one if income varies strongly from cohort to cohort independently from age and if income is strongly affected by period-specific shocks (see e.g. Lillard and Willis, 1978). To make the age-income profiles and the results of the welfare analysis comparable across countries, we use US Dollar PPP conversion factors. All values are then adjusted to the year 2000 using the national consumption price deflators.

[insert Figure 1 here]

For the analysis of the economic feed-back effects, we calibrated for each country a neo-classical Cobb-Douglas production function using National Accounts data and typical values for partial production elasticities taken from the literature.

The observed population structure and the computed steady state population structure for each country is presented in Figure 2. For our developing countries one can note a rather young population age structure in the base year and in the steady state. In contrast, the age structure in Germany is quite old at present and moves to an even older population structure in the steady state. Figure 2 shows also the population structure which results when a cohort of 1,000 individuals is sent—as described in Section 2.3—through a life-table based on the observed country-specific mortality conditions. This population model is called a ‘stationary population’ and is used for the lifetime welfare measure. All populations are constructed by computing for a given level of life expectancy the age-specific mortality rates with a Ledermann-Model life-table (Ledermann, 1969).

[insert Figure 2 here]

In our analysis we compute the steady state population for four different mortality scenarios. The first scenario is the ‘observed’ or ‘stable’ mortality scenario, based on observed life expectancy at birth of the respective countries. The second scenario is called the ‘low’ mortality scenario. Here we take the minimum value of life expectancy of 27.5 years used by the United Nations to compute the *Human Development Index* (HDI) for almost all countries in the world (UNDP, 2004). The third scenario is called the ‘high’ mortality scenario, which is, in contrast, calculated on the basis of the maximum value of life expectancy of 87.5 years used to compute the HDI (UNDP, 2004). For the fourth scenario, called the ‘low/AIDS’ mortality scenario, we introduce a mortality pattern which resembles that of a population strongly affected by AIDS, i.e. we take again the minimum value of life expectancy at birth, but leave the mortality rates unchanged for the age groups 5 to 14 and 65 and above with respect to their observed values and adjust—respecting the Ledermann model life tables—only the mortality rates of the age groups 0 to 5 and 15 to 64 such that the resulting life expectancy is equal to 27.5.

## 4 Results

### 4.1 Welfare changes without economic feed-back effects

Table 1 compares the population mean income observed in the base year with the mean income obtained using the steady state population as weighting scheme. As described above, the steady state population is computed for four different scenarios: ‘stable’, ‘low’, ‘high’, and ‘low/AIDS’. In addition we provide for each scenario the steady state dependency ratio (inactive population over active population), the steady state population growth rate, and the steady state Gini-coefficient, which takes only into account ‘between-group’ inequality, given that income is assumed to be homogenous within age groups.

[insert Table 1 here]

First of all one can state that for each country considered the steady state income under the current mortality conditions (‘stable’) is above the observed income in the base year, except for Germany when retirement payments are not included in the welfare measure. The transition to the steady state, would last between 12 to 15 periods, that is 60 to 75 years. However, the major changes occur within the first 40 to 50 years.

For Burkina Faso and Côte d’Ivoire—the two low life expectancy and Least Developed Countries (LDC) in our sample—the steady state mean income is higher than the observed mean income, because the dependency ratio in the steady state is lower than in the base year. This is the effect of a very high population growth rate in the past, which, given its recent decrease, results in a higher share of the active population in the medium and

