An Evolutionary Approach to Below Replacement Fertility

by

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I. Introduction

Over the past 120 years, there have been dramatic changes in fertility rates throughout the world. In most of Europe, North America, New Zealand and Australia, a detectable change in fertility rates (10% reduction in I_f) occurred between 1880 and 1920; with the exception of France where the fertility transition occurred at the beginning of the 19th Century [see Caldwell and Caldwell (1998), Coale and Treadway (1986), and Knodel and van de Walle (1979) for reviews]. A second major transition has occurred over the last 30 years. In most countries in Asia, Latin America, and the Middle East, as well as parts of sub-Saharan Africa, marked reductions in fertility occurred between 1965 and 1985 (see Caldwell and Caldwell (1998) and Bongaarts and Watkins (1996) for reviews). During the same period, many countries in developed nations underwent another decline in fertility, leading to “below-replacement” fertility levels (i.e., total fertility rates below 2.2 -(Davis et al., 1986; Lesthaeghe and Williems, 1999; Morgan, 1996).

This paper provides a theoretical framework, *the embodied capital theory of life history evolution*, for explaining the pattern of those fertility transitions, and presents a series of specific hypotheses about the reduction to below-replacement levels, with a focus on the United States. We propose that these fertility transitions result from the interaction of evolved psychological and physiological mechanisms governing human fertility with specific changes in the economy and public health.

Our thesis is that natural selection acted on human physiology and psychology to produce a coordinated and flexible response system that regulates fertility and parental investment. Since all but the last 10,000 years of human evolution occurred among foraging peoples, this system is adapted to the selection pressures acting on the hunting and gathering life way. Cross-cultural research on foraging peoples shows that humans are adapted to a skill-intensive foraging niche, requiring years of learning before adult competence is reached (Kaplan, 1997; Kaplan et al., manuscript; Kaplan et al., 2001; Kaplan and Lancaster, 2000). This foraging niche selected for a co-evolved complex of life- history traits; including prolonged development and dependency on parents, a large expensive brain, a very long adult life span (during which foraging competence increases for 20 or more years), and a three-generational system of resource flows in which grandparents as well as parents actively provision children and adolescents (ibid.). Because of the skill-intensive foraging niche, natural selection acted on human psychology in such a way that people are sensitive to environmental variation in learning opportunities and payoffs. They adjust both their own investments in learning and the amount of time they are willing to subsidize children in response to that variation.

These behavioral adjustments impact fertility via two pathways in maternal physiology. Fecundity (and hence the length of inter-birth intervals) is affected by both the length of breastfeeding and maternal nutrition, which is, in turn, determined by the distribution and production of food in families. When all wealth is in the form of food energy consumed, there is a direct link between parental investment and the energetics of reproduction. This link mediated adaptive (i.e., fitness maximizing) increases and decreases in fertility in response to changing payoffs to parental investment.

In the context of modern economic, technological and social conditions, this evolved psychology and reproductive physiology produces responses that do not maximize fitness, but which are patterned nevertheless. The emergence of extra-somatic wealth (i.e., land, money, and other forms of physical capital) largely broke the link between parental investment and the energetics of reproduction. The severing of this link appears to generate lower fertility and greater production and consumption of wealth than would maximize fitness. We hypothesize that the demographic transition to small families can be understood in terms of changing payoffs to human capital investment. These changes are due to the increased importance of education in the determination of wages and to reductions in mortality and to the use of money to purchase consumer goods, both of which motivate people to delay fertility and to limit family size.

The subsequent transition to below-replacement fertility is due to further changes in technology with multiple effects. First, new technologies changed the distribution of jobs in the economy, increasing in the benefits of schooling and on-the-job training for both men and women. Second, they increased the relative payoffs of market to home labor for women, increasing the costs of child rearing and decreasing marital stability. Third, they increased efficiency of birth control. These three effects produced a greater tendency to limit fertility to two children and further delays in the onset of reproduction, especially for those individuals expecting to invest heavily in their own and in their children's embodied capital. Our proposal is that below-replacement fertility is largely a phenomenon of the more educated sector of society, where many individuals involuntarily fall short of their ideal fertility due to excessive delay (given the physiological decline in fecundity with age and effective birth control). We hypothesize that the delay is due to two factors: 1) increased investments in education and on-the-job training and 2) greater selectivity in obtaining a suitable partner with whom to co-invest in children, due to the greater threat of divorce. The principal focus of this paper therefore is an examination of the causes of delay in initiating reproduction and of reduction in target fertility to two children.

The next section presents a brief overview of the embodied capital theory of life history evolution. We then apply the theory to hunter-gatherer ecology, with a specific emphasis on the evolved psychology and physiology of human reproduction. Next we examine the interaction of this evolutionary heritage with modern socio-economic conditions in an attempt to account for modern demographic transitions and below-replacement fertility. Throughout this section, we consider the interaction of micro- and macro- level processes and of public and private investments in an attempt to understand the historical dynamics.

We then present a series of empirical analyses regarding changing patterns of fertility, parental investment and marital dissolution in the U.S., using both a national probability sample (The National Survey of Families and Households) and a sample of men in Albuquerque, New Mexico. The results of those analyses provide a good deal of support for hypotheses derived from the embodied capital theory. They do not constitute definitive tests, however, since we conducted some of the analyses prior to the development of the hypotheses and more direct evidence about the causes of delay is required. The paper concludes with a discussion of further directions for theory development and empirical research.

II. Embodied Capital Theory and the Evolved Psychology and Physiology of Human Reproduction

A. The action of natural selection on fertility and parental investment

According to the theory of evolution by natural selection, the evolution of life results from a process in which variant forms compete to harvest energy from the environment and convert that energy into replicates of those forms. Those forms that capture more energy and convert that energy more efficiently into offspring than can others become more prevalent through time. This relationship between harvesting energy and reproduction generates many complex, time-dependent problems.

Fertility contributes most directly to an organism's fitness. In fact, all other fitness components, such as mortality, only affect fitness through their effects on fertility (for example, mortality rates affect fitness by affecting the probability of living to the next reproductive event). All else being constant, any increase in fertility increases an organism's fitness. However, there are two trade-offs that affect natural selection on fertility.

The first trade-off balances expenditures between present and future reproduction. Imagine a sexually-reproducing organism that is newly independent of support from its parents. It can use its time to harvest energy from the environment. It can use some or all of its energy to reproduce. However, another potential use of the energy is to buy more time. By using some of the energy for physical maintenance and to defend against diseases and predators, it can live longer to harvest more energy in the future. Another use of energy is to grow and build tissue. By growing, an organism can increase its energy capture rates in the future and thus increase its future fertility. The allocation of energy to growth also can increase the length of the life span by lowering size-dependent mortality and can increase success in intra-sexual competition for mates, ultimately affecting reproductive rate. For this reason, organisms typically have a juvenile phase in which fertility is zero until they reach a size at which some allocation to reproduction increases fitness more than does growth. Similarly, among organisms that engage in repeated bouts of reproduction (humans included), some energy during the reproductive phase is diverted away from reproduction and allocated to maintenance so that it can live to reproduce again. Evolutionary theory expects natural selection on age of first reproduction and on adult reproductive rate to maximize total energetic allocations to reproduction. Over the life course, this will depend on ecological factors, such as mortality rates (Charnov, 1993) and the effects of body size on both energy capture (Charnov, 1993) and vulnerability to predation (Werner, 1986).

The second trade-off is between quantity and quality of offspring, where quality is a function of parental investment in an offspring and reflects its ability to survive and reproduce. In general, natural selection on offspring number and investment per offspring is expected to maximize the number of offspring that survive to reproduce (Smith and Fretwell, 1974). Ecological factors, such as mate pool competition, food supply, disease and predation rates, also affect the optimal fertility rates and optimal expenditures on offspring.

Virtually all, complex organisms exhibit flexibility in both age-at-first-reproduction and fertility rates. Natural selection has resulted in physiological and psychological mechanisms by which individuals adjust fertility onset and fertility rates in relation to changing environmental conditions. For example, plants often exhibit many, thousands-fold variation in fertility rates in relation to yearly and season variation in rainfall and other environmental factors. Extensive research on many bird species has shown that this phenotypic plasticity tracks fitness quite well See Godfray and associates for a review (Godfray et al., 1991). Birds under variable conditions adjust clutch sizes in ways that tend to maximize the number of surviving young produced during the life course. The pervasiveness of adaptive phenotypic plasticity in fertility among non humans suggests that humans are also likely to possess adaptations to adjust fertility onset and fertility rates in relation to changing environmental conditions.

B. The embodied capital theory

The embodied capital theory generalizes existing life history theory in biology by treating the processes of growth, development and maintenance as investments in stocks of somatic or embodied capital [for a more complete review (Kaplan, 1997; Kaplan and Lancaster, 2000). In a physical sense, embodied capital is organized somatic tissue - muscles, digestive organs, brains, etc. In a functional sense, embodied capital includes strength, immune function, coordination, skill, and knowledge. Since such stocks tend to depreciate with time, allocations to maintenance also represent investments in embodied capital. Thus, the present/future reproduction trade-off can be understood in terms of optimal investments in own embodied capital vs. reproduction, and the quantity-quality trade-off can be understood in terms of investments in the embodied capital of offspring vs. the number of offspring produced.

The embodied capital theory allows us to address problems not yet explored with standard life history models. First, an exclusive focus on physical growth per se provides an impoverished understanding of development. The large human brain, for example, embodies a stock of capital that includes a great deal of skill and knowledge acquisition during both the juvenile and adult periods. Growth in the form of knowledge may be as important as growth in body size with respect to providing benefits through time. Second, parental investment not only affects survival to adulthood, but also the adult income (productivity) of offspring. This is especially true of humans both in modern societies and among traditional hunter-gatherers.

Models of investment in embodied capital have produced some fundamental results. One set of models shows that investments in embodied capital affecting adult income or energy capture co-evolve with investments affecting mortality and longevity (Kaplan et al., 2000a; Kaplan et al., 2000b; Kaplan and Lancaster, 2000). The longer the time spent growing and learning prior to reproducing, the more natural selection favors investments in staying alive to reap the benefits of those investments. Similarly, any investments that produce increased energy capture rates later in life select for additional investments to reach those older ages. The converse is also true. Ecological features or investments that increase the probability of survival to older ages also produce selection for greater investments in income-related embodied capital. These co-evolutionary effects have been particularly important in human life history evolution (see Section C below).

A second set of models concerns optimal parental investment in offspring (Kaplan, 1996). Those models decompose parental investment into those investments that affect offspring survival and those that affect offspring income as an adult. With a fixed parental income, increased investment in offspring embodied capital decreases parental fertility, because parental fertility is determined by dividing average investment per offspring into total parental income.

The models of parental investment also show that the investments in income/energy production and survival co-evolve. If the average level of investment in either offspring survival or offspring income increases, the production of each additional offspring is more costly. All things being equal, this favors further increases in offspring quality and hence increased investment in both survival-related and income-related embodied capital (see Becker (1981) and Becker and Lewis (1973) for the original treatment of quantity/quality interactions, and Rogers and Blurton Jones (1992) for a similar result). In addition, exogenous changes in offspring survival rates affect fertility through two routes. First, increases in offspring survival during the period of parental investment increase the expected cost of raising an offspring, because it will have a higher likelihood of reaching each age to receive the investment. With a fixed parental income constraint, this necessarily reduces offspring quantity. Second, this increase in the expected cost of raising an offspring also favors an increase in optimal investments in child quality, in terms of both child survival and child income. These results also imply that if payoffs to investments in both offspring income and survival increase, large changes in fertility are expected.

C. The application of embodied capital theory to traditional humans

Hominids lived as hunter-gatherers for the vast majority (more than 2 million years) of their evolutionary history. Agriculture originated only 10,000 years ago and has been practiced by the majority of the world's population for just two or three millennia, a relatively brief period of time for selection to act. The shift to a fully-mercantile, highly-urbanized economy with competitive wage-labor markets and a vast array of consumer goods over the last 150 years is completely novel. Since natural selection is an historical process, humans should be well adapted to the foraging lifestyle. There is no reason to expect that they will respond adaptively (in the sense of maximizing reproductive fitness) to today's novel circumstances [see (Kaplan et al., 1995a; Kaplan et al., 1995b), for evidence that modern fertility behavior does not maximize fitness]. Therefore, an evolutionary explanation of human fertility and parental investment has three requirements: 1) it must be consistent with our general understanding of evolution by natural selection, 2) it must explain the behavior of humans living under traditional hunting and gathering conditions characteristic of our evolutionary history with adaptive models, and 3) it must be able to predict the pattern of modern responses to novel conditions.

