American Demographic Transition
and Married Female Labor Force Participation:
What Role for Health?

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I. Introduction

Between the latter parts of the nineteenth century and the onset of WWII there was a dramatic revolution in American families: Family size continued its long-term decline. The schooling of older children expanded tremendously, as epitomized by the 'high school movement.' Finally, the proportion of married females' adult life cycle devoted to market-oriented activities increased, even as market-oriented activity performed at home declined. This paper develops a framework in which fertility, child quality and lifetime married female labor supply are determined simultaneously and then examines the potential of health-related mechanisms to explain this constellation of behaviors in the United States. In particular, beginning in the late nineteen century there were dramatic reductions in mortality, especially among the young. There were also impressive reductions in morbidity and improvements in life expectancy at all ages. This health revolution may reduce fertility (which, by itself, frees mother for market work) and increase maternal investments in children's human capital, potentially lowering mother's labor supply.

We develop and then simulate a model featuring household choices over the quantity and quality of children, and the labor force participation of wives. We find that reductions in child mortality are unlikely to have contributed to the transformation in the American family. Indeed, in our preferred calibration, reductions in child mortality lead to a modest *decline* in human capital and *increase* in fertility, with little effect on MFLFPRs. However, reductions in morbidity (shown to operate similarly to increases in adult longevity) are shown to encourage the demographic transition and increase the market work of mothers. In combination these mechanisms deepen our understanding of the American family transformation, complementing the explanations based on sectoral shift and skill-biased technical change. The paper continues in section II with further discussion of the trends to be explained. The third section provides a review of literature and motivates the model. Section IV develops the framework. The models' calibration is discussed in Section V; the sixth section discusses results and summarizes. Prior to the conference a revised version, including more discussion of the simulations, will be emailed to all conference participants

II. Trends in fertility, education, and market work of married women.

II.1 Married women's labor force participation

The Census Bureau reports that the MFLFPR among white married women increased from 2.5% in 1890 to 9.8% in 1930. However, for at least three reasons these cross-section snap shots are of limited value for analysis of change across several cohorts. First, those cross-section Census estimates are based on Census questions that, especially in the nineteenth century, differed appreciably from the modern participation concept, first used in 1940. Beginning in 1940 the Census tabulates as 'in the labor force' respondents indicating they either worked for pay in the past week, who were temporarily away from work (on vacation, for example), or had engaged in job search over that period. Prior to 1940, the concept was that of gainful occupation (though the question varied a bit from Census to Census). Goldin (cf. 1990) notes that in the nineteenth century many women who worked on their husband's farm or kept boarders viewed themselves as principally housewives; and this is the 'occupation' they reported to the Census takers. She constructs a labor force measure for 1890 consistent with the 'modern' notion, finding that the Census measure needed to be revised upwards by almost 10% points (roughly increasing the MLFPR for 1890 by a factor of 5 compared to the Census). Sobek (1997) replicates Goldin's methodology using IPUMS data for Census years 1880, 1900, 1910 and 1920. He finds that adjusted MLFPRs were relatively stable over this entire period, followed by a rapid acceleration post-1940.

A second shortcoming of the census figures is that our framework is based on decisions of *lifetime* labor supply made as young adults. This suggests a lifetime measure of market work, which requires cohort data. However, even with cohort data which correctly measures work in each year, there remains the question whether young adult females accurately foresaw their mid-life participation rates. Indeed, Goldin (1990) examines survey data from young women regarding their expected future MLFPRs and finds that when rates have increased rapidly young women have underestimated their future participation (154-157)).

Another limitation of labor force *participation* data is that the number of hours worked varies tremendously across those within the labor force at a point in time, as well as across time. This creates an additional complication since our framework addresses the allocation of time to an activity, rather than participation in that activity.

We construct a measure which reflects both the available cohort information as well as the cross-section adjustments to MLFPRs, to provider a lifetime measure of married female market work across several birth cohorts. First, cohort participation profiles for white married females attaining adulthood between 1880 and 1940 are taken from Roberts' (2007, Fig. 1.9). For those born 1931-1940, achieving adulthood in 1960 (extrapolations made for ages 60-69), Table f85-126 from Historical Statistics of U.S. (1-702) is used. This component is based on actual behavior at different ages and is consistent perfect foresight on the part of young adults. Second, the adjustments to the Census cross-section MLFPR for a given year from Sobek (Table 2.5) are added to the Census averages from step 1; this is a static expectations component, based on the cross-section in the year the young female commences adulthood (about age 20). Finally, this sum is multiplied by .75 in each year to produce the reported MLFPR, which assumes that the average married woman in the labor force devotes three-quarters of her time endowment within a year to market work and that this ratio is constant across time. These calculations are shown in Table 1.

These cohort measures are appreciably greater for a birth cohort than is the Census cross-section number for the same year. Also, notice that the cohort attaining adulthood (age 20) in 1930 has roughly twice the lifetime participation of the young female adult of 1880 (18.1 compared to 9.2). The reconciliation of these findings with the relatively trendless cross-section adjusted MLFPRs reported by

Sobek is that young wives after 1920, say, began to re-enter the labor force in greater numbers once their children matured.

