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AGING OF POPULATIONS, DEPENDENCY AND ECONOMIC BURDEN IN DEVELOPED COUNTRIES

Dov Friedlander
The Hebrew University of Jerusalem, Jerusalem, Israel
and
Ruth Klinov-Malul
The Hebrew University of Jerusalem, Jerusalem, Israel and the Falk Institute

Résumé — Les tendances démographiques dans les sociétés plus développées indiquent une augmentation considérable dans la proportion des gens âgés de l'avenir. Le vieillissement provenant d'une longévité augmentée doit être différencié de cela à cause de la fécondité décrue. Par une série de suppositions simplifiées on a montré que le vieillissement dû à la longévité augmentée est associé à un déclin de la consommation par tête et à un besoin de transferts inter-générations, tandis que le vieillissement provenant de la fécondité déclinante ne mène pas à une réduction en consommation. Le vieillissement dû à une fécondité déclinante ne semble pas être forcément un fardeau.

Abstract — The demographic trends in the more developed societies indicate a substantial increase in the proportion of the aged in the future. Aging resulting from increased longevity has to be distinguished from that due to decreased fertility. Under a set of simplifed assumptions, it is shown that aging due to increased longevity is associated with a decline in per capita consumption and a need for increased inter-generational transfers, while aging from declining fertility does not lead to a reduction in consumption. Aging from declining fertility does not seem to be necessarily a burden.

Key Words — **aging, declining fertility, increased longevity, economic burden**

I. *Introduction*

The process of aging of populations in the more developed countries has long been studied. It has been demonstrated that in the past, aging processes were the result of declines in fertility. Before today's secular decline in fertility in developed countries, a typical population age strucutre might be 33, 62, and five per cent in the 0-14, 15-64, and 65+ age categories, respectively. Aging, associated mainly with the fertility transition, shifted this structure to 24, 63, and 13 per cent in the respective age categories.[1] Fertility continues to decline in many more developed countries. Total fertility rates of 1.50-1.75 and gross reproduction rates in the region of 0.75-0.85 are not uncommon. Assuming that life expectancy remains constant, a further shift towards older age distributions may be expected. The proportion aged 65 and over may be expected to approach nearly 18 per cent within 60 years and eventually over 22 per cent (see Table 1). These prospects cause concern because such extensive aging may have many negative implications for society.[2]

In the past, aging was a consequence of declining fertility only. Generally, mortality declines were felt to have little effect on the age structure, and the few effects actually observed produced younger age structures, if anything. This, however, may be changing. In those countries where a life expectancy of 70 years or more has been reached, increases in longevity or fertility will have an aging effect (Coale, 1959). At such high levels of life expectancy, probability of survival at younger ages is close to unity, so that any further

mortality decline must be concentrated at more advanced ages. Hence, two kinds of aging should be clearly distinguished when considering future demographic processes: that which results from declining fertility and that which results from declining mortality.

One often discussed implication of aging is the increased economic burden created by the ratio of people aged 65 and over, to the total or the working-age population. Such ratios have been used irrespective of the source of aging. The main purpose of this paper is to argue that the source of aging declines in either longevity or fertility, must be clearly specified in discussion of an implied economic burden. There may be two interpretations to the concept of economic burden: one is in terms of the present value of life-time per-capita consumption, and the other is in terms of its current value. This paper concentrates on the first interpretation. Briefly, the following argument will be made.

Depending on whether aging results from declining fertility or from increasing longevity it is associated with different change patterns in the proportions of the working age population and in population growth.

A. When aging results from a decline in fertility it is associated with a shift to a higher proportion of working age population for approximately 70 years stabilizing thereafter at nearly the initial level. A decline in the growth rate of the population accompanies this aging process. Therefore, when aging results from declining fertility there is a net reduction in the economic burden.

B. When aging results from a decline in mortality it is associated with a shift to a lower proportion of working age population as compared to the initial state. This aging is also associated with an increase in the growth rate of the population. Therefore, when aging results from declining mortality there is usually a net increase in economic burden.

