A MODEL OF DEMAND FOR LONGEVITY

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Abstract

To the extent that a person's lifestyle affects the length of the person's life, personal lifestyle choices provide a means of formalizing the endogeneity of longevity. In this essay the demand for medical care is considered a lifestyle choice, motivated by the person's desire to prolong her lifetime. A fully-informed consumer chooses lifestyles in order to maximize her lifetime utility. The model is necessarily dynamic because a person's lifetime has multiple periods. The optimization yields the person's survival-motivated demand for medical. Mathematically, endogeneity of longevity implies that the upper limit of integration is determined in the model. The key policy question is the following: If your life is completely under your control, how long would you choose to live? Literature review is in section 2. The model is presented in section 3.

Results and policy implications are discussed in section 4, with conclusions and references in sections 5 and 6 respectively.

Introduction

The main issue addressed in this essay is the endogeneity of longevity. Suppose you had chance to choose how long you want to live, how long would you choose? Regardless of how one answers this question, the fact is that people do indicate how long they wish to live, not necessarily by their answers to survey questions, but by their lifestyle choices and behaviours. The basic reality is that death and illness impose real costs. As a result, rational persons are not indifferent to illness and death. For example, people do not generally wait helplessly for death to happen to them. That is, 'fear of death' can motivate personal action such that a risk-averse consumer embarks on conscious survival-induced attempts, efforts or actions in order to prolong his or her own life and the lives of loved ones. Depending on the degree of success or failure of such self-protection endeavors, a person's longevity becomes endogenous, more or less. As such, it is reasonable to assume that death plays a part in decisions of rational consumers. Nowhere is death more likely to play an important part than in the person's health care decisions because of 'the often intimate and immediate relation of health care to the quality and quantity of life' (Relman and Reinhardt 1986, p.217). Stated differently, health care is one of the survival-induced conscious actions and lifestyle choices a risk-averse consumer undertakes (or relies on) to help prolong life. Therein is a useful means of formalizing the relation between health care and longevity. According to Ehrlich and Chuma (1990 p.762), it is "possible to convert basic economic resources into marginal increments in opportunities for longer life".

It is an empirical question whether there are individuals who utilize medical care solely for survival motives, or whether there are portions of a person's medical care usage motivated by considerations of death and survival. These empirical questions about survival motivations suggest that formal considerations of the phenomenon of death are required for a fuller understanding of the demand for medical care. This essay explores the possible economic implications of the phenomenon of death itself and of the endogeneity of its occurrence. A 'pure survival' model of demand for medical care is developed in which a person demands medical care solely in order to prolong her life. Such a model may be a more appropriate representation of the medical care decisions of that proportion of any population for whom survival and longevity are the overwhelming motivations for medical care usage.

What is the individual's demand for longevity? The appropriate measure of a person's demand for longevity is how much resources she is willing to expend in order to increase her life by an additional period of time. A person seeking to prolong a life is faced with the question of how much the life is worth or how much potential benefits are expected from gaining an additional period of life. According to Murphy and Topel (2006 p.872), "Life extension is valued because utility from goods and leisure is enjoyed longer." Such value of life extension helps determine how much is worth spending on the life extension. The logic of this cost-benefit analysis is to spend to maintain a life as long as the marginal benefits of the life exceed its marginal costs or equal zero (Hall and Jones 2007, Murphy and Topel 2006, Ehrlich and Chuma 1990). In principle, human life is to be valued just like anything else that has economic value.

The present essay uses optimal control to study a fully-informed consumer's lifestyle choices in a lifecycle model with neither uncertainty or investment. The optimization yields the person's survival-motivated demand for medical care. The analysis indicates two results. The first is the possibility of periods of zero medical care usage during which the person abstains from medical care in spite of continued health depreciation. The phenomenon of abstinence corresponds to findings in cross-sectional data that many observations have zero medical care utilization (Wedig 1988, Manning et al. 1987) even in situations of free access to care. Likewise, time-series data show medical care utilization in some time periods but not in others periods. The location of periods of abstinence is of policy relevance because of a general belief that young people value their lives relatively less than the old value theirs, leading to sayings such as 'youth is wasted on the young', or people are more ‘adventurous when young and more cautious when old’ (Ng 1989 p.13). Observed lifecycle differences in health outlays can be related to the "tendency of relatively young persons to participate in activities considered detrimental to their health" (Ehrlich and Chuma 1990 p.764). The present model attempts to replicate formally the stylized fact that the periods of abstinence tend to occur relatively early in the lifecycle.