Table 1: Lifetime Labor Supply Among White Married Women

		(1)	(2)	(3)
Birth Cohort	Attain adulthood	Census Cohort	Adjustment	MFLFPR
1855-64	1880	2.5	9.8	9.2
1865-74	1890	3.7	9.9	10.2
1875-84	1900	4.4	8.7	9.8
1885-1894	1910	6.8	6.4	9.9
1895-1904	1920	11.8	6.4	13.6
1905-1914	1930	21.0	3.2*	18.1
1911-1921	1940	28.7	0.0	21.2
1921-1931	1950	36.1	0.0	27.0
1931-40	1960	41.3	0.0	31.0

*There is no adjustment measure for 1930, the last year before the modern concept. We assume one-half the adjustment for 1920 applies to 1930. (Hist. Stat. U.S. for 1940 on, I-702, extrapolated for 60-69 for 1960 adulthood cohort. Averages across age groups of 20-29,…, 60-69. Column 3 is (.75) of the sum of columns 1 and 2.

II.2 Schooling

Murphy, Simon and Tamura (2008) construct estimates of the years of schooling completed by children born in census years 1850 -2000 using enrollment data from IPUMS. They find that the cohort of children born in 1880 would ultimately complete 5.02 years of school. This had more than doubled to 10.5 years by 1930. Another perspective is afforded by the explosive increase in the high school graduation. This rate had been but 2 percent in1870, rising modestly to 8.8 percent in 1911-1912. Then the 'high school movement' rapidly raised graduation rates, which had reached 45.6 percent only 25 years later in 1936-1936 (Goldin and Katz, 2008, p. 27).

II.3 Fertility

Fertility declined in the United States from at least the early nineteenth century until the 1930s. Jones and Tertilt (2007) have recently analyzed historical cohort fertility in the United States based on self reports of retrospective fertility of ever-married women contained in the 1900 and 1940 U.S. Census. For the cohort of females born 1856-1960, who would attain adulthood around 1880, children ever born was 4.9. Fertility fell rapidly so that women reaching adulthood in 1900 (born 1876-1880) had but 3.25 children. Cohort fertility reached a nadir in their survey results for those born 1906-1910 (reaching adulthood about 1930); the following cohorts were the leading edge of the baby boom.

III. Literature Review

There is an immense literature on the topics of the high school movement, fertility decline, and the rise in the married female labor force rates (MFLFPRs). The following sample is only suggestive of the breadth and depth of research in these areas. Existing research on American fertility, schooling, and labor force participation in the period from late nineteenth century through the 1930s does not address the HS movement, fertility, and MFLFPRs simultaneously. Claudia Goldin's career (cf , 1990 and 2006) has detailed the record of schooling and female labor market work over long periods including the interval we examine. Her preferred theoretical mechanisms are principally that: the rising importance of clerical work increased the returns to skill, encouraging the high school movement; the decline in the gender wage gap combined with respectable white collar jobs for women to reduce the stigma of working wives, contributing to the rise in married female labor force participation; the ability of high school grads with clerical skills to return to respectable office jobs after children became older accounts for much of the accelerated rise in cross-sectional MLFPRs in the 1940s and 1950s. The Depression and consequent strengthening of marriage bars retarded this increase in the 1930s. A variation on Goldin's view is that of Adeshade (2008) and Rotella (198x) who envision an exogenous increase in high school attendance which *induced* skill-biased technical change in office work. Galor and Weil (1996) suppose that capital deepening accompanying the second industrial revolution decreased the return to strength, narrowing the gender wage gap, reducing fertility and increasing MLFPRs.

Other theories of the rise in MFLFPRs appeal to technological change. According to Greenwood, Seshadri and Yorukoglu (2005) the rise of labor-saving capital goods in the household (clothes washers, dryers, vacuum cleaners, dishwashers, etc.) reduced the marginal product of females in the household sector. In their model, increases in the quantity and quality of durable household appliances (which they model as declines in their price) reduce the reservation wages of females, increasing MFLFPRs in the middle of the 20th century. They conduct a theoretical calibration exercise and find that half of the increase in women's LFPRs was due to labor-saving technology. Albanesia and Olivetti (2007) argue that technological improvements related to the bearing and nursing of children were instrumental to the rise in the labor force participation of mothers. Finally, Fernández, Fogli and Olivetti (2004) propose a role for culture in the rise of MLFPRs, arguing that men whose own mothers had worked are more likely to prefer a spouse who works.

Implications of Mortality Decline

Our paper considers implications of the mortality transition in the United States for fertility, education and married female market work. After a few general remarks about the transition, we consider recent theory about the implications of these improvements in health. Mortality was high and variable in the United States until the last decades of the nineteenth century. High baseline mortality was spiked by periodic epidemics of cholera, yellow fever, influenza and other infectious diseases. However, in the 1870s or 1880s mortality began a rapid descent to much lower levels. Haines (Table x, EHOUS) reports that life expectancy at birth among the white population in 1880 was 39.6 years, rose to 49.6 in 1900, 57.4 by 1920, and reached 69.1 in 1950. Much of the mortality decline in the first decades of transition was concentrated among infants and children (so that increases in life expectancy at age 10 were less spectacular). White infant mortality, i.e., deaths in the first year of life per thousand live births, which was a horrific 214.8 in 1880 had declined to 120.1 in 1900 and to 26.8 by 1950 (Haines, EHOUS). However, there was also a significant improvement in rates of survival among older children of those living to age one. For example, the probability of surviving to age 1 in 1880 was .829, while the probability of living to age 15 in 1880 was .707. So, of 100 children born in 1880, an additional 12 died between the ages of 1 and 15 (Murphy, Simon Tamura, 2008, Tables 14 and 15 ?).

Preston and Haines (Fatal Years) describe how the mortality transition was facilitated by massive public investments in clean drinking water and hygienic waste removal. Also important were advances in scientific understanding. Once the germ theory of disease gained acceptance, practices such as washing hands before eating, quarantining those who are ill, purifying water, heating milk, and keeping living areas clean boosted health and reduced mortality. Many vaccines were introduced at the turn of the century lower rates of contraction of infectious diseases. The discoveries of sulfa drugs in the 1930s, then of penicillin, helped further reduce mortality and perhaps morbidity.