These results are derived under conditions of full foresight by the individual, and/or by government, the assumption being that savings and dissavings functions are done optimized. If this assumption is dropped, *additional burdens* appear resulting from sub-optimal saving patterns.

In the subsequent sections a simplified model of economic burden in relation to population change will be presented and some implications derived and discussed.

II. The Economic Burden — A Simple Model

An increase in economic burden is defined here as the decline in present value of life-time per-capita consumption of an *average* person that results from a given demographic change. This definition assumes that consumption is the individual's primary source of utility and disregards two other important utility, or disutility, types: the utility of having children and that of having a longer or shorter lifespan. The definition does not deal with distributive problems. Specifically, the mode of financing consumption at retirement age is not considered, nor is the question of whether saving for old age via social security is better or worse than private saving, so long as the same present value of consumption is guaranteed. If a young man, A, supports an old man B, and is in turn supported in old age by C, welfare is not reduced, as it is in a situation in which A himself saves and then dissaves privately. The definition assumes that the economy as a whole can transfer consumption from period to period; this actually can be done either by not renewing capital or by investing and disinvesting in foreign markets. Within the model, let

t = current time in units of m years,
N = total population,
L = employed labour force (assumed to be a fixed proportion of the population aged 15-64),

K = stock of capital,
I = investment,
C = total current consumption,
Q = gross national product,
δ = depreciation rate,
r = annual rate of growth of the labour force,

$$\alpha_t = \frac{L_t}{N_t} \rightarrow N_t = \frac{(r_t + 1)\, L_{t-1}}{\alpha_t}$$

Assuming a constant-returns-to-scale production function,

$$\frac{Q_t}{L_t} = f\left(\frac{K_t}{L_t}\right) \tag{1}$$

investment policy is assumed to be such that per-worker capital remains constant.

$$I_t = r_t K_{t-1} + \delta K_{t-1} \tag{2}$$

We can then write:

$$\frac{C_t}{N_t} = \alpha_t \left[f\left(\frac{K}{L}\right) - \left(\frac{r_t+\delta}{r_t+1}\right) \frac{K}{L} \right] \tag{3}$$

According to equation (3) it can be seen that

A. $\frac{\partial}{\partial \alpha} > 0$ since usually $f\left(\frac{K}{L}\right) > \left(\frac{r+\delta}{r+1}\right) \frac{K}{L}$ (the first is about ¼ − ½ of $\frac{K}{L}$, where as the second is about 1/10 of $\frac{K}{L}$, so that per-capita consumption increases with the proportion of the labour force in total population.

B. $\frac{\partial}{\partial r} < 0$, as $\frac{K}{L} > 0$, so that an equal increase in the rate of growth of the population and the labour force reduces per-capita consumption. We can therefore deal with a change in economic burden in terms of the ratio of the labour force to the total population α_t and the growth rate r_t. This is justified when the labour force grows at the same rate as the total population, as for example, in the case of shifts in stable populations. However, when transitional states are considered, as in the following section, it can be seen that the growth rates of the total and the working-age populations change in the same direction relative to the initial state.

III. Demographic Effects of Future Declines in Fertility or Mortality on Economic Burden.

The purpose of this section is to analyze the effect of fertility and mortality changes on the two determinants of change in economic burden: α, the proportion of the labour force in the total population, and r, its annual rate of growth. This will be done by means of transformation projections, shown in Table 1. Our starting point is a stable population with life expectancy of 72.5 years, and a gross reproduction rate (GRR) of 1.25, which could have been considered a typical situation in the more developed countries before the recent declines in fertility. Three alternative 100-year demographic transformations are applied to the initial population. In transformation I, fertility declines and stabilizes at a low GRR of 0.80, while life expectancy is assumed constant. Transformation II assumes that life expectancy rises from 72.5 years to 82.5, while fertility remains unchanged. In

transformation III both changes are assumed to occur.[3] In the analysis it is useful to distinguish between short-run and long-run effects; the short and long runs are defined respectively as up to 45 years and 100 years or more.

