The Baby Boom and Baby Bust

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What caused the baby boom? And, can it be explained within the context of the secular decline in fertility that has occurred over the last 200 years? The hypothesis is that:

(i) The secular decline in fertility is due to the relentless rise in real wages that increased the opportunity cost of having children.

(ii) The baby boom is explained by an atypical burst of technological progress in the household sector that occurred in the middle of the last century. This lowered the cost of having children.

A model is developed in an attempt to account, quantitatively, for both the baby boom and bust. (JEL E1, J1, 03)

The fertility of American women over the last two hundred years has two salient features, portrayed in Figure 1.[1] First, it has declined drastically. The average white woman bore 7 children in 1800. By 1990 this had dropped to just 2. This decline in fertility ran unabated during the 140-year period between 1800 and 1940. Second, fertility showed a surprising recovery between the mid 1940's and mid 1960's. The upturn was large, a "baby boom."[2] Just how large depends upon the concept of fertility used. For example, the number of births per fecund woman increased by 41 percent between 1934 and 1959. Alternatively, the number of realized lifetime births per female was 28 percent higher for a woman born in 1932 (whose average child arrived in 1959) vis à vis one born in 1907 (whose average child came in 1934).[3] The difference between these two numbers suggests that the rise in fertility was compressed in time for two reasons. First, older women had more children. Second, so did younger women. But, the high rates of fertility that younger women had early in their

lives were not matched by higher rates of fertility later on. This leads to the last point. After the mid 1960's fertility reverted back to trend, or the "baby bust" resumed.

Conventional wisdom links the baby boom with the end of World War II and the Great Depression. The popular view is that these traumatic events led to a drop in fertility. Part of the decline in fertility was due to economic hardship or a gloomy outlook about the future, which made it difficult to start a family. Part of it was due to the absence of so many young men, who had gone off to fight the war. After World War II fertility bounced up, as the men returned, the economy boomed, and a general feeling of optimism prevailed. Fertility rose to above-normal levels to make up for lost fertility during the depression and war years.[4] This explains the baby boom, according to conventional wisdom.

Conventional wisdom is often wrong. It is here too, or so it will be argued in Section V. Specifically, the pattern and timing of fertility do not support the belief that the baby boom was the outcome of World War II and the Great Depression. In particular:

1. It is highly unlikely that the boom baby can be the result of delayed fertility from the Great Depression and World War II. Figure 1 shows *completed lifetime* fertility for the women who gave birth during the baby boom. A pure catch-up effect should have had no influence on lifetime fertility, since one less child today would just be made up for by having one more child tomorrow. Yet, lifetime fertility rose.

2. Take the peak of the baby boom for the U.S., or the year 1960. As will be discussed in Section V, the cohort of women contributing the most to the baby boom then (those in the 20-to-24-year-old age group) were simply too young for either the Great Depression or World War II to have had much of an impact on them. They were not alive during the Great Depression, and were less than 9 years old at the end of World War II.

3. The data show that the baby boom actually started in the 1930's for the U.S. and many OECD countries. This will be detailed in Section V. Furthermore, for many countries fertility *grew* throughout World War II. Additionally, the neutral countries, Ireland, Sweden, and Switzerland, all had baby booms. Also, it's hard to detect a

2

percepitous drop in U.S. and many other OECD countries' fertilities due to the Great Depression.

So, what could have caused the baby boom?

Turn attention, then, to the hypothesis entertained here. For the journey through the baby boom and baby bust, a vehicle is constructed using conventional macroeconomic theory. To begin with, an off-the-shelf overlapping generations model of population growth is used as the chassis for the analysis. The chassis is based upon Assaf Razin and Uri Ben-Zion's (1975) well-known model of population growth. Another classic paper on population growth, taking a different approach but still close to the analysis undertaken here, is by Gary S. Becker and Robert J. Barro (1988). Next, Oded Galor and David N. Weil (2000) in important work have explained the $\cap$-shaped pattern of fertility that has been observed over epochs in the Western world. The U.S. only experienced the right-hand side of the $\cap$. The engine in the Galor and Weil (2000) analysis for the decline in long-run fertility is technological progress. This engine is dropped onto the chassis here. Specifically, over the period in question real wages rose at least 10 fold due to technological advance – see Figure 1.[56] Since raising children requires time, this represents a tremendous increase in the (consumption) cost of kids.[7] The rest of the vehicle is built from household production theory, à la Becker (1965) and Margaret G. Reid (1934). The idea here is that the successful production of kids is subject to technological progress, just like other goods. It will be argued that technological advance in the household sector, due to the introduction of electricity and the development of associated household products such as appliances and frozen foods, reduced the need for labor in the child-rearing process. This lowered the cost of having children, and should have caused an increase in fertility, other things equal. This lead to the baby boom; at least that is the hypothesis here.

I The Economy

A The Populace

The economy is populated by overlapping generations. An individual lives for $I + J$ periods, I as a child and J as an adult. Suppose that a person is fecund only in the first period of adult life.

An age-1 adult's preferences are given by

$$(1) \quad \sum_{j=0}^{J-1} \beta^j U(c_{t+j}^{j+1}) + \frac{1 - \beta^J}{1 - \beta} Q(n_t^1)$$

$$= \sum_{j=0}^{J-1} \beta^j \phi \ln(c_{t+j}^{j+1} + \mathfrak{c}) + \frac{1 - \beta^J}{1 - \beta}(1 - \phi)\frac{(n_t^1)^{1-\nu} - 1}{1 - \nu},$$

where c_{t+j}^{j+1} represents period-$(t + j)$ consumption by an age-$(j + 1)$ adult and n_t^1 is the number of children that he chooses to have (in the first period of adult life). The sustained descent in fertility that occurred over the last 200 years provides an interesting backdrop for the baby boom. The constant $\mathfrak{c}$ is an elementary, yet powerful, device for generating a secular decline in fertility. It can be thought of as a simple nonhomotheticity in tastes. As will be seen, this results in a demand for kids that decreases in wages. Alternatively, the constant $\mathfrak{c}$ can be thought of as representing the household production of (some fixed amount of) consumption goods.[8] The simplicity of this device is a great virtue for the quantitative analysis undertaken. There are other mechanisms for generating this secular decline. To illustrate this, an example using Becker's (1960) famous quantity-quality model is presented in Section IV.

An adult's income derives from two sources. First, he can use his time for either working or raising kids. Market work in period t is remunerated at the wage rate w_t. Second, an individual can borrow or lend on a loan market, where the gross interest rate prevailing between periods t and $t + 1$ is denoted by r_{t+1}. Hence, an individual earns income on past saving.

Kids are costly. In particular, children are produced in line with the household production

function shown below

$$(2) \qquad n_t^1 = H(l_t^1; x_t) = x_t(l_t^1)^{1-\gamma},$$

where l_t^1 is the input of time and x_t is the state of household technology.[9] The household production technology can be purchased in period t for the time price g_t. The cost function for having kids is therefore given by

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\begin{aligned}
C(n_t^1; x_t, w_t, g_t) &= \min_{l_t^1}\{w_t l_t^1 + w_t g_t : n_t^1 = H(l_t^1, x_t)\} \\
&= w_t(\frac{n_t^1}{x_t})^{1/(1-\gamma)} + w_t g_t.
\end{aligned}
$$

Note that this cost function is homogenous of degree one in the wage rate, w_t.

A young adult's goal in life is to maximize his well-being. This translates into solving the following maximization problem for an age-1 adult:

$$P(1) \qquad \max_{\{c_{t+j}^{j+1}\},n_t^1} \{\sum_{j=0}^{J-1} \beta^j U(c_{t+j}^{j+1}) + \frac{1-\beta^J}{1-\beta}Q(n_t^1)\},$$

subject to

$$(3) \qquad \sum_{j=0}^{J-1} q_{t+j}c_{t+j}^{j+1} = \sum_{j=0}^{J-1} q_{t+j}w_{t+j} - q_t C(n_t^1; x_t, w_t, g_t),$$

where the j-step-ahead present-value price q_{t+j} is defined by $q_{t+j} = q_{t+j-1}/r_{t+j}$ with $q_1 = 1$.[10] This problem will have a solution characterized by

$$(4) \qquad U_1(c_{t+j}^{j+1}) = \beta r_{t+j+1} U_1(c_{t+j+1}^{j+2}), \text{ for } j = 0, ..., J-2,$$

and

$$\frac{1-\beta^J}{1-\beta}Q_1(n_t^1) = U_1(c_t^1)C_1(n_t^1; x_t, w_t, g_t),$$

or

$$(5) \qquad \frac{1-\beta^J}{1-\beta}(1-\phi)\frac{1}{(n_t^1)^\nu} = \phi\frac{1}{c_t^1 + \mathfrak{c}} \times \frac{1}{1-\gamma}w_t(\frac{n_t^1}{x_t})^{1/(1-\gamma)}\frac{1}{n_t^1}.$$

Let s_{t+j+1}^{j+2} denote the optimal level of savings, connected to this problem, that the agent will do in period $(t+j)$ for period $(t+j+1)$ – when the agent will be age $j+2$.

5

B Firms

Market goods are produced in line with the constant-returns-to-scale production technology

$$y_t = F(k_t, e_t; z_t) = z_t k_t^\alpha e_t^{1-\alpha},$$

where y_t denotes period-t output, z_t is total factor productivity (TFP) in this period, and k_t and e_t are the inputs of capital and labor. Market goods can be used for nondurable consumption and capital accumulation. The aggregate stock of capital, k_{t+1}, evolves according to

$$k_{t+1} = \delta k_t + i_t,$$

where i_t is gross investment and δ is the factor of depreciation.