long term and therefore also in the steady state population. This positive dynamic would not show up, if only current income levels were considered. Inequality remains more or less constant for Burkina Faso and decreases slightly for Côte d'Ivoire. If the population age structure which results from the 'high' life expectancy scenario is used as weighting scheme, per capita income is lower than under stable mortality conditions for both countries. This is due to the higher dependency ratio, or equivalently to a higher population weight in the age groups having rather lower per capita income (compare with the age-income profiles presented in Figure 1a and 1b). Conversely, the pure demographic effects of lower life expectancy ('low') result in a per capita income, which is higher or at least not lower than in the steady state under constant mortality conditions. This is however not anymore the case, if the lower life expectancy is introduced such that it increases mortality like the AIDS epidemic only among the newborn and the active population. Under these conditions mean income is clearly lower. In sum, the pure demographic effects suggest, given the inverse 'U'-shaped age-income profiles, that higher population growth leads to a higher dependency ratio and therefore lower per capita income and lower population growth leads to a lower dependency ratio and therefore higher per capita income. This corresponds to the traditional thesis advocated by 'population pessimists' that population growth per se is an obstacle to development (see e.g. Ehrlich, 1968). We also find a kind of *repugnant* conclusion in the sense that the considered reductions in longevity increase per capita welfare. However, so far we did neither account for any economic feed-back effects nor did we try to take explicitly into account lost lives connected with the different mortality scenarios.

For the middle income countries, Indonesia and South-Africa, the effects are similar to those computed for the LDC's. However there are two interesting differences. First, in Indonesia the steady state income in the 'high' scenario is lower than the observed income in the base year. This is due to the fact, that the dependency ratio tends to increase in these countries, given the significantly higher observed level of life expectancy than in the LDC's and an increasing share of older individuals (aging). Second, in both countries even under the 'low/AIDS' scenario lower life expectancy leads to significantly higher per capita income.

For Germany the effects are very different. This follows from several particularities. First of all, the current observed life expectancy is already very high with 77.7 years. Second, it is the only country out of the five, with an observed negative population growth rate. Third, the German population is by far the oldest in the sample and has due to the negative population growth rate, by far the lowest share of young people and therefore a very low dependency ratio despite the high life expectancy. Recall, that the dependency ratio is here only defined by age and independent of actual labor market participation behavior (the population 15 to 64 years old is

considered as active). Fourth, given the public pension system the German age-income profile is not shaped like an inverted ‘U’, but is instead a concave increasing function of age (Figure 1c). If the current mortality conditions prevailed, Germany would experience a higher per capita income, due to the fact that the population would further age and therefore have a higher population density among the richer age groups. This ‘positive effect’ is of course even reinforced, if life expectancy is assumed to increase further as in the ‘high’-scenario. Surprisingly, a switch to a regime characterized by a very low life expectancy would not much alter the per capita income relative to the ‘stable’-scenario. This is because, the ‘low’-scenario is characterized not only by higher old-age mortality, but also by higher child mortality. Whereas the first effect reduces mean per capita income given the age-income profile, the second effect increases mean per capita income. In sum, mean per capita income does not change much. However, both ‘low’ scenarios yield significantly lower inequality. All these effects are completely different, if we take the age income profile shown in Figure 1d, which excludes pensions and retirement payments. Then welfare decreases when moving to the stable population. A lower life expectancy has a positive and a higher life expectancy a negative effect, but in none of these scenarios income per capita is higher than in the base year.

Again, so far we only analyzed the pure demographic effects assuming a constant age-income profile and maintaining a strict period-specific view, side-stepping the issue of lost or gained life due to higher or lower mortality. Both issues will be addressed in the two following sections.

## 4.2 Welfare changes with economic feed-back effects

To take into account the economic feed-back effects of demographic change, we use the methodology presented in Section 2.2. This methodology allows to compute the change of mean per capita income for a one percentage point change in the equilibrium population growth rate under the ‘golden-rule’ assumption. In this framework the direction and magnitude of the change is driven by two forces: the steady-state physical capital per capita divided by the steady-state consumption per capita on the one hand, and, by the difference of the mean age at activity and the mean age at consumption in the steady-state population at the other hand (see Equation (17)). The results are shown in Table 2. In each case the comparison is done relative to the stable population. In other words, we ask, what would be the demographic effect including the economic feed-back effect of a higher (lower) life expectancy with respect to the pure demographic effect under constant mortality conditions.