Compared to other primates and mammals, there are at least four distinctive characteristics of human life histories: 1) an exceptionally long life span, 2) an extended period of juvenile dependence, 3) support of reproduction by older post-reproductive individuals, and 4) male support of reproduction through the provisioning of females and their offspring. Kaplan, Hill, Lancaster and Hurtado have propose (Kaplan, 1996; Kaplan, 1997) that a dietary shift towards high-quality, difficult-to-acquire food resources, that are nutrient dense and come in large packages, is responsible for the evolution of those life history characteristics and the large brains upon which human cultural evolution relies.

The following logic underlies our proposal. First, high levels of knowledge, skill, coordination and strength are required to exploit the suite of high-quality, difficult-to-acquire resources humans consume. The attainment of those abilities requires time and a significant commitment to development. This extended learning phase during which productivity is low is compensated for by higher productivity during the adult period, with an intergenerational flow of food from old to young. Since productivity increases with age, the time investment in skill acquisition and knowledge leads to selection for lowered mortality rates and greater longevity. This in turn will favor a longer juvenile period if there are important gains in productive ability with body size, and growth ceases at sexual maturity. Second, we believe that the characteristics of the feeding niche, with associated food sharing, provisioning of juveniles, and tool use led to lower mortality during the juvenile and early adult periods. This too, favors a longer juvenile period and higher investment in further mechanisms to increase life span. Thus, we propose that the long human life span co-evolved with the lengthening of the juvenile period, increased brain capacities for information processing and storage, and intergenerational resource flows - all as a result of an important dietary shift. These changes are all consistent with the predictions of the models discussed above.

In support of this hypothesis, Kaplan, Hill, Lancaster and Hurtado (Kaplan et al., 2000b) present data showing that: 1) human hunter-gatherers rely almost exclusively on extracted and hunted foods, whereas chimpanzees rely much more heavily on easily-collected foods; 2) the rate at which both hunter-gatherer children and chimpanzee juveniles acquire foods depends directly on the difficulty of acquisition, with extracted and hunted foods requiring the longest time to master; 3) as a result, hunter-gatherer children do not acquire as much food as they consume until late adolescence or early adulthood, in contrast to chimpanzees who do so after about age six; 4) peak production rates for both human males and females do not occur until the mid-thirties for the most difficult-to-acquire resources, but ultimately these peaks compensate for the lost energy production during the learning period; and 5) the provisioning of hunted foods by men is an essential component of human reproductive energetics and the support of long juvenile period. Our analyses also suggest that the feeding niche indirectly lowered mortality rates, due to the effects of provisioning and food sharing on the ability to resist illness and recover from injury, and the use of tools to fend off predators.

The human adaptation is broad and flexible, in one sense, and very narrow and specialized, in another sense. It is broad in the sense that as hunter-gatherers, humans have existed successfully in virtually all of the world's major habitats. This has entailed eating a very wide variety of foods, both plant and animal, both within and among environments. It also has entailed large flexibility in the contributions of different age- and sex- classes of individuals. The relative contributions of men and women to food production vary from group to group, as do production profiles by age. The human adaptation is narrow and specialized in that it is based on extremely high investments in brain tissue and learning. In every environment, human foragers consume the largest, highest quality and most difficult-to-acquire foods, using techniques that take years to learn (Kaplan et al., 2000b). The first major demographic transition separating our species from apes is a shift to low mortality, an increased life span, a long dependent development period, a large commitment to learning and intelligence, and an age-profile of production shifted towards older ages with wealth flows downward between generations.

D. Ecology and the proximate mechanisms governing fertility and parental investment

The mortality and production profiles discussed above have direct implications for fertility regulation. Since human parents and grandparents provision children, natural selection probably produced mechanisms by which fertility could respond to the number of children parents could afford to raise in any given socio-ecology. Figure 1 presents a conceptual model of the evolved mechanism of fertility regulation in humans and their responsiveness to physical, biological and social conditions (*socio-ecology*). The figure depicts two classes of socio-ecological factors affecting survival and embodied capital respectively, and three domains of evolved responses; psychology and culture, behavior, and reproductive physiology. The plain text and bold arrows refer to the traditional hunting and gathering life way, which we consider first. The italicized text and lighter arrows include additional factors and causal pathways existing under modern conditions.

Two main causal pathways regulate fertility, both related to the energetic constraints in provisioning offspring; one involves breastfeeding and the other involves the age-profiles of work and food distribution. Natural selection on the timing and rate of weaning should reflect a balance between quantity effects (favoring earlier weaning) and quality effects on survival and growth of offspring (favoring later weaning). Socio-ecological conditions, such as the availability of easy-to-digest weaning foods and disease threats, impact the relationship between age at weaning and survival. Similarly, infant condition is likely to vary individually and be differentially affected by weaning. We expect that natural selection acted on both infant and maternal psychology to make them responsive to those variable conditions. For example, sickly infants may be more demanding of the breast and larger, and healthier babies more interested in weaning foods. In the human case, individual experience and sensitivity to infant's condition guide maternal perceptions regarding breastfeeding in conjunction with the cumulative experience of the group, as reflected in cultural conventions and ideas about proper breastfeeding practices. Maternal and infant psychologies interact in determining the timing of supplementation and the length of breastfeeding. The evolved reproductive physiology translates this pattern of breastfeeding into differing degrees of fecundity.

The additional energetic constraints involved in provisioning children form the second causal pathway. The age/sex-profile of work and productivity determines the total energy available for consumption. Given some age profile of food distribution and of mortality, the requirement that energy consumed does not exceed energy produced constrains fertility rate. The longer children are provisioned and the greater the proportion of their food needs subsidized by parents and grandparents, the lower the supportable reproductive rate with a given adult income. Natural selection should therefore act both on psychological abilities to assess the short and long term costs and benefits of different activity profiles and on fertility regulation so that energy flows are balanced.

One fundamental trade-off with respect to activity profiles is between present and future production (Bock, 2001; Kaplan, 1996). If children engage in easy-to-perform foraging activities, such as fruit collection, this provides immediate caloric benefits and lowers the parental subsidy required. However, time allocation to those activities detracts from time spent learning more difficult activities, such as hunting and extractive foraging. During the learning phase, those activities produce very little food, but generate high rates of return in the future. Another fundamental trade-off is between production and mortality risks, since foraging exposes people to predation, accidents, and getting lost. This suggests that parental psychology should be responsive to age-specific mortality rates and how they are affected by alternative activity profiles, and on their short- and long-term productive consequences.

A growing body of evidence supports the view that people in foraging societies are sensitive to these tradeoffs and they adjust behavior accordingly. In a seminal series of papers, Blurton Jones, Hawkes, Draper and O'Connell (Blurton Jones et al., 1994a; Blurton Jones et al., 1994b; Hawkes et al., 1995) show that !Kung hunter-gatherer parents consciously assess foraging risks to children and that differences between !Kung and Hadza children's productivity result from features of the local ecology related to ease of resource extraction and dangers associated with productive tasks. Bock (2001; 1995) in a study of forager/agro-pastoralists in

Botswana shows that the age-profiles of children's activity budgets reflect both immediate skill and strength requirements as well as opportunities to learn. In all foraging societies for which data are available, people are aware of the many years of learning required to become a competent hunter and young men are provisioned while they learn those skills (Kaplan et al., 2000b).

These time allocation decisions affect fertility through maternal energetics. In addition to the direct breastfeeding effects, fecundity responds to women's energy status, energy balance and rate of energy flow (Ellison, 1990; 1994). Seasonal changes of food intake (Bailey et al., 1992), net energy expenditure (Hurtado and Hill, 1987) and weight (Bailey et al., 1992; Tracer, 1996) all have been shown to predict fecundity as do individual differences among women (Hill and Hurtado, 1996).

To summarize, in this model the interaction of individual psychology and cumulative cultural knowledge, beliefs and practices; behavior; and reproductive physiology determine fertility. Each of these domains co-evolved by natural selection to respond to ecological variability in mortality regimes and payoffs to parental subsidization of skill acquisition. The connection between psychology and fertility is indirect in that psychology adjusts parental investment (through productive behavior, wealth flows and breastfeeding) and reproductive physiology translates parental investment decisions into fertility. The key to this system is that maximizing lifetime expected resource production through the optimal allocation of activities and wealth flows tends also to maximize fitness when all wealth is in the form of food, and extra food translates into higher fertility.

III. Modern Demographic Transitions

A. The initial transition from high to low fertility

The next step in the analysis is to determine which aspects of modernization, in interaction with those evolved psychological and physiological mechanisms, lead people to lower their fertility. In Figure 1 the additional socio-ecological factors and causal pathways proposed to result in fertility transition are shown with italicized type and thin arrows. The two critical new factors are the existence of extra-somatic capital and changes in the payoffs to embodied capital, especially in the form of education.

Extra-somatic wealth: Breaking the link between wealth and fertility

With few exceptions (e.g., the coastal areas of California and British Columbia and late Pleistocene archeological sites in the Ukraine), all wealth among hunter-gatherers appears to be energy stored in people's bodies. This wealth serves to produce offspring and to increase survival. Under these circumstances, an evolved psychology and physiology that maximizes total wealth produced by the lineage would maximize fitness. The storage of wealth in the form of extra-somatic resources, such as land, cattle or money, probably is a relatively recent phenomenon. It is unclear therefore whether we should expect selection to have optimized fertility and the management of extra-somatic wealth, given this preexisting suite of evolved proximate mechanisms. Where wealth is held outside the body, there is no mechanism to ensure that it is eventually converted into reproduction. In fact, it may be that the evolved psychological mechanisms that are sensitive to the impacts of behavior on future wealth may promote wealth-maximization at the expense of fertility. In the case of modern fertility, it appears that people are attempting to circumvent the physiological mechanisms regulating fertility, by preventing pregnancies that would otherwise occur.

Changing payoffs to investment in embodied capital

Changes in the payoffs to embodied capital occur for two reasons. During the 19th century, there were large changes in the scientific understanding of disease (see Preston and Haines (Preston and Haines, 1991) for a review). This led to a dramatic decline in both infant, child and adult mortality rates that continued for close to a century. As scientific advances enabled reductions in mortality rates, there was strong pressure to increase public investments in health and disease prevention, from the protection of the water supply to the development of vaccines and public access to medical care. The decline in mortality rates increased the return on parental investment and own investment in embodied capital affecting wage rates. Increased survival rates during the period of parental investment increase the expected costs per child born, favoring further increases in offspring quality (Kaplan, 1996). Increased survival during the adult period increases the expected years of return to educational investments. This further increases the incentive to invest in children's education (see Meltzer (1992) for supporting data and theory, but see Preston (Preston, 1980) who argues for a comparatively small effect of changing mortality patterns on rates of return to education).

At the same time, scientific advances also led to changes in the economics of production. The economic changes increased wage premiums paid for skills and led to very high returns on parental investments in children's education (Vinovskis, 1994). Increased private interest in education may have inspired more public investment in education. The quality of public education, in turn, increased the rate of return on private investments in education.

These factors, in combination with parental psychology, result in fertility being regulated by a consciously determined fertility plan realized through birth control technology and/or controlled exposure to sex. In response to the increased payoffs to investments in education and the expected costs of those investments, parents determine the number of children they can afford to raise, given their wealth. The low mortality rates also allow parents to plan reproduction at the outset, because the number of children born accurately predicts the number of children that will be raised to adulthood.

According to this view, the reason why the transition begins with a negative association between wealth and fertility is that the payoffs to investment in own and offspring embodied capital were not the same across economic strata. First, infant and child mortality rates were much lower among the wealthy than the poor (Preston and Haines, 1991) in both Europe and America. Second, wealthy parents tended to be more educated and to have greater access to educational resources. Our hypothesis is that, as a result, wealthier parents could educate their offspring more efficiently than poorer parents could and had a greater return on investments in both own and offspring education.

Public and private sector responses to these trends then begin to change the payoffs to such investments among the poorer and less educated sectors of the society. Increased public investments in health and schooling decreased mortality rates and increased the efficiency of private investments in children's schooling for all sectors of the society. More effective and less costly forms of birth control technologies allowed for a significant reduction in birth rates. An increasingly educated populace increased the expertise in firms with respect to both management and the technology of production, further increasing the demand for skilled-workers. Ultimately, those interactions produce equal fertility among economic strata. The wealthier, more educated people invest more per child than poorer, less educated, because they are still more efficient at embodying capital in their children, but their higher wealth allows them to have as many children (although more costly) as less wealthy individuals. Thus, what appears to be a gradual decrease in fertility through time according to national-level statistics may actually be a process in which an increasing proportion of the population exhibits very low fertility.

B. The transition to below-replacement fertility

Fertility has not declined steadily throughout this century. For example, in the U.S. total fertility rates declined from about 1880 until the mid 1930s, then rose to a peak in the late 1950s during the Baby Boom, and then declined to below-replacement levels by the mid-1970s (Morgan, 1996). Following the logic of embodied capital theory, Figure 2 presents a qualitative model of the relationship between changes in the economy and the transition to below-replacement fertility.