Firms desire to maximize profits as summarized by

P(2)
$$\max_{k_t, e_t} \{ F(k_t, e_t; z_t) - (r_t - \delta)k_t - w_t e_t \}.$$

Note that the rental rate on capital, $r_t - \delta$, is equal to the net interest rate on loans, $r_t - 1$, plus depreciation, $1 - \delta$. The efficiency conditions associated with this problem are

(6)
$$F_1(k_t, e_t; z_t) = r_t - \delta,$$

and

(7)
$$F_2(k_t, e_t; z_t) = w_t.$$

C Equilibrium

How will the population evolve over time? To answer this, let p_t^j denote the period-t size of the age-j adult population. The law of motions for the population are

(8)
$$p_{t+1}^{j+1} = p_t^j, \text{ for } j = 1, \cdots, J - 1,$$

and

(9)
$$p_{t+i}^1 = p_{t+i-I}^1 n_{t+i-I}^1, \text{ for } i = 1, \cdots, I.$$

The first equation simply states that the number of $(j + 1)$-period-old adults alive in period $t + 1$ equals the number of j-period-old adults around in period t. The second equation says that the number of age-1 adults around in period $t + i$ equals the size of their parent's generation times the per-capita number of kids that this generation had in period $t + i - I$. Note that I is the gestation lag in the model, or the time from conception to adulthood.

To complete the model, several market-clearing conditions must hold. First, the goods market must clear. This implies that

$$(10) \qquad p_t^1 c_t^1 + p_t^2 c_t^2 + \cdots + p_t^J c_t^J + i_t = y_t.$$

Second, period-t savings must equal investment so that

$$(11) \qquad p_t^1 s_{t+1}^2 + p_t^2 s_{t+1}^3 + \cdots + p_t^{J-1} s_{t+1}^J = k_{t+1}.$$

Start the economy off at some time, say period 1. To do this, some initial conditions need to be specified. At this time there will be J generations of adults around. The initial population structure of adults will therefore be described by the J-vector $(p_1^1, \cdots, p_1^J)$. All but the youngest generation will have savings denoted by $(s_1^2, s_1^3, \cdots, s_1^J)$. The economy will begin period 1 with some level of capital, k_1. This capital was funded by the savings of the oldest $J - 1$ generations. Therefore, the initial distribution of wealth must satisfy the start-up restriction that

$$(12) \qquad p_1^2 s_1^2 + \cdots + p_1^J s_1^J = k_1.$$

There will also be $I - 1$ generations of children around waiting to mature. This is captured by the $(I - 1)$-vector $(p_0^1 n_0^1, \cdots, p_{-I+2}^1 n_{-I+2}^1)$, which starts with the youngest generation and goes to the oldest.[11]

It is time to take stock of the discussion so far.

Definition: *A competitive equilibrium is a time path for interest and wage rates $\{r_t, w_t\}_{t=1}^{\infty}$, a set of allocations for households $\{c_t^j, n_t^1\}_{t=1}^{\infty}$ for $j = 1, \cdots, J$, and a set of allocations for the firm, $\{k_t, e_t\}_{t=1}^{\infty}$, such that for some given initial state $(k_1, s_1^2, \cdots, s_1^J, p_1^1, \cdots, p_1^J, p_0^1 n_0^1, \cdots, p_{-I+2}^1 n_{-I+2}^1)$ satisfying (12) the following is true:*

1. *The allocations $\{c_t^j, n_t^1\}_{t=1}^{\infty}$ solve the household's problem P(1), given $\{r_t, w_t\}_{t=1}^{\infty}$.[12]*

2. *The allocations $\{k_t, e_t\}_{t=1}^{\infty}$ solve firms problem P(2), given $\{r_t, w_t\}_{t=1}^{\infty}$.*

3. *The population obeys the laws of motion (8) and (9).*

4. *The goods and asset markets clear, or (10) and (11) hold.*

II   Theoretical Analysis

Recall that the pattern of U.S. fertility displayed in Figure 1 has two distinct features. First, fertility shows a secular decline. Second, there is a temporary boom in fertility in the middle of the twentieth century. Two ingredients are incorporated into the framework to capture these features. First, it will be assumed that there is technological progress in the market sector. This will propel the secular decline in fertility. Second, it will be presupposed that there is technological advance in the household sector. This will cause the baby boom. Will these two ingredients be sufficient to account for the observed pattern of U.S. fertility? While the resolution to this question is ultimately a quantitative matter, the following proposition suggests that, theoretically speaking, the answer is yes.

Proposition: *For a given interest rate path, $\{r_t\}_{t=1}^{\infty}$:*

1. *A rise in household-sector productivity, x_t, causes fertility, n_t^1, to increase.*

2. *A fall in the time price of the household technology, g_t, leads to a rise in n_t^1.*

3. *An increase in market-sector productivity, z_t, causes n_t^1 to decline.*

Proof. See Appendix. ∎

The intuition for the above proposition can be gleaned from the first-order condition governing fertility (5). The lefthand side of this equation gives the marginal benefit from having an extra child. The marginal cost of having an extra kid is given by the right-hand side. The consumption cost of having an extra child is $C_1(n_t^1; x_t, w_t, g_t) = [1/(1 -$

$\gamma)]w_t[n_t^1/x_t]^{1/(1-\gamma)}(1/n_t^1)$. To get the utility cost, this must be multiplied by the marginal utility of current consumption, $U_1(c_t^1) = \phi/(c_t^1 + \mathfrak{c})$.

Now, consider the impact of technological progress in the market sector. This will increase wages, w_t. Consequently, the cost of having children rises, ceteris paribus, because the time spent raising extra kids could have been used instead to work and purchase consumption goods. The increase in wages will also make the adult wealthier. Hence, he will consume more consumption goods, and this will decrease his marginal utility. This effect will operate to reduce the utility cost of having children. Along a balanced growth path wages and consumption must grow at the same rate. If $\mathfrak{c} = 0$, then the above two effects would cancel out, and the cost of having children would remain constant. There would be no change in fertility, a fact evident from (5). The marginal utility of consumption will drop slower than the increase in wages when $\mathfrak{c} > 0$. In this situation, the cost of having kids will rise and fertility will fall. In other words, $\mathfrak{c}$ operates to lower the marginal utility of consumption, and mitigate its decline with growth. The impact of $\mathfrak{c}$ is larger at low levels of c_t^1, so this term works to promote fertility at low levels of income.

Technological advance in the household sector operates to reduce the cost of children, other things equal. It is readily seen from (5) that an increase in x_t lowers the cost of kids. When interest rates are held fixed a change in x_t has no effect on w_t.[13] It may transpire that an increase in x_t leads to a change in c_t^1, but this effect is of secondary importance given the adopted functional forms for tastes and household production. Therefore, technological progress in the household sector promotes fertility. Last, when the time price, g_t, for the household technology drops consumers have more disposable income. This income effect increases the consumption of market goods, other things equal, and consequently reduces their marginal utility. Hence, the utility cost of having children falls and higher fertility results.[14]

To carry the inquiry further the model must be solved numerically for two reasons. First, the above analysis presumes that technological progress in the market and household sectors has no effect on the equilibrium time path for interest rates. In general equilibrium this

is unlikely to be true. It is difficult to say much about the general equilibrium impact of technological progress using pencil-and-paper techniques alone. To analyze the general equilibrium effects of technological progress the model must be solved numerically. Second, the question of whether or not the proposed framework can account for the observed pattern of U.S. fertility is quantitative in nature.

III   Quantitative Analysis

A   Technological Progress

To get the model up and running, information is needed on the pace of technological progress in the market sector over the last two hundred years. Total factor productivity (TFP) grew at an annual rate of 0.55 percent between 1800 and 1840, according to Robert E. Gallman (2000, Table 1.7). He also estimates (*ibid*) its growth rate to be 0.71 percent between 1840 and 1900. Between 1900 and 1948 total factor productivity grew at an annual rate of 1.41 percent – *Historical Statistics* (1975, Series W6). Next, the growth rate in TFP jumped up to 1.68 percent between 1948 and 1974 – Bureau of Labor Statistics. Note that the growth rate of TFP seems to have accelerated from 1800 to 1974. The period after 1974 is problematic. This period is the productivity slowdown. TFP grew at paltry 0.57 percent per year between 1974 and 1995 – *ibid*. Casual empiricism suggests that this was a period of rapid technological progress associated with the development of information technologies. If this is true, then the productivity slowdown is basically a mirage. There is a growing literature suggesting that this is indeed the case. In fact, measured TFP growth seems to have slowed down at the dawning of both the First and Second Industrial Revolutions. And, from 1995 to 2000 TFP growth seems to have been rebounding, growing at an annual rate of 1.2 percent – *ibid*. The bottom line is that it is hard to know what to do about the productivity slowdown years. A conservative approach would take the productivity numbers as given. This is what will be done here.

The productivity data between 1800 and 1900 is sparse – only three points. To make up

for the missing observations a trend line is fitted over the entire 1800 to 2000 sample. This is done by estimating the following statistical model:

$$\ln(\text{TFP}_t) = a + bt + dt^2 + \varepsilon_t,$$

where

$$\varepsilon_{t+1} = \rho\varepsilon_t + \xi_t, \ \text{with } \xi_t \sim N(0, \sigma).$$

The results of the estimation are

$$a = \underset{(1.72)}{0.4611}, \ b = \underset{(4.18)}{0.0045}, \ d = \underset{(2.00)}{0.00002}, \ \rho = \underset{(53.75)}{0.9766}, \ \sigma \ = \ 0.0299,$$

$$\text{with } R^2 \ = \ 0.9960, \ \text{D.W.}{=}2.25, \ \#\text{obs.}{=}102,$$

where the numbers in parentheses are t statistics. Observe that the trend rate of TFP growth increases over time. The trend line that results from this estimation is shown in Figure 2 – the initial level for TFP is normalized to unity. Market sector TFP increased slightly more than 7 fold over the 200-year time period in question.

B   Calibration and Estimation

Take the length of a period in the model to be 10 years. Let $I = 2$ and $J = 4$ so that an individual lives for 20 years as a child and for 40 years as an adult. Between 1800 and 1990 (the length of the data series on fertility) there will then be 20 model periods.

   The task at hand is to pick values for the parameters governing tastes and technology. This will be done in two ways.

1. *A priori information, α, δ, β, z's:* Some parameters are common to a wide variety of macroeconomic models and can be pinned down using *a priori* information. Labor's share of income is roughly 70 percent. In line with this, set $\alpha = 0.30$. On the basis of investment and capital stock data taken from the national income and product accounts, the (annualized) depreciation rate for private nonresidential equipment and structures is estimated to be 4.7 percent.[15] For (the equally-weighted version of) the

model this results in a steady-state investment-to-GDP ratio of 12.1 percent, very close to U.S. postwar average of 11 percent. The discount factor, β, is chosen so that the (annualized net) interest rate in the model's final steady state is 6.9 percent.[16] This interest rate coincides with the average return on capital for the postwar U.S. economy, as estimated by Cooley and Prescott (1995). Last, for the z's, the observed levels for economy-wide TFP will be inputted into the model. For the years between 1800 and 1900 the missing observations will be read off of the estimated trend line. Specifically, the circles in Figure 2 indicate the data points for TFP that are used in the analysis.