[insert Table 2 here]



Burkina Faso and Côte d'Ivoire have both a very low mean age at consumption and a relatively high age at activity, that is a difference between both in the steady state of roughly ten years. Therefore, given the model assumptions, additional population growth has a negative effect on per capita income because higher population growth means more children being supported by relatively fewer productive people. However, the so-called 'capital-widening-effect' is rather low, given the relatively low ratio between capital per capita and consumption per capita. In other words, as Table 2 shows, it is easier to maintain the per capita endowment with capital in Burkina Faso and Côte d'Ivoire than in Germany. Therefore, paradoxically, accounting for economic feed-back effects makes lower life expectancy and therefore lower population growth in these countries even more beneficial and, conversely, higher life expectancy and therefore higher population growth less beneficial. However, the 'low/AIDS'-scenario is clearly worse than the 'low'-scenario. The quantitative effects involved are now much higher than in the previous section. For instance the absolute difference in per capita mean income for Burkina Faso between the 'low' and the 'high' scenario is more than 200 USD PPP per capita per year.

For Indonesia and South-Africa, the difference in the mean age at consumption and the mean age at activity is lower than in the LDC's therefore the effects involved are less important but go in the same direction as for Burkina Faso and Côte d'Ivoire.

In contrast, for Germany when including retirement payments into the welfare measure we have exactly the opposite result. The mean age at consumption is—given the rather 'old' population—significantly higher than the mean age at activity. Under these conditions lower life expectancy and therefore lower population growth has a negative effect on mean income per capita (-125 USD PPP) and higher life expectancy and therefore higher population growth has a positive effect on income per capita (+250 USD PPP). However, the pure feed-back effect is very small, first, because Germany has already a very high life expectancy, and second, because Germany would rather need population growth through higher fertility, that is a higher share of young people than population growth through lower old-age mortality, that is a higher share of old people. If in comparison, we deduce retirement payments from the welfare measure, we receive again exactly the opposite result. Hence, a crucial issue is whether the old-age security system can be maintained in its current form in Germany and to what extent individuals will transfer income through private savings from activity to retirement.

### 4.3 Welfare changes in a life-time perspective

Now we change the perspective of our analysis by using a lifetime instead of a period welfare measure.<sup>4</sup> According to the methodology described in Section 2.3, we send an (representative) individual through four different mortality patterns or life-tables: ‘observed’, ‘low’, ‘high’ and ‘low/AIDS’ and compute the corresponding welfare measure formulated in Equation (18). As time discount rate we choose arbitrarily 1.5 percent. The age structure which follows in the case of the ‘observed’ scenario is shown in Figure 2 (‘stationary population’). Given that we take for each country one single individual and thus the same birth cohort size, the results are comparable across countries. We have thus a very simple, but intuitive tool to take into account the welfare effects of changes in life expectancy.

Table 3 shows for each country and each mortality scenario lifetime income and lifetime income per year expected to live. Regarding lifetime income per year expected to live, we have, as one can expect no substantial difference with respect to the results presented in Table 1 and 2. But if we retain lifetime income as welfare measure, we receive significant differences in our welfare rankings. A low life expectancy now reduces substantially welfare despite the related economic feed-back effects. The so-called ‘low/AIDS’ scenario is even worse. Conversely, a high life expectancy is connected with important welfare gains. For instance, for South-Africa, the ratio between observed lifetime welfare (50,938 USD PPP) and lifetime welfare under the ‘low/AIDS’ scenario with economic feed-back effects (27,428 USD PPP) is almost 1.9. That means welfare measured in these terms could be nearly twice as high in the steady state without the AIDS epidemic than with the AIDS epidemic. If the optimistic scenario of an increasing life expectancy is taken as reference point, this ratio attains even almost 2.3.

[insert Table 3 here]

If we compare the two West-African countries, Côte d’Ivoire and Burkina Faso, using observed mean income, we find that Côte d’Ivoire is much richer than Burkina Faso. Lifetime income under the current mortality conditions is in Côte d’Ivoire also 1.6 times as high as in Burkina Faso. However, Côte d’Ivoire is today harder hit by the AIDS epidemic than Burkina Faso. If we make the hypothetical experiment that AIDS remains on a high level in Côte d’Ivoire and remains on the actual and lower level in Burkina Faso, we find that both countries end up with quite similar lifetime welfare, i.e. 19,173 USD PPP in Côte d’Ivoire and 17,572 USD PPP in Burkina Faso. If a favorable development of life expectancy is assumed for Burkina Faso, the ranking is even completely reversed: Burkina Faso would then enjoy a

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<sup>4</sup>When constructing the lifetime welfare measure, we may underestimate incomes in older ages, given that we confound age and cohort effects (see Section 3).

welfare level almost 1.2 times as high than Côte d’Ivoire (22,865 USD PPP vs. 19,173 USD PPP).

