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THE BABY BOOM AND BABY BUST: SOME MACROECONOMICS FOR POPULATION ECONOMICS

by

Jeremy Greenwood, Ananth Seshadri and Guillaume Vandenbroucke

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Contact information:
Jeremy Greenwood
Department of Economics
Harkness Hall
University of Rochester
P.O. Box 270156
Rochester, New York 14627-0156, USA.
(585) 275-5252, Fax: (585) 256-2309
E-mail: gree@troi.cc.rochester.edu

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Abstract

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.

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Authors: Jeremy Greenwood, Ananth Seshadri and Guillaume Vandenbroucke
Address: Department of Economics, University of Rochester, Rochester, NY 14627

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* *Updates*: http://www.econ.rochester.edu/Faculty/GreenwoodPapers/bb.pdf

1 Introduction

Facts: 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 women increased by 41 percent between 1934 and 1959. Alternatively, the number of realized lifetime births per female was 28 percent higher for a woman borne in 1932 (whose average child arrived in 1959) vis a vis one borne 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 1960s fertility reverted back to trend – or the "baby bust" resumed.

The Easterlin Hypothesis: Surprisingly, there is a dearth of viable theories explaining the baby boom. The one circulating with the highest value is due to Easterlin (2000). His theory is based on the concept of 'relative income.' Fertility is high (low) when families's 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 your 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,

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

[2] The baby boom in the U.S. is conventionally dated as occurring between 1946 and 1964.

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

since they were both borne 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.

The hypothesis has some shortcomings, as almost all do. First, its microeconomic foundations are weak. Modern microeconomics would suggest that both material aspirations and fertility choices should be based on rational projections about lifetime income. Why should fertility choices alone, and not ones about consumption, be based on lifetime income? It would seem equally plausible to assume that views about family structure are formed early in life, while consumption decisions are based on projections about lifetime income. Second, empirically speaking, while the theory has had some successes it also is lacking on some dimensions. For instance, how can it explain the secular decline in fertility? The answer requires that material aspirations must have grown relative to income for most of the last 200 years. It is also hard to operationalize concepts such as material aspirations. One implication of the hypothesis is that fertility should move procyclically, since expansions (recessions) are presumably times when income is high (low) relative to material aspirations. Yet, this doesn't appear to hold, at least for the postwar period. This is shown in Figure 2, which plots Hodrick-Prescott detrended fertility and GDP. The correlation between the two series is -0.38. The shaded areas portray economic contractions as dated by the NBER. It's clear that fertility shows a countercyclical pattern over the postwar period.[4]

The Hypothesis: To explain the baby boom and baby bust, the current analysis builds on 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

[4] Butz and Ward (1979) argue that the countercyclical movement in fertility will be stronger the higher is the rate of labor-force participation for fecund women. Theory suggests that the fertility of working women will be negatively related to the wage they earn. As female wages have risen over the postwar period so has female labor-force participation. This secular increase in female labor-force participation can be expected to strengthen the negative aggregate correlation between fertility and female wages. This is what Butz and Ward (1979) found, but Easterlin (2000) disputes the veracity of their findings due to the (so-called "faulty") wage series they used. The findings reported here don't use wage data and suggest that postwar fertility is countercyclical, as Butz and Ward (1979) claim.

Razin and 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 Becker and Barro (1988). Next, Galor and 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 $\cap$, and the engine in the Galor and Weil (2000) analysis for the decline in long-run fertility is technological progress.[5] 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.[6] [7] Since raising children requires time, this represents a tremendous increase in the (consumption) cost of kids.[8] The rest of the vehicle is taken from Greenwood, Seshadri and Yorukoglu's (2002) work on the rise of female labor-force participation that occurred in the 20th century. They argue that technological progress in the household sector, due to the introduction of electricity and the development of associated household products such as appliances, reduced the need for labor in the home. An ancillary implication of the hypothesis is that such labor-saving technological progress would have reduced the cost of having children too.

[5] In Galor and Weil (2000) technological progress is endogenous. Here it is taken to be exogenous.

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

[7] The relationship between long-run growth and fertility has also been investigated by Doepke (2000). 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 Eckstein, Miro and Wolpin (1999), who conclude that this is the major factor in explaining the decline 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.