2. *Estimation,* $\phi, \mathfrak{c}, \nu, \gamma, x$'s: Other parameters are specific to the analysis at hand. Little is known about their magnitudes. Therefore, values for these parameters will be estimated using the U.S. fertility data. Let $\{n_t\}_{t \in \mathcal{T}}$ denote the U.S. time series for fertility, where $\mathcal{T} \equiv \{1800, 1810, \cdots, 1990\}$. In order to estimate the model, a simplified process for technological progress in the household sector will be assumed. Specifically, let $x_{1800} = x_{1810} = \cdots = x_{1940} \leq x_{1950} \leq x_{1960} = x_{1970} = \cdots = x_{1990}$. That is, technological progress in the household sector is only allowed to occur in 1950 and 1960. The realism of this assumption is discussed in Section V. Additionally, it is assumed that technology can only advance. Now, for a given set of parameter values the model will generate a series for fertility denoted by $\{n_t^1\}_{t \in \mathcal{T}}$. Describe the mapping from the model's parameter values to predicted fertility by $n_t^1 = \mathbf{N}(t; \phi, \mathfrak{c}, \nu, \gamma, x_{1800}, x_{1950}, x_{1960})$.[17] The function $\mathbf{N}$ corresponds to the solution to the nonlinear difference equation system that describes the model's general equilibrium. It should be noted that the model is not stable for all possible combinations of parameter values. Let $\mathcal{S}$ denote the set of parameter values for which the model is stable. The estimation procedure can be described by[18][19]

$$\min_{\substack{\phi, \mathfrak{c}, \nu, \gamma, \\ x_{1800}, x_{1950}, x_{1960}}} \sum_{t \in \mathcal{T}} (n_t - \mathbf{N}(t; \phi, \mathfrak{c}, \nu, \gamma, x_{1800}, x_{1950}, x_{1960}))^2,$$

subject to

$$0 < x_{1800} \leq x_{1950} \leq x_{1960},$$

and

$$(\phi, \mathfrak{c}, \nu, \gamma, x_{1800}, x_{1950}, x_{1960}) \in \mathcal{S}.$$

Note that the first constraint restricts technological change in the household sector to advance only. The second constraint demands that the parameter estimates yield a stable solution for the model.

Table 1 lists the parameter values that result from the above baseline estimation procedure.[20] The model's ability to match the time path of U.S. fertility will now be examined.

C   The Baby Boom

The Computational Experiment.– Imagine starting the economy off in 1800. The level of TFP, or z, is low. Over the next 200 years technological progress occurs. In particular, let two things happen. First, presuppose that TFP grows in line with the U.S. data. Second, after 140 years assume that there is a burst of technological progress in the household sector, say due to the introduction of modern appliances – washing machines, dryers, dishwashers, and alike – arising from the Second Industrial Revolution. What is the outcome of this experiment?

The pattern of fertility arising from the baseline model is shown in Figure 3. This derives from the solution, at the estimated set of parameter values, to the nonlinear difference equation system that characterizes the model's equilibrium. This figure also shows the number of kids per parent in the U.S. data over the period 1800 to 1990, as taken from Micheal R. Haines (2000, Table 4.3).[21] Qualitatively speaking, the pattern of fertility generated by the baseline model matches the U.S. data fairly well. There is a secular decline in fertility punctuated by a temporary rise spawned by technological progress in the household sector. The model underestimates the size of the baby boom. This can *easily* be rectified by allowing

13

household-sector TFP to grow at a slightly faster rate. This creates a problem, though, with the decline in fertility after 1960 – when the baby bust resumes.

To see this, reestimate the model placing equal weight on the baby boom and baby bust segments of the fertility time path.[22] Figure 4 shows the upshot. Note that the baby boom is now much more pronounced. It can be made even more pronouced by placing a 75 percent weight on the baby boom segment, as can be seen. Measured market-sector TFP does not grow fast enough, though, to generate the observed rapid decline in fertility after the baby boom. The estimation routine must trade off any gain in improved fit before 1960, obtained by increasing the amount of technological progress in household sector, against the loss in fit after this date. Overall the equally-weighted estimation scheme seems to give the preferred results for the issue at hand. Last, it may be possible to account for the rapid decline in fertility after the baby boom by modifying the model to incorporate factors such as a quantity-quality tradeoff in fertility, public education, and a female labor-force participation decision, in addition to adjusting upward the rate of TFP growth to correct for the inflation bias in aggregate prices indices.[23]

Technological Progress in the Household Sector.– So, how much technological progress was there in the household sector? The equally-weighted estimation scheme suggests that TFP in the home sector must have risen by a factor of 1.2 between 1800 and 1990. In particular, x is estimated to rise by a factor of 1.13 between 1940 and 1950, and by an additional factor of 1.06 between 1950 and 1960. Are these numbers reasonable? TFP in the market sector increased by a factor of about 7 between 1800 and 1990. The assumed rise in household-sector TFP lies considerably below this number. Figure 4 also illustrates the decline in time spent on child rearing in the model, given the indicated patterns of market and (normalized) household productivity. The estimated increase in household TFP implies that the time spent on child rearing should decline by a factor of 1.22, holding the number of kids constant. The number of children declines secularly, and, with it, so does the time spent on child rearing. Stanley Lebergott (1993, Table 8.1) reports that time spent on housework fell by a factor of 3 between 1900 and 1975. The time spent on raising children in the model

14

drops by a factor of 4 over the period in question.

IV   The Quantity-Quality Model – An Example

A   The Setup

The above framework has little trouble generating the observed 200-year secular decline in fertility. A simple nonhomotheticity in tastes does the trick. Specifically, the marginal utility of market consumption declines at a slower rate than the increase in wages, w, due to the presence of a simple constant term, $\mathfrak{c}$, in tastes (1). Thus, the marginal cost of an extra kid, in terms of forgone consumption, rises over time. While the simplicity of the setup is a big virtue for both the theoretical and quantitative analysis, it may seem a bit mechanical. The gist of the analysis is likely to carry over to some richer models of fertility; however, for example, a Beckerian (1960) style quantity-quality model, operationalized here along the lines of Galor and Weil (2000).

To see this, suppose a worker's endowment of labor is made up of two components, brawn and brain. Brawn earns w for each unit supplied on the labor market, while brain receives v. An age-1 parent living in period t must now choose both the quantity of kids that he desires, n_t^1, and the quality of each child, or the fraction of the kid's labor endowment that will be skilled, $h_{t+I}^1 \in [0,1]$.

Change the specification of preferences to

$$(13) \qquad \sum_{j=0}^{J-1} \beta^j U(c_{t+j}^{j+1}) + \frac{1-\beta^J}{1-\beta} Q(n_t^1, h_{t+I}^1; \{w_{t+I+j}, v_{t+I+j}, q_{t+I+j}\}_{j=0}^{J-1})$$

$$= \sum_{j=0}^{J-1} \beta^j \phi \frac{(c_{t+j}^{j+1})^{1-\rho}}{1-\rho} + \frac{1-\beta^J}{1-\beta}(1-\phi)\frac{(n_t^1)^{1-\nu}}{1-\nu}\{\sum_{j=0}^{J-1} q_{t+I+j}[w_{t+I+j}(1-h_{t+I}^1) + v_{t+I+j}h_{t+I}^1]\}^{1-\xi},$$

with $\mathrm{sgn}(1-\nu) = \mathrm{sgn}(1-\xi)$. This utility function is similar to (1) with three modifications. First, the child's skill level now enters tastes. In the formulization adopted, the parent cares about this because it will determine how much the child earns when he grows up, or $\sum_{j=0}^{J-1} q_{t+I+j}[w_{t+I+j}(1-h_{t+I}^1) + v_{t+I+j}h_{t+I}^1]$. Second, the utility function for market consump-

tion is now of the more general constant-relative-risk-aversion variety. Third, the constant term $\mathfrak{c}$ has been dropped.

There are now two types of costs associated with raising children. The first is associated with producing them. In particular, let the quantity of kids be once again produced in line with (2). The second cost is tied to educating them. Specifically, let the quality of each child be determined in line with

$$h^1_{t+I} = a_t(m^1_t)^{1-\eta},$$

where m^1_t is the input of time connected with educating the child and a_t is the state of the educational technology. For simplicity these costs are borne in the first-period of an adult's life.

Now, in period-t an age-1 adult will have a skill endowment, h^1_t, that was determined by his parent I periods ago. The young adult must choose $\{c^{j+1}_{t+j}\}^{J-1}_{j=0}$, n^1_t, and h^1_{t+I} so as to maximize his lifetime utility, as given by (13), subject to the budget constraint shown below

$$\sum_{j=0}^{J-1} q_{t+j} c^{j+1}_{t+j} = \sum_{j=0}^{J-1} q_{t+j}[(1-h^1_t)w_{t+j} + h^1_t v_{t+j}]$$
$$- [w_t(1-h^1_t) + h^1_t v_t](\frac{n^1_t}{x_t})^{1/(1-\gamma)} - [w_t(1-h^1_t) + h^1_t v_t]n^1_t(\frac{h^1_{t+I}}{a_t})^{1/(1-\eta)}.$$

Market goods are now produced in line with the CES production technology

(14)
$$y_t = [\alpha z_t k^\theta_t + (1-\alpha)u^\theta_t]^{\lambda/\theta} e^{1-\lambda}_t,$$

where u_t and e_t denote the quantities of brawn and brains hired. The parameter θ controls the degree of substitutability between capital and brawn in production. It plays an important role in the analysis. Suppose that $\theta > 0$, so that the elasticity of substitution between capital and brawn, $1/(1-\theta)$, is bigger than one. To complete the setup note that, as before, all markets must clear. Now, the demand and supplies for brawn and brain must be equalized so that

$$u_t = p^1_t(1-h^1_t)(1-l^1_t-m^1_t) + p^2_t(1-h^1_{t-1}) + \cdots + p^J_t(1-h^1_{t-J+1}),$$

and

$$e_t = p^1_t h^1_t(1-l^1_t-m^1_t) + p^2_t h^1_{t-1} + \cdots + p^J_t h^1_{t-J+1}.$$

16

Can a version of the quantity-quality model mimic the observed pattern of U.S. fertility over the last two centuries? To demonstrate the potential of the above framework to address this question, a numerical example will now be presented. The example is intended for illustrative purposes only; it should not be construed as a serious quantitative analysis. It does suggest, however, that the quantity-quality model has promise.