When fertility declines and life expectancy remains constant (transformation I), there is an almost immediate decline in the proportion of young (age 0-14). Since quite large birth cohorts originate in the higher fertility period and remain in the working-age category or are due to enter it after fertility has begun to decline, there is a marked short-run increase in α, the proportion of this age group (15-64). The percentage of aged (65+) increases only very slightly in the short run. It is only when the effect of declining fertility has moved along the whole age range that the age structure begins to assume its final shape. In the final stable age structure, the percentage of aged is much higher, the percentage of children much lower, and the percentage of working-age population, α, is almost unchanged. Finally and most important, these age-structural changes are associated with a considerable decline in the growth rate of both the labour force and the total population. Hence, both changes in α_t and r_t lead, according to equation (3), to increased annual per capita consumption and therefore to reduced economic burden.

When life expectancy increases from an initially high level and fertility remains constant, an aging process also occurs. In this case, however, it begins immediately and is associated with a continuous decline in the proportion of working-age population for some 45 years. Here, the short-run and long-run effects on the age distribution differ in the dimensions of the change, rather than in its direction, as in transformation I. Also in contrast to transformation I, the age-structural effects are associated with an increase in growth rates, which is more pronounced in the short run. Hence, in this case aging is associated with a decrease in α_t and an increase in r_t relative to the initial situation and there is therefore an increase in economic burden on both accounts.[4] In such a case, the magnitude of the *present value of consumption* does not necessarily decline, due to the increased length of the period considered and the level of $\frac{C_t}{N_t}$, the breakeven point depending on the level of the social discount rate. The higher the discount rate rises, the lower the age at which the breakeven point is reached.

When there is both a decline in fertility and an increase in life expectancy, the result is a combination of the two previous effects, as in transformation III (Table 1). The table shows that in this case there is a considerable decline in the proportion of young, an increase in the proportion of old, and a decline of the proportion of working-age population. Hence, since both α_t and r_t are reduced the production function must be stated explicitly in order to determine whether this transformation implies an increase in the economic burden.

Table 2 illustrates in a more systematic manner the relationship between demographic change and associated changes in economic burden at the midpoint of what has been defined here as the short run. In this table the effects of reductions in fertility or mortality on α and r are measured from stable populations with the initial levels indicated. Section (a) of the table shows the effects of reductions of 0.25 from varying initial levels of the Gross Reproduction Rate, and Life Expectancy. The effects are considered in terms of the percentage labour force, α, and its growth rate, r. Section (b) of Table 2 is similar except that it illustrates the effects of increments of 2.5 years to Life Expectancy. The table shows that declines in fertility (mortality remaining constant) lead invariably to increases in α and reductions in r. Hence, within the fertility and mortality ranges considered in Table 2, reduced fertility is always associated with a decline in economic burden. This pattern is reversed, however, when Life Expectancy increases

