Allocating Public and Private Resources across Generations

Riding the Age Waves—Volume 2

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CHAPTER 9. CONSEQUENCES OF EDUCATIONAL CHANGE FOR THE BURDEN OF CHRONIC HEALTH PROBLEMS IN THE POPULATION

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Changes in the public and individual burden of chronic health problems have significant implications for the allocation of public and private resources across generations. Preston (1984) noted almost two decades ago that population ageing in the United States was accompanied by the rapid expansion of public programs benefiting the health of elders while public programs benefiting children's education contracted. Health care is the principal public service provided to the elderly while education is the counterpart for children.

Within a historical time period, political choices about the funding of age-targeted service programs have an urgency that oftentimes sweeps aside the fact that investments in children's well-being pay substantial dividends decades later when children become the elders of a population. In large part, this reflects a lack of attention both by policy makers and by demographers of these long-run associations. Here, we provide new insights into the long-run consequences of investments in children for the burden of chronic health problems by conducting a thought experiment in which we simulate how sweeping historical changes in a population's educational achievement potentially alters active life expectancy and the prevalence of functioning problems in the population.

Our thought experiment is based on a multistate life table model that first documents the educational disparities in active life expectancy for males and females with 0–6 years of education compared to persons with 12 years of education. We use morbidity and mortality data from a major longitudinal study of morbidity experience in a population, the Health and Retirement Study (HRS), as inputs for the life table model. An advantage of the model is that it explicitly takes into account how education shapes active life expectancy, as well as the prevalence of functioning problems, through its associations with functional

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changes and mortality. We then use simulations to illustrate how changes in the aggregate educational attainment and mortality of a population potentially alter active life expectancy and the prevalence of functional problems. The simulations combine historical information on American mortality since 1900 from the U.S. Social Security Administration with information on educational disparities in morbidity and mortality incidence derived from the HRS. We simulate in a backward fashion how changes in the burden of chronic health problems in a population over a 90-year period are associated with declining levels of mortality and higher levels of educational attainment.

Other nations are at various stages of economic development and the spread of mass education. At the same time that national populations are being transformed in terms of their characteristics, the "quiet" demographic revolution of population ageing is drawing policymakers' attention to the possible dilemma of coping with the burden of chronic health problems for burgeoning elderly populations while dealing with the exigencies of economic development. This study attempts to underscore the idea that while these may appear to be zero sum short-run decisions, investments in children potentially have substantial payoffs both in terms of reducing the burden of elders' health problems at the societal level and in improving the quality of life for individuals.

1. Implications of Educational Attainment for Population Health

A consistent finding in the population sciences is the strong association between educational attainment and adult health in cross-sectional data. This relationship holds across the life-cycle even into old age, although some research suggests that the association may diminish at advanced ages as genetic factors take on a more significant role in influencing health (Preston and Taubman 1994). Typically, the association has been gauged in terms of mortality and self-reported health, but research also shows a strong association between education and functional limitations (Crimmins, Hayward, and Saito 1996; Freedman and Martin 1999). The consistency of the findings across numerous studies is not surprising given the strong association between education and the risk of a range of chronic diseases—the primary source of mortality and functional limitations at older ages in developed nations (Hayward et al. 2000).

The association between education and adult health highlights the importance of understanding how shifts in the educational composition of a population are associated with trends in the health problems of a population. Assuming that the association between education and health is relatively stable over time, increases in educational attainment in a population ought to foster improvements in the health of a population (e.g., lower levels of mortality, the postponement of chronic diseases to older ages, and lower levels of functioning problems). Empirical evidence on historical trends in the association between greater levels of educational attainment in a population and health is relatively sparse, limited to relatively short historical periods, and largely restricted to developed nations. Some evidence points to a widening of educational disparities in mortality as average levels of education have increased in Western developed nations (Preston and Taubman 1994). More recent evidence for the United States points to a temporally stable association (Manton and Stallard 1997; Freedman and Martin 1999). There is also evidence of a strong association between education and functional limitations in a developing nation with low average levels of education among its elderly population (Zimmer et al. 1998) and between education and chronic diseases in a sample of U.S. Civil War veterans (Costa 1999). Available evidence, therefore, points to persistent educational disparities in health even in the face of economic development and the institutionalization of mature health care systems. For purposes of our thought experiment, we *assume* that the association between education and adult health remains constant over a relatively lengthy historical period—almost a century. The implications of imposing this assumption for distorting our analysis must await additional empirical studies.