B   Numerical Example

To see whether the framework presented above can potentially replicate the U.S. data, the model will be solved for, and compared across, four steady states. Think about each steady state as giving a snapshot of the U.S. at a point in time. The first steady state will represent the U.S. in 1800. The U.S. in 1940, or at the dawn of the baby boom, will be depicted by the second steady state. The peak of the baby boom, or the year 1960, will be emblematized by the third steady state. The fourth steady state will denote the year 1990, which is the end of the baby bust.

The parameter values used in the example are presented in Table 2. These parameter values have not been chosen to satisfy any calibration or estimation scheme. They have been picked so that the example replicates, in a loose sense, the U.S. fertility and GDP data. As one moves across time, or steady states, the levels of technology in the market and household sectors change. Specifically, in the analysis the movement in the level of the market technology, z, is picked to match the growth in GDP for the U.S. economy. Note that given the form of (14), movements in z now represent capital-embodied technological change and not neutral technological change as before. Thus, changes in z are now difficult to obtain directly from the data. In line with the earlier analysis, the movement in the level of the household technology, x, is chosen to generate the baby boom.

The upshot of the analysis is depicted in Figure 5. In the first steady state, fertility is 3.5 kids per person, which exactly matches the U.S. data for 1800. Now, move forward in time to 1940. Between 1800 and 1940, U.S. GDP grew 7.4 times. In the model GDP grows 7.2 fold. This is obtained by letting the level of technology in the market sector rise 3.8/2.0=1.9

17

times. The example is fairly successful in replicating the drop in fertility observed in the data. Model fertility drops to 1.6 children per person, as compared with 1.1 in the data. When there is technological progress in the market the capital stock rises. Fertility will drop faster the more substitutable capital and brawn are in production (i.e., the bigger θ is). As the skill premium rises, parents will substitute away from quantity toward quality of children. The drop-off in fertility will also be larger the more concave utility is in child quality, and the less concave it is in the consumption for market goods (i.e., the bigger is ξ and the smaller is ρ). This transpires because, along with economic development, the value of an extra child will decrease relative to an extra unit of consumption. Next, advance in time from 1940 to 1960. This is the baby boom period. GDP in the U.S. rose by a factor of 1.6. This is achieved in the model by letting z increase 1.4 times. As in the earlier analysis, technological advance in the household sector promotes fertility. By letting x rise from 3.6 to 26.0, a baby boom is generated in the model. Specifically, model fertility rises to 2.0 kids per person vis à vis 1.8 in the data. Last, GDP rose 2.1 times between 1960 and 1990. To attain this z is set at 5.8. Fertility in the model is now 1.0, which exactly matches the data.

In summary the numerical example illustrates that the quantity-quality model has the potential to match the time series on U.S fertility quite well. In particular, the example has little trouble matching the secular decline in fertility observed over the last two centuries. Refinements of the theoretical setup together with a serious quantitative analysis could undoubtedly match the exact features of the fertility time series better still. Such an analysis should take account of the rise of publicly available free education. This lowered the private cost of having children, just as technological advance in household sector did. Ideally, one would also like to match the model up with the U.S. data on the skill premium and educational attainment.[24]

V Historical Discussion

A Technological Progress in the Household Sector

Direct evidence on the increase in the efficiency of raising children does not seem to be available. Economic history unequivocally documents, though, that the twentieth century was a time of rapid and unparalleled technological advance in the household sector. Prior to 1860 the household sector in the American economy was basically an arts and craft industry. The same forces propelling the mechanization and rationalization of production in the market sector at that time were also at operation in the household sector.

The mechanization of household tasks began in the latter half of the 1800's. The vacuum cleaner made its first appearance in 1859, the dishwasher in 1865, and the washing machine in 1869. The initial incarnation of an idea into a product often does not meet with great success. These inventions were mechanical in nature. Before triumph they had to bide their time until the coming of electricity. The fully automated washing machine only appeared in the 1930's. It's a complicated machine involving several processes that must be regulated: inserting and extracting water from the tub, washing and rinsing, and spin drying. Refrigerators enter household service in the 1920's. They replaced the icebox. Clarence Birdseye patented the idea of flash freezing in 1925. Frozen foods, which changed the way of life, only appeared in the early 1930's and began to take off in the 1940's. Between 1929 and 1975 the household appliance-to-GDP ratio increased by a factor of 2.5.[25] After 1975 the stock of appliances relative to GDP levels off or even declines. The increase in the stock of appliances was undoubtedly propelled by the rapid decline in their price.

While the development of new consumer durables was important in liberating women from the shackles of housework, so too was the rationalization of the household. The principles of scientific management were applied to the home, just as in the factory. Domestic tasks were studied with the aim of improving their efficiency. Christine Frederick was an early advocate of applying the principals of scientific management to the home. She was captivated by the fact that a man, named Frank B. Gilbreth, had been able to increase the

output of bricklayers from 120 to 350 bricks per hour by applying the principals of scientific management. He did this by placing an adjustable table by the bricklayer's side so that the latter wouldn't have to stoop down to pick up a brick. He also had the bricks delivered on it in the right position so that there would be no need for the bricklayer to turn each one right-side up. Additionally, he taught bricklayers to pick bricks up with their left hands and simultaneously take trowelfuls of mortar with their right hands. Frederick (1912) applied the idea to dishwashing first, and then to other tasks. She broke dishwashing down into three separate tasks: scraping and stacking, washing, and drying and putting away. She computed the correct height for sinks. She discovered that dishwashing could be accomplished more efficiently by placing drainboards on the left, using deeper sinks, and by connecting a rinsing hose to the hotwater outlet – she estimated that this saved 15 minutes per dinner. In 1913 she wrote: "Didn't I with hundreds of women stoop unnecessarily over kitchen tables, sinks, and ironing boards, as well as bricklayers stoop over bricks?"[26] Frederick and others in the home economics movement had a tremendous impact on the design of appliances and houses. Take the kitchen, for example. The kitchen of the 1800's was characterized by a large table and isolated dresser. An organized kitchen with continuous working surfaces and built-in cabinets began to appear in the 1930's, after a period of slow evolution. The kitchen became connected with the dining room and other living areas in the 1940's, ending the housewife's isolation.

B   The Timing of the Baby Boom, U.S., U.K., France and Switzerland

The above analysis suggests that it is not unreasonable to conjecture that the impact of technological advance in the household sector began to gather steam in the 1930's and 1940's. How does this match up with the pattern of fertility displayed in the U.S. data, as shown in Figure 6? Observe that fertility fell continuously from 1800 to about 1936. It then began to rise. One interpretation of the graph is that the baby boom started in the 1930's. The upward trend suffered a slight drop from 1943 to 1945 during World War II. Note that

fertility fell during World War I and then rebounded. Additionally, note that there is no unusual decline in fertility associated with the Great Depression. In fact, one could argue that the baby boom might have started earlier if the Great Depression hadn't happened. A non-demographer eyeballing this graph might date the baby boom as occurring from 1936 to 1972.[27] Last, observe that it would be hard to build a model explaining the baby boom on the basis of movements in market TFP, wages, or GDP.[28][29]

Could the baby boom be some sort of catch-up effect associated with World War II? First, if the baby boom was merely the result of couples postponing family formation during the war years then there should be no increase in lifetime births for a woman. Yet, lifetime births did increase for fecund women during the baby boom years, as Figure 1 shows. Second, many of the women giving birth during the baby boom were simply too young for such a catch-up effect to be operational. Figure 7 plots the fertility rates for various age groups of white women.[30]These fertility rates are weighted by the relative size of each group. Therefore, the diagram provides a measure of the contribution of each group to the baby boom. Take the 20-to-24-year-old age group. They contribute the most to the baby boom. This series peaks in 1960. But, at the peak, the members of this group were somewhere between 1 to 5 years old in 1941 and 5 to 9 years old in 1945. Hence, a catch-up effect is impossible for them. It's implausible that the Great Depression affected their fertility decision either. Fertility for the 25-to-29-year-old age group rises until about 1952, then levels off until 1957, and declines thereafter. A strong catch-up effect is not very plausible for this group. Those giving birth in 1952 would have been in the 14-to-18-year-old range in 1941 and in the 18-to-22-year-old range by 1945, while those having kids in 1957 would have been somewhere between 9 to 13 years old in 1941 and 13 to 17 in 1945.

Having said this, some evidence of delayed fertility can be gleaned from the diagram, but it looks small. For example, note that the fertility rate for the 20-to-24 year-old age group starts to fall in 1942 – this is marked by the point A. In 1947 these women would have been in the 25-to-29-year-old age group. Note the small peak in 1947 for the latter age group – marked by point A'. Similarly, the fertility rate for the 15-to-19-year-old age group begins

21

to fall in 1943 – point B. The majority of this group would have been in the 20-24 age group around 1948. Note the spike in 1947 for this age group – point B'.

U.K. fertility dropped more or less unabated from 1876 to 1940, with one exception – see Figure 8.[31] There was a sharp decline and rebound associated with World War I. The United Kingdom suffered a prolonged depression during the interwar years. Again, it would be hard to argue that there was an unusual decline in fertility during these years. Interestingly, fertility rose throughout World War II. The non-demographer might date the baby boom as occurring between 1941 and 1972. France shows a similar pattern with fertility rising throughout World War II – see Figure 9. One might date the French baby boom as happening between 1942 and 1974. Last, even neutral countries, such as Switzerland, had a baby boom – see Figure 10. Observe that Swiss fertility rose throughout World War II. Reasonable dates for the Swiss baby boom are 1937 to 1971.