TABLE 1 THE POPULATION DYNAMICS OF THREE DEMOGRAPHIC TRANSFORMATIONS

	Years							
	0 stable	15	30	45	60	75	90	100 stable
Transformation I								
Gross Reproduction Rate	1.25	1.09	0.92	0.80	0.80	0.80	0.80	0.80
Life Expectancy at Birth	72.5	72. 5	72. 5	72. 5	72. 5	72. 5	72. 5	72. 5
Age distribution (per cent):								
0-14	24. 2	23. 1	19. 4	16. 1	14. 7	14. 5	14. 5	14. 6
15-64 (α_t)	63. 0	64. 0	66. 8	68. 4	67. 1	64. 3	63. 2	63.
65+	12. 8	12. 9	13. 8	15. 5	18. 2	21. 2	22. 3	22. 2
Aged dependency ration (65+/15-64)	0.203	0.202	0.207	0.227	0.271	0.330	0.353	0.351
Annual Growth rate (per cent) of :								
Total population	0. 67	0. 44	0. 08	-0. 26	-0. 52	-0. 89	-1. 10	-1. 17
Working-age population (r_t)	0. 67	0. 63	0. 25	-0. 32	-0. 78	-1. 18	-1. 19	-1. 17
Transformation II								
Gross reproduction rate	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Life expectancy at birth	72. 5	75. 0	77. 5	82. 5	82. 5	82. 5	82. 5	82. 5
Age distribution (per cent):								
0-14	24. 2	24. 2	23. 4	23. 2	23. 1	23. 1	23. 1	23. 1
15-64 (α_t)	63. 0	62. 5	60. 7	59. 9	59. 8	59. 7	59. 7	59. 7
65+	12. 8	13. 3	15. 9	16. 9	17. 1	17. 1	17. 2	17. 2
Aged dependency ratio (65+/15-64)	0.203	0.213	0.262	0.282	0.286	0.286	0.288	0.288
Annual Growth rate (per cent) of:								
Total population	0. 67	0. 95	0. 91	0. 81	0. 78	0. 76	0. 75	0. 75
Working-age population (r_t)	0. 67	0. 76	0.75	0.73	0. 76	0. 74	0. 75	0. 75
Transformation III								
Gross reproduction rate	1.25	1.09	0.92	0.75	0.75	0.75	0.75	0.75
Life expectancy at birth	72. 5	75.0	77. 5	82. 5	82. 5	82. 5	82. 5	82. 5
Age distribution (per cent)								
0-14	24. 2	23. 0	18. 6	15. 1	13. 6	12. 4	12. 1	11. 9
15-64 (α_t)	63. 0	63. 5	64. 2	64. 4	62. 3	58. 8	56. 1	55. 4
65+	12. 8	13. 5	17. 2	20. 5	24. 1	28. 8	31. 8	32. 7
Aged dependency ratio (65+/15-64)	0.203	0.213	0.268	0.318	0.387	0.489	0.567	0.590
Annual Growth rate (per cent) of:								
Total population	0. 67	0. 68	0. 29	-0. 05	-0. 38	-0. 67	-0. 93	-1. 07
Working-age population (r_t)	0. 67	0. 75	0. 36	-0. 46	-0. 67	-1. 09	-1. 08	-1. 07

TABLE 2 SHORT RUN[1] EFFECTS OF REDUCTIONS IN THE GROSS REPRODUCTION RATE (GRR) AND IN LIFE EXPECTATIONS (e_o^o) ON THE CHANGE IN THE PERCENTAGE LABOUR FORCE AND ITS GROWTH RATE, AT DIFFERENT INITIAL LEVELS OF GRR AND e_o^o.[2]

Initial Levels of GRR	Initial Levels of e_o^o							
	70		72.5		75		77.5	
	Change in		Change in		Change in		Change in	
	% Labor Force α	Rate of Labor Force Growth r	% Labor Force α	Rate of Labor Force Growth r	% Labor Force α	Rate of Labor Force Growth r	% Labor Force α	Rate of Labor Force Growth r
a.	Effects of a Reduction of 0.25 in GRR							
1.50	+2.57	-0.448	+2.52	-0.435	+2.49	-0.462	+2.44	-0.461
1.25	+2.48	-0.458	+2.46	-0.477	+2.41	-0.470	+2.36	-0.468
1.00	+3.15	-0.540	+2.53	-0.559	+2.46	-0.531	+2.36	-0.530
0.80	+2.30	-0.570	+2.24	-0.550	+2.15	-0.560	2.04	-0.580
b.	Effects of Increments of 2.5 Years in e_o^o							
1.50	-0.31	+0.082	-0.35	+0.065	-0.39	+0.045	-0.77	+0.010
1.25	-0.39	+0.070	-0.44	+0.058	-0.51	+0.035	-1.09	+0.021
1.00	-0.51	+0.084	-0.59	+0.052	-0.81	+0.024	-1.58	+0.008
0.80	-0.64	+0.088	-0.77	+0.074	-0.92	+0.079	-2.15	+0.013

(1) The measurement of these effects relate to the middle of the short run period, i.e. 20-25 years after the change in GRR or e_o^o takes place.