The figure presents two principal routes by which social, economic and technological changes result in below replacement fertility. The first route (on the left side of the figure) depicts changing payoffs to investment in education for the population as a whole and the second route (on the right) focuses specifically on work force participation by women and its impact on family formation. The box at the top of the diagram represents macro-level socio-economic changes affecting individual decisions. While those macro-level processes are partially determined by individual decisions (i.e., growth in technology depends, in part, on the educational attainments of the workforce), individuals must treat those conditions as givens when making decisions about how much to invest in education, when to marry and how many children to have. Growth in technology and world trade has had profound effects on socio-economic conditions in developed countries. First, the relationship between education and income has increased (see, for example, Bound and Johnson (1992) and Figure 3 below). Second, there has been a changing distribution of jobs in the economy with a shift from the industrial sector to the service sector, increasing the employment opportunities for women, and especially increasing the earning power of educated women (Murphy and Welsh, 1989). Third, public investments in education increased substantially, with a great expansion of public institutions of higher learning. At the same time as opportunities for college education expanded, the costs of obtaining a college degree increased (in real dollars), especially in private institutions.

In responses to those socioeconomic changes, both men and women increased time spent in schooling and presumably their expected investments in their children's schooling. We propose, however, that differences in pre-school experiences, quality of public schools attended, and home environment, all of which are associated with parental education, cause there to be large variation in individual rates of return to education. Those that perform poorly in school and learn less per time spent in school will be motivated to terminate schooling investments sooner. It is this variation in rates of return and perhaps in the ability to finance the costs of higher education (Becker, 1975) that is associated with variation in modern life course decisions and ultimately fertility.

In addition, some macro-level changes had large impacts specifically on the work force participation of women. The increase in labor-saving devices in the home decreased the value of household work. The increased efficiency of birth control allowed women to delay fertility and exert greater control over the scheduling of reproduction. The increase in expected investments in children's education led to a small target family size and thus less lost time from the workforce due to the care of young children (with the emergence of the daycare industry augmenting this effect). All of those changes increased the relative pay off to wage labor for women and thus the payoffs to investment in education. We also hypothesize that the shift from the mother-homemaker/father-provider to the dual-earner family structure decreased marital stability, because women were no longer as financially dependent on men and men were less dependent on homemakers.

Finally, the model proposes that those general changes in rates of return to education interact with the forces impinging specifically on women in determining the life history of fertility. First, increased investment in own embodied capital leads to a delay in family formation for both educated men and women (Tucker et al., 2001). Second, those who invest more in their own embodied capital are also likely to get higher returns on their investment in children’s embodied capital and to invest more as a result. Marital stability is hypothesized to be of greater importance to people if they expect to invest more in their offspring, because of both the high costs of college education (requiring two incomes) and the time investments in school-aged children. This logic implies that those who invest more in their own education will respond to the increased risks of marital dissolution by taking longer to choose a suitable partner (i.e., being more selective) and by increasing the time from marriage to reproduction as a further trial period. Those delays due to time spent in education and training and greater selectivity in mate choice result in some couples never achieving their target fertility, because of the physiological decrease in female fecundity with age.

Thus, the model proposes that below-replacement fertility is primarily a phenomenon of the most educated sector of our society and that it is due primarily to delay rather than to a reduction in target fertility. The combination of delay and increased efficiency of birth control means that more people fail to achieve their target fertility (due to excessive delay) than those who exceed it (due to unwanted pregnancies). Fundamental to this model is the notion that changing payoffs to investments in education are the driving force in the movement to below-replacement fertility augmented by reduced payoffs to household production and increased efficiency and reduced costs of effective birth control.

The remainder of the paper examines how the fertility behavior of the U.S. population and the relationship between education and fertility has changed over time as a preliminary test of the model. The model, however, was not developed independently of those empirical results. It is the outcome of applying the logic of embodied capital theory to empirical data and modifying it in response those findings. Thus, definitive tests of the model await future research and further development of its unique predictions in comparison with other theories.

IV. Empirical Results

This section of the paper examines how the fertility behavior of the U.S. population and the relationship between education and fertility has changed over time. Three birth cohorts (born before 1920, between 1920-1941, and between 1942-1970) are examined, since they correspond roughly to those reproducing prior to, during, and after the Baby Boom. It is this last cohort that exhibits below-replacement fertility, at least among those with higher educational attainments. Two sets of data are used in the analysis. The first set is a study of male fertility and parenting conducted by interviewing a representative sample of men from Albuquerque, New Mexico. The second is a national probability sample of men and women, the National Survey of Families and Households.

A. The Albuquerque Men and the National Survey of Families and Households Data Sets[i1]

Albuquerque Men

The research design for the Albuquerque Men sample consisted of two complementary interviews, a short interview administered to a large representative sample and a longer interview administered to a subset of the men in the short interview sample. Between July 1990 and July 1993, 7,107 short interviews and 1,325 long interviews were conducted. The total short interview sample included 2789 Hispanics, 3762 Anglos and 556 individuals belonged to other ethnicities. The long interview sample consisted of 401 Hispanics, 858 Anglos, and 66 others. In New Mexico, the term, 'Hispanic', is preferred over 'Latino', because most people of Hispanic origin consider themselves native New Mexicans, tracing their family history as far back as living memory to residence in this area. In our sample, very few Hispanics were of recent Mexican origin, and even fewer were from other Latin countries. Anglo (an ethnic classification peculiar to the Southwestern US) refers to non-Hispanic men who classify themselves as white and speak English rather than Spanish in the home. Details of the sampling method and the content of the interviews can be found in Kaplan and Lancaster (2000).

The National Survey of Families and Households

The National Survey of Families and Households (NSFH) is a study funded by the Center for Population Research of the National Institute of Child Health and Human Development, with the explicit purpose of providing a data set for researchers from a broad range of disciplines and theoretical perspectives. Two rounds of the survey were conducted. We analyze data collected in the first round (NSFH1) only. The data set consists of a probabilistic sample of 13,007 individuals (men and women) from the United States. Houses were selected randomly within stratified sampling blocks and a primary respondent was selected randomly from among a sampled household's permanent occupants. The sampling procedure, which focused on households, is robust for the purpose of generalizing to the national population. Some deficiencies exist, however. In particular, the sample excludes entirely certain populations, such as the homeless and the institutionalized (i.e., the sick, insane, incarcerated, and, importantly for this study, the elderly living in nursing homes). This sampling technique resulted in a nationally representative primary respondent sample of 5226 men and 7781 women (see Sweet and associates (1988) for details).

B. Results

Education and Income

Figure 3 displays the changing relationship between education and income (in 1997 dollars) between 1940 and 1990 for men and 1963 and 1990 for women and the changing educational attainments of U.S. workers, as depicted in the model (Bureau, 1998). Panels A and B show the increase in the wage differentials associated with different education and income levels over time, especially for men (Panel A). For men without high school degrees, real wages actually dropped from 1958 to 1990. In 1958, men with graduate education earned about 2.3 times as much as men with elementary education; by 1990, they earned more than 3.5 times as much. Wage differentials among men with some college education, bachelor’s degrees, and graduate degrees also increased substantially. For women, wage differentials among educational attainment levels increased substantially in the 1980s.

Panels C and D show the changing educational make-up of the U.S. workforce, presumably in response to the changing payoffs to education. In 1958, 56% of the male workforce was composed of individuals with less than high school education (38% with only elementary education), whereas only 16% had college degrees or higher education. By 1990, the percentage of the male workforce with less than high school had dropped to 20%, whereas those with college degrees increased to 25%. The same trends are true for women (Panel D). Also, during the same period, the percentage of the workforce composed of women increased substantially from 40% in 1963 to 51% in 1990.

Fertility

The fundamental hypothesis underlying the model in Figure 2 is that excessive delay in the onset of reproduction, coupled with a target fertility of two is largely responsible for below replacement fertility and that this delay is related to investments in own and offspring education. Figure 5 shows the changing patterns of marriage age, onset of reproduction and education over the course of the twentieth century for the cohorts represented in the NSFH1 sample.

Holding education constant, the median age at marriage and the delay from marriage to reproduction was higher for both men and women born early in the century than those born between 1920 and 1941. Median age at marriage and fertility onset then increased again for men and women born between 1942-67. The role of education in delays to marriage and from marriage to reproduction increases dramatically, however, for those born after 1942 (the cohort evidencing below-replacement fertility). Compare, for example, differences between those with high school diplomas and those with bachelor’s degrees. For men, the difference in median age of marriage was only 1.6 (25.7 vs. 24.1) years and 1.4 years for the cohorts born before 1920 and 1920-41, respectively, whereas the difference increased to 2.2 years for those born after 1942. Similarly, for women, the age difference increased from 2.4 and 2.9 years for the first two cohorts to 3.7 years for the last cohort.

Delays from marriage to reproduction show the same directional effects, but even more dramatically. The difference between men with high school diplomas and those with bachelor's degrees was only .8 and .2 years for the first two cohorts and rose to 2.3 years for the last cohort. For women, the difference rose from .9 and .7 years for the older two cohorts to 2 years for the last cohort. The sharpest contrast can be seen in comparison between those with the least to those with the most education. While delays to both marriage and reproduction increased for all men in the youngest cohort with high school diplomas or more education, they actually decreased for high school dropouts. Among men born after 1942, there is a 4.7year difference in median age at marriage and 3.6 year difference in median delay from marriage to reproduction (a total of 8.3 years) between high school dropouts and those with graduate and professional degrees. Among women of the same cohort the corresponding differences between high school dropouts and those with graduate and professional degrees are 6 years in median age of marriage and 4.5 years from marriage to reproduction for a total of 10.5 years.

These delays have powerful effects on completed fertility for both men and women. For men over 40 years of age, the probability of having no children increases from 7% for men who marry or cohabit before the age of 25 to 82% for men who marry after age 40. The probability of having three or more children decreases from 54% for men who marry or cohabit before the age of 25 to close to zero for men who marry after age 40. For women, the probability of having no children increases from 5% for women who marry or cohabit before the age of 25 to 88% for women who marry after age 40. The probability of having three or more children decreases from 55% for women who marry or cohabit before the age of 25 to close to 8% for women who marry after age 40.

The differential impacts of education on delay across the cohorts are also evident when completed fertility is examined. For the older cohorts, the effect is modest. For men over age 45, the probability of nonreproduction increases from 16% for men with less than high school to 19% for men with graduate degrees. The probability of having three or more children decreases from 48% for men with less than high school to 40% for men with graduate degrees. For women, the probability of nonreproduction increases from 11% among those with less than high school to

32% for those with graduate degrees. The probability of having three or more children decreases from 55% for women with less than high school to 20% for women with graduate degrees.

The effects of education on fertility completed by the time of the interview are stronger for the younger cohorts, reproducing in the last 20 years. Figure 4 shows that men 35-44 years of age with less than high school have a mean of 2.6 children, whereas men with graduate degrees have an average of 1.5 children. Only 21% of high school dropouts have zero or one child, rising to 34% for those with high school degrees, 38% for those with bachelor’s degrees and 43% for those with graduate degrees. Conversely, 52% of high school dropouts have three or more children, dropping to 26% for those with high school degrees, 25% for those with bachelor’s degrees and 20% for those with graduate degrees.

The effects appear to be somewhat stronger among women 35-44 years of age. High school dropouts have a mean of 2.77 children, dropping to 2.22 for those with high school degrees, 1.95 for those with bachelor’s degrees and 1.43 for those with graduate degrees. Again, only 21% of high school dropouts have zero or one child, rising to 24% for those with high school degrees, 36% for those with bachelor’s degrees and 50% for those with graduate degrees. Finally, 60% of high school dropouts have three or more children, dropping to 36% for those with high school degrees, 33% for those with bachelor’s degrees and 17% for those with graduate degrees. Although there may be some catch-up among the more educated as this cohort ages, especially for men, all of the evidence suggests that the effects of education on male and female fertility have increased dramatically during this period of below replacement fertility.

The data from the Albuquerque men study reveal a similar pattern of results. For both Anglos and Hispanics, education has a strong negative effect on reproduction during the late teens and even through the 20s. The effect of education weakens with age, and in fact, is mildly positive among Anglos in the 35-39 and 45-49 age classes, suggesting differential timing of births in the life course (Kaplan and Lancaster, 2000). The negative effect of education is largely due to delay to marriage and reproduction (Kaplan et al., 1998). As is the case with the NSFH1 sample, men born prior to 1920 delay reproduction longer than those born between 1920 and 1940, who, in turn, reproduce earlier than those born after 1940 (ibid.). Moreover, the effect of education on fertility increases dramatically for men born after 1940 (Kaplan and Lancaster, 2000). The period and cohort effects on fertility interact, however, with previous parity. Table 1 displays the results of a year-by-year analysis of the fertility of married and cohabiting couples in the Albuquerque men sample. The left panel shows the probability of having a birth for couples that have not yet reproduced together (although one or the other may have had a child in a previous relationship). The right panel examines the probability of birth for couples that have already had two children together. Among couples that have not yet reproduced Hispanics have their first child sooner than Anglos. The woman's years of education (i.e., if she is working for wages or a salary) decrease the probability of having a first child, even after the woman's age is controlled for. The husband' s education and income appear to have no effect, after the wife' s education and employment are controlled for.