The association between education and chronic health problems is, in large part, a reflection of the creation of health capital over the individual life-cycle. Greater levels of education indicate greater human capital. And, as a relatively exogenous factor in the life-cycle, education fosters good health by improving economic resources over the life-cycle, access to health care, and home and work environments relatively free of risk (Caldwell 1979; Behrman et al. 1991; Feinstein 1993; Freedman and Martin 1999; Hayward et al. 2000; Ross and Wu 1996; Zimmer, Hermalin, and Lin 2002). Education, because of its association with delayed gratification or because educated people are better consumers of biomedical information, is also associated with the avoidance of health risk behaviours such as smoking, obesity, and substance abuse (Winkleby et al. 1992; Brunner et al. 1996; Lynch, Kaplan, and Salonen 1997). Education also reduces the risk of some chronic diseases by fostering psychological resources including a sense of autonomy and control over one's surroundings and social support (Elo and Preston 1992; House et al. 1994; Ross and Mirowsky 1999).

Viewed historically, improvements in a population's level of education reflect improvements in individuals' capacity to reduce risks having a negative impact on long-term health. Not surprisingly, this type of long-term life course perspective has become an important organizational theme at the World Health Organization (WHO). A major program of WHO's Department of Noncommunicable Disease Prevention and Health Promotion (NPH), for example, is *Ageing and the Life Course*. This program emphasizes the importance of making significant investments in children, including improving education, as a primary prevention strategy in reducing chronic diseases in later life (http://www.who.int/hpr/ageing/lifefactsheet.pdf).

The association between education and the levels of adult health in a population is also a reflection of macro level factors embodied in aggregate measures of education (Palloni 1981). The level of educational attainment in a society reflects not only the stock of human capital but also the capacity of a social system to address societal health needs (Easterlin 1997). At the earlier historical stages of rising educational levels, the growth in mass education is made possible by the proliferation of schools. The spread of schools typically coincides with other health-related infrastructural changes in communities such as the introduction of the spread of modern sanitation practices, health care services, and medical technologies—the latter has been posited as having a significant influence on changes in adult health (Preston 1975; Palloni 1981).

Evaluating how *improvements* in a population's educational level lead to *improvements* in health is an indeterminate problem. In all likelihood, the association represents multifarious and complex mechanisms. A useful way to think about a population's educational level is in terms of the "social capacity" for population health—that is, the confluence of individual life course and institutional conditions favourable to improvements in health. Here, we attempt to gain insights into the consequences of improvements in the social capacity for population health by posing the following questions. What is the burden of disease in a population that has relatively low levels of education and high levels of mortality compared to an educated population with low mortality? Does an increasingly educated older population result in improvements in life expectancy and a relatively compressed period of morbidity, or are improvements in life expectancy accompanied by an extended period of morbidity? How are these changes in morbidity and mortality reflected in the prevalence of functional problems in the population?

In large part because of the absence of data, the body of empirical evidence addressing these questions is quite small. A recent study by Freedman and Martin (1999), however, provides some important clues about how population health changes as educational levels rise in a population. Their study examined changes in the prevalence of several major functional limitations in the 65 years of age and older population in the United States between 1984 and 1993. Using a decomposition approach, Freedman and Martin's analysis showed that improvements in educational attainment over the 9-year period were strongly associated with the declines in the prevalence of functional limitations—indeed, education had the greatest effect among a range of demographic and socioeconomic factors. Based on projected prevalence rates, Freedman and Martin also posit that the United States will experience continued declines in the prevalence of major functional limitations with rising educational levels of the future birth cohorts entering old age. If we extend the logic of Freedman and Martin's analysis, their results point to a pattern in which rising educational levels, an indicator of improved social capacity for population health, are accompanied by increased life expectancy, a compression of the years spent with functional problems, and a lower prevalence of functional limitations in the population.

2. Historical and International Differences in Educational Attainment

Americans born in the first half of the 20th century grew up in an era in which mass education became a reality. The median number of years of completed schooling for males 25–34 years of age in 1910 was 7.4; the median for females was 8.1 (Gustavus and Nam 1968). Only 15–16 percent of men and women had completed a high school education or more. Fifty years later, the median years of completed schooling for males and females 25–34 years of age had jumped to over 12.

