Title: Comparing the efficiency of mortality changes between countries: an evaluation of past and forecast levels in advanced economies.

Author: Jim Oeppen
Affiliation: Max Planck Institute for Demographic Research

Long Abstract.

Governments are concerned with the efficiency with which health investments are translated into health outcomes. This paper attempts to define a demographic measure for the efficiency of mortality changes; to discover which countries can be regarded as efficient; and to speculate as to whether that efficiency will continue in the future.

These questions matter because the social and monetary values of the investments and outcomes are enormous. On the investment side, the percentage of US GDP spent on health has risen from 5% in 1960, to 15% today, and is projected to rise to 18% by 2015. If other countries follow the US lead, we could see a century in which advanced economies are dominated by their health sectors.

On the outcome side, conventional national economic accounting does not value extension of total lifetime and healthy lifetime, but some estimates are available. For Britain, Crafts has estimated that the rise in life expectancy between 1950 and 2000 was worth about 50% on top of the rapid rise in real incomes as conventionally measured over the same period. This estimate does not include the values attached to the associated falls in morbidity and the variance of lifetimes.

One strand of the debate on health provision asks if too much is being spent. In many countries the political will to spend increasing proportions of public money on health investment seems to be lacking. However, because of the high values that individuals place on health and survival, some economists believe that advanced economies are currently under-spending by as much as 20-25% of GDP.

A second strand asks if current spending is efficiently allocated, but the answers seem to concentrate on the meso- and micro-scales, discussing forms of hospital funding, drug provision, disease-specific interventions, etc.. There seems to have been no attempt to utilize the macro-scale approach to international comparisons afforded by mathematical demography.

To bring such tools into play, this paper imagines how a social planner might view mortality change. Her simplest objective would be to choose age-specific health investments that maximized period life-expectancy at birth in a population, discounted in a period perspective, and subject to a budget constraint. This view contrasts with the individual's concern to maximize, over a cohort perspective, a stream of discounted utility of which healthy living and longer life are just two components.

To make progress with the demography of the social planning scenario, we assume that the weighted average annual change in mortality rates across ages is set by the budget and that the planner can influence mortality rates at will. To simplify

the discussion, we make the huge assumptions that age-specific mortality rates are responsive to the investment at that age, and that the elasticity of their response is age-independent. This reduces the planner's problem to one of deciding how to optimize a portfolio of health interventions on the basis of age alone.

Demographers are familiar with the answers to the questions "What age would you choose if: a) you could save one life, and b) you could change one mortality rate". For b) one should choose an age where there is both a significant number of deaths and period of remaining life expectancy. While the latter answer is technically correct, a social planner should assume that changes at only one age would be subject to rapidly diminishing returns to investment.

An optimized age portfolio can be defined with reference to equation 12 in Vaupel and Canudas Romo (2003). They exactly decompose the time-derivative of life-expectancy into two components. The first is the product of the average proportion of deaths averted by mortality improvement and the average number of years gained by a saved life, which we can think of as a "quantity" measure. The second term is the d(x) weighted covariance between mortality change and remaining life-expectancy. The authors called this a "level 2 change", but for our purposes we can interpret it as a measure of efficiency or "quality". This equation tells us that a social-planner can increase life-expectancy through the quantity of mortality improvement in the first term, but also by choosing to invest in ages x that have large values of both d(x) and e(x), so that the covariance term is maximised. In modern populations aligning the peaks of m(x), d(x) and e(x) is impossible because high values of d(x) are generally associated with low values of e(x), but there is still an optimum distribution. The analysis shows that it is still worthwhile investing in reducing infant rates, but the bulk of the investment should follow the shape of the d(x) density although shifted towards younger ages since the e(x) function declines approximately linearly with age.

The same equation can also be used if quality of life is to be considered. If healthy life expectancy is substituted for overall life expectancy in the analysis, we can expect a further shift of the efficiency peak towards younger ages.

This approach is applied to countries from the Human Mortality Database. The analysis shows that countries like Norway and Sweden that have remained close to the advancing linear frontier for life expectancy have been efficiently shifting the pattern of mortality change for 150 years. In the last 50 years, newcomers to the top rankings like France, Japan and Switzerland have been among the most efficient, suggesting a positive association between the quantity and efficiency of mortality change. It may also be significant that these countries offer a high degree of patient choice in health care demand. The United States has made both smaller and less efficient changes, and there is some evidence that the US pattern may be more closely aligned to the age pattern of mortality change that would optimize individual utility (Hall and Jones, 2005).

One should ask if these efficiency levels will continue in the future. We don't know the answer, but we do know that mortality forecasting models do not take explicit account of this process. A group of distinguished demographers has provided a set of forecasts for 18 European countries over the years 2004-2050 on the Web at

http://www.stat.fi/tup/euupe/. By the end of the forecast period, efficiency considerations require mortality changes to peak for 90 year-olds, but the pattern of forecast mortality changes is almost independent of age – effectively a proportional-hazard assumption. This may be the most neutral view of the future efficiency of mortality change, but it has never been observed in the historical record. If on the other hand efficiency is maintained at historic levels, life expectancy must exceed these forecasts. This efficiency analysis of forecasts will be expanded for Lee-Carter models.

It is plausible that the enormous projected increase in health spending may sustain the process whereby innovations in health technology are efficiently targeted at the ages where they have the most impact. If this occurs, then the frontier for life expectancy may continue to shift at its current rate and efficient countries will be making their biggest mortality changes among those aged from 90 to 100. It seems that rising pension ages and lower levels of disability will not close the temporal gap between the ages at which people can fund their health care and the ages at which they will need it most.

The economic implications of life expectancy changes are enormous. Easterlin (1999) concluded that, under such pressure, the market for mortality change is not beneficent, and that public institutions must intervene to support welfare objectives. Several authors have proposed that societies have successfully mobilized resources to "plane off" the high spots in mortality (see Tuljapurkar et al. 2000). This paper offers quantitative support for the hypothesis. Advanced economies have been able to sustain social efficiency in mortality change and may continue to do so in the future.