[8] 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. This channel is absent in the current model, unlike in the Becker and Barro (1988) and Galor and Weil (2000) analyses.

2 The Economy

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 an adult is fecund only in the first period of adult life.

Tastes: An age-1 adult's preferences are given by

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

where c_{t+j}^j represents period-$(t+j)$ consumption by an age-j adult and n_t^1 is the number of children that he chooses to have (in the first period of adult life). The constant $\mathfrak{c}$ can be thought of as representing the household production of consumption goods.

Income: An adult can use his time for either working or raising kids. Market work in period t is remunerated at the wage rate w_t. 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 any past saving.

Cost of Children: Kids are costly. In particular, children are produced in line with the household production function shown below

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

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 q_t. The cost function

[9] The classic reference on household production theory is Becker (1965). The concept was introduced into macroeconomics by Benhabib, Rogerson and Wright (1991), who studied its implications for business cycle analysis – see also Gomme, Kydland, and Rupert (2001). Rios-Rull (1993) uses this notion to study the time allocations of skilled versus unskilled workers between the home and the market. Parente, Rogerson and Wright (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 Rogerson (2002).

for having kids is therefore given by

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

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

The Age-1 *Adult's Decision Problem*: A young adult's goal in life is to maximize his well being. This translates into solving the following maximization problem:

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

subject to

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

where the j-step-ahead present-value price p_{t+j} is defined by $p_{t+j} = p_{t+j-1}/r_{t+j}$ with $p_1 = 1$. This problem will have the solution:

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

and

$$\frac{1-\beta^J}{1-\beta} Q_1(n_t^1) = U_1(c_t^1) C_1(n_t^1, x_t, w_t, q_t). \qquad (3)$$

Let b_{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 $j+2$.

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

$$o_t = O(k_t, e_t, z_t) = z_t k_t^{\alpha} e_t^{1-\alpha},$$

where o_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.

The Firm's Problem: The firm desires to maximize profits as summarized by

$$\max_{k_t, e_t} \{O(k_t, e_t, z_t) - (r_t - \delta)k_t - w_t e_t\}. \qquad \text{P(2)}$$

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

$$O_1(k_t, e_t, z_t) = r_t - \delta, \tag{4}$$

and

$$O_2(k_t, e_t, z_t) = w_t. \tag{5}$$

Population Growth: Let s_t^j denote the period-t size of the age-j adult population. The law of motions for the population are

$$s_{t+1}^{j+1} = s_t^j, \text{ for } j = 1, \cdots, J-1, \tag{6}$$

and

$$s_{t+i}^1 = s_{t+i-I}^1 n_{t+i-I}^1, \text{ for } i = 1, \cdots, I. \tag{7}$$

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.

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

$$s_t^1 c_t^1 + s_t^2 c_t^2 + \cdots + s_t^J c_t^J + i_t = o_t. \tag{8}$$

Second, period-t savings must equal investment so that

$$s_t^1 b_{t+1}^2 + s_t^2 b_{t+1}^3 + \cdots + s_t^{J-1} b_{t+1}^J = k_{t+1}. \tag{9}$$

Initial Condition: Start the economy off at some time, say period 1. 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 $(s_1^1, \cdots, s_1^J)$. All but the youngest generation will have savings denoted by $(b_1^2, b_1^3, \cdots, b_1^J)$. 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

$$s_1^2 b_1^2 + \cdots + s_1^J b_1^J = k_1.$$

There will also be $I-1$ generations of children around waiting to mature. This is captured by the $(I-1)$-vector $(s_0^1 n_0^1, \cdots, s_{-I+2}^1 n_{-I+2}^1)$, which starts with the youngest generation and goes to the oldest.[10]

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

Definition 1 *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 condition* $(b_1^2, \cdots, b_1^J, s_1^1, \cdots, s_1^J,\ s_0^1 n_0^1, \cdots, s_{-I+2}^1 n_{-I+2}^1)$ *the following is true:*

1. *The allocations* $\{c_t^j, n_t^1\}_{t=1}^{\infty}$ *solve the household's problem P(1), given* $\{r_t, w_t\}_{t=1}^{\infty}$.[11]
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 (6) and (7).*
4. *The goods and asset markets clear, or (8) and (9) hold.*

2.1 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 mid 1900's. Two ingredients are incorporated into the framework to capture these features. First,

[10] If $I = 1$ then this vector is void; i.e., define $(s_0^1 n_0^1, s_1^1 n_1^1)$ to be empty since the youngest generation, or the first element, is older than the oldest generation, or the second element.