## 5 Conclusion

We incorporated the dynamics of demographic change in aggregate welfare measures to illustrate the direction and magnitude of the transmission channels between mortality, life expectancy, and welfare. The comparison between the two high population growth countries—Burkina Faso and Côte d’Ivoire—, the two low population growth countries—Indonesia and South-Africa—and the the negative population growth country—Germany—, revealed interesting differences in the long-term welfare consequences of demographic change. Moreover, Germany as the only country in the sample with a substantial social security system, has also a very different, namely increasing, and not inverted ‘U’-shaped, age-income profile. In the high population growth countries a further increase in population growth leads to a higher dependency ratio and therefore lower income per capita and, on the contrary, a decrease in population growth leads to a lower dependency ratio and therefore higher income per capita. This is the case whether economic feed-back effects are taken into account or not. This type of result is inherent in classical utilitarianism, but is however incompatible, with value judgements one may like to postulate when undertaking welfare comparisons over time and space. Or, as Blackorby, Bossert and Donaldson (2005, Chapter 5) show, classical utilitarianism leads to the ‘repugnant conclusion’ and this can be seen as a significant shortcoming. Classical utilitarianism is a fixed population principle and thus not adapted to rank alternatives with different populations. By extending the period welfare measure to a lifetime welfare measure, thus taking into account the length of life, it is possible to develop welfare measures which avoid the repugnant conclusion. Finally our considerations show nicely—as does the study of Anderson (2005)—that a life-time welfare measure instead of period welfare measure can substantially alter the conclusions regarding the economic effects of AIDS, which are in many studies rather low, because the usual period and per capita consideration is adopted (see e.g. Young, 2005).

## Appendix: Data sources

[insert Table A1 here]

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Table 1  
Welfare changes without economic feed-back effects  
(USD PPP 2000)

	Burkina Faso	Côte d'Ivoire	Germany	Germany w/o retirement payments	Indonesia	South-Africa
	46.50	52.25	77.70	77.70	62.75	63.00
Current life expectancy						
Mean income						
Base year (2000)	545.49	761.22	8604.64	6506.50	1383.66	1185.91
Stable population	549.57	772.26	8927.53	6181.57	1389.08	1256.13
Low scenario	549.41	774.27	8934.62	6389.59	1398.93	1302.93
High scenario	548.13	768.71	9183.02	5793.50	1381.90	1250.80
Low/AIDS scenario	548.02	768.48	8978.23	6220.65	1391.75	1280.08
Dependency ratio						
Base year (2000)	0.529	0.494	0.344	0.344	0.360	0.400
Stable population	0.479	0.448	0.413	0.413	0.372	0.375
Low scenario	0.457	0.417	0.354	0.354	0.348	0.351
High scenario	0.501	0.471	0.488	0.488	0.427	0.427
Low/AIDS scenario	0.475	0.446	0.400	0.400	0.377	0.380
Gini-coefficient						
Base year (2000)	0.054	0.079	0.099	0.133	0.044	0.143
Stable population	0.054	0.077	0.097	0.149	0.043	0.144
Low scenario	0.055	0.077	0.090	0.131	0.042	0.140
High scenario	0.054	0.077	0.098	0.177	0.044	0.143
Low/AIDS scenario	0.055	0.078	0.094	0.143	0.043	0.141
Population growth rate						
Stable population	0.027	0.025	-0.012	-0.012	0.007	0.009
Low scenario	0.011	0.001	-0.037	-0.037	-0.016	-0.015
High scenario	0.038	0.031	-0.012	-0.012	0.011	0.012
Low/AIDS scenario	0.015	0.004	-0.037	-0.037	-0.015	-0.014

Source: Own calculations.