Mokyr (200x) argues that increased understanding of the role of good hygiene in preventing sickness and death led mothers to devote more time to housework, delaying the rise in MLFPRs.   Mothers, he argues, now believed that through their efforts they could directly lower the probability of child death. Further, with the mechanisms of disease still poorly understood, housewives made sure that any error in their effort would be by on the side of too much, rather than too little, cleanliness. Whereas God's Will had previously been the sole determinant of which children lived and which died, now cleanliness had risen next to Godliness. Mothers' obsession with cleanliness, he argues, *delayed* the onset of female market work.

In the context of economic development, a recent paper by Soares and Falcao (2008) considers linkages among increases in adult longevity and married female labor force participation. Thus, it is similar to our framework below, but with important differences. In SF increases in adult life expectancy are the major driver of the rise in human capital, the decline in fertility and the movement of married women from the home to the market sector. They assume that increases in own adult longevity increase the period over which investments in own market-oriented human capital can be recouped. This increases human capital investments by females in their early adulthood, *inducing them to substitute away from fertility and increase market work*. They also consider implications for investments in the human capital of children. To the extent the production of child quality utilizes mother's time (and no goods), adult longevity has an ambiguous effect on child quality: greater adult longevity for children increases the returns to their market human capital, but mother's higher human capital increases the opportunity cost of investing in children.

Hazan (2009) points out that, empirically, increases in adult longevity are typically associated with *reductions* in the total amount of hours worked over the life cycle. This was true in the U.S. from the end of the 19th century through the middle of the 20th century: the work week became shorter and the age upon retirement declined (cf Costa (2000)). Consequently, modeling increased adult longevity as causing longer labor market attachment is problematic.

Hazan and Zobai (2006) focus on the effects of increased adult longevity perfectly foreseen by parents investing their children's human capital. They point out that when parents receive utility from the aggregate earnings of children in adulthood, increases in longevity increase the returns to *both* quantity and quality. Consequently, increased longevity need not lead to fertility decline and increased education.

Soares and Falcao briefly consider implications of child mortality. In their framework parents receive utility from surviving children and as child mortality declines, so does fertility. They note that lower child mortality increases the returns to parental investments in quality, so that investments per child increase. In their framework the increase in parental investments per child more than offsets the decline in fertility, so that total time investments in children increase. Thus, lower child mortality *reduces* married female labor force participation, whereas higher adult longevity increases it: Lower child mortality increases mother's investments in children (reducing labor supply), whereas increased adult longevity increases adult human capital, and the incentives for labor market attachment.

Of course, not all children exposed to infectious disease died from them. There is growing evidence that those subjected to harsh physiological insults at one point suffer increased morbidity at later ages (cf Costa (2009). That is, survivors of serious disease(s) and/or harsh working conditions may be physically compromised in ways that depress 'ability' and, therefore, the returns to human capital accumulation. Consequently, morbidity *decline* may increase the capacity to produce human capital. Bleakley (2007, 2009) provides important examples of how reductions in morbidity stimulated human capital. Debilitating hookworm disease had been prevalent in the American South through the early 20th century. However, J.D. Rockefeller funded a highly effective campaign to eradicate hookworm. Bleakley finds that the curtailment of hookworm was associated with significant increases in schooling and sizeable reductions in fertility among the affected populations. His findings are similar for the curtailment of malaria in the American South circa 1920, with an income boost of about 15% in the next generation of states with the greatest reductions (compared to baseline states).

Our paper builds on the recent theoretical work of, especially, Hazan and Zobai, and Soares and Falcao, and the empirical findings of Bleakley, Costa, and Hazan. When addressing implications for human capital accumulation in the late nineteenth and early twentieth century U.S., it is appropriate to focus on parental investments in child human capital, as do Hazan and Zobai. In light of the dramatic implications for human capital and earnings associated with the curtailment of infectious diseases , as stressed by Bleakley and Costa, we attempt to quantify morbidity improvements in a well-articulated model. Following Soares and Falcao we are interested in explaining MFLFPRs in terms of health factors. However, we treat seriously the findings of Hazan that work lives have shortened as adult mortality has increased. In the framework of Soares and Falcao all costs of children are related to child quality. However, Becker (1981) argues there are also costs of children which are increasing in the *quantity* of children, which are largely unrelated to child quality.

Important examples include the reductions in female productivity during and after pregnancy, the costs of basic clothing, perhaps extra living space, and the costs of 'picking up' after children and feeding them (whether these activities are implicit costs associated with mother's foregone labor earnings, or direct costs if the services of a nursemaid and domestic help are purchased). Including such costs may alter the conclusions of Soares and Falcao that reductions in child mortality unambiguously increase total, or even per child, investments in child quality.

IV. Modeling The Household

IV. A. Preferences

Parental utility is increasing in household production and the aggregate income in adulthood of their children (of which half are boys and half are girls):

$$U = \ln H_t + \psi\left(\ln\left(\left(n_{t+1}/2\right)w_{t+1}\pi_{t+1}h_{t+1}\right) + \left(\left(n_{t+1}/2\right)\gamma_{t+1}w_{t+1}\pi_{t+1}h_{t+1}\right)\right) \quad (1)$$

Here, H_t is household production, n_{t+1} is the number of children surviving to adulthood, half of which are boys. $w_{t+1}(\gamma w_{t+1})$ is the wage per unit of human capital earned by adult males (females) at time t+1, where $1-\gamma$ is the gender gap in labor market wages. h_{t+1} is the human capital of each adult child (where boys and girls are assumed to receive equal human capital bequests). As discussed below, π_{t+1} is the productive time endowment of adults. Consequently, $\pi_{t+1}w_{t+1}h_{t+1}(\pi_{t+1}\gamma_{t+1}h_{t+1})$ is the aggregate potential earnings of each child in adulthood. ψ captures the preference for adult-child earnings relative to H_t. With logarithmic preferences, the utility function is strictly quasi-concave and monotonically increasing in each argument. Parental choices over H_t, n_{t+1}, and h_{t+1} are constrained in various ways, which we now explain.