[11] *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.*

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 assumed that there is technological progress in household sector. This will cause the baby boom. Will these two ingredients be sufficient to account for the observed pattern of U.S. fertility? The following lemma suggests that the answer is yes.

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

(a) A rise in x_t *causes* n_t^1 *to increase.*

(b) A fall in q_t *leads to a rise in* n_t^1*.*

(c) An increase in z_t *causes* n_t^1 *to decline.*

Proof. First, focus on the household's problem P(1). Given the functional forms adopted, the first-order condition for fertility (3) is

$$\frac{1-\beta^J}{1-\beta}(1-\phi)\frac{1}{(n_t^1)^\nu} = \phi\frac{1}{c_t^1+\mathfrak{c}} \times \frac{1}{(1-\gamma)}w_t(\frac{n_t^1}{x_t})^{1/(1-\gamma)}\frac{1}{n_t^1}. \tag{10}$$

This equation can be rewritten as

$$\frac{c_t^1+\mathfrak{c}}{w_t} = [\frac{1-\beta^J}{1-\beta}\frac{1-\phi}{\phi}(1-\gamma)]^{-1}x_t^{-1/(1-\gamma)}(n_t^1)^{[1-(1-\nu)(1-\gamma)]/(1-\gamma)}. \tag{11}$$

Note that $(c_t^1+\mathfrak{c})/w_t$ is increasing in n_t^1, and that $(c_t^1+\mathfrak{c})/w_t = 0$ when $n_t^1 = 0$. Call the equation defined by (11) the n locus. The n locus can be concave or convex depending upon the sizes of ν and γ. By using the first-order condition for consumption (2) in conjunction with the budget constraint (1), the following equation can be obtained:

$$\frac{c_t^1+\mathfrak{c}}{w_t} = \frac{1-\beta}{1-\beta^J}[\sum_{i=0}^{J-1}\frac{(w_{t+i}+\mathfrak{c})}{w_t(\prod_{s=1}^{i} r_{t+s})} - \frac{C(n_t^1, x_t, w_t, q_t)}{w_t}], \tag{12}$$

where $\prod_{s=1}^{0} r_{t+s} \equiv 1$. 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. Now, $(c_t^1+\mathfrak{c})/w_t$ is decreasing and convex in n_t^1. Additionally, it can easily be deduced that $(c_t^1+\mathfrak{c})/w_t \to [(1-\beta)/(1-\beta^J)][\{\sum_{i=0}^{J-1}(w_{t+i}+\mathfrak{c})/[w_t(\prod_{s=1}^{i} r_{t+s})] - q_t\}$ as $n_t^1 \to 0$, and that $(c_t^1+\mathfrak{c})/w_t \to 0$ as $n_t^1 \to x_t\{\sum_{i=0}^{J-1}(w_{t+i}+\mathfrak{c})/[w_t(\prod_{s=1}^{i} r_{t+s})] - q_t\}^{(1-\gamma)}$. Label (12) the c

locus. The c and n loci define a system of two equations in two unknowns, viz $(c_t^1 + \mathfrak{c})/w_t$ and n_t^1. This solution is portrayed in Figure 3. Note that the position of the n locus will be a function of x_t, while the position of the c locus will depend upon x_t, $\{w_{t+i}\}_{i=0}^{J-1}$, and q_t. Second, consider the firm's problem P(2). Using the efficiency conditions (4) and (5), it is easy to show that[12]

$$w_t = (1-\alpha)\alpha^{\alpha/(1-\alpha)} z_t^{1/(1-\alpha)} (r_t - \delta)^{\alpha/(\alpha-1)} \equiv W(r_t, t). \tag{13}$$

The lemma can now be easily proved. Part (a) follows from noting that an increase in x_t will cause the n locus to shift down and the c locus to shift up – see (11) and (12). This will lead to a rise in fertility, as Figure 3 shows. To establish Part (b), observe that a fall in q_t will induce the c locus to shift up – it has no effect on the n locus. Hence, fertility will rise. Last, note that an increase in z_t will cause w_t to rise, as is evident from (13). This will cause a downward shift in the c locus – observe that $C(n_t^1, x_t, w_t, q_t)/w_t = C(n_t^1, x_t, 1, q_t)$ – so long as $\mathfrak{c} > 0$. This is true 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. A decline in n_t^1 will therefore occur. This proves Part (c) of the lemma. ■