Note: The Gini coefficients show only the between age-group inequality and consider no within age-group inequality.

Table 2  
Welfare changes with economic feed-back effects  
(USD PPP 2000)

	Burkina Faso	Côte d'Ivoire	Germany	Germany w/o retirement payments	Indonesia	South-Africa
<b>Without feed-back effects</b>						
Mean age	22.29	21.10	43.00	43.00	28.00	27.00
Mean age of active population	32.78	32.00	40.45	40.45	34.10	33.41
Mean income base year (2000)	545.49	761.22	8604.64	6506.50	1383.66	1185.91
<b>Steady state</b>						
Mean age	22.31	24.50	47.92	47.92	33.23	32.62
Mean age of active population	32.91	33.79	42.22	42.22	37.46	37.21
capital widening (k/c)	3.715	2.445	5.095	5.095	4.028	2.702
Mean income stable population	549.57	772.26	8927.53	6181.57	1389.08	1256.13
<b>With feed-back effects</b>						
<b>Low scenario</b>						
Proportional consumption pc change	1.229	1.276	0.985	0.985	1.190	1.175
Mean income stable population	675.23	987.66	8800.88	6293.95	1664.53	1530.69
<b>High scenario</b>						
Proportional consumption pc change	0.843	0.931	1.000	1.000	0.970	0.980
Mean income stable population	461.88	715.52	9183.02	5793.50	1336.27	1223.47
<b>Low/AIDS scenario</b>						
Proportional consumption pc change	1.172	1.24	0.960	0.960	1.182	1.1680
Mean income stable population	642.14	951.03	8843.84	6127.54	1644.50	1494.52

Source: Own calculations.

Table 3  
Welfare changes with a lifetime welfare measure  
(USD PPP 2000)

	Burkina Faso	Côte d'Ivoire	Germany	Germany w/o retirement payments	Indonesia	South-Africa
Observed mortality pattern						
Lifetime income per year expected to live	362.03	505.81	4734.07	3892.65	852.69	779.72
Lifetime income	17,572	27,515	379,605	312,136	555,489	50,938
Low scenario						
Lifetime income per year expected to live	381.68	539.64	5168.57	4670.77	932.57	821.03
Lifetime income	11,100	15,694	150,315	135,837	27,122	23,877
Low scenario with feed-back effects						
Lifetime income per year expected to live	469.09	688.37	5091.20	4600.85	1109.63	964.55
Lifetime income	13,642	20,020	148,65	133,804	32,271	28,051
High scenario						
Lifetime income per year expected to live	303.21	430.12	4494.21	3586.33	753.94	694.31
Lifetime income	27,137	38,496	402,235	320,979	67,479	62,141
High scenario with feed-back effects						
Lifetime income per year expected to live	255.47	400.36	4494.21	3586.33	729.05	679.14
Lifetime income	22,865	35,833	402,235	320,979	65,250	60,783
Low/AIDS scenario						
Lifetime income per year expected to live	380.61	539.03	5151.35	4659.77	928.29	817.35
Lifetime income	10,939	15,439	148,061	139,932	26,681	23,492
Low/AIDS scenario with feed-back effects						
Lifetime income per year expected to live	445.98	667.08	5074.24	4590.02	1096.87	5,486
Lifetime income	12,818	19,173	145,845	131,927	31,526	27,428