There are also powerful effects of period. The following periods are defined: Pre-Boom years are all risk years prior to 1946; Baby Boom years are all years between 1946 and 1962; Post-Boom years are all years between 1963 and 1992. The Boom period is treated as the baseline. Relative to the Boom years, there is a longer delay to first reproduction for both the Pre- and Post- Boom periods. This effect is very strong, with odds-ratios of .65 and .31, respectively. The effect of women's age is also considerable. With the 20-24 year age bracket as the baseline, there are no differences between them and women less than 20 or those that are 25-29. The effects become dramatic for women over the age of 30. The odds-ratio drops to about half (0.45) for women 30-34, to less than a third for women 35-39 (0.27) and .06 for women 40-44. Thus, there are two additive effects of education on first births. First, it delays entry into marriage and then increases the delay to reproduction within marriage, in both the NSFH1 and the Albuquerque samples. Finally, men who have had children in a prior relationship are significantly less likely to reproduce again than men who have not. The result is not significant for women.

The right panel shows a similar pattern of effects in the probability of progressing from a parity of two to a parity of three. There are two major differences, however. First, wife's education has no direct effect on the probability of giving birth, after age is controlled for. However, there are sharp declines in fertility with age of wife. Thus, the effects of education on progression to higher parities are indirect, operating through the age of the wife. Second, the period prior to the Boom is not significantly different from the Baby Boom years, but the Post-Boom years evidence a sharply decreased probability of progressing from two to three children, with an odds-ratio of 0.02. This reveals an increased tendency to stop at two children in the later cohorts.

Our interpretation of these results from the NSFH1 and Albuquerque Men data sets is that the Great Depression of the 1930s and the World Wars delayed fertility for all men and women who survived to their late 80s or so. During the post-war Baby Boom, low-cost loans for affordable housing and the GI bill allowed men and women to reproduce at earlier ages, even though investment in education was increasing. Following the Baby Boom, the onset of fertility is again delayed for everybody, but especially for men and women investing more in human capital. These reflect increasing costs of education as well as increasing importance of education in the determination of wages (Burck, 1976; Herrnstein and Murray, 1994; Newcomer, 1955; Vinovskis, 1994). (Those effects were particularly important for women, since greater commitment to career implied greater opportunity costs associated with reproduction.

Investment and Outcomes

A fundamental hypothesis underlying the model in Figure 2 is that delays to marriage and reproduction are due to both investments in own embodied capital and expected investments in offspring embodied capital. We proposed that the expected investments in offspring would interact with the increased risk of divorce in later cohorts, with those who expected to invest more being more reluctant to reproduce until they were sure of a secure, viable marriage. We have no direct evidence that this reluctance results in a greater selectivity in mate choice and a longer latency period from marriage to reproduction. However, there is evidence that the educational status of both men and women affect time and monetary investments in children, divorce rates when children are young, and ultimately, the educational outcomes of children. An analysis of men’s time investments in children during their elementary school years showed significant positive effects of a man's education on both time spent alone with children and their involvement in the child's educational progress (Kaplan and Lancaster, 2000).

The effects of education on divorce when children are young are striking. Figure 6 [adapted from Lancaster and Kaplan (2000)] shows the probability that a man will cease to live with a child before the age of 6 as a function of the child's birth cohort, and its father's education. The increase in divorce rates is clearly evident in this figure. However, there is a very interesting interaction effect between a man's education and the child's birth cohort on the probability of separation between a child and its father. Among children whose father had less than high school education, the percent of children who ceased to live with him before age 6 rose from about 5% for children born before 1960 to 23% for children born in the 1980 cohort. Among children whose father had a graduate degree, the percent of children who ceased to live with him before age 6 did not change significantly during this period, and remained between 5% and 8%.

Table 2 shows the results of three analyses examining investments in older children and their educational outcomes from the Albuquerque Men sample (Anderson et al., 1999). Column A shows the probability of a child over age 18 attending college. Anglos are more likely to attend college. The father's income and education are also positively associated with college attendance, as is the mother's education. Number of stepsiblings, but not biological siblings, is negatively associated with college attendance. Parental divorce and separation have a very strong negative effect on college attendance. Column B shows the probability of the child receiving financial support for her college education from her father, given that she attended college. Again, we find that Anglos are more likely to provide financial support and that father's education and income (but not mother's education) are positively associated with support for college. Number of both genetic and step siblings are negatively associated with support. Parents who remain together are also more likely to provide support.

Thus, both marital stability and education have strong effects on investments in offspring and on their educational achievements. Age at marriage and the educational levels of both men and women are both strong predictors of marital stability and completed fertility (Wineberg, 1990).

VI. Discussion and Conclusions

This paper has examined the very low fertility exhibited in recent years in light of human evolutionary history. It is clear that current fertility behavior does not maximize fitness [see Kaplan and associates (Kaplan et al., 1995a) for a definitive test], but an understanding of evolutionary history can help illuminate and predict those patterns of deviation from fitness-maximization. It was argued that as a result of human evolutionary history, human parents invest heavily in the embodied or human capital of offspring. The large human brain, the long period of juvenile dependence, long life span and male support of reproduction are the co-evolutionary result of a niche based on skill-intensive techniques of resource accrual.

The high level of investment in embodied capital affects virtually all the life-history characters typical of our species. Growth is both slow and prolonged. Reproduction is delayed as a result. Increases in productivity continue into mid-adulthood, well after reproduction has begun, and people remain quite productive well into old age after reproduction has ceased. Adult mortality rates are extremely low, and aging occurs very slowly. Children are provisioned for many years after weaning, and parents support multiple, dependent young. The high productivity of males and of older people results in a three-generational system of resources flows, in which both grandparents and men assist women in the production and support of offspring.

The regulation of fertility under traditional conditions is based upon a co-evolved psychology and physiology. The fundamental features of the evolved psychology affecting fertility are the adjustments of investment in offspring depending upon the returns to skill and mortality hazards. When all wealth is somatic, the hormonal system controlling ovulation and implantation translates income into genetic descendants. When some wealth is extra-somatic, there can be a conflict between consciously desired fertility and the fertility output potential of the hormonal system, leading to the practice of birth control.

This commitment to intensive investment in embodied capital (both for self and offspring) also appears to be related to responses to modernization. Changing technologies of production and improved public health may have interacted to increase the payoffs to investments in skill and education, investments in health and longevity, and investments in child quality. Although such increases in investments may be a predictable consequence of our evolutionary heritage, they may not be adaptive in the strict sense of being fitness-maximizing. Thus, the demographic transition may be the result of the interaction of the evolved psychology of parental investment and investment in own embodied capital with modern conditions in which most wealth is held extra-somatically.

In the last three decades, education has become an increasingly important determinant of wage rates, fertility behavior and parental investment. As a result of investment in own education, fertility can be delayed enough that target fertility is not reached, because of age-specific physiological reductions in fertility. In that sense, there may be a mismatch between social maturity and physiological maturity and reproductive senescence. Most people desire only two children and exhibit a strong tendency to stop reproducing after the birth of their second child (Coleman, 1996). In the context of effective birth control, below replacement fertility may be the result of an increase in individuals involuntarily falling short of their ideal due to excessive delay and a decrease in those involuntarily exceeding their ideal due to failed birth control.

Although the results presented here do not constitute tests of this hypothesis, they show the dramatic effects of investment in own and offspring embodied capital on fertility. Investments in own education delay marriage and delay the onset of fertility following marriage. These effects have increased dramatically in the most recent cohorts, who are displaying below-replacement fertility. Individuals pursuing different levels of education are increasingly divergent in the timing of family formation and as a result, in completed fertility. They are also increasingly divergent in parental investment and marital stability. These differences directly impact the achieved education of their children.

A particularly striking finding of the present study is that education is not only increasingly associated with fertility and delays to marriage and reproduction among women, but among men as well. This is important because it suggests that we must understand why men choose to delay as well and why educational homogamy is on the rise (see, for example, (Mare, 1991; Oppenheimer, 1988)). Men and women appear to be matching in terms of investments in own and children's capital and in the delays to marriage and reproduction. It does not appear that female empowerment (Handwerker, 1993) and the opportunity costs of women's time (Desai and Waite, 1991) are the only, or even principal, determinants of low fertility.

If the hypothesis is correct that below-replacement fertility is largely the result of people failing to achieve target fertility because of delay in reproduction interacting with physiological declines in fertility with age, what can we expect for the future? Will advances in infertility treatment reduce the number of people exhibiting below replacement fertility and how large will be the effect? Will observations of older people experiencing fertility problems lead younger people to marry and reproduce earlier? If the model is correct, we should expect to see some reversals of the effects of education on below-replacement fertility. To detect those effects, it will be necessary to distinguish the effects of education on delay from the self-selection effects of delay on education (i.e., those failing to marry and reproduce continuing longer with education as a result).

Even if this model is correct, we are still left with the question of why those social and economic changes and differential investments in capital have such large effects on fertility. We still need a better understanding of the psychological and cultural processes underlying decisions about reproduction and the expenditures of resources on consumption goods. Our hypothesis is that extra-somatic wealth is the principal novelty to which our evolved psychology responds by desiring less than fitness-maximizing fertility. But, why are the effects so strong? One possible hypothesis is that social dynamics of small groups in hunting and gathering economies resulted in greater fitness for those of higher social standing and selected for a psychology in which relative social position of self and offspring is valued highly. Such a psychology would also emerge if people judged the well being of themselves and their children based upon the wealth and consumption of others. This psychology may have been fitness maximizing under traditional conditions. If relative, as opposed to absolute, wealth and social standing guide human decisions regarding wealth flows, parental investment, and fertility, it is possible that "run-away" consumption and investment in children's education result from the interaction of this psychology and modern education-based labor markets and consumption possibilities (Frank, 1985).

In modern society, people face a tremendous array of consumption goods, including housing, clothing, electronic equipment, vehicles, etc. The medium of exchange for obtaining those goods is money. Money is highly fungible in that it can be translated into any one of those goods. As diminishing returns to consumption of one category is reached, money can then be allocated to another. With all the goods available, there is always some good of which little has been consumed and returns to purchasing some amount of it are still high. The same can be said for investment in offspring's embodied capital, which appears to include not only investments in schooling but in items associated with social training and social status, such as hobbies and sports, clothing, and toys. Much of these investments function as commitments to favorable eventual placement of children in the mating market. Our best guess at this time is that the low fertility exhibited in modern societies is due to the combined effects of lowered mortality, higher payoffs to investments in offspring income, a perceived lack of diminishing returns to other forms of consumption, and increasingly effective birth control technologies.

If the existence of extra-somatic wealth is the critical condition to which our evolved proximate mechanisms do not respond so as to maximize fitness, it may be that deviations from fitness maximization are likely to be observed in other contexts as well. When there is heritable wealth, such as cattle or land, the breast-feeding/energy-balance system may generate higher fertility than parents' desire. Adjustments to this situation may involve primarily differential inheritance, such as primogeniture and illegitimacy (Mace, 1998), but may also include late age of marriage (Coale and Treadway, 1986) or even celibacy (Boone, 1995), and lowered rates of polygyny by wealthy men (Luttbeg et al., 2000). Thus, perhaps we should not be surprised to find deviations from fitness maximization soon after there are forms of extra-somatic wealth and social stratification. We are only beginning to investigate the evolved psychology and physiology of human reproduction and parental investment and their interaction with changing economic, social and cultural conditions.

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[i] One potential bias of both these data sets is that people had to survive until the late 80s/early 90s in order to contribute data. Thus, among old cohorts, if there is a trade-off between higher

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fertility and adult mortality, the sample will be biased towards people who were less likely to reproduce, or had fewer children.