The educational attainment of the older population in the United States during the latter part of the 20th century largely reflects the lagged effect of the educational attainment of young adults in the first half of the century. Among persons of 70–79 years of age, for example, over 80 percent of males had completed 8 years of schooling *or less* in 1940 (estimates calculated by authors using U.S. Census data). By 1992, this dropped to less than 25 percent (estimates calculated using data from the Assets and Health Dynamics Study). Females experienced a similar improvement in educational attainment. In a historical sense, this change represents the spread of mass education—especially at the secondary level—in the older population of the United States. The effects of mass education were relatively small until after 1960 when the older population showed dramatic improvements in educational attainment. Future improvements in educational attainment have been projected for the next 30 years (Day and Bauman 2000).

Global data show that the levels of educational attainment in developing nations fall far below current levels shown for the United States and other industrialized countries (Ahuja and Filmer 1995; Wils and Goujon 1998). Recent estimates of adult literacy rates in sub-Saharan Africa, Arab countries, and Southern Asia are approximately 60 percent for men and 30–40 percent for women (Wils and Goujon 1998), with lower literacy rates corresponding to larger gender gaps. Although adults in much of the developing world have very low levels of educational attainment—levels comparable to that of the U.S. older population at the start of the 20th century—most regions of the world have experienced significant growth in the educational attainment of young age groups. Southern Asia, the Arab countries, and Latin America are now approaching universal primary education (the exception is a worrisome trend in sub-Saharan Africa) (Wils and Goujon 1998). Ultimately, this trend toward mass education—at least at the primary level—points to gradual increases in the educational attainment of the adult population as members of recent birth cohorts age into adulthood. Globally, this signals an increase in the social capacity for improvements in population health at the older ages (Easterlin 1997).

3. Approach, Data and Measures

3.1. APPROACH

The analytic problem for this study is how to gauge changes in the burden of disease in the older population associated with improvements in education. Our simulation approach to the problem is built around a multistate life table model of active life expectancy in which persons can experience the onset of functional limitations, functioning can be regained, and mortality can occur from either of the two health states. Functional limitations are problems in performing basic physical and cognitive activities used in daily life. Our choice of functional limitations as the measure of the burden of disease is based on the idea that functional problems are the downstream outcomes of fatal and nonfatal chronic disease processes. Functional limitations are also the target of lengthy personal and medica care. In this sense, disease burden takes on a distinct social quality.

The multistate life table model imposes the need for longitudinal data to identify transition: on the state space—in this case, between health states and from the two functioning state: to death. At the same time, our analytic goal focuses our attention on *changes* in the burdei of disease associated with *improvements* in education. In the ideal world, we would us historical data referencing the morbid and mortal transitions of the type in the life tabl model along with data on changes in the level of educational attainment. In the absence o such data, we first make use of recent data on educational disparities in the active lif expectancy process. Based on the idea of extrapolating historical trends from currer observed levels of inequality, educational disparities provide us with a crude approximatio of how population health changes as a country moves from a regime of low education t high education.

Our simulation approach also combines information about educational disparities in the active life expectancy process with historical information on mortality changes at the older ages. Our intent is to illustrate the consequences for the burden of disease of a regime of low education and relatively high mortality. As described later, for example, we calculate a life table model for persons aged 50 years and older who have 0–6 years of completed schooling and are subject to the mortality experience of the 1900 and 1940 U.S. population. The 1900 simulation yields a rough approximation of a population's burden of disease when the social capacity for population health is low—e.g., at the early stages of the transition to universal education. We also calculate a life table model for same-aged persons with 12 years of completed schooling subjected to the mortality experiences of the 1992 U.S. civilian noninstitutionalized population. This model provides a rough approximation of the burden of disease after the transition to universal education under a regime of low mortality—a model reflective of the social capacity of most developed nations. We calculate a third model holding the 1900 education and morbidity transition rates constant, but in which 1900 mortality rates are presumed to decline to the levels in 1940. This scenario is used to illustrate what might happen to the burden of disease when mortality in a population declines but improvements in education lag behind—a situation that is likely to occur relatively early in the process of modern disease fighting. We compare these models to evaluate how educational improvements are associated with the burden of disease in the population.

