RELATIVE ECONOMICS OF HUMAN LIFE SPAN

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ECONOMICS OF HUMAN LIFE SPAN

A fundamental question concerning aging is whether the life spans of organisms evolve, and if so, what forces govern their evolution. In this article I argue that life spans do evolve and present a general theory of life spans, with a particular focus on humans. I employ a qualitative definition of life span : the amount of time between birth and the age at which the likelihood of death becomes high, relative to the likelihoods at younger ages. Most multi cellular organisms exhibit a phase in which mortality decreases with age and then a second phase in which mortality increases with age. My definition focuses on this second phase, on the age at which death becomes imminent because of physiological deterioration or some environmental condition (Such as winter). I chose this approach over the “maximum life span” concept, because it is more biologically meaningful. It focuses on the length of time that organismic function is adequate to sustain life. Since it is concerned with possibilities rather than actual events, it assumes that many individuals donot live their full life span. For many organisms, including humans, this qualitative definition corresponds to a more precise quantitative definition : the modal age at death, conditional on reaching adulthood. The principal argument I develop is that life spans evolve as part of an integrated life-history program and that the program for development and reproduction is fundamentally related to the age of death.

My first section outlines an evolutionary economic frame work for understanding the effects of natural selection on life histories, previously referred to as “embodied capital theory”. It combines the basic structure of life-history theory as developed in biology with the formal analytical approach developed in the analysis of capital in economics. I next discuss specialization and flexibility in life histories, with special emphases on the fast-slow continuum and on the relationship between brain evolution and life-history evolution. My second section focuses on the special features of the human life course. The theory posits that large brains and slow life histories result from a dietary specialization that has characterized the last two million years of human evolution. Empirical findings suggest that humans have a particular life course with characteristic schedules of growth, development, fertility, mortality and aging. The approach here does not assume that those schedules are fixed and unresponsive to environmental variation. Rather it implies structured flexibility based upon the variation experienced in human evolutionary history and a set of specialized anatomical, physiological and psychological adaptations to the niche humans occupied during that history. Together, those adaptations result in a life span for the species that can vary within a limited range. I conclude with a discussion of two themes : Short and long term flexibility in the human life span and the building blocks for a more adequate theory of senescence and life span.

SPECIALIZATION AND FLEXIBILITY IN LIFE HISTORIES

Variation across conditions in optimal energy allocations and optimal life histories is shaped by ecological factors, such as food supply, disease and predation rates. It is generally recognized that there are species-level specializations that result in bundles of life history characteristics, which, in turn can be arrayed on a fast slow continuum (Promislow and Harvey 1990). For example, among mammals, species on the fast and exhibit short gestation times, early reproduction, small body size, large litters and high mortality rates, with species on the slow end having opposite characteristics. Similarly among plants, some species that specialize in secondary growth are successful at rapidly colonizing newly available habitats, but their rapid life history means that they invest little in chemical defense and structural cells that would promote longevity. On the other end of the continuum are trees, such as the bristle cone pine, that are slow to mature but suffer very low mortality rates and are very long lived. (Finch 1998).

A central thesis of this article is that both specialization and flexibly are fundamental to understanding the human life span. on the one end, the large human brain supports the ability to respond flexibility to environmental variation and to learn culturally, facilitating short-term flexibility, on the other hand, the commitment to a large brain and the long period of development necessary to make it fully functional constrains the human life course by requiring specialization for a slow life history.

EMBODIED CAPITAL AND LIFE-HISTORY THEORY

The embodied capital theory integrates life-history theory with capital investment theory in Economics (Becker 1975, Mincer 1974) by treating the process of growth, development and maintenance as investments in stock of somatic or embodies capital. In a physical sense, embodied capital is organized somatic tissue : muscles, digestive organs, brains and so on. In a functional sense, embodied capital includes strength, speed, immune function, skill, knowledge and other abilities. Since such stocks tend to depreciate with time, allocation to maintenance can also be seen as investments in embodied capital. Thus, the present future reproductive tradeoff becomes a tradeoff between investments in own embodied capital and reproduction, and the quantity-quality tradeoff becomes a tradeoff between the embodied capital of offspring and their number.

THE HUMAN LIFE COURSE AND HUMAN LIFE SPAN

My fundamental thesis in this article is that human life course is an integrated adaptation to a specialized niche. Digestive physiology and anatomy; nutritional biochemistry; brain growth and cognitive development; tempo of body mass increases and appetite; as profiles of productivity; reproduction, parental investment and mortality; and ultimately, the life span are co adopted to a learning-intensive feeding niche, giving humans access to the most nutrient dense and highest quality resources. The joint examination of these domains suggests a highly structured life course, in which six distinctive stages can be recognized.

Brain growth occurs from the early fetal stage to about 5 years of age, with 90% occurring by age 3.0 to 3.5. Human mothers and their babies maintain large fat reserves to support this brain growth (Ellison 2001; Kuzawa 1998). While cognitive development unfolds over many more years, a great deal of linguistic competence, especially comprehension, is achieved during this first stage of life. Thus it would seem that the human specialization evident in the first stage of life is building the “Physical plant” (i.e. the brain) and the knowledge acquisition pathway (i.e. language ability) to support a long period of learning.