C   The Size and Start of the Baby Boom in OECD Countries

In line with the previous argument, households living in richer countries should on average have been better able to afford labor-saving household goods. A question arises: Was the baby boom bigger in richer countries? To answer this question, data on income and fertility is collected for 18 OECD countries – all the OECD countries for which data is available.[32] The birth rate data is obtained from Mitchell (1998a, Table A.6, pp. 68-83; 1998b, Table A.6, pp. 93-119; and 1998c, Table A.6, pp. 69-79). For each OECD country a graph similar to Figures 8 to 10 is constructed. The baby boom is measured by the area below the fertility curve and above the horizontal line connecting the dates for the beginning and the end of the baby boom, as shown in Figure 10 for Switzerland. The income data comes from the *Penn World Tables 5.6*, and measures a country's real GDP in 1950.

The results of this exercise are plotted in Figure 11. As can be seen, there is a positive relationship between the size of the baby boom and a country's income. The Pearson correlation coefficient between the two series is 0.68, which is significantly different from zero at the 95 percent confidence level. There is no reason to presume that the relationship between

the two variables is linear. Kendall's τ gives a nonparametric measure of the association between two series.[33] A value of 0.48 is obtained for Kendall's τ. By either measure the two series are positively related to one another.

Likewise, one would expect that the baby boom should have started earlier in richer countries. This appears to be true. Figure 12 shows that there is a negative relationship between the start of baby boom and a country's income.[34] The Pearson correlation coefficient between the two series is -0.62, and it is significant at the 95 percent confidence level. Similarly, the Kendall rank correlation coefficient is -0.31. Finally, for a *very limited* set of countries it is possible to plot the relationship between the size and start of the baby boom, on the one hand, and a measure of modern household technologies adoption, on the other.[35] Figure 13 shows the scatters. As can be seen, the size of the baby boom appears to be positively correlated with the diffusion of household technologies, while the start of baby boom is negatively associated with it. This is what the theory suggests.

D Fertility and Female Labor-Force Participation: A Suggestion for Future Research

Before concluding, a suggestion for future research is offered. Female labor-force participation rose continuously over the last century. In 1890 only 4 percent of married women worked. By 1980 this had risen to 50 percent. The number of married women in the labor force rose from 15 to 40 percent, over the subperiod 1940 to 1970. That is, female labor-force participation grew over the baby boom years. What could have accounted for the fact that women chose *both* to work and to have more children? The answer here is that technological innovation in the household sector made this possible by freeing up women's time. Women who chose to labor in the market have always had less children than those who chose to labor at home. Yet, in the baby boom years it was working women who showed the biggest percentage rise in fertility!

Table 3 should not be construed as implying that the baby boom was caused by a rise in the fertility of working women; it was not. Most women didn't work at the time.

The increase in fertility between 1940 and 1960 can be decomposed into three factors: the change in fertility for homemakers, the change in fertility for women in the labor force, and the change in female labor-force participation. The results of this decomposition are given in Table 4.[36]

Working women have a lower fertility rate than homemakers (about 0.3 kids versus 3.0 in 1940 and 1.8 versus 4.7 in 1960). Hence, an increase in female labor-force participation will operate to lower fertility, as the table shows. Employed women accounted for 16.2 percent [=19/(19+98) percent] of the increase in fertility between 1940 and 1950. This jumped up to 35.2 percent for the 1950-to-1960 period, versus a participation rate of 31 percent – the peak of the baby boom was 1957. Therefore, a significant proportion of the increase in fertility during the baby boom years is accounted for by a rise in fertility for working women. Again, why did these women choose to have more kids?

It would be interesting to develop a model to address the above facts. Imagine what some of the ingredients in such a model might be. There could be two sexes, with some specialization in labor by sex. Males do solely market work. Females can split their time between market work and nonmarket work. Suppose that there is some indivisibility in market effort, say a fixed work week, and that (as in the real world) the number of children in a family must be a natural number. Now, let families differ according to some characteristics, such as their desire for children, the ability of the female, or the ability of the male. Then, some females will work more than others. The more market work a female does, the less children the family will have, given the time cost of raising them. Some women may choose to have no children. In such a framework, a once-and-for-all decline in the cost of having children could lead to the findings presented in Table 3. A challenge would be to match these facts against the backdrop of a two-hundred-year decline in fertility, and a one-hundred-year rise in female labor-force participation.[37]

VI   Conclusions

The mystery of the baby boom has not been cracked in economics. The fact that the baby boom was an atypical burst of fertility that punctuated a 200-year secular decline adds to the enigma. Conventional wisdom ascribes the baby boom to the effects of the Great Depression and/or World War II. This story has several shortcomings. First, for the U.S. and many OECD countries it is hard to detect a strong structural break in fertility due to the Great Depression. Second, fertility in the U.S. and many OECD countries started to rise before World War II. Third, at the peak of the U.S. baby boom the most fertile cohort of women was just too young for the Great Depression or World War II to have had a direct effect on them.

The story told here attributes the secular decline in fertility to the ten-fold rise in real wages that occurred over this time period. This increased the cost, in terms of forgone consumption, of raising children. The baby boom is accounted for by the invention of labor-saving household capital, or other labor-saving household products and management techiques, that occurred during the middle of the last century. The analysis suggests that the increase in the efficiency of the household sector needed to explain the baby boom is not that large. In fact, the 1.2-fold increase estimated here is much smaller than the documented 7-fold improvement in market productivity.

VII   Appendix

A   Proof of Proposition

Proof. By using the first-order condition for consumption (4) in conjunction with the budget constraint (3), the following permanent-income type equation can be obtained:

$$(15) \qquad \frac{c_t^1 + \mathfrak{c}}{w_t} = \frac{1 - \beta}{1 - \beta^J} \Big[\sum_{j=0}^{J-1} \frac{(w_{t+j} + \mathfrak{c})}{w_t (\prod_{i=1}^{j} r_{t+i})} - \frac{C(n_t^1; x_t, w_t, g_t)}{w_t} \Big],$$

where $\prod_{i=1}^{0} r_{t+i} \equiv 1$. This equation just states that an age-1 agent will consume the fraction $(1-\beta)/(1-\beta^J)$ of the present value of his income, net of the cost of rearing his kids. Using equation (15) in conjunction with the first-order condition for fertility (5) allows for a single implicit equation in n_t^1 to be obtained. Specifically, one obtains

$$(n_t^1)^{[1-(1-\nu)(1-\gamma)]/(1-\gamma)} = \frac{(1-\phi)}{\phi}(1-\gamma)x_t^{1/(1-\gamma)}\Big[\sum_{j=0}^{J-1} \frac{(w_{t+j}+\mathfrak{c})}{w_t(\prod_{i=1}^{j} r_{t+i})} - \frac{C(n_t^1; x_t, w_t, g_t)}{w_t}\Big].$$

By totally differentiating this condition, it is easy to deduce that

$$\frac{dn_t^1}{dx_t} > 0, \frac{dn_t^1}{dg_t} < 0, \text{ and } \frac{dn_t^1}{dw_t} < 0.$$

Note the last result obtains even if all of the w_{t+i}'s (for $i \geq 0$) rise by the same proportion; i.e., even when technological progress is permanent so that $dw_{t+i}/w_{t+i} = dw_t/w_t$ for all $i \geq 0$. Using the efficiency conditions (6) and (7), it is easy to show that

(16) $$w_t = (1-\alpha)\alpha^{\alpha/(1-\alpha)}z_t^{1/(1-\alpha)}(r_t-\delta)^{\alpha/(\alpha-1)}.$$

Thus,

$$\frac{dn_t^1}{dz_t} < 0.$$

Again, note that the result in the Proposition is true even if all of the z_{t+i}'s (for $i \geq 0$) rise by the same proportion. ∎

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Notes

[1] The source for the data used is Donald J. Hernandez (1996, Tables 9 and 10).

[2] The baby boom in the U.S. is conventionally dated as occurring between 1946 and 1964. These dates will be questioned in Section V.

[3] Note that the average childbearing age was 27, roughly the horizontal distance between the two curves.

[4] Surprisingly, there is a dearth of economic theories explaining the baby boom. One well-known theory connecting the Great Depression and World War II to the baby boom is due to Richard A. Easterlin (2000). His theory is based on the concept of "relative income." Fertility is high (low) when families' material aspirations are low (high) relative to their projections about their lifetime income. On the one hand, consumption plans are based on material aspirations. The latter are formed very early in life, while growing up with one's parents. On the other hand, young adults base their fertility decisions on projections about lifetime income. The generation that spawned the baby boomers had low material aspirations, and hence modest desires for consumption, since they were both born in the Great Depression and experienced World War II. The boomers' parents entered the labor force in the late 1940's to 1960's, economically speaking a good time. Therefore, they had low material aspirations relative to their expected lifetime income. The surfeit wealth was channeled into family formation, and high fertility resulted.

[5] The source for the real wage data is Jeffrey G. Williamson (1995, Table A1.1).

[6] The relationship between long-run growth and fertility has been investigated by Matthias

30

Doepke (2004). Jesus Fernandez-Villaverde (2001) examines the ability of technological advance to explain, quantitatively, the fall in British fertility. A similar exercise for the U.S. is conducted by Greenwood and Seshadri (2002). Over time child mortality has also declined. This has been analyzed well by Zvi Eckstein et al. (1999), who conclude that this is the major factor in explaining the fall in Swedish fertility. For the U.S. (unlike Sweden) infant mortality did not unambiguously begin to drop until 1880, at which point it fell sharply. As Figure 1 shows, the decline in U.S. fertility was already under way by then. Still, the decline in child mortality undoubtedly did play a role in explaining the decline in U.S. fertility. For the purposes at hand, though, abstracting from this issue probably does little harm to the analysis.

[7]Part of this increase in wages is due to the fact that the labor force has also become more skilled. Over time parents have chosen to educate their children so that the latter can enjoy the higher wages associated with skill. They have traded off quantity for quality in children. While this channel is absent in the baseline model, it is discussed in Section IV.

[8]For the details, see footnote 10.

[9]The classic references on household production theory are Becker (1965) and Reid (1934). The concept was introduced into macroeconomics by Jess Benhabib et al. (1991), who studied its implications for business cycle analysis – see also Paul Gomme et al. (2001). José-Víctor Ríos-Rull (1993) uses this notion to study the time allocations of skilled versus unskilled workers between the home and the market. Stephen L. Parente et al. (2000) employ the concept to analyze cross-country income differentials. Last, in Western economies there has been a secular shift in employment out of manufacturing and into services. The growth of the service sector in several European countries, however, has been encumbered by institutional rigidities. These services have been provided by the household sector instead. This phenomena is analyzed by Richard Rogerson (2002).