3.2. DATA AND MEASURES

Information on educational differences in the morbidity and mortality experiences of persons aged 50 years and older is based on the first two waves of the Health and Retirement Survey (HRS) and the Assets and Health Dynamics Survey (AHEAD). The HRS and AHEAD are nationally representative, longitudinal surveys of middle-aged and older Americans. The HRS is representative of persons 51–61 years of age and their spouses in 1992. The AHEAD is representative of persons 70 years of age and older and their spouses in 1994. Wave 2 surveys for both the HRS and AHEAD occurred approximately 2 years after the baseline survey. Age-ineligible spouses have no sample weights.

We have pooled the two surveys in order to estimate morbidity and mortality incidence from middle age into advanced old age ($N = 19{,}797$).[1] We ignore the sampling weights for the present analysis, because we use information on age ineligible spouses to estimate the incidence rates for the ages not covered by the two companion surveys (ages 50 and 62–69 at baseline).

Functional limitations are measured by a series of overlapping items in both the HRS and AHEAD. We use five measures to identify whether a person has functional limitations. The measures are:

- Walking several blocks
- Picking up a dime from a table

[1] The total sample size is 19,799. Two respondents did not provide sufficient information to classify their functioning.

- Climbing stairs without resting
- Lifting or carrying weights over 10 pounds
- Pulling or pushing large objects like a living room chair.

Mobility functioning is referenced by walking several blocks and climbing stairs. Strength measures include lifting weights, and pulling/pushing large objects. The measure, picking up a dime from a table, reflects functional limitations in fine motor skills. For the present, we ignore the possible hierarchical nature of these items.

Persons are defined as "inactive" if they report that *three or more* of these activities are:
AHEAD survey: a little difficulty/very difficult/cannot do
HRS survey: some difficulty/a lot of difficulty.

The "inactive" status thus references the confluence of multiple functional limitations, tapping into the idea of severity. We chose this approach rather than focusing on the severity levels defined by the specific item responses because of comparability problems across the surveys and over time. Although we have not conducted an exhaustive assessment of the shortfalls of our measurement approach, our results are highly consistent with results from prior research using a variety of measurement approaches (Rogers, Rogers, and Belanger 1989, 1990; Crimmins, Hayward, and Saito 1994).

Education is measured in terms of years of completed schooling. Education is categorized into 0–6 years, 7–8 years, 9–11 years, 12 years, 13–15 years, and 16 or more years of schooling. As noted above, we are especially interested in the lowest educational group and those persons who have completed 12 years of education. These groups roughly approximate the educational levels pre and post the spread of universal education.

As described later, educational disparities in morbidity and mortality experiences are directly estimated using the HRS/AHEAD data. Mortality rates for earlier historical periods, 1900 and 1940, are estimated by increasing the age-specific mortality rates by 200 percent and 225 percent. This produces life expectancies for persons aged 50 that closely approximate published life expectancies for 1900 and 1940 produced by the Social Security Administration (Bell, Wade, and Goss 1992).

3.2.1. Estimation of Transition Rates and the Multistate Life Tables

We estimate the transition rates for the multistate life table model using a hazard modelling approach (Hayward and Grady, 1990; Land, Guralnik, and Blazer, 1994). In this approach, the instantaneous transition rate, $\mu_{ij}(x)$, is the force of transition from state i to state j. The rate is defined as:

$$\mu_{ij}(x) = \lim_{\Delta x \to 0} \frac{p_{ij}(x, x + \Delta x)}{\Delta x} = \mu_{ijx} \quad (0.1)$$

Note that the transition rate is specified to be equal to a constant quantity, μ_{ijx}, for individuals aged x to $x + n$, but may vary across different ages x. This is a piece-wise exponential transition rate model.

We estimate the transition rates using a log-linear modelling approach, i.e.,

$$\ln \mu_{ijx} = \beta_0 + \beta_1 \text{AGE}_x + \beta_2 \text{Male} + \beta_3 \text{Educ}_{0-6} + \ldots + \beta_7 \text{Educ}_{13-15} \qquad (0.2)$$

where the education group of 16 years or more of completed schooling is treated as the reference group. The parameter estimates of the statistical model are then used to calculate predicted transition rates, $m^*(x)$, based on an exponential function of the log-linear equation. The predicted rates serve as the inputs for the multistate life table model.