Intuition: The intuition for the above lemma can be gleaned from the first-order condition governing fertility (3), or (10) given the functional forms adopted. 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 righthand side. The consumption cost of having an extra child is $C_1(n_t^1, x_t, w_t, q_t) = [1/(1-\gamma)]w_t[n_t^1/x_t]^{1/(1-\gamma)}(1/n_t^1)$. 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 their marginal utility. This effect will

[12] The market technology shock, z_t, is taken to a function of time, t.

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 (10). 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. The impact of $\mathfrak{c}$ is larger at low levels of c_t, 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 (10) 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. 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, q_t, for the household technology drops consumers have more disposable income. This increases the consumption of market goods, other things equal, and consequently reduces their marginal utility – see (12). Hence, the utility cost of having children falls and higher fertility results.

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, except in balanced growth. 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.

3 Quantitative Analysis

3.1 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 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.[13] 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 a 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:

$$\ln(\mathrm{TFP}_t) = a + b * t + d * t^2 + \varepsilon_t,$$

where

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

The results of the estimation are

$$\begin{aligned} a = \underset{(1.72)}{0.4611},\ b = \underset{(4.18)}{0.0045},\ d = \underset{(2.00)}{0.00002},\ \rho = \underset{(53.75)}{0.9766},\ \sigma &= 0.0299, \\ \text{with } R^2 &= 0.9960, \text{ D.W.}{=}2.25, \ \#\text{obs.}{=}102, \end{aligned}$$

[13] For discussion of the productivity slowdown see Hornstein and Krusell (1996).

where the numbers in parentheses are t statistics. Observe that the trend rate of TFP growth increases over time, as Romer (1989) has suggested. The trend line that results from this estimation is shown in Figure 4 – 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.

3.2 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*, $\beta, \alpha, \gamma, \delta, z$'s: Some parameters are common to a wide variety of macroeconomic models and can be pinned down using *a priori* information. Take the discount factor to be $\beta = 0.94^{10}$, roughly the value recommended by Cooley and Prescott (1995). Labor's share of income is roughly 2/3. In line with this, set $\alpha = 0.33$. Labor's share of income is fairly constant across sectors in the U.S. economy. Therefore, it will be presumed that its value in the household sector is the same as in the market sector; i.e., $\gamma = 0.33$. The annual depreciation rate on capital is set at 10 percent, a standard value. This dictates setting $\delta = (1 - .10)^{10}$. 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 4 indicate the data points for TFP that will be used in the analysis.

2. *Estimation*, $\phi, \mathfrak{c}, \nu, x$'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 $\{f_t\}_{t=1800}^{1990}$ denote the U.S. time series for fertility. 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 detail later on. 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 $\{\widehat{f}_t\}_{t=1800}^{1990}$. Describe the mapping from the model's parameter values to predicted fertility by $\widehat{f}_t = F(t; \phi, \mathfrak{c}, \nu, x_{1800}, x_{1950}, x_{1960})$. The function F corresponds to the solution to the nonlinear difference equation system that describes the model's general equilibrium – this difference equation system is discussed in the appendix. 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[14]

$$\min_{\phi,\mathfrak{c},\nu,x_{1800},x_{1950},x_{1960}} \sum_{t=1800}^{1990} (f_t - F(t; \phi, \mathfrak{c}, \nu, x_{1800}, x_{1950}, x_{1960}))^2,$$

subject to

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

and

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

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. The stability properties of the model will be discussed shortly.

Table 1 lists the parameter values that result from the above procedure.

[14] The estimation procedure employed is similar to that used by Andolfatto and MacDonald (1998). Note that given the length of a time period in 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.

Table 1: Parameter Values

Tastes	$\beta = 0.94^{10}$, $\phi = 0.47$, $\mathfrak{c} = 3.53$, $\nu = 0.00$,
Market Technology	$\alpha = 0.33$, $\delta = (1 - .10)^{10}$,
Home Technology	$\gamma = 0.33$, $q = 0$, $x_{1800} = 0.50$, $x_{1950} = 0.77$, $x_{1960} = 0.81$,
Generational Structure	$I = 2$, $J = 4$.