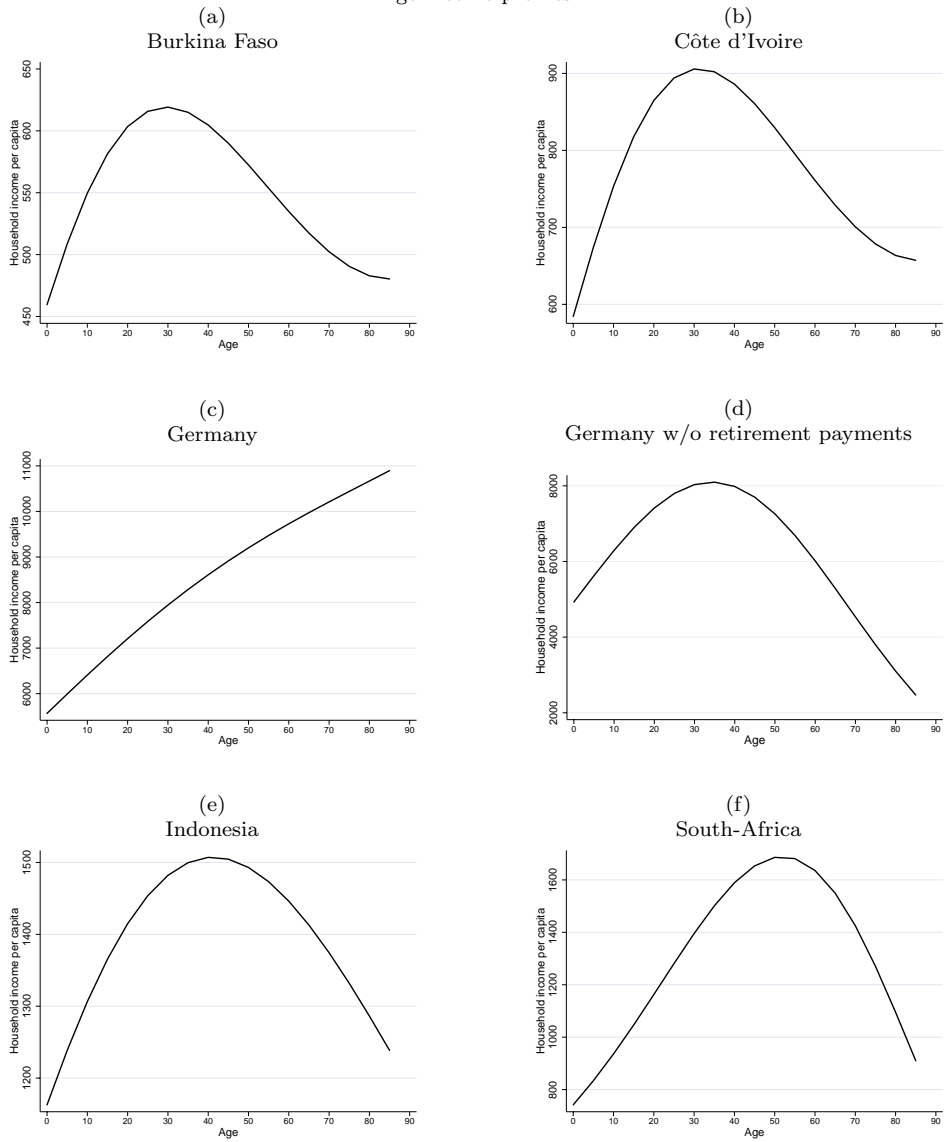
Source: Own calculations.



Table A1  
Data sources

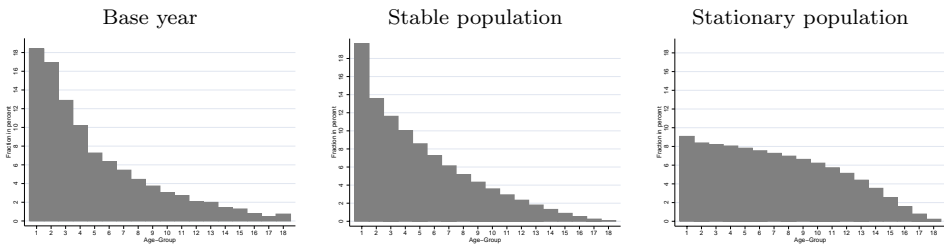
Data	Source
Household survey data	
Burkina Faso	Priority survey (National Statistics Office and World Bank) 1998
Côte d'Ivoire	Priority survey (National Statistics Office and World Bank) 1998
Germany	German socio-economic panel study 2000 (DIW)
Indonesia	Indonesian family life survey (IFLS3) 2000 (RAND)
South-Africa	Income and expenditure household survey (World Bank) 2000
Demographic data	
Population by age	United Nations demographic yearbook
Age-specific fertility rates	Demographic and health survey macro
Age-specific mortality rates	Ledermann model life tables (Ledermann, 1969)
Life expectancy	United Nations demographic yearbook
Economic data	
GDP	World development indicators 2003
GDP deflator	World development indicators 2003
PPP conversion factors	Penn world tables 2000
Gross fixed capital formation	World development indicators 2003
Labor force	United Nations demographic yearbook
Physical capital	Nehru and Dhareshwar (1993) data set
Partial production elasticities	Taken from the literature