It is possible to mimic a life table by estimating $m^*(x)$ for single years of age. This would entail creating age-specific dummy variables for each single year of age (minus 1). Exponentiating the parameter estimates would yield age-specific transition rates. Here, we take a somewhat different approach. Age is assumed to be continuous, and (in the above equation) the log of the rate is specified to be a linear function of age. This is similar to the exponential smoothing techniques used in life table construction, only now applied to individual level data.

We tested a variety of functional forms of age-dependency in the transition rates (e.g., polynomial and Weibull specifications) to determine the "best fitting" model for each transition rate. We also tested for nonproportionality in the effects of sex by interacting sex and age. We found no statistical evidence that the effects of sex on the transition rates differed significantly by age. The Gompertz specification shown in equation 1.2 consistently provided the best fitting model for all of the morbid and mortality transitions.

All of the final hazard models used to calculate the transition rates for the multistate life tables include the effects of sex and education, regardless of whether the effects are statistically significant. We based our decision on nonstatistical reasons. First, we were concerned that nonsignificant effects could have a substantive impact, if the effect was persistent over a long period of time (e.g., we consider 50 years of life in this analysis). Second, we wanted to allow for the possibility of reinforcing nonsignificant effects across multiple transitions. Presently, we are engaged in methodological work using a bootstrapping approach to develop estimates of the standard errors for the multistate life table state probabilities and life expectancies based on the variance–covariance matrix of the hazard model parameter estimates.

Using the transition rates as inputs, we first calculated sex-specific life tables for persons with 0–6 years of education and persons with 12 years of education. For each education–sex group, the life table cohort (100,000) was allocated to the functioning states at the radix age 50 according to the prevalence observed for persons aged 45–54 (centred on age 50) at baseline. Persons in each functioning state at age 50 were then subjected to the transition rates. Next, we recalculated the life tables using mortality rates that were adjusted to produce life expectancies approximating those observed in 1940 and 1900 (by sex).

We rely primarily on the years of life a life table cohort can expect to spend in each functioning state as our metric for the life-cycle burden of disease in a population. That is, what is the expected number of years the average person at a given age could expect to live with and without functional limitations, given the mortal and morbid conditions defined by the hazard rates. We also show the corresponding age distribution of functional limitations for each of the life table cohorts to gauge the societal level of burden of disease, i.e., the health conditions of a population that a society must grapple with at a particular time point.

3.3. FINDINGS

3.3.1. Educational Disparities in the Burden of Disease Process

The hazard model results shown in Table 1 provide strong evidence of the associations between the level of education, functioning changes, and mortality. Relative to persons with 16 years of education or more (i.e., the reference category), persons with 0–6 years of education have higher rates of functional loss (2.67 times higher) and higher rates of death among persons having no major functional problems (1.63 times higher). Not surprisingly, the gap between the lowest education group and persons completing high school is not as great. Persons with the lowest education have a rate of functional loss that is 1.64 times greater than persons who completed high school (this effect is statistically significant). Among active persons, persons with the lowest level of education face a risk of death that is 1.15 times higher than persons completing high school.[2]

The results also illustrate that education affects the burden of disease primarily through its association with the onset of functional problems and mortality. Once functional problems occur, however, education does not appear to influence subsequent improvements in functioning or mortality. The education effect, in a sense, is played out relatively early in the disease process (a similar finding was reported by Zimmer et al. 1998). This pattern differs from that defined by sex, where sex effects operate in a synergistic fashion throughout the process. Females are more likely to experience the onset of functional limitations and less likely to recover or experience death, pointing to a lengthy period of functional limitations for females compared to males.

3.3.2. Active Life Expectancy Under Conditions of Improving Mortality and Education

The right-hand side of Table 2 illustrates the *current* disparity in active and inactive life expectancy separating persons with only a primary education from those completing high school. Note that the life table results substantively reflect the statistical associations shown in Table 1. Men aged 50 years, for example, with only a primary education can expect to live 2 years less than high school educated men. Primary school men are even more disadvantaged in terms of active life—they can expect more than 3 years *less* of active life than high school men. Inactive life is 1.5 years longer for primary school men compared to high school men even though primary school men at this age have a 2-year shorter

[2] The pattern of results shows differing and (for some events) non-linear associations between the risk of an event and education. For example, persons with 9–11 years of education have the lowest rate of functional recovery and the highest rate of death among persons who are active. We do not focus on the substantive interpretation of these patterns given that the focus of our thought experiment is based on a contrast of high and low educational groups. Nonetheless, these results point to potential negative health consequences for Americans of not completing high school.