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Table 1. Logistic Regression of Probability of Having a Birth for Couples: Albuquerque Sample

	First Birth for Nulliparous Couples*			**Third Birth for Couples w/ Two Children**		
	Risk Years=3966 Years with Births = 476 Years without Births = 3490 P-value for the Model < 0.0001			Risk Years=2579 Years with Births = 166 Years without Births = 2413 P-value for the Model < 0.0001		
Variable	**Parameter Estimate**	**P-value**	**Odds-Ratio**	**Parameter Estimate**	**P-value**	**Odds-Ratio**
Intercept	1.31	0.0007		-1.05	0.0791	
Ethnicity	-0.48	0.0001	0.62	-0.31	0.1263	0.736
Wife’s Education	-0.06	0.0118	0.95	0.00	0.9881	1.001
Husband’s Education	-0.02	0.3696	0.98	0.03	0.3672	1.028
Husband’s Income	0.00	0.2397	1.00	0.01	0.1033	1.006
Pre Baby Boom	-0.43	0.0556	0.65	-0.30	0.4957	0.74
Post Baby Boom	-1.17	0.0001	0.31	-1.20	0.0001	0.302
Wife’s Age < 20	-0.18	0.2967	0.83	-0.29	0.5779	0.746
Wife’s Age 25-29	0.07	0.5766	1.07	-0.19	0.4802	0.831
Wife’s Age 30-34	-0.80	0.0001	0.45	-0.64	0.022	0.53
Wife’s Age 35-39	-1.32	0.0001	0.27	-1.63	0.0001	0.195
Wife’s Age 40-44	-2.83	0.0001	0.06	-3.97	0.0001	0.019
Wife’s Age 45-49	-3.55	0.0004	0.03	-14.66	0.9545	0
His Prior Fertility	-0.21	0.0151	0.81	-0.50	0.2375	0.606
Her Prior Fertility	-0.13	0.1905	0.88	-0.53	0.2482	0.591

* Some individuals in this sample have had children from a previous relationship

Table 2. Determinants of College Attendance and Parental Support for Higher Education

	A. Probability of child attending college		**B. Probability of child receiving money for college**		**C. Log of amount of money child received**[c]	
	Full sample		College sample		Funded sample	
	Logistic regression N = 1947, χ^2 =439.0, df = 7, $p < 0.00001$		Logistic regression N = 1132, χ^2 =152.7, df = 8, $p < 0.00001$		OLS regression N = 637, $R^2 = 0.201$, $F_{6,630} = 26.4$, $p < 0.00001$	
Variable	**Parameter estimate**	**Partial *p***	**Parameter estimate**	**Partial *p***	**Parameter estimate**	**Partial *p***
Intercept	-3.66	0.000	-080	0.090	5.93	0.000
Child's age (censored at 30)	0.04	0.041	-0.44	0.074	0.10	0.000
Respondent is Anglo	0.44	0.000	0.54	0.001	—	ns
Respondent' s income[a,b]	0.08	0.000	0.11	0.000	0.08	0.000
Respondent' s education	0.11	0.000	011	0.000	—	ns
Child' s mother' s education	0.14	0.000	—	ns	0.07	0.000
No. of genetic kids respondent has by current mate [a]	—	ns	-0.21	0.000	-0.11	0.000
No. of step kids respondent has by current mate [a]	-0.31	0.005	-0.67	0.000	—	ns
Respondent and child' s mother are together	0.66	0.000	1.38	0.000	0.82	0.000

a. Evaluated when offspring was age 18
b. In tens of thousands of 1990 dollars
c. In thousands of 1990 dollars

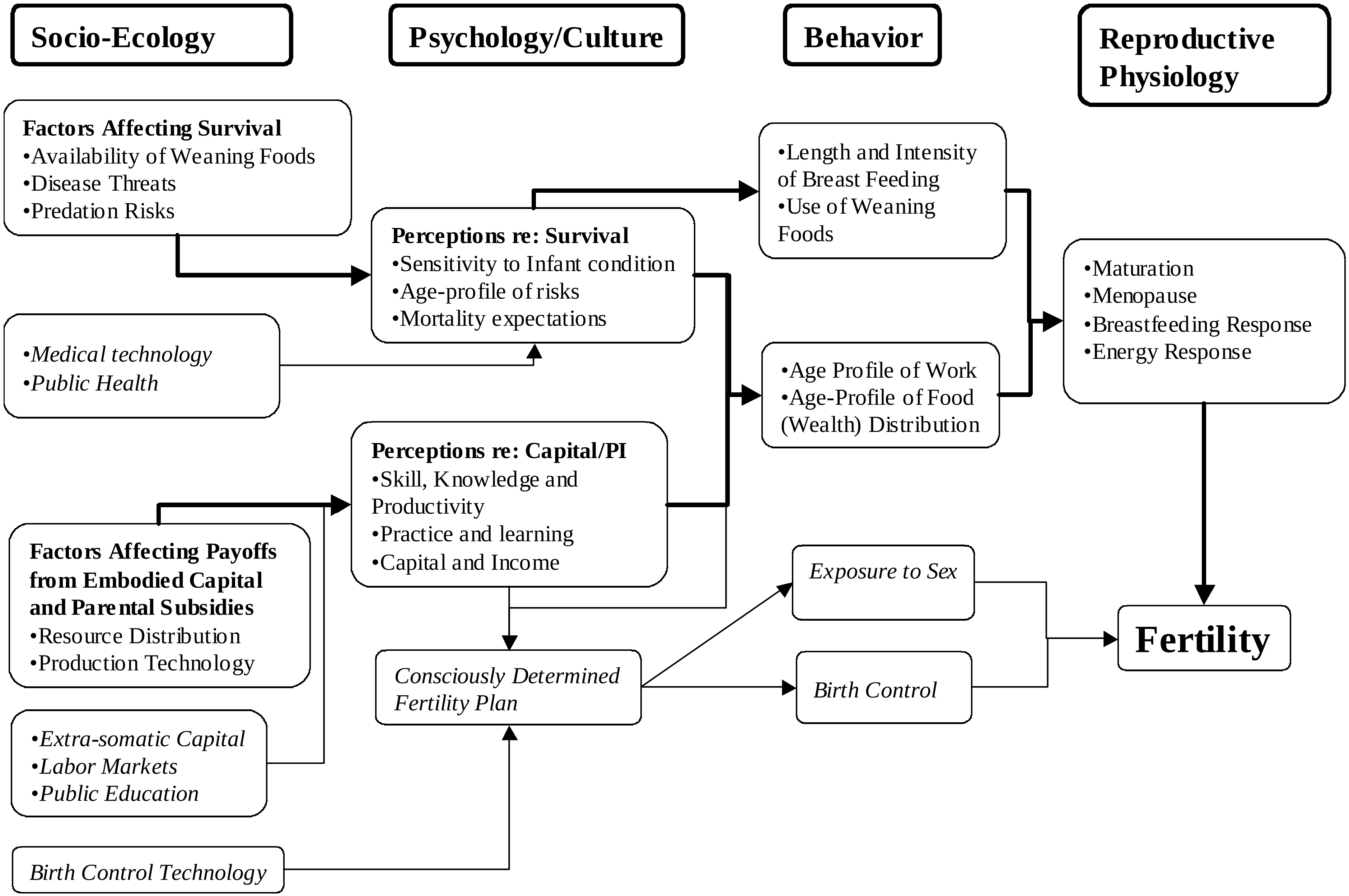

Socio-Ecology
Psychology/Culture
Behavior
Reproductive Physiology
Factors Affecting Survival
•Availability of Weaning Foods
•Disease Threats
•Predation Risks
Perceptions re: Survival
•Sensitivity to Infant condition
•Age-profile of risks
•Mortality expectations
•Length and Intensity of Breast Feeding
•Use of Weaning Foods
•Maturation
•Menopause
•Breastfeeding Response
•Energy Response
•Medical technology
•Public Health
•Age Profile of Work
•Age-Profile of Food (Wealth) Distribution
Perceptions re: Capital/PI
•Skill, Knowledge and Productivity
•Practice and learning
•Capital and Income
Factors Affecting Payoffs from Embodied Capital and Parental Subsidies
•Resource Distribution
•Production Technology
Exposure to Sex
Fertility
Consciously Determined Fertility Plan
Birth Control
•Extra-somatic Capital
•Labor Markets
•Public Education
Birth Control Technology

Figure 1.

Figure 2

The Shift to Below Replacement Fertility

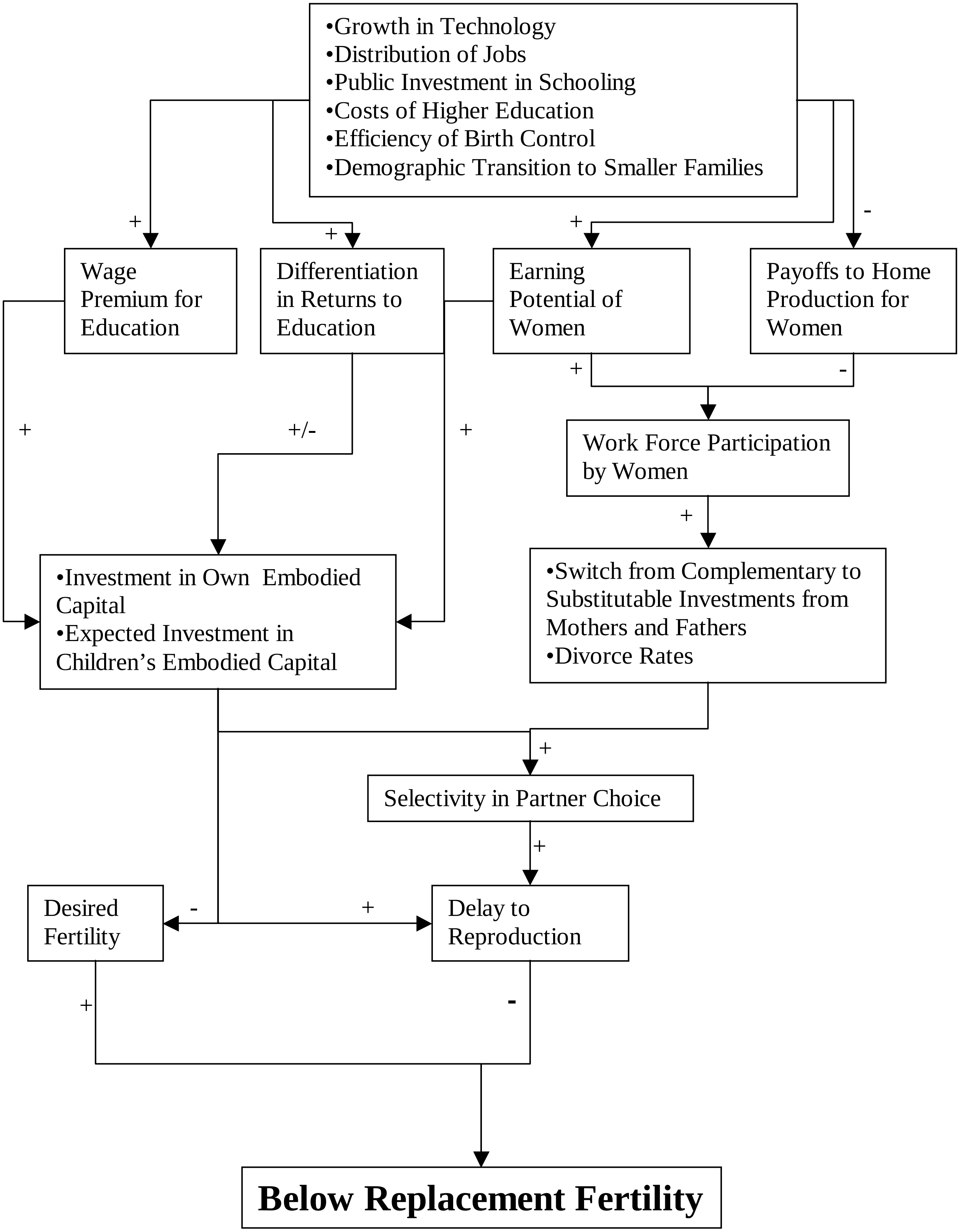


Figure 3a.