The second result is that both medical care utilization and nonmedical consumption increase with age. First, as a Fisherian-type model, a person’s nonmedical consumption increases with age if the market rate of interest exceeds the person's rate of time preference (Yaari 1965 p.l38). Second, medical care usage increases with age because health depreciates increasingly with age in the human-capital model such that an old person requires more medical care than the young even to maintain the same level of health, all else equal. This latter result has the intuition and empirical support that medical care use is highest towards the end of a person’s life. Hall and Jones (2007 p.40) suggest a different explanation viz, "As we get older … which is more valuable: a third car, yet another television, more clothing—or an extra year of life? There are diminishing returns to consumption in any given period and a key way we increase our lifetime utility is by adding extra periods of life." That is, both consumption and health expenditures increase with age (and with income) but health expenditures increase relatively more rapidly because the marginal utility of consumption decreases as consumption rises but the marginal utility of longevity does not fall.

Review of Related Literature

What is the value of your life? According to Bergstrom (1982 p.3), "… even in ‘matters of life and death’ there must be a logic of choice and a theory of ‘pricing the priceless’.” The 'logic of choice' dictates that, due to scarcity, the value of your life or any other life cannot be infinite. According to Schelling (1968 p.127): “It is not the worth of human life that I shall discuss, but of ‘life-saving,’ of preventing death. And it is not a particular death, but a statistical death. What is it worth to reduce the probability of death – the statistical frequency of death – within some identifiable group of people none of whom expects to die except eventually?” Schelling's original idea is not to price any particular person's life but, instead, to determine a society's demand for survival defined as the society's willingness to pay (WTP) for a reduction in the probability of death, mortality rates, etc. Subsequently, Schelling's idea has been broadened to WTP for a reduction in the risk of death (which incorporates probability of death). Conversely, how much would a society be willing to accept in compensation for a small increase in the risk of death? Note that the WTP for reductions in the risk of death, however manifested, whether as WTP for health care or willingness to spend time, effort and money on improved lifestyles, all of these efforts and behaviours amount to the same thing; each is motivated by survival (Jones-Lee 1976, 1982). As such, the cost-benefit of life-saving endogenizes survivability. There has developed a subsequent literature, referred to as 'Value of Statistical Life (VSL),' that attempts to determine numerical values a society would attach to a statistical life (for example, Viscusi and Aldy 2003).

Consider a government project such as a local government ambulance service that can help save people’s lives in your community. What is your willingness to contribute to the extra life-saving the project helps make possible? In many cases, before the project is introduced, it is usually not known whose life will be saved by the project. Therefore, the relevant WTP is ex ante, before it is known who will be affected. This is a cost-benefit analysis of public programmes that increase life expectancy or decrease mortality rates (Rice 1968, Klarman 1968, Rottenberg 1968). Whether or not the project is undertaken depends on whether the aggregate WTP in the local government is high enough to cover the cost, etc. of the life-saving project. Because of the public goods nature of such projects, individual's WTP is relevant only to the extent that the project is not undertaken unless 'enough' persons pay enough for it (Deaton 1988). According to Mishan (1971), the appropriate measure of a person's WTP for a public project intended to save a life is the person's compensating or equivalent variation (CV or EV) which depends on who has the right to have the life saved. Such property rights are relevant because public projects can yield benefits to some persons while jeopardizing some other persons, in which case the project would not be undertaken unless benefits are great enough for 'gainers' to compensate 'losers.'

The foregoing analysis suggests implicitly the absence of private markets for reductions in the risk of death, or some other sort of market failures that justify socially provided reduction in the risk of death. Otherwise, why else would society take on the duty of saving the lives of people who can save their own lives? In reality, people do engage in activities and behaviours intended to influence the risks of their lives. Why not incorporate a person's attitude towards risks of death in calculating the value the person attaches to life (Fromm 1968, Conley 1976, Thaler and Rosen 1976, Gould and Thaler 1980, Freeman 1985)? It follows that a person's WTP for saving her own life incorporates her WTP for public projects as well as her WTP for personal risk reduction such as medical care, non-market activities including physical exercise, etc. (Weisbrod 1978).