3.3 Local Dynamics[15]

Cycles and echo effects: The notion of cycles in economic models of fertility is at least 200 years old, going back to Malthus. The Easterlin (2000) model predicts a cycle in fertility associated with the baby boom. The baby-boom generation was large in size. The baby boomers would have high material aspirations, since they were raised by affluent parents. When they grew up, however, they would be faced with abnormally low wages given the large supply of labor associated with their cohort. According to his hypothesis, then, the baby-boom generation will have low fertility since their material aspirations are high relative to their income. Their kids, in turn, will grow up with low material aspirations. Since this generation is small in size they will meet with good fortune on the labor market. Two generations after the baby boom, therefore, high fertility will again result. That is, a self-generating, two-period fertility cycle occurs.[16] What does the current model say about cycles in fertility? To answer this question, the local dynamics of the model will be analyzed.

The nonlinear difference equation system: To investigate the model's local dynamics, suppose that there is no technological progress. It is easy to deduce that the solution to the model can be represented as a nonlinear difference equation system of the form

$$D(r_{t+4}, r_{t+3}, \cdots, r_{t-1}, r_{t-2}, \theta_{t+2}, \theta_{t+1}) = 0, \tag{14}$$

where $\theta_{t+2} \equiv s^1_{t+2}/s^1_{t+1}$ – the full details are in the appendix. This difference equation system derives from the facts that:

[15] **The reader can omit this section without loss of continuity.**

[16] Samuelson (1976) analyzes the two-generation cycle that emerges out of the Easterlin framework.

(i) Savings must equal investment in each period t so that equation (9) holds.

(ii) Population must follow its prescribed law of motion, as given by (6) and (7).

The form of this nonlinear difference equation system is easy to understand. First, consider the lefthand side of (9); that is, period-t savings. This will involve three generations of adults, ages one to three. Take an age-1 adult. It is readily apparent from P(1) that his decisions will depend solely upon $r_{t+3}, \cdots, r_t$ – recall from equation (13) that $w_t = W(r_t)$, where time can now be suppressed since there is no technological advance.[17] Now, given the perfect foresight nature of the equilibrium, an age-2 adult can be thought of as making all of his decisions in period $t-1$ on the basis of $r_{t+2}, \cdots, r_{t-1}$. Likewise, the interest rate vector relevant for an age-3 adult is $r_{t+1}, \cdots, r_{t-2}$. Therefore, period-t savings involves the interest rates $r_{t+3}, \cdots, r_{t-2}$. Second, now focus on the righthand side of (9), or investment in period t. Investment in period t is predicated upon aggregate demand (or production) in period $t+1$. This depends upon the behavior of the 4 generations of adults who will be alive then. The decisions of an age-1 adult in period $t+1$ will depend on $r_{t+4}, \cdots, r_{t+1}$. An age-4 adult will have made his decisions in period $t-2$ so that his behavior will be a function of $r_{t+1}, r_t, \cdots, r_{t-2}$. Thus, period-$t$ investment is a function of $r_{t+4}, \cdots, r_{t-2}$. Last, the (relative) size of each generation matters for computing aggregate savings and investment. This can be controlled for using the variable $\theta_{t+2} \equiv s^1_{t+2}/s^1_{t+1}$. The law of motion for θ_{t+2} captures population dynamics for the model – see equation (18) in the appendix, which derives from (6) and (7). It turns out that θ_{t+2} can be expressed as function of θ_{t+1} and $r_{t+3}, \cdots, r_t$.

Local stability: A stable solution to the model is desired for both economic and computational reasons. To investigate stability the above nonlinear difference equation system is linearized.[18] To this end, let $x_{t+1} \equiv (r_{t+4}, r_{t+3}, \cdots, r_{t-1}, \theta_{t+2})^T$, and define x^* to be the steady-state value of this vector associated with a situation where there is no technological

[17] If there is technological progress then time, or t, needs to be entered into (14) as a separate argument.