[10]It can now be seen that the constant $\mathfrak{c}$ can be thought of representing some fixed amount of home production. Write momentary utility as $\widetilde{U}(\widetilde{c}_{t+j}^{j+1}) = \phi \ln(\widetilde{c}_{t+j}^{j+1})$, where $\widetilde{c}_{t+j}^{j}$ denotes period-$(t+j)$ consumption by an age-j adult. Note that $\widetilde{U}(\widetilde{c}_{t+j}^{j+1}) = U(\widetilde{c}_{t+j}^{j+1} - \mathfrak{c})$. Let the indi-

vidual produce at home a constant amount of consumption goods, $\mathfrak{c}$, each period. His budget constraint will now appear as $\sum_{j=0}^{J-1} q_{t+j} \tilde{c}_{t+j}^{j+1} = \sum_{j=0}^{J-1} q_{t+j}(w_{t+j} + \mathfrak{c}) - q_t C(n_t^1, x_t, w_t, g_t)$. Rewrite the budget constraint as $\sum_{j=0}^{J-1} q_{t+j}(\tilde{c}_{t+j}^{j+1} - \mathfrak{c}) = \sum_{j=0}^{J-1} q_{t+j} w_{t+j} - q_t C(n_t^1, x_t, w_t, g_t)$. Next, define $c_{t+j}^{j+1} = \tilde{c}_{t+j}^{j+1} - \mathfrak{c}$ so that $\tilde{c}_{t+j}^{j+1} = c_{t+j}^{j+1} + \mathfrak{c}$. Use this to substitute out for $\tilde{c}_{t+j}^{j+1}$ in $\widetilde{U}(\tilde{c}_{t+j}^{j+1}) = U(\tilde{c}_{t+j}^{j+1} - \mathfrak{c})$ and the above budget constraint. This setting has transformed into the one presented in the text.

[11]If $I = 1$ then this vector is void; i.e., define $(p_0^1 n_0^1, p_1^1 n_1^1)$ to be empty since the youngest generation, or the first element, is older than the oldest generation, or the second element.

[12]There will be $J - 1$ households older than age 1 at date 1. These households will solve their analogues to problem P(1), given their initial asset holdings.

[13]See equation (16) in the Appendix.

[14]What about the substitution effect from a decline in g_t? Note that in the analysis g_t is modeled as a fixed cost. So, as long as the individual has any kids he must incur this cost. Thus, the substitution effect will only be (potentially) operational in influencing the decision of parents who would have chosen *not* to have kids in the absence of the price decline.

[15]Specifically, given data on investment and the capital stock the period-t depreciation factor, δ_t, can be estimated from the formula $\delta_t = (k_{t+1} - i_t)/k_t$. The depreciation rate obtained is close to the 4.8 percent that Thomas F. Cooley and Edward C. Prescott (1995) back out from their calibration procedure.

[16]This amounts to a (nonlinear) constraint on the estimation scheme discussed below.

[17]In the analysis the technology variables g_t, x_t, z_t are taken to be functions of time, t. For simplicity, set $g_t = 0$ for all t.

[18]The estimation procedure employed is similar to that used by David Andolfatto and Glenn M. MacDonald (1998). Note that given the length of a time period in the model (10 years), there are only 20 data points. Hence, given the paucity of observations there is little point adding an error structure to the estimation.

[19]Some constraints on parameters values also had to be satisfied: $0 < \beta, \phi, \gamma < 1$, and $\nu \geq 0$. Recall that β is chosen, as a function of $\phi, \mathfrak{c}, \nu, \gamma, x_{1800}, x_{1950}$, and x_{1960}, so that the

net interest rate in the model's final steady state is 6.9 percent per year.

[20]The numbers in the table are rounded to the second decimal.

[21]The Haines (2000) figures have been divided by two to get the number of children per parent (as opposed to the number of kids per woman). In the model each child has only one parent, not two as in the real world. Therefore, the U.S. fertility data should be divided by two, otherwise the rate of population growth in the model will be far too high.

[22]This estimation scheme weights the years 1940, 1950 and 1960 more heavily to put a greater emphasis on the baby boom. Specifically, in the baseline estimation, each of these years gets a 5 percent weight (since there are 20 observations) as opposed to the 16.7 percent weight in the new procedure.

[23]The quantity-quality tradeoff and female labor-force participation are discussed in Sections IV and V.D.

[24]A consistent high-quality time series for the skill premium is not currently available for the 200-year period under study. From the fragmentary evidence available, it is hard to detect any trend in the skill premium for the antebellum period. The skill premium may have declined between 1914 and 1924. This coincided with a rapid rise in the amount of schooling. When travelling through the model's four steady states, the skill premium rises modestly by a factor of 1.4. Note that technological advance in the educational technology, measured here by an increase in a, will lead to a fall in the skill premium. So, without doing more rigorous analysis, it is hard to know if the predictions of the quantity-quality model would contradict the data on this dimension.

[25]For more detail, see Greenwood, Seshadri and Mehmet Yorukoglu (2004), especially Figures 1, 2 and 7.

[26]As quoted by Siegfried Giedion (1948, p. 521).

[27]The model, which has a time period of ten years, is matched up with the Haines (2000) fertility series, shown in Figure 3, which uses decennial data. Hence, the first jump in the series associated with the baby boom is 1950. This is why estimated household productivity jumps in 1950. The Hernandez (1996) series shown in Figure 6 uses annual data. Here the

baby boom starts earlier in 1936. (An unpublished annual series by Haines starting in 1933 also shows the baby boom as starting in 1936.) If a higher frequency version of the model was matched up with this series instead, then estimated household productivity would start to rise in 1936. In a higher frequency model women should be allowed to bear children in more than one period. While this would introduce a nontrivial complexity into the analysis, it should not change the gist of things.

[28]The fertility series plots the general fertility rate and is taken from Hernandez (1996, Table 9). The GDP data is taken from Brian R. Mitchell (1998a, Table J1). It is deflated by Haines's (2000, Table 4.1) population series. The dates for the Great Depression shown in Figures 6, 8, 9 and 10 are based on the timing procedure of Harold L. Cole et al. (2003).

[29]Note that fertility appears to decline faster between 1917 and 1936 than it does from 1800 to 1917. But, also observe that real wages grow faster from 1917 on too. In fact, they grow *much* faster as the following regression analysis using data from 1830 to 1972 (or to the start of the productivity slowdown) shows:

$$\ln w_t = -\underset{(6.24)}{13.282} - \underset{(6.73)}{30.273}d_t + \underset{(8.31)}{0.0094}t + \underset{(6.75)}{0.015}d_t t + \varepsilon_t,$$

where

$$\varepsilon_t = \underset{(15.99)}{0.810}\varepsilon_{t-1} + \zeta_t \text{ with } \zeta_t \sim N(0, 0.053),$$

with $R^2 = 0.99$ and $D.W. = 1.72$. In the above regression d is a dummy variable that takes the value one from 1917 on and assumes the value zero otherwise. The numbers in parenthesis are t statistics. As can be seen, real wages grow at about 1.5% a year faster after 1917 than before. Hence, the accelerated decline in fertility between 1917 and 1936 is consistent with the story being told here.

[30]This diagram is based on unpublished data kindly supplied by Michael R. Haines.

[31]The birth rate data for France and the U.K. are from Mitchell (1998b, Table A6).

[32]Data is missing for Japan for the years between 1943 and 1947. It fits in well, though, with the story told below. No data was available for Turkey.

[33]Kendall's τ is a measure of the degree of order between two series, $\{x_i\}_{i=1}^n$ and $\{y_i\}_{i=1}^n$.

Consider the case where the two variables are positively associated with each other. Count the number of times when $x_j > x_i$ *and* $y_j > y_i$. Call the number of times the series are congruent, C. There are a total of $n(n-1)$ comparisons to do. Kendall's τ is given by

$$\frac{C - [n(n-1) - C]}{n(n-1)}.$$

Essentially, Kendall's τ is the probability of congruence less the probability of incongruence.

[34]Italy and Spain are now omitted since they did not experience a baby boom. Hence, there is no starting date for these countries.

[35]The data is from Lebergott (1993, Table II.17). For each of the 6 countries reported, a simple average is taken across the diffusion rates for hot-running water, washing machines, refrigeration, sewing machines, stoves (except the US), and automobiles.

[36]The decline in fertility is decomposed as follows: Total fertility, n, is a weighted average of the fertility for working women, w, and homemakers, h, where the weights f and $1-f$ are the fractions of women who are in and out of the labor force. Thus, $n = fw + (1-f)h$. The change in fertility between any two dates can then be written as $n' - n = [\frac{f'+f}{2}(w' - w)] + [\frac{(1-f')+(1-f)}{2}(h' - h)] + [\frac{(w'-h')+(w-h)}{2}(f' - f)]$. The first term in brackets gives the contribution of the increase in the fertility of working women to the total increase in fertility, the second measures the amount arising from the increase in homemaker fertility, while the third term shows the amount due to changes in labor-force participation. The data used for these calculation is taken from Cho et al. (1970, Tables 6.1 to 6.3). A working woman is defined to be any woman who is in the labor force, and a homemaker is taken to be one who is outside of the labor force.

[37]One way of doing this could be to combine some features of the current analysis with aspects of Galor and Weil (1996) and/or Greenwood, Seshadri and Yorukoglu (2004).