Human-capital models of demand for health care provide a convenient way to incorporate personal efforts towards survival and longevity. Imagine that a person's health depreciates increasingly with age and the person dies if her health falls to the 'death level'. This idea can be specialized such that the only role played by the person's health status is to help determine the instant of the person's death. Medical care usage counteracts the health depreciations (Grossman 1972) and if enough medical care is utilized, the person's health can be maintained at any desired level. But because health depreciation increases with age, the marginal cost of maintaining any positive level of health eventually exceeds its marginal benefits as the person ages (Eze 2018). Then, health investment stops and the person dies because of budgetary reasons. Even if her life was completely under her control, she would not necessarily choose to live indefinitely. It is unclear why Murphy and Topel (2006 p.871) distinguish two types of health improvements: "those that extend life and those that raise the quality of life." What matters is good health.

The Model

Consider a person's lifetime from birth at $t = 0$ to death at $t = T > 0$. At birth, the person inherits a given initial level of health or wellness represented by $H(t=0) = H_0 > 0$. The person's level of health in each subsequent period is represented by $H(t)$ which depreciates at a given rate $\delta > 0$, interpreted as aging. Death occurs when the person's health attains a particular level, the death level, $H_d \geq 0$. This assumption, $H_d \geq 0$, is needed in order for T to be finite. From the time of death $T \geq 0$ onward a person's health remains at the death level H_d (death is an 'absorbing state'). It is assumed that $H(t) > H_d$, for all $0 \leq t < T$. Unless a person takes lifestyle actions, including health care, diet, etc. to counter the health depreciation, her level of health falls to the death level eventually. A person is assumed to have a nonhuman asset $A(t)$ with a constant net rate of return $r \geq 0$ and given initial and terminal values, $A(0) = A_0 \geq 0$ and $A(T)$, respectively. It is assumed that in each living period the person gets a fixed income $Y \geq 0$. Although income can be a function of a person's health such that $Y = Y(H)$, but for many elderly and unemployable persons whose incomes are in the form of social security, etc., income is fixed, independent of level of health. Moreover, the dependence of income on health can be ignored if the person can insure her income fully against its vicissitudes and can receive annuities. For simplicity, the present analysis assumes that $Y = 0$. The person can spend his or her wealth as she pleases on consumption $C(t)$ that yields utility, on medical care $M(t)$ used to produce health $H(t)$ using a health production function $h(M)$; the remainder can be invested. $M(t)$ is purchased at a constant price p. Nonmedical consumption $C(t)$ is the numeraire good. The person's lifetime problem is:

3.1. $V(H,A,t) = \max_{C,M} \int_{t=0}^{T(H)} e^{-\rho t} U(C(t)) dt$

Subject to

3.2. $\dot{H}(t) = h(M(t)) - \delta H(t)$

3.3. $\dot{A}(t) = rA(t) - C(t) - pM(t)$

3.4. $H(0) = H_0 > 0$ given

3.5. $H(T) = H_d > 0$ given

3.6. $A(0) = A_0 > 0$, given

3.7. $A(T) \geq 0$

3.8. $C(t) \geq 0$, $M(t) \geq 0$.

3.9. $U(0) = 0$, $U'(t) > 0$, $U''(t) < 0$, $\lim_{C \to 0} U'(C(t)) = \infty$, $h'(t) > 0$, $h''(t) < 0$, $T'(H) > 0$, $T''(H) < 0$.

For expositional simplicity, arguments of some functions are dropped. $\rho > 0$ is a rate of time preference, assumed $\rho < r$. The current value Hamiltonian for this model is

$$L = U(C(t)) + \lambda_h(t)[h(M(t)) - \delta H(t)] + \lambda_a(t)[rA(t) - C(t) - pM(t)] + \gamma C(t) + \eta M(t)$$

where $\lambda_h(t)$, $\lambda_a(t)$, $\gamma = \gamma(t)$ and $\eta = \eta(t)$ are current value multipliers, with given initial conditions. $\lambda_h(t)$ is the marginal contribution of health to lifetime utility or value of health; $\lambda_h(t) \geq 0$. Also, $\lambda_a(t)$ is the marginal utility of the asset. The optimality conditions are the following:

3.11. $U'(C) - \lambda_a(t) + \gamma(t) = 0$

3.12. $\lambda_h(t)h'(M) - p\,\lambda_a(t) + \eta(t) = 0$

3.2. $\dot{H}(t) = h(M(t)) - \delta H(t)$

3.3. $\dot{A}(t) = rA(t) - C(t) - pM(t)$

3.13. $\dot{\lambda}_a(t) = (\rho - r)\,\lambda_a(t)$

3.14. $\dot{\lambda}_h(t) = (\rho + \delta)\,\lambda_h(t)$

3.15. $e^{-\rho t}U(C(T)) + \lambda_h(T)[h(M(T)) - \delta H(T)] + \lambda_a(T)[rA(T) - C(T) - pM(T)] + \gamma(T)C(T) + \eta(T)M(T) = 0$.

The key mathematical problem is that the upper limit of integration, $T = T(H)$, $T'(H) > 0$, $T''(H) < 0$, is endogenous because the person, through medical care usage, can determine when T occurs, when health H attains the death level H_d (Grossman 1972 p.226). This mathematical problem can be handled as follows. Let the relationship between a person's health H and her age t be given by a function, $H = g(t)$. If g(t) is monotonic in the relevant range, it can be inverted as $t = \tau(H) \equiv g^{-1}(H)$. Let T be a dummy variable for the value of t when $H = H_d$. That is, $T \equiv \tau(H_d) = g^{-1}(H_d)$. Some previous authors, for example, Shepard and Zeckhauser (1982 p.105), regard T as a large number that a person's lifetime cannot exceed, referring to T as a "maximum possible survival time".

Equation 3.15 is the transversality condition. Additional optimality (that is, Kuhn-Tucker) conditions are

$\gamma(t) \geq 0 C(t) \geq 0$ $\quad\gamma(t)C(t) = 0$

$\eta(t) \geq 0$ $\quad M(t) \geq 0$ $\quad \eta(t)M(t) = 0$

ISSN: 2811-1753(Paper) ISSN: 2811-1761(Online)
Vol. 1, No. 1: 38-47, 2021

Muurinen (1982 p.12) recognizes that the Kuhn-Tucker form of the necessary conditions allows medical care utilization to be zero in some periods. From Equations 3.13 and 3.14, respectively:

$$\lambda_a(t) = \lambda_a(0)\, e^{(\rho - r)t}$$

$$\lambda_h(t) = \lambda_h(0)\, e^{(\rho + \delta)t}$$

where $\lambda_a(0)$ and $\lambda_h(0)$ are the initial values of $\lambda_a(t)$ and $\lambda_h(t)$, respectively. For ease of representation, let $\lambda_a \equiv \lambda_a(0)$ and $\lambda_h \equiv \lambda_h(0)$. Applying the Inada condition: $\lim_{C \to 0} U'(C) = \infty$, Equation 3.16 gives $C(t) > 0$ and $\gamma(t) = 0$ for $0 \leq t < T$. Then, from Equation 3.11,

3.20. $U'(C) = \lambda_a(t)$

Differentiating both sides of Equation 3.20 with respect to t, using Equations 3.13 and 3.20, and rearranging terms gives

3.21 $\dot{C}(t) = (\rho - r)\frac{U'(C)}{U''(C)} > 0$

The optimal value of nonmedical consumption can be obtained from Equation 3.20:

3.22. $C^*(t) = U'^{-1}(\lambda_a(t))$

where U'^{-1} is the inverse of U'(.). In view of Equations 3.20 and 3.21, Equations 3.22 implies that optimal nonmedical consumption rises with age at a predetermined rate. Consumption is 'smoothed out'. From Equation 3.19, the value of a person's health $\lambda_h(t)$ increases with age. In the present model, the only purpose of medical care is survival and life is maintained so long as the person's health is above its death level. It follows that a person with a level of health 'substantially' higher than the death level can maintain her life 'for a while' without utilizing medical care at all. Thus, abstinence from medical care is conceivable in periods the person has relatively high levels of health. Rather than acquire more health in such periods of high health, a person may 'sell' her health and the use the proceeds for other purposes. For example, health is sold to the extent that a person undertakes relatively high-paying activities with relatively high health hazards. According to Cropper (1981), the rate of health depreciation depends on, among other things, the intensity of use of health capital. Likewise, Weisbrod imagines a market in which the person can buy or sell her survival probability at a price. Survival probability could be sold or bought to the extent that the person undertakes activities that alter his or her survival probability but at the same time raise her personal income (Thaler and Rosen 1976). Equilibrium in such a market requires the value of benefits from small reduction in the risk of death to equal its costs. According to Fromm (1968 p.170), "The price of life saving must equal (or be less than) the marginal rate of substitution of survival and income-asset utilities," which equals marginal utility of survival divided by marginal utility of income-wealth.