[18] The classic source on linearization is King, Plosser and Rebelo (1987).

progress. The linearized version of (14) can be expressed as

$$(x_{t+1} - x^*) = A(x_t - x^*).$$

In order for the solution to be both locally stable and determinate there must be exactly 4 eigenvalues with a modulus less than one in absolute value. Connected with each of these stable eigenvalues is an initial condition. Three of these derive from the economy's initial wealth distribution and are due to the fact that oldest three generations of adults bring assets into the initial period. The last is a start-up condition for the relative population size variable. For the estimated parameter values, the 7×7 matrix A has exactly four stable eigenvalues, $\{\lambda_i\}_{i=1}^4$. Specifically,

$$\lambda_1 = 0.3333, \lambda_2 = -0.9808, \lambda_3 = -0.4077 + 0.5763i, \lambda_4 = -0.4077 - 0.5763i.$$

Observe that one of these eigenvalues is negative while another two are complex, implying the presence of a cycle.[19] All have a modulus less than one, so the solution is stable.

Fertility waves: To examine the model's propagation mechanism consider the following experiment. Let z^* denote the steady value of z. Now, compute an alternative steady state associated with $z = z^*/1.10$; i.e., one where TFP in the market sector is roughly 10 percent lower. Start the system off at this alternative steady state and let z suddenly jump up to z^* and remain there. Figure 5 shows the time path obtained for interest rate. It converges rapidly, and more or less smoothly, to its steady-state value. That is, there does not appear to be much of a cycle. Asymptotically, the negative root dominates the system, as putting the tail of the path under a microscope reveals. This can take sometime, though, and by then most of the transitional dynamics have transpired. This can be deduced by examining the solution obtained for the interest rate difference equation:

$$\begin{aligned} r_t - r^* &= 0.3120 \times 0.3333^t + 0.0014 \times (-0.9808)^t \\ &\quad + 0.0240 \times (0.7059)^t \times \cos(-2.7963 + 2.1865t), \end{aligned} \tag{15}$$

[19] Azariadis et al (2000) suggest that cycles are ubiquitous in overlapping generations models.

where r^* is the steady-state value for the interest rate. As can be seen, the coefficients of the terms associated with negative and complex eigenvalues are small. Hence, these terms only matter as t becomes large. The upshot of the analysis is that the model does display a cycle in fertility. The cycles generated by a disturbance, however, damp rapidly. The data doesn't seem to display much of a cycle in fertility, if at all, so the model seems consistent with the evidence.[20]

3.4 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, assume 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 model is shown in Figure 6. 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 Haines (2000, Table 4.3).[21] Qualitatively speaking, the pattern of fertility generated by the model matches the U.S. data well. There is a secular decline in fertility punctuated by a temporary rise spawned

[20] As the next section will show, when the forcing variables are added back into the system the cycles become imperceptible. Also note that while the above analysis focuses on the interest rate, the same story holds for all of the model's variables. That is, an equation similar to (15) holds for fertility. Specifically,

$$\begin{aligned}\theta_{t+1} - \theta^* &= 0.0147 \times 0.3333^t + 0.0151 \times (-0.9808)^t \\ &\quad + 0.0044 \times (0.7059)^t \times \cos(-1.6860 + 2.1865t),\end{aligned}$$

where $\theta^*$is the steady-state value for θ.

[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.

by technological progress in the household sector. The model underestimates the size of the baby boom. This could easily be rectified by allowing 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. *Measured* market sector TFP does not grow fast enough – due to the productivity slowdown – to generate the observed rapid decline in fertility. 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.

Technological Progress in the Household Sector: So how much technological progress was there in the household sector? The analysis here suggests that TFP in the home sector must have risen by a factor of 1.6 between 1800 and 1990. In particular, x is estimated to rise by a factor of 1.5 between 1940 and 1950, and by an additional factor of 1.1 between 1950 and 1960. Are these numbers reasonable? TFP in the market sector increased by about a factor of 7 between 1800 and 1990. The assumed rise in household-sector TFP lies considerably below this number. Figure 6 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 2, holding the number of kids constant. The number of children declines secularly, and, with it, so does the time spent on child rearing. This drop actually accelerates during the baby boom years. The improvement in household technology allows households to have additional time both for more children and other activities, here working in the market. 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 drops by a factor of 2.5 over the period in question.