IV. B Constraints

All adults marry for life upon reaching adulthood and make all decisions for the household's remaining life at the beginning of adulthood. Fathers work full-time. Mothers allocate time π_t among household production, market work, and children.

The market earnings of fathers, mothers, and older children are spent on family consumption and developmental inputs for young and older children. By accounting for these time and goods constraints we develop an overall budget constraint for the family.

B1. The Life Cycle and Time Use

Period Structure

Childhood is spent under the direction and care of parents. Childhood is two periods long; 'early' and 'later' childhood. Upon reaching adulthood, adults live an additional π_t periods. The proportion d_t of a mother's ever-born children die in the first period of dependency. All children surviving the first period also survive the second period of dependency and the π_t periods of adulthood. During the second period of childhood surviving children may work or school.

Mother's time allocation

Mother's devote time to household production, raising children and the labor market. Of the considerable time mothers devote to the rearing of children, some portion is 'chores,' with the rest being used to augment the child's human capital development. In the first period of motherhood, mothers devote $\bar{\rho}_t$ units of time on children to activities largely unrelated to the child's quality. These include many time-costs of pregnancy, 'picking up' after children, laundry, dishwashing, etc. She spends an additional ρ_t units of time performing chores induced by each older (i.e., surviving) child. These time requirements related to the *quantity* of children are exogenously determined in our model by the state of household technology. Further, since most such chores require little skill, we assume that the time required is independent of the stock of mother's human capital h_t. Mothers devote $\overline{m}_{th}$ of time to the development of human capital in each young child. This time includes activities such as reading to, talking and educational play with, the young child. It also can reflect, as in Mokyr (2000), time spent learning about and preparing safe and nutritious foods, household cleaning directed at reducing the population of bacteria and viruses in the household, monitoring activities designed to protect the child from accidents. We suppose that the productivity of mom's time devoted to human capital increases linearly in her human capital. z_t units of time are allotted to household production in which market goods are combined with mother's time to produce household consumption goods H_t. These goods are consumed by parents throughout their adult lives; H_t also includes any household public goods which are enjoyed by children and parents. (With logarithmic preferences mom's time allocation proves independent of whether household productivity benefits from skilled labor; of course H_t and utility are higher when skills matter.) Mothers may also devote time to the labor market m_{tl}. In combination, these uses of time are constrained by the π_t units of time at moms disposal. Thus, mother's time use must satisfy

$$n_{t+1}\overline{m}_{th}/(1-d_t)+m_{tl}+\left(\rho_t+\overline{\rho}_t/(1-d_t)\right)n_{t+1}+z_t=\pi_t \quad (2)$$

Children's time budget

Although there are two periods of dependency, each surviving child has only $T<1$ units of productive time, since very young children cannot work at all and older children lack the stamina and strength and concentration to work full time (see Lord and Rangazas (2006). In early childhood all children are schooled for some minimum fraction $\overline{s}$ of T. This schooling is exogenous and has no opportunity cost due to the young child's lack of strength, concentration and understanding. In the second half of childhood parents decide how much the child should contribute to the household budget through market work $\hat{l}_t$ and how much he should prepare for adulthood through schooling $\hat{s}_{th}$. Hence, the time constraint faced by each child is given by $\hat{s}_{th}+\overline{s}+\hat{l}_t=T$.

B2. Sources and Uses of Money income

In addition to goods c_t used in household production there are goods outlays on the quantity and quality of children. $(\tau_t + \bar{\tau}_t/(1-d_t))\pi_t(1+\alpha\gamma_t)$ of parent's labor earnings are spent on each surviving child on clothes, housing, and other child consumption items that tend to mechanically increase with a family's standard of living, yet have little effect on child quality (such goods are the numeraire). τ_t is consumption goods per older (i.e., surviving) child and $\bar{\tau}_t$ are the consumption goods for each young child. In the 19th century such purchases of market goods were probably predominantly based on father's earnings, alone, while in contemporary times the earnings base is that of both parents. For this reason we posit that a fraction α of mom's potential earnings is included with father's earnings in determining such consumption.

Parents also spend for children's developmental inputs. In early adulthood parents choose goods inputs $\bar{c}_{th}$ each costing $\bar{p}_t$. Since the public financing of primary schooling is independent of usage, the average cost $\bar{p}_t$ of all goods inputs (including books, educational toys and broadening vacations, etc.) is less than one. For older children developmental inputs are denoted by $\hat{c}_{th}$, with an average cost of $\hat{p}_t$. The high school movement dramatically lowered $\hat{p}_t$. Total goods expenditures across all children are therefore

$$n_{t+1}\left(\hat{p}_t\hat{c}_{th} + \bar{p}_t\bar{c}_t/(1-d_t) + w_t h_t\left(\tau + \bar{\tau}_t/(1-d_t)\right)\pi_t(1+\alpha\gamma_t)\right)$$