If there exist periods in a person's life when the consumer chooses not to incur medical expenses, then each period is to be considered in turn. Either a person utilizes medical care or not [either $M(t) = 0$ and $\eta(t) > 0$, or $M(t) > 0$ and $\eta(t) = 0$ in Equation 3.17]. Consider first a period in which $M(t) = 0$. Using Equation 3.18 in Equation 3.12 gives, with $h'(0) \equiv h'(M)\big|_{M=0}$, etc.

3.23. $\eta(t) = pU'(C) - \lambda_h(t)h'(0) > 0$

It follows from Equation 3.23 that a person does not utilize medical care if the price of medical care exceeds the adjusted marginal benefits of medical care (Muurinen (1982 eq.10).

3,24. $p > \frac{\lambda_h}{\lambda_a}h'(0)$, where $\lambda_h \equiv \lambda_h(t)$ and $\lambda_a \equiv \lambda_a(t)$.

The optimal level of health in abstinence or optimum H(t) when $M(t) = 0$, Equation 3.2 becomes

3.25. $\dot{H}(t) = h(0) - \delta H(t)$

The solution of Equation 3.25 is

3.26. $H^*(t) = k_1 □^{-□□} + h(0)/\delta$, $\delta \neq 0$.

The optimal value of assets A(t) when M(t) = 0 is obtained from Equation 3.3:

3.27. $\dot{A}(t) = rA(t) - C(t)$

3.28. $A^*(t) = e^{rt}\{-\int e^{-rt} C^*(t)dt + k_2\}$

where use is made of Equation 3.22. k_1 in Equation 3.26 and k_2 in Equation 3.28 are constants of integration to be determined. When M(t) = 0, equilibrium is characterized by Equations 3.18, 3.19, 3.22, 3.26 and 3.28. In general, $\lambda_h(t)$ and $\lambda_a(t)$ depend on the optimal values $H^*(t)$, $A^*(t)$, $M^*(t)$ and $C^*(t)$ of health, asset, medical care and consumption (Arrow and Kurz 1969 p.71).

In a period of positive medical care usage, M)t) > 0, $\eta(t) = 0$; Equation 3.2 becomes

3.29. $\lambda_h(t)h'(M) - p\lambda_a(t) = 0$

3.30. $p = \frac{\lambda_h}{\lambda_a}h'(M)$

Equation 3.30 is an equilibrium equation for a period in which medical care is in use. The marginal cost of medical care in a competitive market is its price, while its marginal benefit is the product of the adjusted marginal value of health and the marginal health product of medical care. In such a period, the marginal benefit must, at least, equal the marginal cost of medical care in order for medical care to be utilized.

Let $g(t) \equiv \frac{□}{h'(□)}$. Then Equation 3.29 can be manipulated to get $r + \delta - \dot{□}(t)/g(t) = 0$;

the user cost of health is zero in this model. If utility and income depended on health such that U = U(C,H) and Y = Y(H), one gets (Cropper 1977 p.1279, Muurinen1982 p.12, Ehrlich and Chuma 1990 p.769): $r + \delta - \dot{□}(t)/g(t) = \frac{U_h}{U_a} - Y'(H)$, where $U_h = U_h(.)$ and $U_a = U_a(.)$ the marginal utility of health and assets, respectively. Rearranging Equation 3.30 gives

3.31. $h'(M) = p\frac{\lambda_a}{\lambda_h}$

Differentiating Equation 3.31 with respect to time, and rearranging, gives:

3.32. $\dot{M}(t) = -(\delta+r)\frac{h'(M)}{h''(M)} > 0.$

Equation 3.32 says that when medical care is utilized, its utilization increases with age. From Equation 3.29, optimal level of M(t) can be solved for:

3.33. $M^*(t) = h'^{-1}p\frac{\lambda_a}{\lambda_h}$

From Equations 3.21 and 3.32, note that both C(t) and M(t) can increase simultaneously. These results do not require $d\delta/dt > 0$ as in Ehrlich and Chuma (1990 p.766) or Cropper (1977 p.1284). In the present model, the youth consumes less and utilizes relatively less medical care, she can save more in order to afford increased expenditures in old age. The optimal values of health and assets $H^*(t)$ and $A^*(t)$ in periods with positive medical care usage, M(t) > 0, are given by Equations 3.34 and 3.35 respectively:

3.34. $H^*(t) = e^{-\delta t}\{\int e^{\delta t} h(M^*(t)dt + k_3\}$

3.35. $A^*(t) = e^{rt}\{-\int e^{-rt}[C^*(t) + pM^*(t)]dt + k_4\}$

where k_3 and k_4 are constants of integration to be calculated. Note that when medical care is utilized M(t) > 0, equilibrium is characterized by Equations 3.18, 3.19, 3.22, 3.33, 3.34 and 3.35.

The following endeavor attempts to locate the periods of abstention. A person's lifetime can be categorized in two parts: positive medical care usage in one part and abstinence in the other part. This statement holds because the period of abstinence is unique in the sense that once medical care is initiated, abstinence does not occur. Let t^* denote the boundary between the two parts of the lifetime: $0 \leq t \leq t^*$ and $t^* \leq t \leq T$. t^* is a choice variable with an optimal value for each individual. 'Early life' or 'youth' and 'late life' or 'old age'

Global Research Journal of Economic and Social Development
ISSN: 2811-1753(Paper) ISSN: 2811-1761(Online)
Vol. 1, No. 1: 38-47, 2021

refer to the two parts of the lifetime, respectively. We propose and attempt to prove a theorem that if abstinence from medical care occurs at all, it occurs in youth.

Proposition 1: The period of abstinence from medical care is unique in the sense that once medical care utilization has occurred, abstinence cannot occur.

Proof: By contradiction. Condition 3.32 is violated if medical care utilization precedes abstinence from medical care.

Proposition 2: Abstinence from medical care can occur early in life [$M(t) = 0$ for $0 \leq t \leq t^*$].

Proof: (a) From Equation 3.32, medical care utilization is non-decreasing over the lifecycle. (b) $M(t)$ is nonnegative. (c) From Equation 3.14, the value of health increases monotonically with age, leading to increased investment in health as the person ages. Therefore, if abstinence from medical care occurs at all, it occurs early in life.

Theorem: If medical care is used at all, it is used later in life; $M(t) > 0$ for $t^* \leq t \leq T$.

Proof: By Propositions 1 and 2.

Having established that the period of abstinence from medical care occurs early in life if it occurs at all, the constant of integration can be solved for in Equation 3.26, for example, for k_1:

3.36. $$k_1 = [H_0 - \frac{h(0)}{\square}]e^{-\delta t} + \frac{h(0)}{\square}$$

From Equation 3.36, it can be seen that the optimal level of health is independent of wealth. This implies that two otherwise identical persons with equal initial health levels but with different endowments of assets will be equally healthy in youth. Values of k_2, k_3 and k_4 can be obtained similarly. Additional results can be obtained by parameterization.

Interpretation of Results

This essay presents a 'pure survival' model of demand for medical care to complement the 'pure consumption' and 'pure investment' models of demand for health (Muurinen 1982). The model yields a derived demand for medical care, derived from the demand for longevity. Our results are in general agreement with results from Hall and Jones (2007), Murphy and Topel (2006) and Ehrlich and Chuma (1990), etc. For example, in our model, both consumption and medical care usage increase with age, contrary to Cropper (1977) who assumed that $A(t) = 0$ for all t, and found that medical care usage falls with age. In either case, the person's budget is 'overstretched' eventually. This means that, to the extent that resources are scarce, even though a person can choose completely the length of her life, she chooses a finite lifetime. This result has policy implications related to long-term care and professionals who do 'everything' to save a life regardless of cost (Fitzgerald 1984).