TABLES

TABLE 1: PARAMETER VALUES

Baseline – unweighted

Tastes	$\beta = 0.98^{10}$, $\phi = 0.83$, $\mathfrak{c} = 0.49$, $\nu = 0.00$
Market Technology	$\alpha = 0.30$, $\delta = (1 - 0.05)^{10}$
Home Technology	$\gamma = 0.20$, $\{g_t\}_{t \in \mathcal{T}} = 0$, $x_{1800} = 2.53$, $x_{1950} = 2.83$, $x_{1960} = 2.84$
Generational Structure	$I = 2$, $J = 4$

Preferred – Equally weighted

Tastes	$\beta = 0.98^{10}$, $\phi = 0.84$, $\mathfrak{c} = 0.40$, $\nu = 0.00$
Market Technology	$\alpha = 0.30$, $\delta = (1 - 0.05)^{10}$
Home Technology	$\gamma = 0.14$, $\{g_t\}_{t \in \mathcal{T}} = 0$, $x_{1800} = 2.76$, $x_{1950} = 3.11$, $x_{1960} = 3.29$
Generational Structure	$I = 2$, $J = 4$

TABLE 2: PARAMETER VALUES, QUANTITY-QUALITY MODEL

Tastes	$\beta = 0.95^{10}$, $\phi = 0.71$, $\nu = 1.20$, $\xi = 3.50$, $\rho = 0.50$
Market Technology	$\alpha = 0.40$, $\theta = 0.40$, $\delta = (1 - 0.09)^{10}$, $\lambda = 0.50$
	$z_{1800} = 2.0$, $z_{1940} = 3.8$, $z_{1960} = 5.2$, $z_{1990} = 5.8$
Home Technology	$\gamma = 0.50$, $\{g_t\}_{t \in \mathcal{T}} = 0$, $\eta = 0.5$, $\{a_t\}_{t \in \mathcal{T}} = 3.6$
	$x_{1800} = 3.60$, $x_{1940} = 3.60$, $x_{1960} = 26.0$, $x_{1990} = 26.0$
Generational Structure	$I = 2$, $J = 4$

TABLE 3: FERTILITY AND FEMALE LABOR-FORCE PARTICIPATION

| | *Percentage Change* | | |
	1940-1950	1950-1960	1940-1960
Total Fertility Rate			
Homemakers	29	21	56
Employed			269
Children per Married Woman			
Homemakers	27	57	100
Employed	38	127	214

Source: Lee-Jay Cho et al. (1970, Table 6.5, p. 193).

TABLE 4: DECOMPOSITION OF THE INCREASE IN FERTILITY

Period	*Employed*	*Homemakers*	*Participation*
1940-1950	19%	98%	-17%
1950-1960	44%	81%	-25%
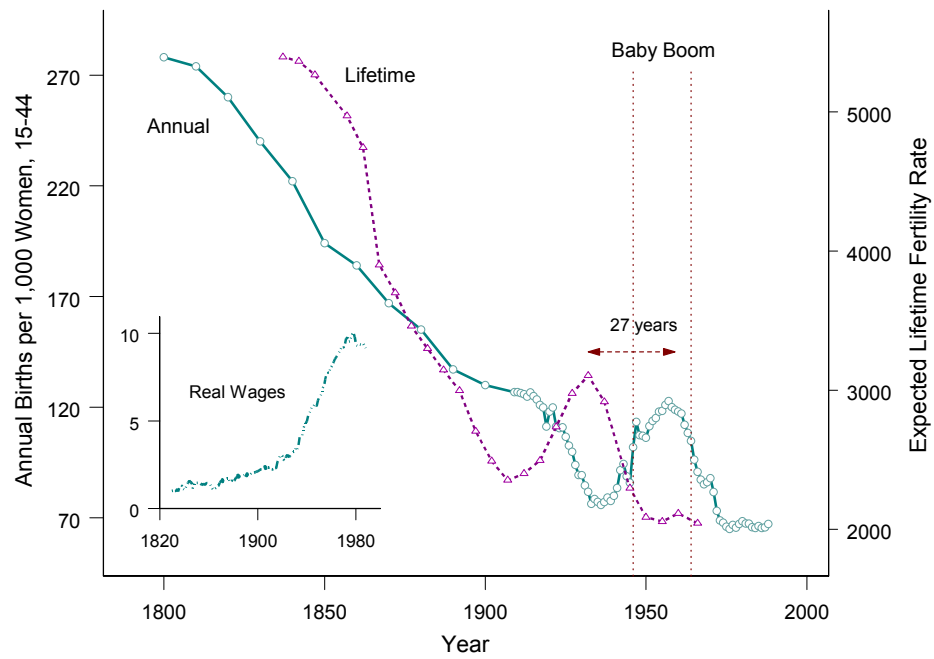
Figure 1: Fertility in the U.S., 1800-1990
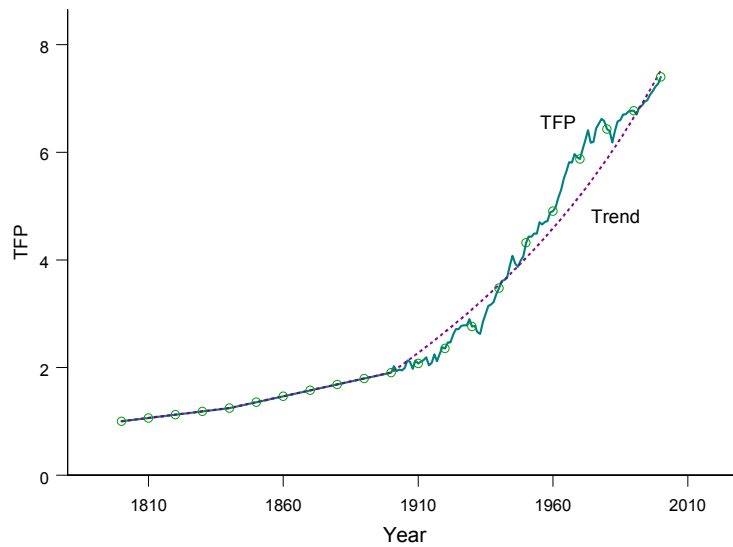
Figure 2: U.S. Total Factor Productivity, 1800-2000
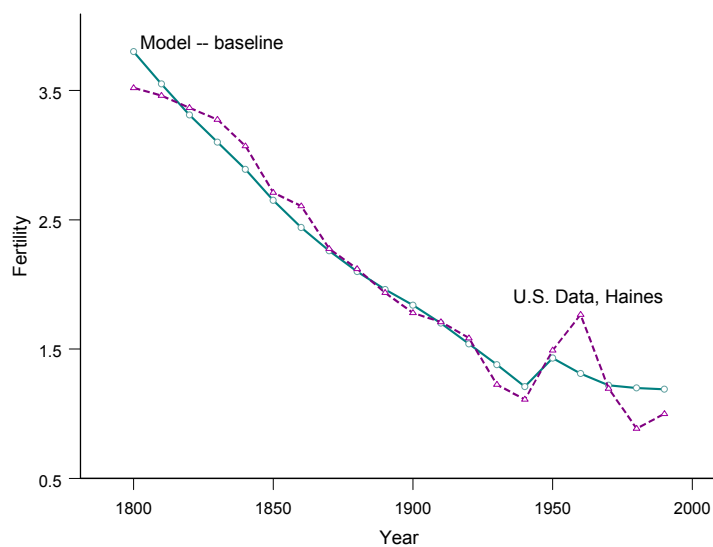
Figure 3: Fertility, 1800-1990 – U.S. Data and Baseline Model