. Hazard models of changes in functional status and mortality.

ion	Intercept	Age	Female	Educ 0–6	Educ 7–8	Educ 9–11	Educ 12	Educ 13–15
o inactive	−7.1681	0.047**	0.3896**	0.9834**	0.9419**	0.9474**	0.4913**	0.4445**
	(0.2027)	(0.0026)	(0.0593)	(0.1325)	(0.1264)	(0.1184)	(0.1143)	(0.1263)
to active	−0.7672	−0.0066**	−0.183**	−0.126	−0.188	−0.2069*	−0.0983	0.0212
	(0.1464)	(0.0018)	(0.0466)	(0.0944)	(0.0968)	(0.0919)	(0.0873)	(0.0986)
o death	−10.3593	0.0865**	−0.5384**	0.4882*	0.4963*	0.6618**	0.3504*	0.0776
	(0.3737)	(0.0047)	(0.0999)	(0.2073)	(0.1957)	(0.1830)	(0.1747)	(0.2070)
to death	−6.1551	0.0522**	−0.6298**	−0.0523	−0.0646	0.0060	0.0161	0.1142
	(0.3136)	(0.0036)	(0.0854)	(0.1770)	(0.1793)	(0.1771)	(0.1720)	(0.1929)

l *$p < 0.05$

. Simulations of active life expectancy in the United States under conditions of improving mortality and educational ent: civilian non-institutionalized population.

1900 mortality with 0–6 years of education			1940 mortality with 0–6 years of education			1992 mortality with 0–6 years of education			1992 mortality with 12 years of education		
Total	Active	Inactive	Total	Active	Inactive	Total	Active	Inactive	Total	Active	Inactive
20.60	18.17	2.43	22.65	19.90	2.76	28.32	24.12	4.19	30.41	27.72	2.69
14.14	12.45	1.68	14.98	13.11	1.87	20.59	17.28	3.31	22.22	19.93	2.29
8.70	7.39	1.31	9.34	7.86	1.48	13.76	10.99	2.78	15.06	13.11	1.95
4.91	3.95	0.97	5.34	4.24	1.10	8.51	6.30	2.21	9.42	7.86	1.56
2.58	1.89	0.69	2.84	2.04	0.79	4.67	3.03	1.65	5.51	4.31	1.21
24.73	19.67	5.06	25.89	21.29	5.60	33.32	24.82	8.50	35.24	29.14	6.09
17.52	13.53	3.99	18.50	14.13	4.37	25.06	17.82	7.24	26.70	21.40	6.30
11.37	8.14	3.23	12.15	8.58	3.57	17.68	11.45	6.23	19.00	14.37	4.63
6.85	4.37	2.48	7.04	4.34	2.69	11.77	6.65	5.11	12.70	8.82	3.88
3.91	2.07	1.83	4.30	2.23	2.07	7.63	3.56	4.08	8.20	5.04	3.15

life expectancy. Education under current conditions both extends total life, active life, and compresses the period of life with functional problems.

The expectancies based on the 1900 mortality schedule for a population with primary schooling or less (see the results in the far left of Table 2) present the situation currently faced by many developing countries. In most of these countries, older populations have a low level of educational attainment; and life expectancy is low compared to that for developed nations. Indeed, the life expectancy estimates using the 1900 mortality schedule are comparable to those for same-aged persons in the North African countries of Algeria and Egypt; the South Asian countries of Bangladesh, Indonesia, and Nepal; the Latin American countries of Bolivia, Ecuador, and Paraguay; and the sub-Saharan African countries of Gambia, Senegal, and Nigeria.[3]

We compare the expectancies based on the 1900 mortality and 0–6 years of schooling to the expectancies based on 1992 mortality and 12 years of schooling, to evaluate how the burden of disease shifts as a population's social capacity for health improves. Note first that the expected number of years with a functional problem increases slightly over the 92-year period. A man aged 50 in 1900 with 0–6 years of education could expect to live 2.4 years with a major functional problem. In 1992, the 50-year-old who completed high school could expect to live 2.7 years with a functional problem. Making this comparison among women, inactive life expectancy rose from 5 years to 6 years.