Figure 1  
Age income profiles

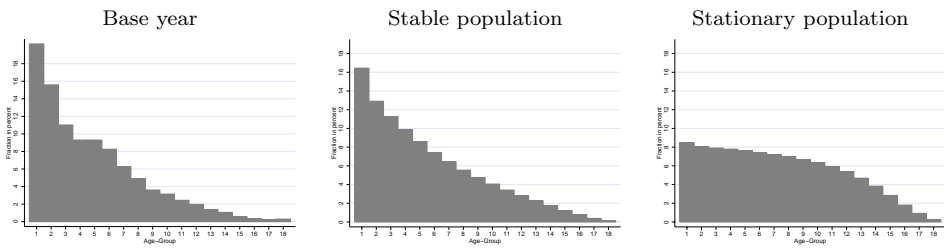


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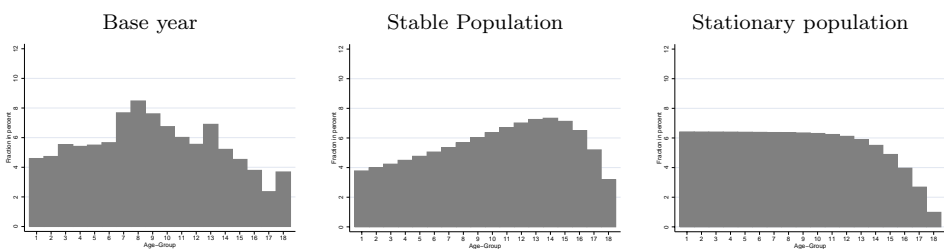
Figure 2  
Population structures  
(a)  
Burkina Faso



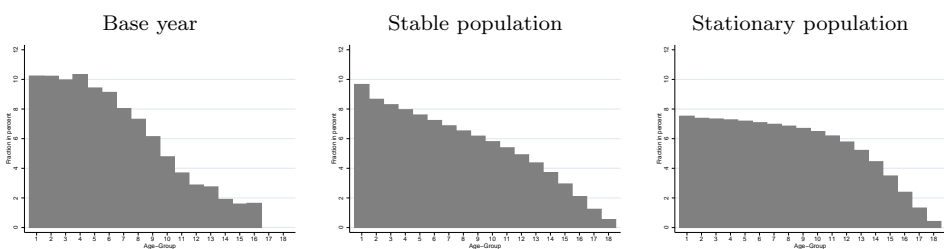
(b)  
Côte d'Ivoire



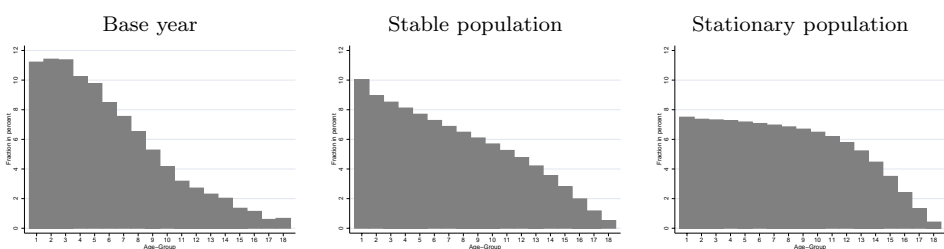
(c)  
Germany



(d)  
Indonesia



(e)  
South-Africa



Source: Own calculations.