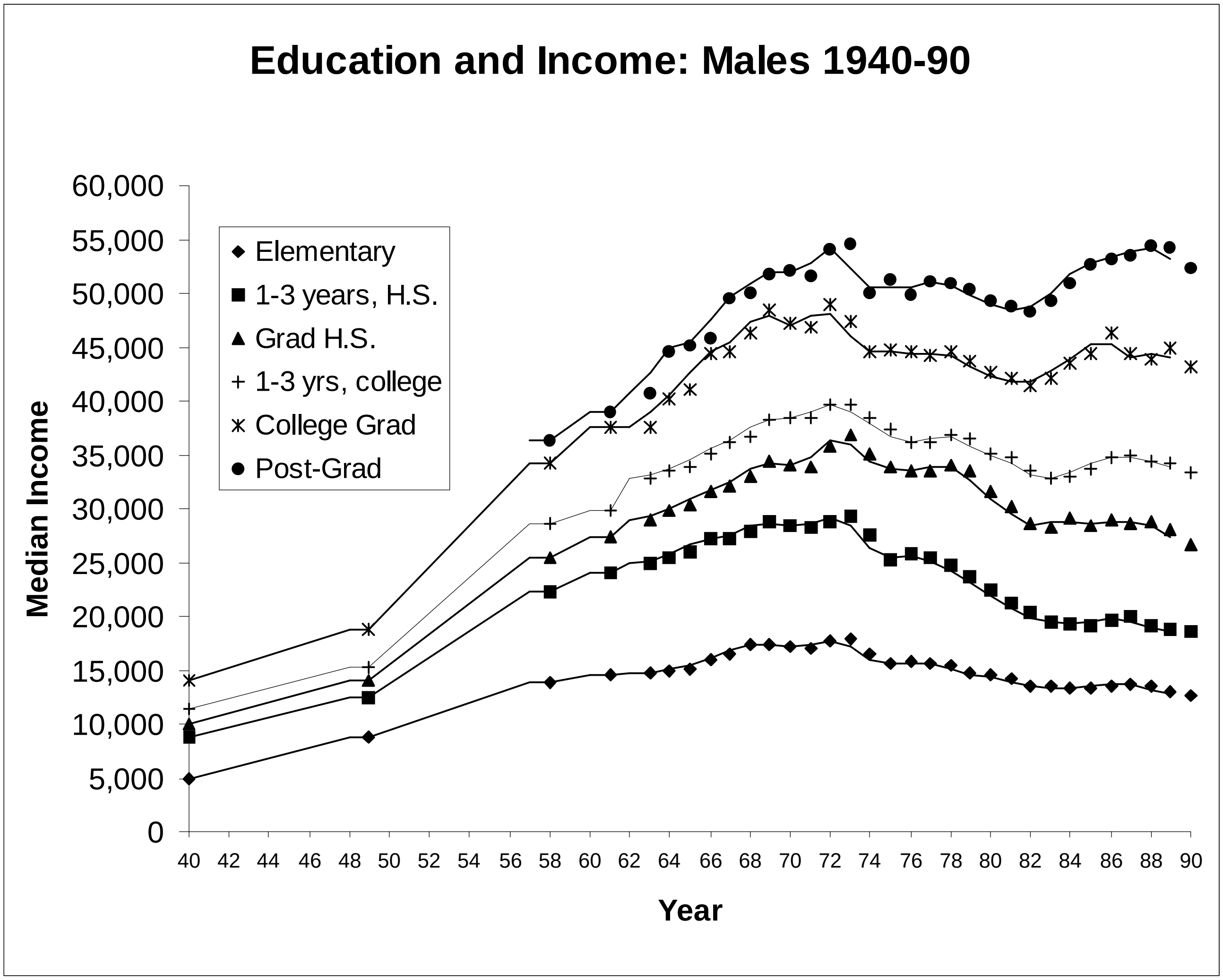

Education and Income: Males 1940-90
Median Income
Year
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
55,000
60,000
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
◆ Elementary
■ 1-3 years, H.S.
▲ Grad H.S.
+ 1-3 yrs, college
⁎ College Grad
● Post-Grad

Figure 3b.

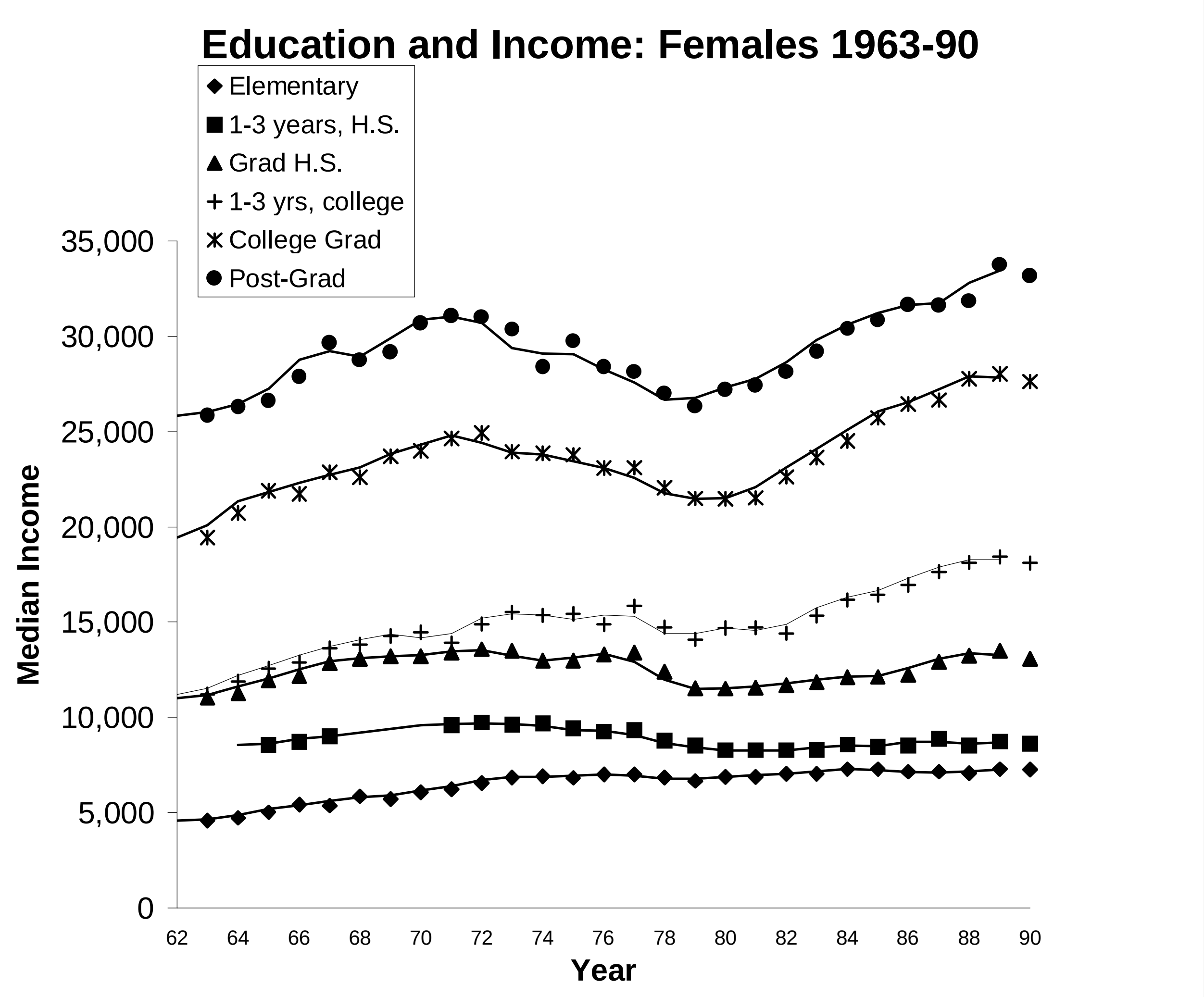

Education and Income: Females 1963-90
◆ Elementary
■ 1-3 years, H.S.
▲ Grad H.S.
+ 1-3 yrs, college
✳ College Grad
● Post-Grad
Median Income
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
Year

Figure 3c.

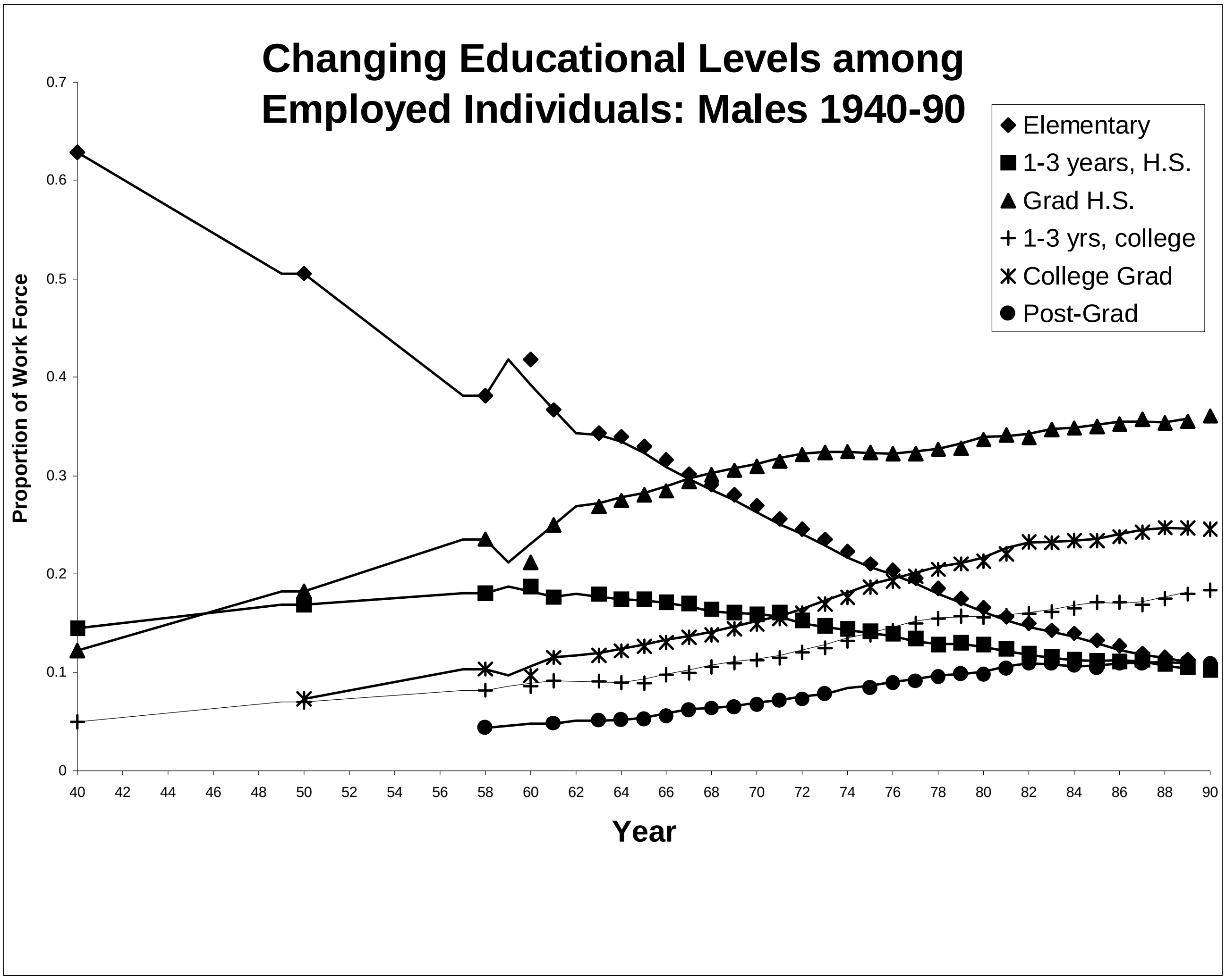

Changing Educational Levels among Employed Individuals: Males 1940-90
Proportion of Work Force
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Year
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
◆ Elementary
■ 1-3 years, H.S.
▲ Grad H.S.
+ 1-3 yrs, college
✳ College Grad
● Post-Grad

Figure 3d.

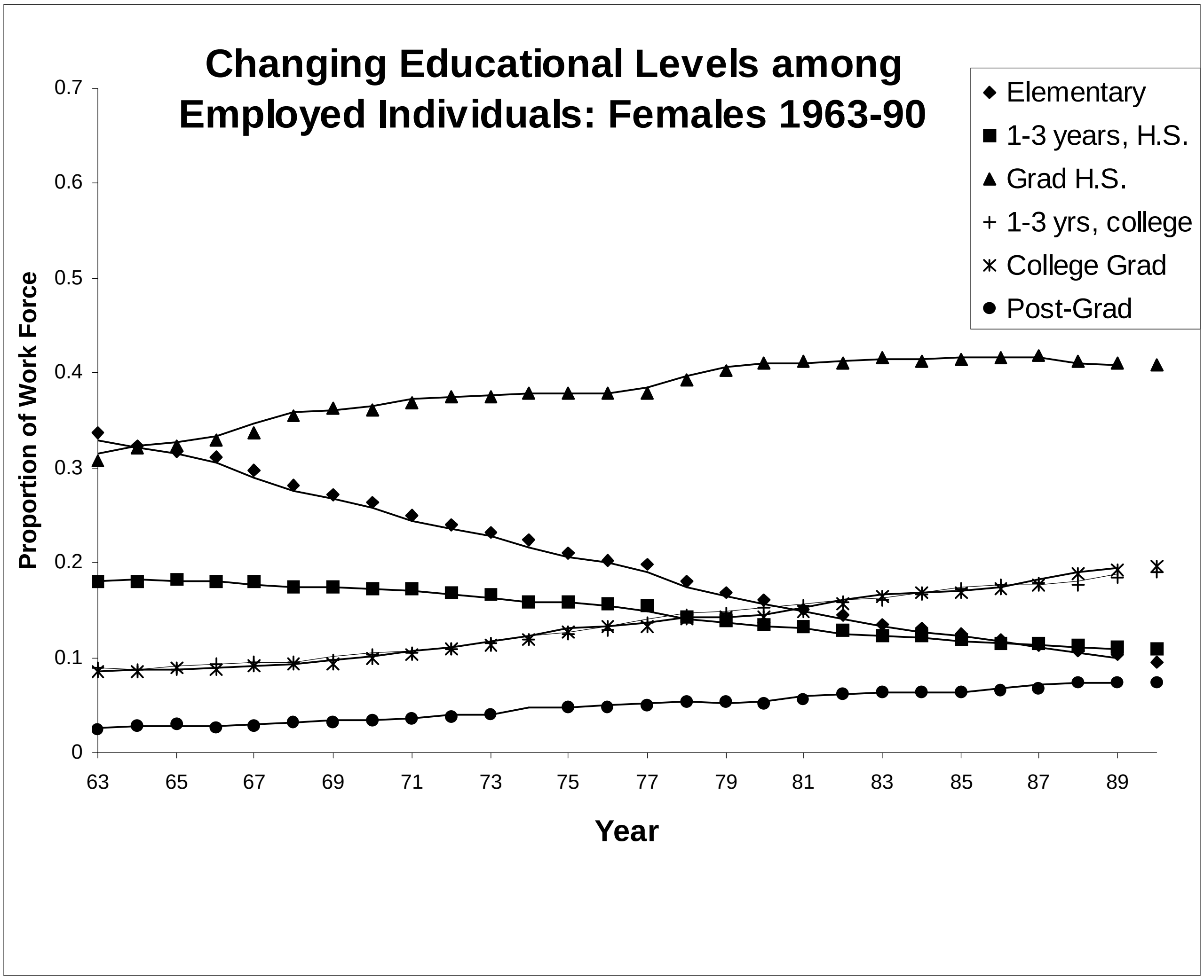

Changing Educational Levels among Employed Individuals: Females 1963-90
Proportion of Work Force
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
63
65
67
69
71
73
75
77
79
81
83
85
87
89
Year
◆ Elementary
■ 1-3 years, H.S.
▲ Grad H.S.
+ 1-3 yrs, college
⁎ College Grad
● Post-Grad

Figure 4a.