(2) Initial stable populations with the appropriate fertility and mortality have been adopted from the Coale-Demeny Female West series. For use of Life Tables, see footnote on p.

while fertility remains constant. These calculations strengthen the validity of the conclusions drawn from Table 1, which attempted to illustrate the effects of changes in fertility and mortality for one particular set of initial conditions.

As mentioned earlier, the approach used here does not specify the mechanism which provides the *right* amount of investment to offset the consequences of demographic change. An implication of this work is that full predictions of demographic changes are necessary (though not solely) in formulating optimal savings policies. A distinction was made in our analysis between firstly, the kind of burden which results from exogenous demographic changes even under perfect foresight and policy, and secondly, the burden which is a result of demographic changes which were either unforseen or unplanned. Only the first type of burden was considered in this paper. Nevertheless it may be that the additional burden, due to lack of foresight, may be heavier in aging, due to mortality decline; information on fertility is at least partly redundant, since private savers often know the number of children they will have while they are still at their early stages of working life. Their knowledge as to future changes in their life expectancy, however, is much more limited. Hence, an unforseen rise in life expectancy is likely to entail an additional eco-

nomic burden to that considered above; and intergenerational transfers to the aged may become necessary.

IV. Summary and Conclusion

Demographic trends under way in today's more developed countries may lead to substantial increases in the percentage of the aged in those populations. Countries like the U.S.A., Austria, Finland, Switzerland, West Germany and East Germany have already experienced such demographic changes. In these countries reductions of approximately 0.75 in the total fertility rate, and increases in the range of 0.5-2.5 years in life expectancy[5] have been recorded since the middle 1960's. The foregoing analysis argues that aging due to increased longevity and due to reduced fertility will be clearly distinguished by their effects. Under a set of extremely simplified assumptions it was found that the first is associated both with a decline in current per-capita consumption and with the need for increased inter-generational transfers due to imperfect foresight. Aging resulting from declining fertility, on the other hand, does not lead to a reduction in consumption, and the foresight necessary to save enough is no problem. Therefore it is not necessarily a burden on both accounts. It follows that any current increases in life expectancy should be followed by appropriate increases in aggregate saving to prepare for the additional consumption years of older age groups of the population. However, such a conclusion does not follow from our analysis when increased aging is a consequence of declining fertility.

Footnotes

1 The first of these two age structures is stable with GRR = 2.25 and life expectancy of 35 years; the second is stable with GRR = 1.25 and life expectancy of 72.5 years of the Coale-Demeny West Female Model Life-Tables and Stable Populations.

2 Discussion of such implications for economic processes in public health, education, and other areas occupied a specialized conference sponsored jointly by the N.I.H. and the W.H.O. in March 1977, at Washington, D.C.

3 In these projections an initial stable population with GRR = 1.25 and e^{o}_{o} = 72.5 of the Coale-Demeny Female West Model has been used. Life Tables up to e^{o}_{o} = 77.5 are also adopted from the Female West Coale-Demeny Models. Two new Life Tables with e^{o}_{o} = 80 and e^{o}_{o} = 82.5 have been specially constructed. These have been based on the assumption that no further mortality declines will take place up to age 40, since the probability of five year survivorship up to that age is already very close to unity. From that age onwards death rates have been scaled down at constant rates until life expectancies of 80 and of 82.5 years have been reached.

4 It may well be argued that increased life expectancy may entail a longer working life. In that case, the argument will hold as long as the length of working life increases at a slower pace than does life expectancy.

5 These increases in life expectancies have partly been due to mortality reductions at the advanced ages (*e.g.* U.N. Economic Survey of Europe in 1974, Part II, p. 27).

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