The major change, however, is in terms of active life expectancy. The simulated population's transformation from low levels of educational attainment and high mortality to high levels of achievement and low mortality resulted in a 9.5-year gain in active life among men aged 50 and almost a 10-year gain in men's total life expectancy. In relative terms, 97 percent of the gain in life expectancy among men aged 50 was in the years of life *without* a major functional limitation. Gauged in this sense, a major transformation in a population's social capacity for health appears to have profound and beneficial effects on the burden of disease. In our simulation, the burden of disease clearly fell in terms of the relative number of years a person can expect to have a functional problem. Given that statistical models were the basis on which the life expectancy estimates were calculated, the results for women parallel those for men.

The prevalence of functional limitations also fell for the 1900–1992 comparison. This is shown in Figure 1 that presents the prevalence rates for males implied by the incidence rates governing the mortality and morbidity experiences of the life table cohorts. The bottom line represents the implied prevalence of functional limitations for the population defined by the 1992 mortality rates and 12 years of education. The middle line represents the prevalence rates for the population defined by the 1900 mortality rates and 0–6 years of education. One way of gauging the magnitude of the fall in prevalence rates is to compare the populations in terms of the ages at which certain levels of functional problems are

[3] The estimates for life expectancy and educational attainment were obtained from the International Data Base developed by the U.S. Census Bureau. The web address for the IDB is http://www.census.gov/ipc/www/idbnew.html.

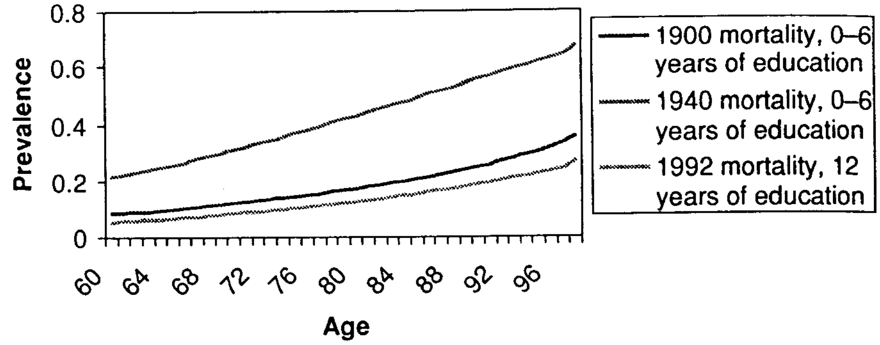

Figure 1. Prevalence of functional limitations, meals: life table cohorts.

reached. The prevalence rate for men aged 70 in 1900, for example, is 12 percent, and this level of functional limitations is not reached until age 78 in the 1992 population. Roughly 8 years separates the two populations in terms of when the prevalence of functional problems in the posttransition population is equivalent to that in the pretransition population.

Holding education and morbidity transition rates in the population constant, we also calculated a life table in which mortality was presumed to decline by 25 percent. In the United States, this approximates the mortality change that occurred from 1900 to 1940. We held education constant in order to approximate what might happen to the burden of disease when mortality is reduced in a population but improvements in education lag behind. As one can observe in Table 2, the pattern in terms of the relative number of years lived with a functional problem is roughly the same as that shown for 1900. Men aged 50 years, for example, can expect to live 12 percent of their total life expectancy (2.76 years out of 22.65) with a functional limitation. A mortality increase of 25 percent, given the base mortality shown for 1900, apparently has little consequence for the burden of disease in terms of disease experience over the life-cycle.

Turning back to Figure 1, however, we can see that the change in mortality, although not substantially altering health expectancies, has a strong effect on the prevalence of functional problems. The prevalence is dramatically shifted upward when mortality declines in a poorly educated population, under the assumption that an equitable decline in mortality occurs across the functioning states. Although the simulated mortality change appears to have had little consequence for the burden of disease experience over the life-cycle, the societal burden of disease is increased dramatically.