Comparing the rich with the poor as defined through their relative levels of wealth, it can be shown that the rich accumulates more assets during the period of zero medical care or $\frac{\square\square(\square)}{\square\square_0} > 0$, and starts old age with relatively larger wealth which allows her to maintain a longer lifetime and/or to sustain a higher quality of life. The ability of the relatively wealthy to maintain longer life can be used to explain the relatively higher life expectancy in asset-rich countries.

A conceptual difficulty arises because two otherwise identical individuals can make different lifetime choices if they face different 'scrap values' in death. According to Conley (1976 p.51), a pleasant hereafter may diminish a person's willingness to undertake high survival and safety expenditures. To get around this problem, the present analysis assumes that, for the individual, death implies the minimum attainable value of utility (Fromm 1968 p.169, Jones-Lee 1974, p.838). Some issues arise with regards to a person's WTP for medical care when her total medical care consumption (or medical care need) exceeds her total lifetime earnings or her total income for the remainder of her life. Allocative efficiency can be used to justify programmes like United States Medicare that provide the elderly with more access to care (Davies 1981).

Another analytical difficulty is that if a person abstains from medical care early in life, how low would she allow her health to depreciate before utilizing medical care? Given that a person's life is sustained so long as her level of health exceeds the death level, there is little need to maintain the health any higher. For example, a person born at time t = 0, with an initial health $H_0 > H_d$ and abstains from medical care until age t^*. By then her health has depreciated to her desired level $H(t^*) = H_d + \varepsilon$, say, for a small $\varepsilon > 0$. From age t^* to the end of life at T, she aspires to maintain a constant level of health $H_d + \varepsilon$ by demanding just enough medical care to maintain that level. Death occurs eventually because increasing health depreciation makes it increasingly 'expensive' to maintain health above the death level. The problem is that, for any chosen consumption path, the person can 'do better' by choosing another feasible consumption path (Yaari 1965 p.138). If she can maintain her life at a health level $H_d + \varepsilon$, she can as easily maintain it at a smaller value of health such that $H_d + \varepsilon_1 < H_d + \varepsilon$; $0 < \varepsilon_1 < \varepsilon$. By choosing a smaller level of health, she can enjoy a longer period of abstinence from medical care because the depreciation from H_0 to $H_d + \varepsilon_1$ takes longer than the depreciation from H_0 to $H_d + \varepsilon$. In addition, total depreciation is smaller for lower levels of health so that the smaller level of health ($H_d + \varepsilon_1$) enables her to spend a relatively smaller amount on medical care during the period of medical care use. As a result, the person with a lower level of health ($H_d + \varepsilon_1$) can live longer and/or enjoy higher consumption. But ε_1 is not unique and life can be maintained so long as health level is above the death level. Therefore, it is rational for health to be maintained infinitely close to the death level. As a result, an equilibrium level of health may not exist at all.

Existence problems apart, this model of endogenous longevity is not unrealistic. Suicide is an extreme example of the fact that 'your life is in your hands'. It is acknowledged that, in general, longevity depends partly on one's behaviours and actions, including health care choices, and partly on technological, environmental and genetic factors beyond the person's control.

Conclusion

The present analysis is restricted to how much a person is willing to pay for a marginal increase in her lifetime. This is the appropriate economic concept of the consumer's demand for longevity. In this model, a person’s potential lifetime is finite and death is inevitable. In that case, medical care is only an attempt to ‘postpone the inevitable’; the Editors of Life and Death and Medicine (1973 p.3) suggest that medicine can do little to promote growing up or to prevent growing old and dying. On the other hand, medical care is special, unlike most other types of consumer goods and services that have little direct effects on a person’s survival (Deaton 1986) and medical care can include genetic engineering which can alter ‘the natural history of the individual’. Then, it is conceivable that finiteness of life and inevitability of death are ultimately technological and economic (Conley 1976 p.46, Ehrlich and Chuma 1990 p.770). That is, there is no biological reason for death to be ultimately inevitable. The present model represents the view that, given resource availability and current medical and biomedical technology, death is inevitable, at least, eventually, and life is finite.

The first economics discussion of death, survival and longevity we got aware of is Thomas Schelling's (1968) presentation at a 1966 Washington D.C. conference on cost-benefit analysis. [We have since become aware of an earlier effort by a French economist named Drèze.]

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