39
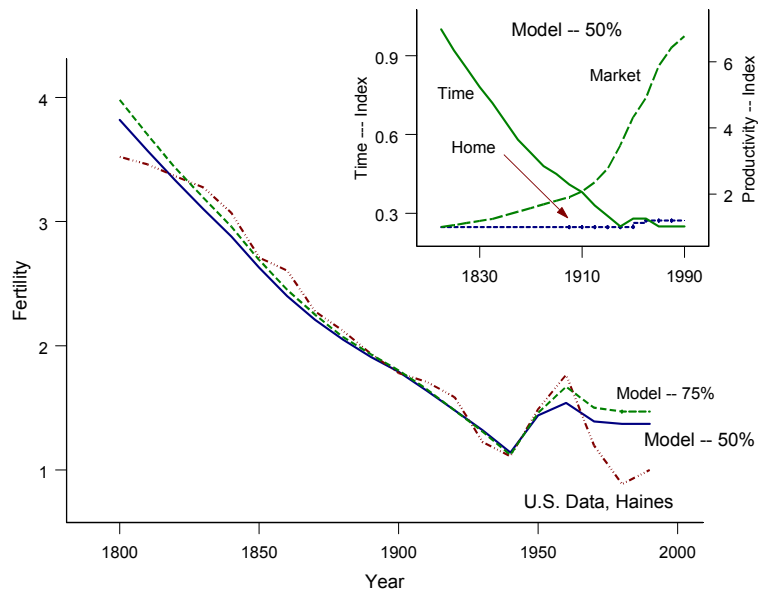
Figure 4: FERTILITY, 1800-1990 – U.S. DATA AND WEIGHTED MODELS
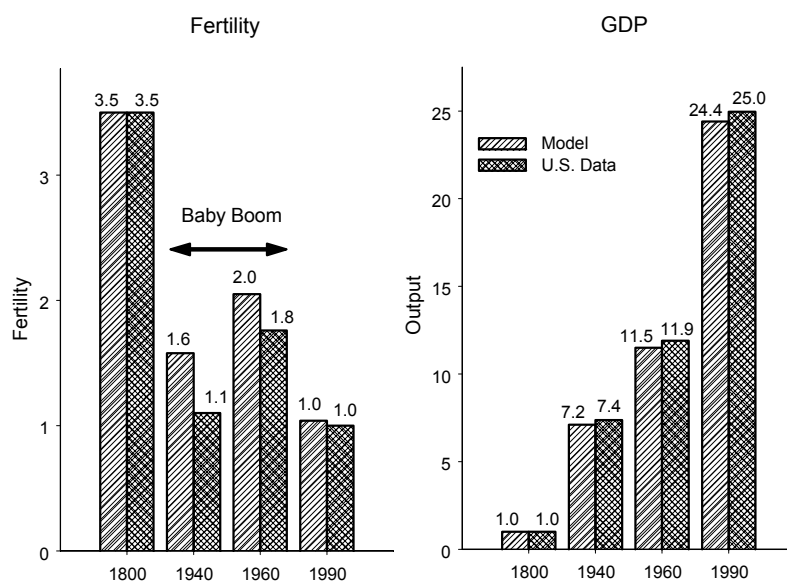
Figure 5: Fertility and GDP, 1800-1990 – U.S. Data and Quantity-Quality Model
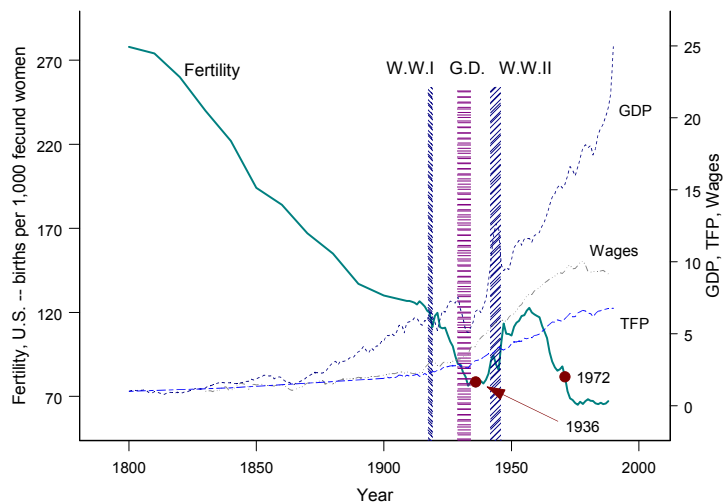
Figure 6: U.S. Fertility, 1800-1990
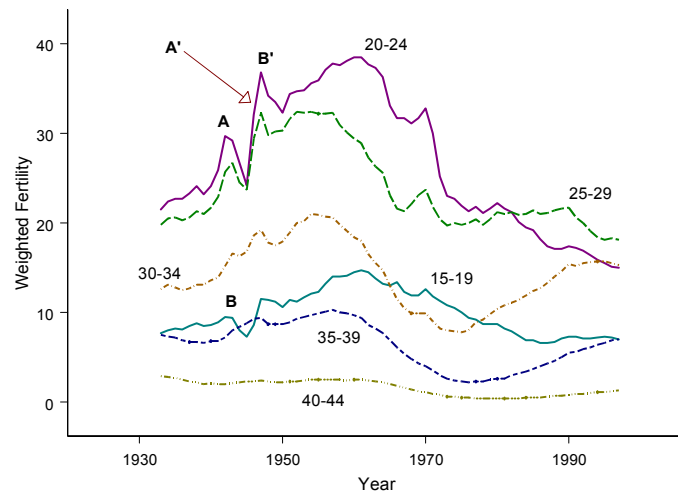
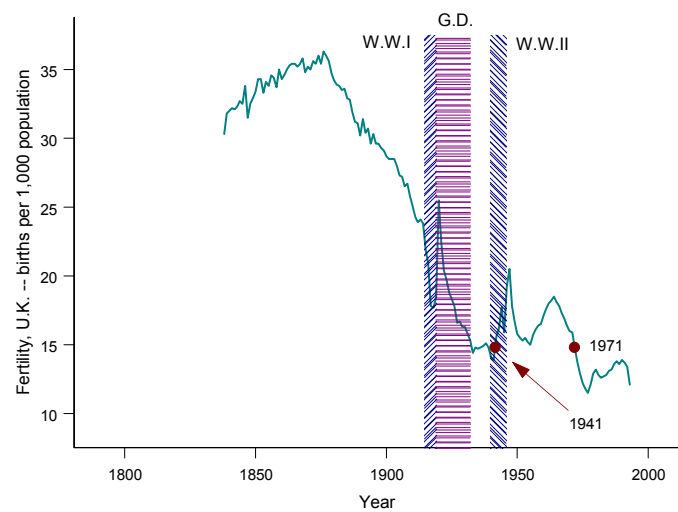Figure 7: U.S. Fertility by Age Group, 1933-1997
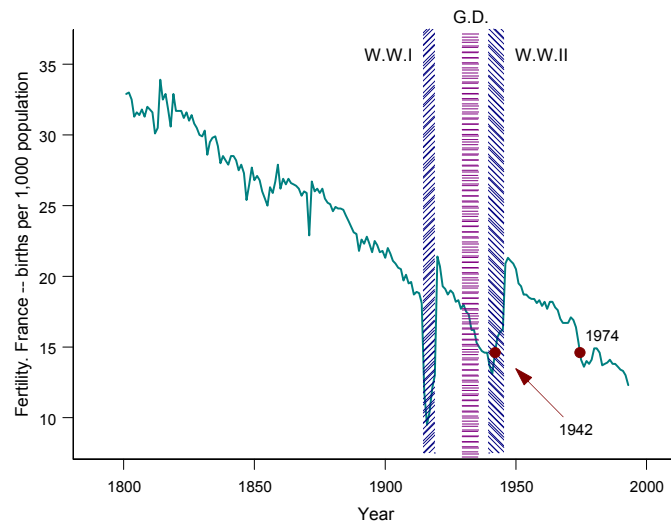

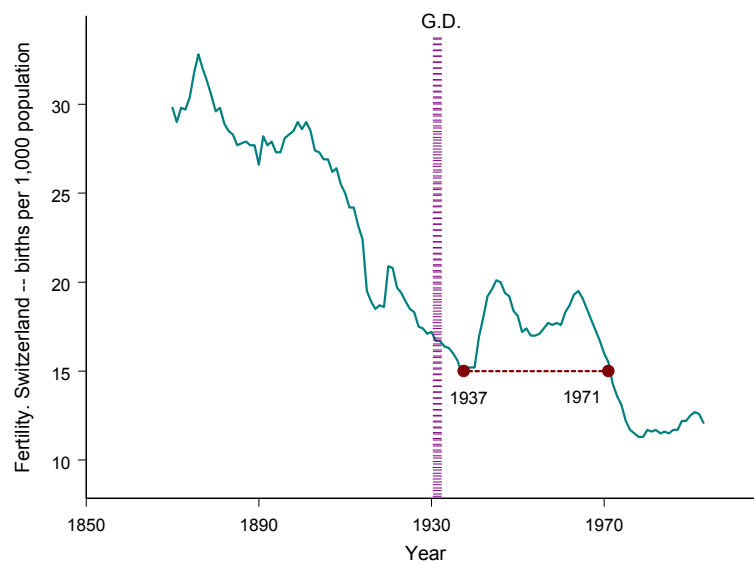Figure 8: U.K. Fertility, 1838-1993

42

Figure 9: FRENCH FERTILITY, 1801-1993
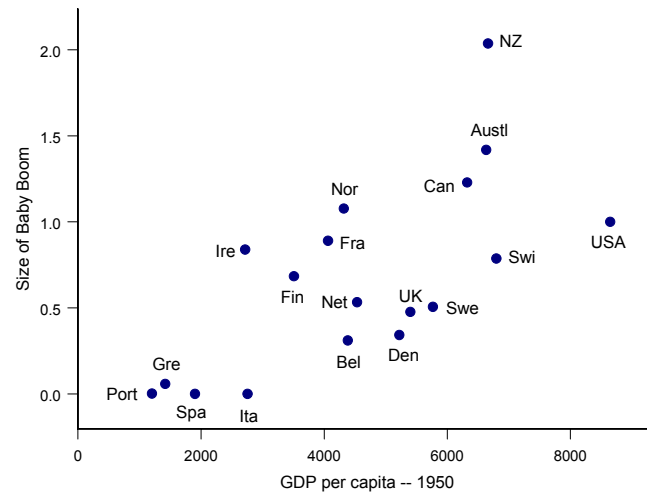

Figure 10: SWISS FERTILITY, 1870-1993

Figure 11: THE CROSS-COUNTRY RELATIONSHIP BETWEEN THE SIZE OF THE BABY BOOM AND INCOME
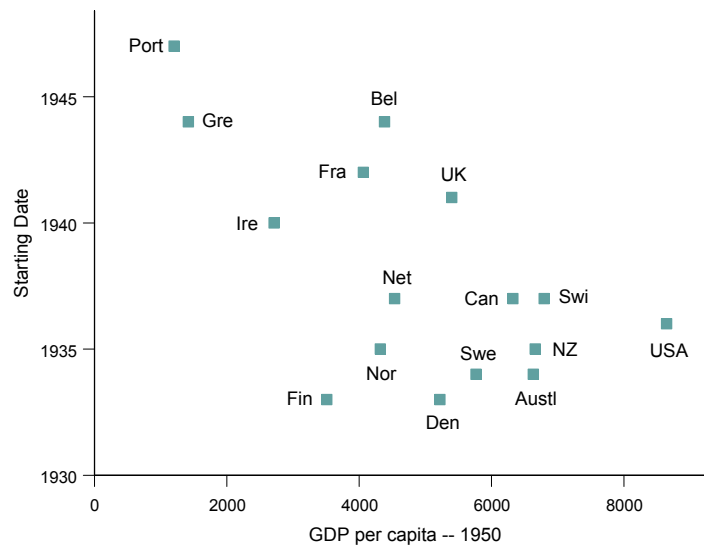

Figure 12: THE CROSS-COUNTRY RELATIONSHIP BETWEEN THE START OF THE BABY BOOM AND INCOME
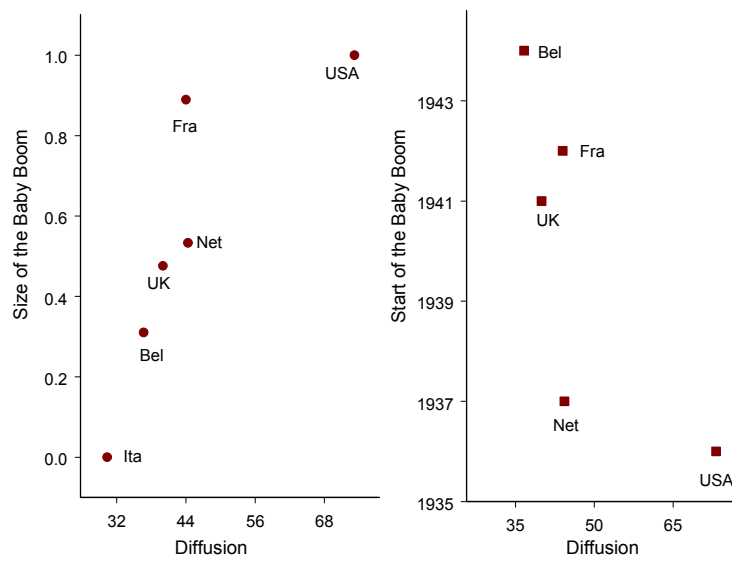
Figure 13: THE CROSS-COUNTRY RELATIONSHIP BETWEEN THE SIZE/START OF THE
BABY BOOM AND THE DIFFUSION OF HOUSEHOLD TECHNOLOGIES