The second stage, childhood is characterized by very slow physical growth, a large energetic allocation to building the immune system (Mc Dade and Worthman 1999). Several important phases of cognitive development facilitated by play and other forms of practice, very low productivity and very low mortality. Parents insist that children remain in safe places and encourage them to produce food only when it is easily and safely acquired (Blurton Jones, Wawkes and Draper 1994). The unique feature of human childhood is that it is fully supported by familial energy inputs, reducing exposure to mortality hazards and allowing time for learning. Faster physical growth would only make children more expensive before their brains were ready for food production.

Adolescence follows, during which physical growth is accomplished rapidly, the reproductive system matures, and the final phases of cognitive development occur. It is during this phase that the brain and the rest of the body become ready for adult productivity. While productivity increases during adolescence, it is also largely supported by familial food inputs.

Old age commences ground age 60, and during this seventh decade of life physical deterioration proceeds rapidly and brain aging becomes evident, followed by a sharp increase in mortality rates. Presenting is finished and work effort decreases along with productivity. This is not to say that there are no positive contributions to fitness during this phase. Older adults attempt to be as productive as possible, reallocating their time to still intensive but less energy intensive activities (e.g., craft production and child care; Gurven and Kaplan 2001) They may also affect the productivity of the younger population through their knowledge of the habitat and through their political skills.

FLEXIBILITY AND VARIATION IN HUMAN LIFE SPAN

The human brain is the physical medium through which culture is maintained and transmitted. As such, Generally thought to have greatly expanded the behavioral flexibility of our species relative to other animals. However, the commitment to building and programming the brain require a highly structured life history that places constraints on the timing of life events. Our species is committed to long term neural and cognitive capital accrual and to a long life span. The characteristic life history of our ancestors have shaped age profiles of growth, tissue repair and physical decline.

In contrast to this increase in the rate of physical development, again may be slowed in response to better nutrition and decreased work and disease loads. Although it is possible that humans would also show slower aging in response to radical reductions in caloric intake. It is also possible that within the usual range of variation, rates of aging are slowed and life spans are lengthened when nutrition is better and disease loads are lower (Fogel and Costa 1997).

On the other hand increased risk of heart disease, diabetes and cancer from overweight and lock of exercise may also be the result of evolved responses. Given the common activity regimes in our past and the variability in food supply, human appetites and nutritional biochemistry may be designed to store fat and increase blood lipid levels when food is abundant. These adaptations might reduce the life span in the context of modern patterns of activity levels and food access and consumption.

Impressments in public health should also promote reinforcing increases in capital investment and staying alive. it is an open question whether we are reaching the upper limit of our flexibility in the life span. It appears that with respect to stature and perhaps age of menarche, we have reached the limit. There appears to be more scope for variation in the life span, given investments in medical technology designed to reduce disease and the effects of aging. In any case, knowledge about the human genome is likely to lead to manipulations of genes and gene products, resulting in life span increases of very large magnitude.

BUILDING BLOCKS FOR AN ADEQUATE THEORY OF SENESCENCE AND THE LIFE SPAN

Senescence is generally defined as an increasing mortality rate with age. Current mortality can be reduced by current energy expenditure. What then causes senescence ? Suppose there are cost functions for building embodied capital and for repairing and maintaining embodied capital. Imagine that the embodied capital stock is described in terms of two state variables, the quantity of the stock and its efficiency. From its inception, the organism builds somatic capital, adding to its quantity until the optimal quantity is reached. However, because of its own metabolic activity and assaults from outside agents, the efficiency of the capital stock is subject to decay. For example, free radicals and other harmful molecules may accumulate in cells, accidents may cause tissue damage, and pathogens may disrupt physiological function and damage cells. In the same sense that the costs of producing new car seats may be different from the costs of repairing tears in those seats, the costs of producing new cells and adding to the quantity of embodied capital may be different from the costs of repairing damage to them. Thus, during development, the optimal life history programme will have to be equalize marginal fitness from three different investments : adding to new capital, repairing existing capital and reducing current mortality. When the capital stock reaches the level at which some allocation to reproduction is also optimal, marginal returns from investments in producing new capital in the form of descendants must also be equalized with the marginal returns from the other three investments.

What are the costs and benefits of reducing the quantities of harmful molecules in cells, of DNA repair, and of differing numbers and kinds of immune cells ? How do those costs and benefits compare to those associated with increase in Muscle mass, brain mass and learning ? As long as production is constant with a constant capital stock, optimal mortality rates remain constant as well.

CONCLUSION

Life span of human can be defined as the amount of time between birth and the age at which the likelihood of death becomes high, relative to the likelihoods at younger ages. Most multi cellular organisms exhibit a phase in which morality decreases with age and then a second phase in which mortality increases with age. Empirical findings suggest that humans have a particular life course with characteristic schedules of growth, development, fertility, mortality and aging. I conclude with a discussion of two themes : short and long term flexibility in the human life span and the building blocks for a more adequate theory of senescence and life span.

A central thesis of this article is that both specialization and flexibility are fundamental to understanding the human life span. On the one hand, the large human brain supports the ability to respond flexibility to environmental variation and to learn culturally, facilitating short term flexibility. On the other hand, the commitment to a large brain and the long period of development necessary to make it fully functional constrains the human life course by requiring specialization for a slow life history.

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