Money Constraint

The market earnings during adulthood for a husband beginning adulthood in t are $w_t h_t \pi_t$. The *potential* earnings of the wife (i.e., if she devoted all time to market labor) are $w_t \gamma_t h_t \pi_t$, remembering that 1-γ_t is the gender wage gap. Potential household labor income also includes *potential* earnings of older children, given by $\mu w_t n_{t+1} h_0 (T - \bar{s})$, where $\mu \in (0,1)$ reflects the wage gap between adult males and children, and h_0 is childhood human capital. In a modest concession to tractability, this expression reflects the assumption that the schooling of children does not affect their earnings until adulthood. Thus the model understates the incentive of parents to school young children, but captures qualitatively how schooling responds to changes in prices and technologies. Actual earnings of children are below potential earnings to the extent that older children spend time $\hat{s}_t$ in school. Altogether the sources of potential household money income are $w_t h_t (1+\gamma) + \mu w_t n_{t+1} h_0 (T - \bar{s})$.

The families overall budget constraint is expressed as

$$w_t h_t \pi_t (1+\gamma) + \mu w_t n_{t+1} h_0 (T - \bar{s}) = \mu w_t n_{t+1} h_0 \hat{s}_t + n_{t+1}\big(\ \rho_t + \left(\bar{\rho}_t + m_{th}\right)/(1-d_t)\big)\gamma w_t h_t$$
$$+ z_t \gamma_t w_t h_t + n_{t+1}\left(\hat{p}_t \hat{c}_{th} + \bar{p}_t \bar{c}_{th}/(1-d_t) + w_t h_t \pi_t (\tau + \bar{\tau}_t/(1-d_t))(1+\alpha\gamma_t)\right) + c_t \qquad (3)$$

The household's potential labor income is given on the LHS. The RHS gives the total spending on, respectively, the implicit costs of schooling older children, the implicit costs of mother's time devoted to household production, the implicit cost of mother's time devoted to the quantity and quality of children, the goods outlays on children, and the goods used in household production.[1]

The production of Human Capital

As noted when deriving the budget constraint, the production of h_{t+1} utilizes market goods while children are young and older ($\bar{c}_t$ and $\hat{c}_t$), mother's effective time $\bar{m}_t h_t$ when children are young, and the kid's time $\hat{s}_t$ when the child is older. Human capital production in children for use in their adulthood h_{t+1} is given by

$$h_{t+1} = (b\hat{s}_{th}\hat{c}_{th})^{\theta_1}(bh_t \bar{m}_{th}\bar{s}\bar{c}_{th}\bar{m}_{th})^{\theta_2} \quad \textbf{(4)}$$

where *b* is an efficiency scalar, and $\theta_1, \theta_2 \in (0,1)$ are production function parameters (elasticities). Thus, all inputs are productive and subject to diminishing marginal returns.

Household Production

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[1] The total cost of raising a child with h_{t+1} level of human capital is given by

$$\left(\left(\hat{p}_t \hat{c}_{th} + \bar{p}_t \bar{c}_{th}/(1-d_t)\right) + w_t h_t\left(\left(\tau_t + \bar{\tau}_t/(1-d_t)\right)\pi_t(1+\alpha\gamma_t) + \gamma_t\left(\rho_t + \left(\bar{\rho}_t + \bar{m}_{th}\right)/(1-d_t)\right)\right) + w_t \mu h_0 \hat{s}_{th}\right).$$

Household production is governed by

$$H_t = c_t^{\bar{v}} z^{\bar{v}-1} h_t \quad \textbf{(5)}$$

We have noted that fathers work full time in market-oriented labor and that older children work when not in school. Of course, especially in the nineteenth century, fathers and children were also engaged in household production. Their labor efforts enter as part of c_t. Intuitively, they have the same productivity in the market as in household production, and place a valuation on their household production time equal to their market earnings. Consequently, the market does not require us to distinguish where the market-oriented work of children and fathers is performed. Similarly, domestic servants are hired inputs and are included in c_t. As men and children leave the home, and as domestic servants are released, intermediate market goods (for example, store-bought flour and washing machines) become more important.

Optimization

Members of generation t (father and mother) choose the quality and quantity of children, $(\bar{c}_{th}, n_{t+1}, \bar{m}_{th}, \hat{c}_{th}, \hat{s}_{th}, z_t)$, and their own consumption (c_t) so as to maximize their utility function given by equation (1), subject to constraints (2) and (3). The Langrangean is written,

$$MaxL = v_1 \ln c_t + (\bar{v} - v_1)\ln z_t + \psi \ln(1+\gamma_{t+1})\left((n_{t+1}/2) w_{t+1}\pi_{t+1}\left(b\bar{s}\bar{c}_{th}\bar{m}_{th}h_t\right)^{\theta_2}\left(b\hat{s}_{th}\hat{c}_{th}\right)^{\theta_1}\right) +$$
$$+\lambda\begin{Bmatrix} w_t h_t \pi_t (1+\gamma) + \mu w_t n_{t+1} h_0 (T - \bar{s} - \hat{s}_t) - z_t \gamma w_t h_t - n_{t+1}\left(\rho_t + (\bar{\rho}_t + \bar{m}_{th})/(1-d_t)\right)\gamma w_t h_t \\ - n_{t+1}\left(\hat{p}_t \hat{c}_{th} + \bar{p}_t \bar{c}_t/(1-d_t) + w_t h_t \pi_t \left(\tau_t + \bar{\tau}_t/(1-d_t)\right)(1+\alpha\gamma_t)\right) - c_t \end{Bmatrix}$$