Our simulations are intended to reflect a plausible scenario of societal and demographic change. During the length of time spanning our simulations, we assume it is unlikely that medical progress in disease diagnosis and treatment or the lifestyle effects of education produce smooth and evolutionary improvements in the burden of disease. Progress across various diseases is likely to be uneven given the societal decisions about the allocation of health care resources, the nature of scientific discovery, and changes in population composition (Crimmins 1996; Hayward, Crimmins, and Saito 1998). Verbrugge (1989) also notes that in the early stages of fatal chronic disease fighting, medical care is often aimed at managing the fatal consequences of a disease. That is, the death of a person with a major health condition is postponed. This has the effect of extending the period of inactive life (Crimmins, Hayward, and Saito 1994; Hayward et al. 1998). As diseases become understood better, later stages of disease fighting focus on prevention and the postponement of disease onset. As prevention becomes the dominant focus in disease fighting, active life is extended and inactive life is compressed. Over a long-term period involving dramatic changes in a population's education and mortality, our basic point is straightforward.

At any one time we are likely to see improvements in some indicators of health and not others, and improvements in some age groups and not others (Crimmins 1996).

Here, we have shown that changes in the life-cycle burden of disease need not parallel changes in the societal disease burden.

4. Conclusions

The pace of fertility and mortality declines and the growth in educational attainment in most developing countries has been extraordinary since the end of World War II, and the trends show signs of continuing well into the present century (Ahuja and Filmer 1995; Easterlin 1997; Wils and Goujon 1998; Hayward and Zhang 2001). These trends will lead to significant population ageing on a global scale, an increase in the world's stock of human capital, and an increase in the social capacity for population health. Although this represents the world's demographic coming of age and an expansion of capabilities in economic development undertakings, many developing nations will nonetheless face the pressing dilemma of coping with the immediate demands of a rapidly growing older population while grappling with the necessity of increasing the stock of human capital among its younger population. Within the United States, this has led to age-targeted public policies pitting in a zero sum fashion the needs of the nation's younger population against those of its elderly citizens (Preston 1984).

There is growing recognition, however, that the education programs benefiting children have far-reaching multiplier effects and that some of these effects are manifested decades later in the reduction of major chronic diseases such as cardiovascular diseases or diabetes. Scientific evidence on this association has been growing rapidly over the past decade (Elo and Preston 1992; Kuh and Wadsworth 1993; Kuh and Davey Smith 1997; Kuh et al. 1997); and this evidence has fostered the development of policy related health programs such as WHO's Ageing and Life Course Program in the Department of Noncommunicable Disease Prevention and Health Promotion. Although public policy programs in the United States are still largely age-targeted, there is growing recognition that health care policies benefiting the elderly are inextricably tied to policies benefiting children. One of the mission's of WHO's Ageing and Life Course Program is to provide guidance for the development of these types of public policies.

Our analysis showcases the implications of the long-term investment in a population's social capacity for the burden of disease in the older population. As we have shown, populations that undergo a major increase in social capacity are likely to experience a substantial decline in the burden of disease. Many years of life are added to the average life-cycle and the vast majority of these years appear to be without major functional limitations. Prevalence rates of functional problems also drop substantially, reducing the short-term demand for protracted health care.

We have also cautioned against inferring that the changes in population health are necessarily linear *during* the transition in social capacity. In a crude sense the 1900–1992 simulation represents the beginning and ending equilibrium states, with disequilibrium defining much of the period in between. This point was exemplified by our 1940 simulation showing that reduced mortality without an improvement in the level of education led to a significant upswing in the prevalence of functional limitations in the population. Although the long-term consequence of the social capacity transition appears to be more years of life in good health and lower levels of functioning problems in the population, the march toward the reduced burden of disease need not be smooth and unidirectional. This reinforces the need to carefully lay out the scientific basis for long-term public policies aimed at reducing the burden of disease in the population, and it heightens the importance of a commitment to a long-term statistical monitoring of population health.

Preston (1984) argued that society as a whole gains more from a life-course perspective than a generational perspective. We concur and view this as a philosophical cornerstone in formulating public policies aimed at reducing the burden of disease in the population. Investing in a population's human capital through education is not only sound policy for economic development, but is also sound policy, both directly and indirectly, for the health of individuals and societies. Individuals gain longer, healthier lives while the collective costs of health care to future generations of elderly are reduced. This is particularly important given that as future cohorts of children become better educated, they may expect to live to older, and still older, ages.

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