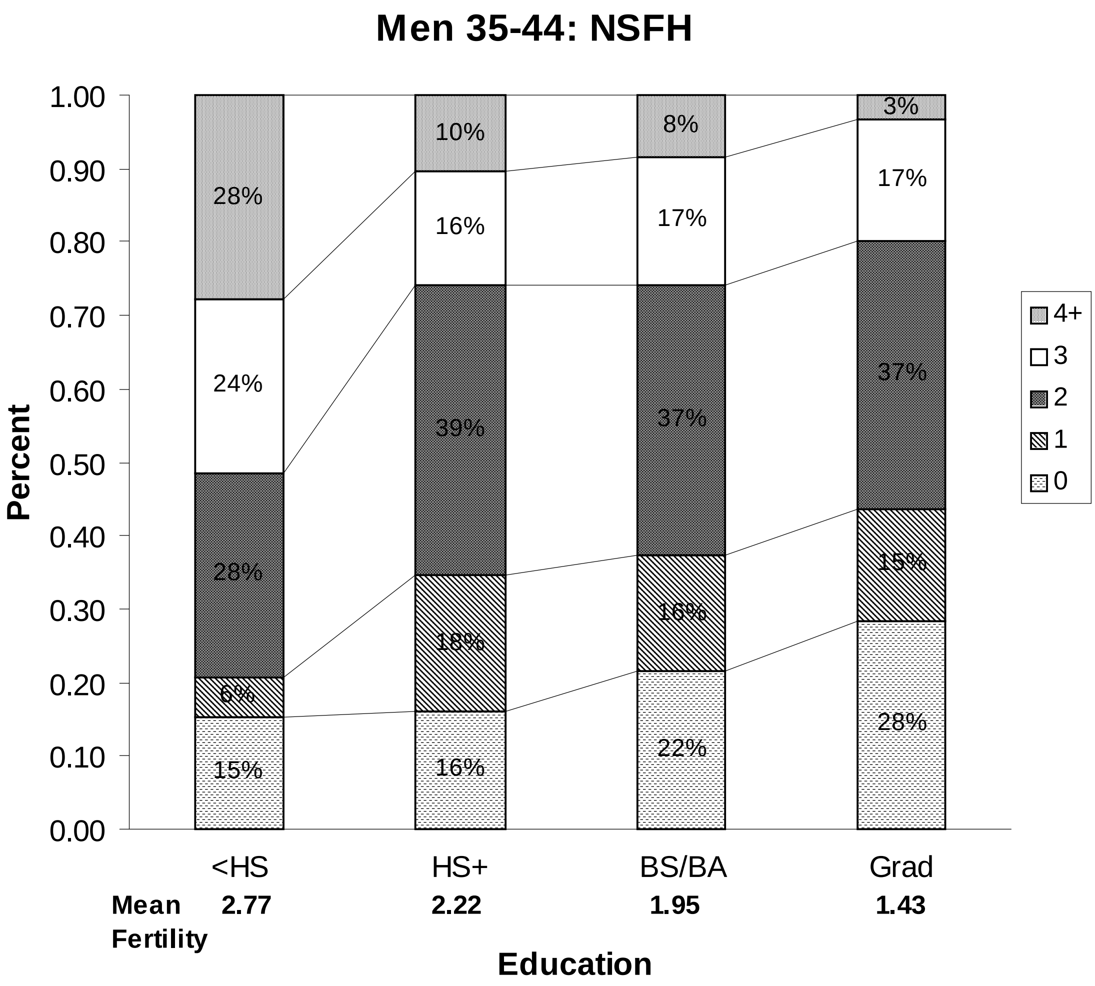

Men 35-44: NSFH
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Percent
28%
24%
28%
6%
15%
10%
16%
39%
18%
16%
8%
17%
37%
16%
22%
3%
17%
37%
15%
28%
4+
3
2
1
0
<HS
HS+
BS/BA
Grad
Mean Fertility
2.77
2.22
1.95
1.43
Education

Figure 4b.

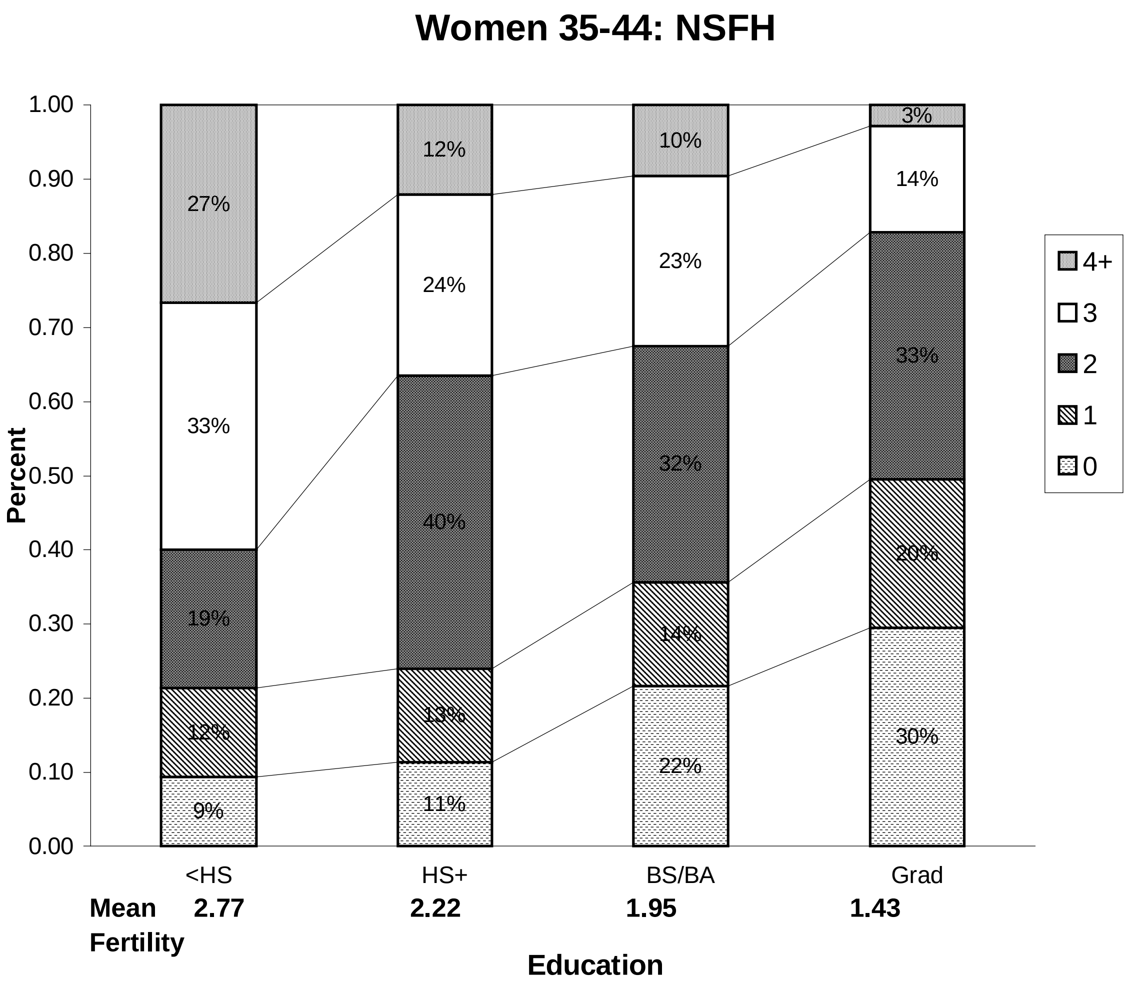
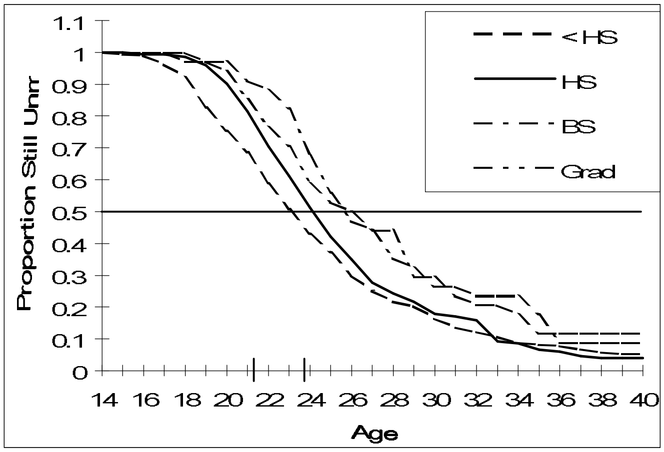

Women 35-44: NSFH
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Percent
27%
33%
19%
12%
9%
12%
24%
40%
13%
11%
10%
23%
32%
14%
22%
3%
14%
33%
20%
30%
4+
3
2
1
0
<HS
HS+
BS/BA
Grad
Mean Fertility
2.77
2.22
1.95
1.43
Education

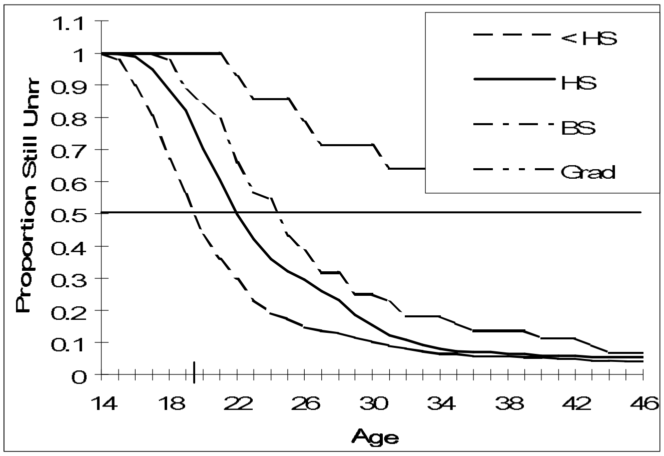
Figure 5a. Survival Functions for

Men Born before 1920 (Aged 68 to 94 Years)



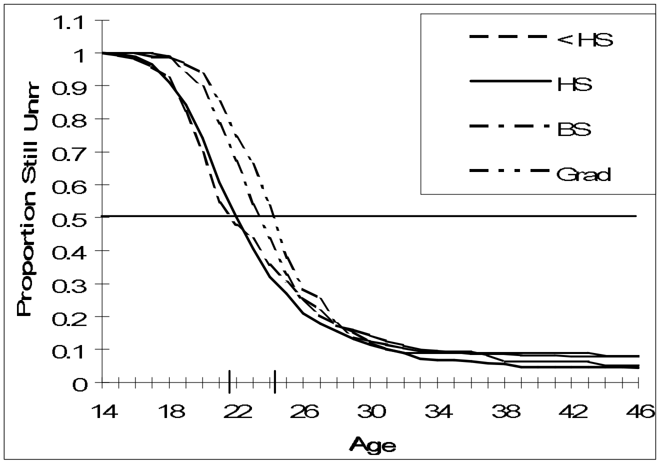
(n < HS to Grad = 207, 152, 34, and 34, respectively.)