The first order conditions for the choices of c_t, z_h, $\bar{c}_t$, $\bar{m}_{th}$, $\hat{s}_{th}$, $\hat{c}_{th}$ & n_{t+1} are

$$\frac{v_1}{c_t} = \lambda, \qquad \text{(6a)}$$

$$\frac{(\bar{v} - v_1)}{z_t} = \lambda \gamma_t w_t h_t, \qquad \text{(6b)}$$

$$\frac{\theta_2 \psi}{\bar{c}_{th}} = \lambda \bar{p}_t\, n_{t+1}/(1-d_t), \qquad \text{(6c)}$$

$$\frac{\theta_2 \psi}{\overline{m}_{th}} = \lambda \gamma_t w_t h_t \, n_{t+1} / (1 - d_t), \quad \text{(6d)}$$

$$\frac{\theta_1 \psi}{\hat{s}_{th}} = \lambda \mu n_{t+1} h_0 \quad \text{(6e)}$$

$$\frac{\theta_1 \psi}{\hat{c}_{th}} = \lambda n_{t+1} \hat{p}_t, \quad \text{(6f)}$$

$$\frac{\psi}{n_{t+1}} = \lambda \begin{pmatrix} \gamma_t w_t h_t \left(\rho_t + (\overline{\rho}_t + \overline{m}_{th}) / (1 - d_t) \right) - \mu w_t h_0 (T - \overline{s} - \hat{s}_{th}) + \\ + \left(p_t \hat{c}_{th} + \overline{p}_t \overline{c}_t / (1 - d_t) + w_t h_t \pi_t \left(\tau_t + \overline{\tau}_t / (1 - d_t) \right) \left(1 + \alpha \gamma_t \right) \right) \end{pmatrix} \quad \text{(6g)}$$

These FOCs are interpreted in standard fashion. To provide a few examples: Equations (6c-6f) govern the demand for human capital inputs. They all balance the left-hand-side marginal utility of raising human capital (and therefore child earnings in adulthood) against the utility price of doing so. Notice that in each equation this price is increasing in fertility $n_{t+1}/(1-d_t)$, so that as stressed by Becker (cf. 1981) the price of quality of children is increasing in the quantity of children. Further, in (6c) and (6d) which govern the inputs for *young perishable* children, this price of quality *per surviving child* is increasing in $1/(1-d_t)$, since the higher is child mortality, the more children must be born in order to produce a surviving one. The price of mom's and older child's time inputs are increasing in their respective relative wages, while the goods input prices enter into their FOCs. Equation (6g) governs the choice of number of surviving children. Notice that all of the human capital inputs enter into the price side of this expression. So, in Becker's symmetry, the price of quantity of children is increasing in their quality. Additionally, this price of quantity also increases in the various fixed costs associated with each surviving child (both goods and time, for both young and older children). Solving the system of optimality conditions above yields explicit demand functions:

Number of Surviving Children

$$n_{t+1} = \frac{\psi \pi_t (1 + \gamma_t)(1 - 2\theta_1 - 2\theta_2)}{(\psi + \overline{v})\left(\left(\pi_t \left(\tau_t + \overline{\tau}_t / (1 - d) \right) (1 + \alpha \gamma_t) + \gamma_t \left(\rho_t + \rho_t / (1 - d_t) \right) \right) - \mu h_0 (T - \overline{s}) / h_t \right)} \quad \textbf{(7)}$$

One easily 'signed' result is $\partial n_{t+1}/\partial d_t < 0.$ A decline in child mortality reduces the time and goods costs of producing a surviving child, *increasing* the number of *surviving* children (this result is also found in Becker and Barro (1988)). Thus, an effect overlooked by Soares and Falcao is that reductions in child mortality also increase the returns to quantity of children. As seen below, this weakens the prospects that reductions in child mortality will increase investments in child quality. The effect on fertility, $\partial(n_{t+1}/(1-d_t))/\partial d_t$ proves ambiguous: A reduction in fertility results only if the fixed costs of older children exceed their potential labor income in the second period of dependency. Increased 'adult longevity' π_t also has an ambiguous effect. There is a wealth effect seen in the numerator which would serve to increase fertility. However, the price of a child also increases with π_t since a constant proportion of potential household income is spent on each child's consumption. Thus, there is a conflicting substitution effect, making the overall result in need of further assessment. Notice that parent's stock of human capital h_t is inversely related to fertility; all else the same, when human capital of parents increases the quantity of surviving children will decrease. Jones and Tertilit (2008) show that fertility and income have varied inversely since at least the middle of the nineteenth century in the United States. Since human capital has also risen over this time, and human capital increase income, this result is comforting.

Early Investment in Childhood

$$\overline{m}_{th} = \frac{\theta_2(1-d_t)\left(h_t\left(\pi_t\left(\tau_t+\overline{\tau}_t/(1-d_t)\right)\left(1+\alpha\gamma_t\right)+\gamma_t\left(\rho_t+\rho_t/(1-d_t)\right)\right)-\mu h_0(T-\overline{s})\right)}{\gamma_t h_t\left(1-2\theta_1-2\theta_2\right)} \quad \textbf{(8a)}$$

$$\overline{c}_{th} = \frac{\theta_2 w_t(1-d_t)\left(h_t\left(\pi_t\left(\tau_t+\overline{\tau}_t/(1-d_t)\right)\left(1+\alpha\gamma_t\right)+\gamma_t\left(\rho_t+\overline{\rho}_t/(1-d_t)\right)\right)-\mu h_0(T-\overline{s})\right)}{\overline{p}_t\left(1-2\theta_1-2\theta_2\right)} \quad \textbf{(8b)}$$

$\partial\overline{m}_{th}/\partial d_t$ and $\partial\overline{c}_{th}/\partial d_t$ can no longer be signed in the presence of fixed goods and time costs $\overline{\rho}_t$ and $\overline{\tau}_t$. Intuitively, lower d_t reduces the fixed costs required to produce a surviving child, inducing a substitution effect away from $\overline{m}_t$ and $\overline{c}_t$. Both human capital inputs rise when the productive adult life π_t increases; with consumption costs per child (unrelated to quality) increasing with π_t, there is a substitution effect away from quantity of children toward child quality. Notice that if these fixed costs were eliminated from the model, the human capital inputs would be independent of π_t. This effect, not present in Soares and Falcao, identifies a new route by which human capital increases with π_t.

Investment in Older Children

$$\hat{c}_{th} = \frac{\theta_1 w_t \left(h_t \left(\pi_t \left(\tau + \bar{\tau}_t/(1-d_t)\right)\left(1+\alpha\gamma_t\right) + \gamma_t \left(\rho_t + \bar{\tau}_t/(1-d_t)\right)\right) - \mu h_0 \left(T - \bar{s}\right)\right)}{\hat{p}_t \left(1 - 2\theta_1 - 2\theta_2\right)} \qquad \textbf{(9a)}$$

$$\hat{s}_{th} = \frac{\theta_1 \left(h_t \left(\pi_t \left(\tau_t + \bar{\tau}_t/(1-d_t)\right)\left(1+\alpha\gamma_t\right) + \gamma_t \left(\rho_t + \rho_t/(1-d_t)\right)\right) - \mu h_0 \left(T - \bar{s}\right)\right)}{\mu h_0 (1 - 2\theta_1 - 2\theta_2)} \qquad (9b)$$

In the presence of the fixed goods and time costs of fixed goods and time costs of quantity, $\bar{\rho}_t$ and $\bar{\tau}_t$, the human capital inputs for older adults unambiguously decline when child mortality declines, $\partial\hat{s}_{th}/\partial d_t > 0$. Significantly, this implies that even if $\overline{m}_t$ and $\bar{c}_t$ were to rise when d_t falls, the overall effect for the human capital bequest h_{t+1} is ambiguous; this issue is addressed through calibration. π_t has the same human capital inducing effects on inputs into older children's human capital as discussed above for that of younger children.

Notice that increases in parent's human capital h_t, by making the fixed costs of goods and time inputs more expensive, create a substitution effect away from n_{t+1} and toward all human capital inputs, unambiguously increasing $\bar{c}_t$, $\hat{c}_t$, and $\hat{s}_t$. However, $\overline{m}_t$, which is based on the cost of mother's time, does fall when her human capital increases. This is consistent with the observation that the time input of children in the production of their own human capital (eg., then high school movement) has increased by more than that of mother.

Mother's Time in Household Production:

$$z_t = (\bar{v} - v_t)/(\bar{v} + \psi).(1+\gamma_t)/(\gamma_t)\,\pi_t \qquad \textbf{(10)}$$

Note that z_t is independent of d_t while the wealth effect from increasing π_t serves to increase household production.

Female Labor Market Work

The mother's time constraint was given in (2). That equation shows that mother's labor market time increases with endogenous reductions in her household production and child investment time, and in the number of surviving children.

V. The Calibration

The expression $1/(1-d_t)$ is the ratio of live births to those surviving young childhood. In the model, the goods cost for *surviving* young children $\bar{\tau}_t$ would then be multiplied by that ratio to generate the goods costs of quantity, given mortality rates, of producing a surviving child. In the data, calculating the costs are a bit more complicated. Suppose there is some constant cost c per year associated with a child surviving to age 10. The estimate $10c/(1-d_t)$ exaggerates the cost of producing a surviving child (especially when mortality is high). This is because whereas the model assumes all children live until the end of the 10th year, in fact those dying young impose no costs in later years. Annual death rates by age are provided beginning in 1900 for those age 0, 1-4, 5-9, 10-14, etc. in Historical Statistics of the United States (Vol. 1, p473). The better estimate of the mortality implications for cost for the first 10 years are:

$$c[1+ S_{1t}4 + S_{2t}5]/ /(1-d_t)$$

where d_t is the proportion of live births failing to reach their 10th birthday. S_{1t} (S_{2t}) are the probabilities of surviving into years 1-4 (5-9). For 1900 the infant mortality rate is .16 (whereas Haines reports .12). S_1 is calculated as the average of the proportion surviving the first year, .84 and that of those surviving the fourth year .76, or .8. S_2 is the average of .80 and .77, or .785. Using the expression above, the cost of a surviving child is then:

$$c[1+ .8(4) + .785(5)]/.77= 1.06(10c)$$

Thus in our calibration model $1/(1-d_{1900}) = 1.06$, so that d_{1900}

is .057 (if based just on survivorship through 10 years, or .77) d would have been the much higher .23.

The same calculations for 1930 produce c[1 + .94(4) + .92(5)]/.92 = 1.029(10c), so that the calibration d = .02 (with rounding). The calculation for 1880 is made more complex by the absence of the sort of detailed data for 1900 and 1930.

Mother's Time Allocation to child quantity

The calibration of $\bar{\rho}$, the fixed time of mother required per young child unrelated to child quality, involves several steps. Ramey (2008) exploits time use surveys conducted in the 1920s to estimate how housewives' time spent in home production varies with the number and ages of children. She finds that a woman with no children and at least some high school spent 44 hours per week of home production. The additional time required by a child decreased as the child matured: A child under one year of age added 17 hours to the housewives' work week. (Similarly, Albanesi and Olivetti's (2007) estimate that breast feeding requires about 14 to 17 hours per week during the first year.) If the youngest child was between one and five years, Ramey finds housewives spent almost seven extra hours per week and if the child was between six and 15 years of age, the housewife spent an extra 2 hours per week.