Women Born before 1920 (Aged 68 to 97 Years)



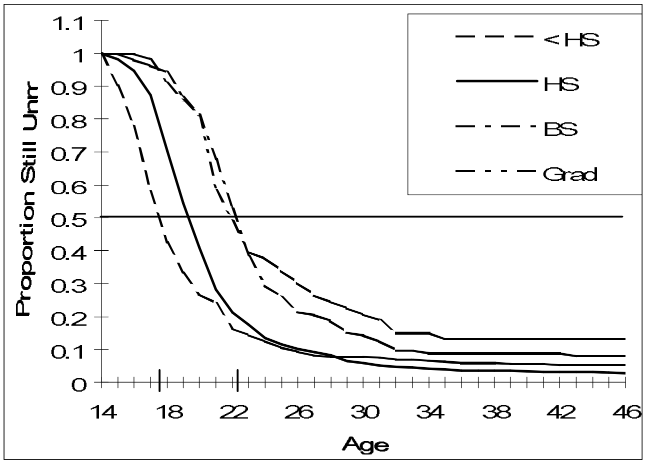
(n < HS to Grad = 387, 370, 44, and 14, respectively.)

Men Born 1920-1941 (Aged 46 to 68 Y



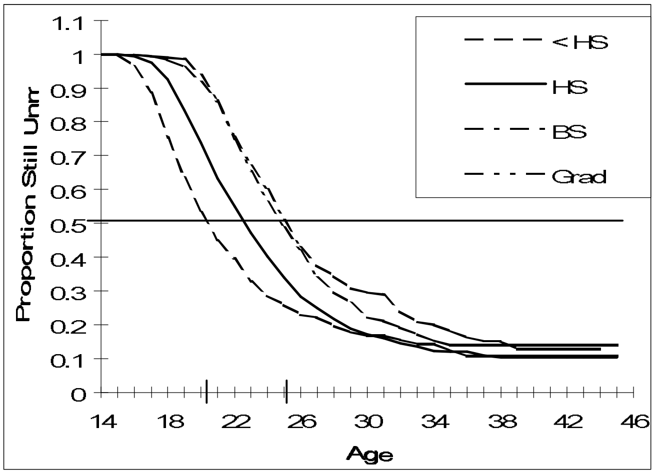
(n < HS to Grad = 238, 493, 98, and 95, respectively.)

Women Born 1920-1941 (Aged 46 to 68 Years)



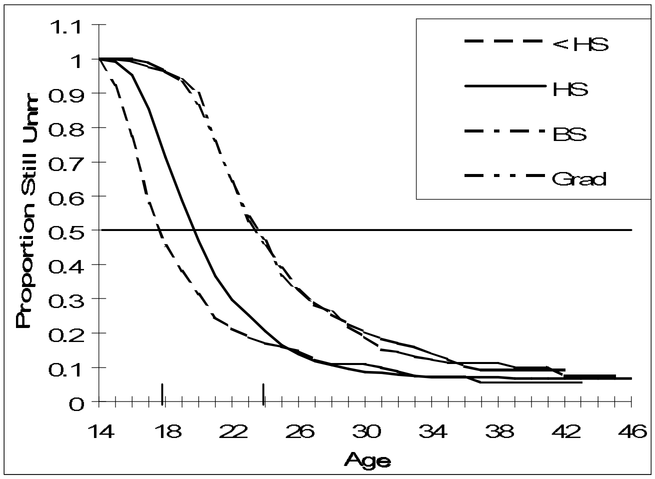
(n < HS to Grad = 317, 842, 112, and 53, respectively.)

Men Born 1942-1970 (Aged 17 to 45 Y



(n < HS to Grad = 231, 1581, 478, and 213, respectively.)

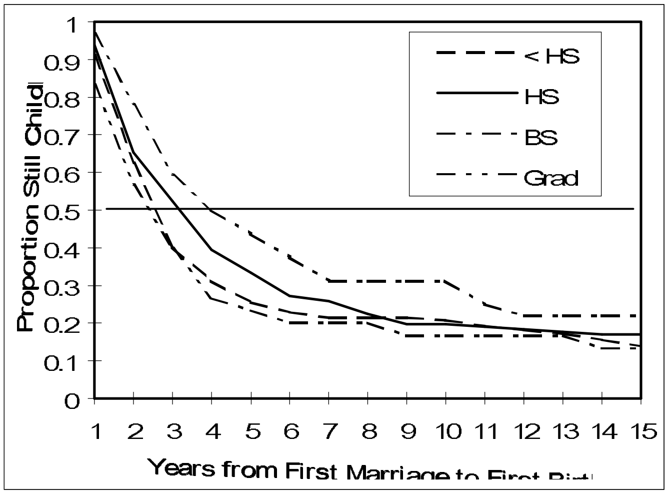
Women Born 1942-1971 (Aged 16 to 45 Years)



(n < HS to Grad = 349, 2271, 473, and 200, respectively.)

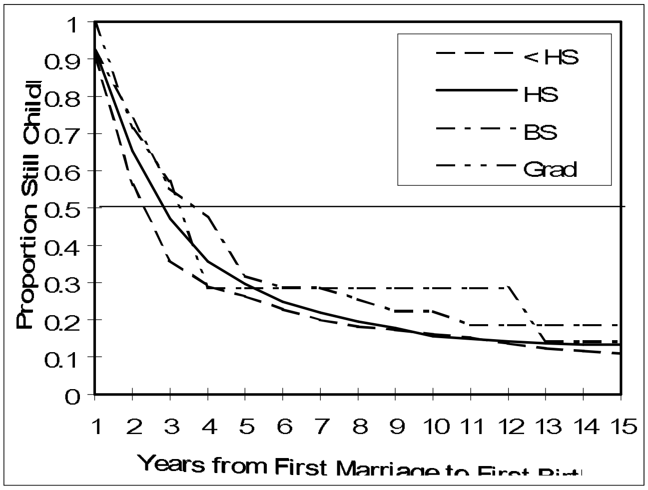
Figure 5b. Survival from First M

Men Born 1893-1919 (Aged 69 to 94 Y



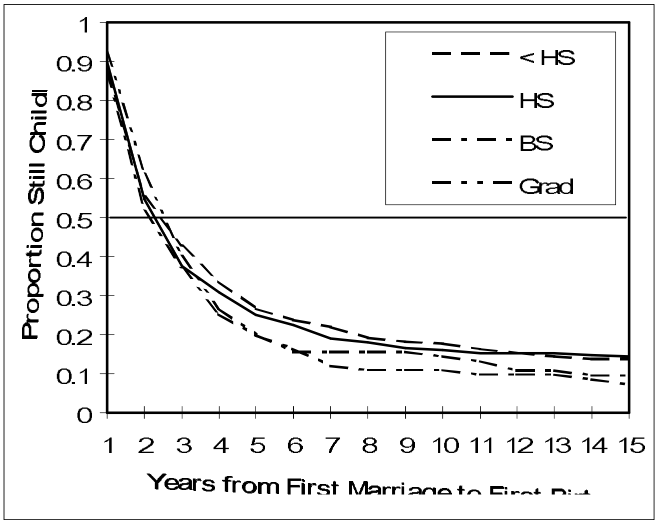
(n < HS to Grad = 192, 147, 32, and 30, respectively.)

Women Born before 1920 (Aged 68 to 97 Years)



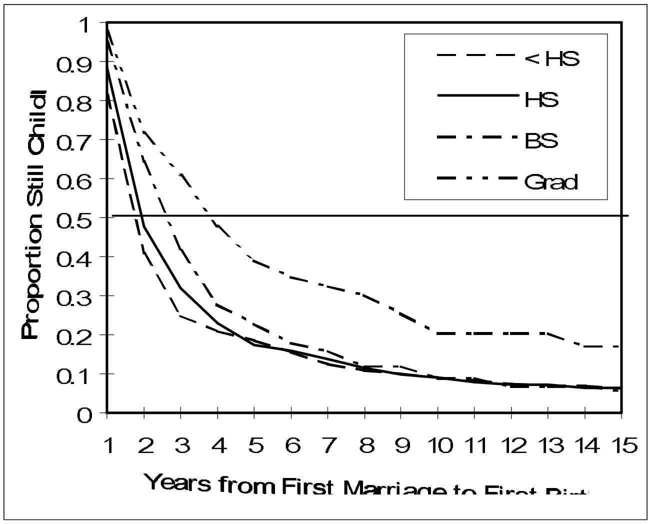
(n < HS to Grad = 363, 348, 39, and 7, respectively.)

Men Born 1920-1941 (Aged 46 to 68 Y



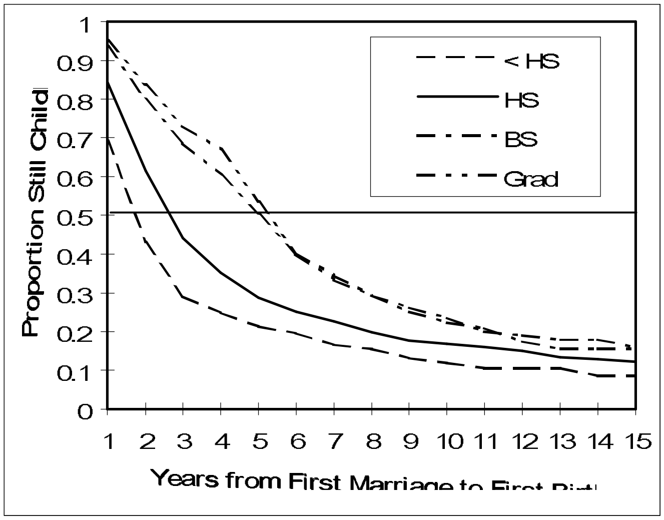
(n < HS to Grad = 219, 471, 91, and 90, respectively.)

Women Born 1920-1941 (Aged 46 to 68 Years)



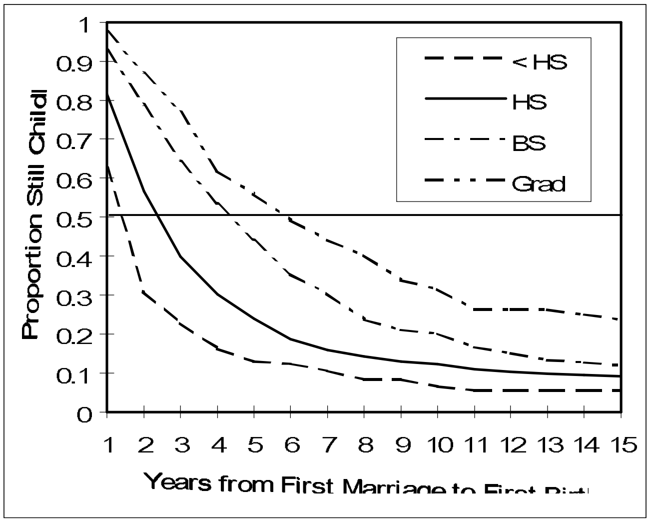
(n < HS to Grad = 301, 813, 101, and 46, respectively.)

Men Born 1942-1970 (Aged 17 to 45 Y



(n < HS to Grad = 173, 1119, 354, and 167, respectively.)

Women Born 1942-1971 (Aged 16 to 45 Years)



(n < HS to Grad = 289, 1891, 361, and 170, respectively.)

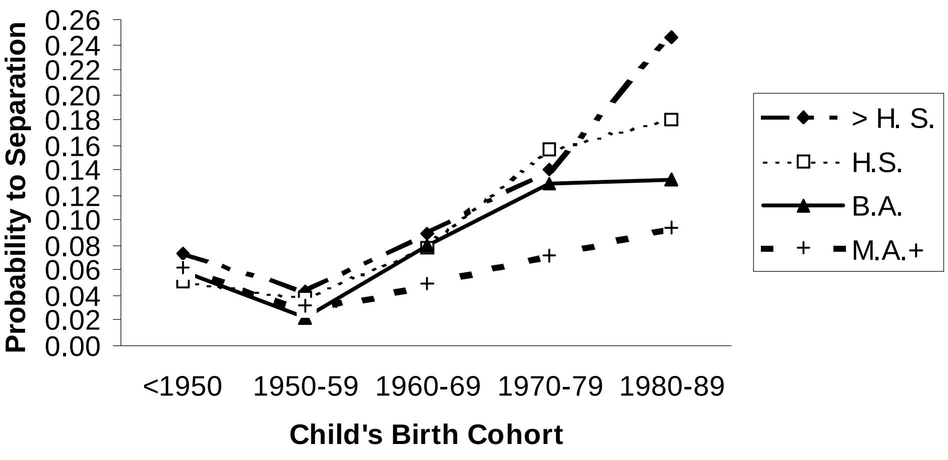


Figure 6. The Father's Probability of Ceasing to Live with the Child Before the Age of 6