Albanesi and Olivetti (2007) estimate that early in the twentieth century episodes of incapacitation of mother during pregnancy and/or following childbirth were more prevalent than today, with each pregnancy, on average, associated with 4.5 unproductive months. All of the pre-pregnancy time loss and some portion of the post-pregnancy time costs should be added to the Ramey figures. We assume incapacitation costs added 10 weeks per pregnancy.

Taking a full-time work week to be 65 hours, 10 weeks represent 650 hours divided by 52 weeks, that is 12.5 hours per week to add in the first year. Hence over 10 years young childhood, the total amount of time spent is (17+12.5)+5(7)+4(2)=72.5 divided by 10 years gives 7.25 hours per week on an average surviving child. But all children do not survive and, as with the goods cost per child, these survival chances affect the calculation. However, whereas it is not unreasonable to assume the goods cost changes little from year to year, the time costs, as seen, vary tremendously.

Employing the numbers for above, we estimate these cost to be: (1)(17+12.5)+ (.8)(4)(7) + (.785)(5)4 = 67.6, or 6.8 for the average for a surviving child over the 10 years. The ratio of costs of a surviving child to the costs of a child with the average survival experience is 7.25/6.8 = 1.066 = $1/(1-d_{1900})$. Thus d_{1900} = Finally, dividing by the number of births $1/(1- d_{1900})$ provides d_{1900} = .062.

In a high mortality world, the front-loading of time costs makes the ratio of time costs of the child with average survival prospects relative to those costs of a surviving child exceed the 'average/surviving' ratio for goods. In turn, this implies that reductions in child mortality should lower the price of quantity more than the price of quality. There are important provisos regarding the change in the relative cost structure. In particular, suppose that parents come to expect that their childrens' stock of human capital would reduce the mortality of grandchildren. For example, this sentiment may have changed following dissemination of the germ theory. This would then encourage greater education of daughters, but perhaps more at advanced (i.e., high school levels).

A final question concerns the disposition of these time costs between activities promoting child quality $\overline{m}$ and those concerning quantity $\overline{\rho}$. As an initial consideration, we suppose tat time is allocated equally between them. During later childhood, the amount of time spent between 10 and 20 years of age is around 2 hours per week, giving a ρ = 2.9% of the total week time of housewife. The foregoing suggests the way the model is calibrated. Unfortunately, we are out of space and time to continue the calibration discussion. We will forward a somewhat longer paper which includes all of the calibration discussion to all participants later.

VI. Preliminary Results

Experiment 1: Consider the drop in child mortality in the fully calibrated framework from 1880 to 1900. Mothers reduce $\overline{m}_t$ from 3.2 percent in the period of young childhood (per surviving child), and older children's schooling time $\hat{s}_t$ falls by .005. Surviving children rise by .4 children, and fertility increases by almost .3 children. Overall, mothers reduce their life cycle market work from 10.3 percent to 9.7 percent. This suggests mortality decline does not increase child quality, but rather increases fertility and ties mothers closer to home.

Experiment 2: Improvements in Morbidity: There have been significant declines in the rates and extent of morbidity within age groups across time. Between 1910 and the 1990s Costa finds that functional disabilities declined by 0.6 per year among men age 60-74; she also reports "that the average decline in chronic respiratory problems, valvular heart disease, arteriosclerosis, and joint and back problems was about 66 percent from the 1900s to the 1970s and 1980s, a decline of 0.7 percent (Costa, 2009, p2)." Since musculoskeletal problems and arteriosclerosis, in particular, often do not impact health greatly before age 40, we suppose that this change is applicable to only half of adulthood. Fogel has stressed changes in adult height as indicators of changes in overall net nutrition, or health. The heights of adult men entering Amherst increased from 169.9 cm in 1870 to 178.1 in 1935, or at an average annual rate of about .01 percent (Hist. Stat. U.S. 2-582, series Bd661). These changes in adult height may be influencing productivity from the beginning of adulthood. The average of these three figures, 0.7, .6 and .01. is about 0.47 percent per year. Thus, if a generation is about 25 years long, the increase in health (from morbidity decline) is about 12.4 percent per generation, or 26 percent over two generations. However, assuming these improvements are just reflected in the second half of adulthood, the increase in the effective time endowment per generation is about 6.2 percent. , or 13.2 percent over two generations, say 1880 to 1930**.** Interestingly, the increase in life expectancy at age 20 between 1880 and 1929-31 is a similar 15.25 percent. This suggests that changes in adult longevity, even if accompanied by a shorter working life, may be a fair proxy for increases in the productivity or health of a work life of unchanging length during this period. In this case, the results of FS hold, even if their portrayal of the underlying mechanism is questionable. We quantify the implications of these health improvements by an increase in the initial baseline of effective adult life π_t of 6.2 percent, or from 4 to 4.25.

The increase in π_t increases human capital investments in children, reduces fertility and increases mother's life cycle market work. $\overline{m}_t$ increases from 3.5 percent of her time while children are young to 4.5 percent. $\hat{s}_t$ rises, as children spend and extra 2 percent of their older childhood in school. Surviving children fall from 3.72 to 2.99, and fertility falls the same percentage. Mother's increase market work from a little over 10 percent to about 12.4 percent. Thus, reductions in morbidity are found here to provide a powerful complementary explanation of the rise in human capital, decline in fertility and increase in mother's work from the latter 19th century into the mid-twentieth century. An extended discussion of results will be forwarded to all participants later.

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