3.5 Historical Discussion

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 meeting with success 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 begin to take off in the 1940's. Figure 7 shows some diffusion curves for modern appliances.[22] Between 1929 and 1975 the household appliance-to-GDP ratio increased by a factor of 2.5, as is illustrated in Figure 8.[23] Observe that 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

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[22] Source: Greenwood, Seshadri and Yorukoglu (2002, Figure 3).

[23] The data on the stock of appliances was taken from *Fixed Reproducible Tangible Wealth in the United States, 1925-1994*, a publication of the U.S. Department of Commerce. The price series for appliances came from Gordon (1990, Table 7.23) and was deflated by the CPI.

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 up bricks up with their left hands and simultaneously to take a trowelful of mortar with his right hand. Fredrick (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?"[24] Fredrick 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.

The Timing of the Baby Boom, U.S., U.K., and France: 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 9? 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

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

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.[25] 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.[26] [27]

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 the lifetime births for a women. 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 10 plots the fertility rates for

[25] The model, which has a time period of ten years, is matched up with the Haines (2000) fertility series, shown in Figure 6, 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 9 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 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.

[26] The fertility series plots the general fertility rate and is taken from Hernandez (1996, Table 9). The GDP data is taken from Mitchell (1998a, Table J1). It is deflated by Haines's (2000, Table 4.1) population series.

[27] Note fertility appears to decline faster between 1915 and 1936 than it does from 1800 to 1915. But, also observe that real wages grow faster from 1915 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:

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

where

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

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 1915 on and assumes the value zero otherwise. The numbers in parenthesis are t statistics. As can be seen, real wage grow at about 1.5% a year faster after 1915 than before. Hence, the accelerated decline in fertility between 1915 and 1936 is consistent with the story being told here.

various age groups of white women.[28] 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 years-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-years-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-years-old range in 1941 and in the 18-to-22-years-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 years-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-years-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-years-old age group begins 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 11.[29] 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 1971. France shows a similar pattern with fertility rising throughout World War II – see Figure 12. One might date the French baby boom as occurring between 1942 and 1974.

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

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

Fertility and Female Labor-Force Participation: 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 rise in fertility!

TABLE 2: FERTILITY AND FEMALE LABOR-FORCE PARTICIPATION

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

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

Table 2 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 3.[30]

[30] The decline in fertility is decomposed as follows: Total fertility, f, is a weighted average of the fertility

Table 3: Decomposition of the Increase in Fertility

Period	*Employed*	*Homemakers*	*Participation*
1940-1950	19%	98%	-17%
1950-1960	44%	81%	-25%

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 chose to have more kids?

Fertility and Husband's Occupation: Wealthier households would have been better predisposed to buy the new labor-saving household capital. Did they then experience the largest increase in fertility? The data presented in Figure 13 sheds some light on the answer to this question.[31] The figure plots the percentage change in fertility for white women aged 20 to 24 against their husband's occupation. The occupations are roughly ordered on the earnings scale starting from the highest to lowest. Now, take the years 1910 to 1940. Higher socioeconomic groups tended to experience the biggest *decline* in fertility, as is shown by the trend line. These groups saw the biggest *decline* in fertility after the baby boom, too, as the bars shows for the years 1960 to 1970. During the baby boom, however, this pattern

for working women, w, and homemakers, h, where the weights p and $1-p$ are the fractions of women who are in and out of the labor force. Thus, $f = pw + (1-p)h$. The change in fertility between any two dates can then be written as $f' - f = [\frac{p'+p}{2}(w'-w)] + [\frac{(1-p')+(1-p)}{2}(h'-h)] + [\frac{(w'-h')+(w-h)}{2}(p'-p)]$. 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 labor force and a homemaker is taken to be one who is outside of the labor force.

[31] *Sources*: The data for this figure derive from three sources: (i) *1960 Census of Population*, *Women by Number of Children ever Born*, subject report, PC(2)-3A, Table 31, p. 147; *1970 Census of Population*, *Women by number of children ever born*, subject report, PC(2)-3A, Table 46, p. 202; (iii) Grabill, Kiser and Whelpton (1958, Table 54, p. 131).

was reversed: higher socioeconomic groups had the biggest *increase* in fertility, as can be seen by the bars for 1940 to 1960. The same pattern is shown by women in the 25 to 29 age group too.

The Size of the Baby Boom and a Country's Income: 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 fertility 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 11 and 12 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. 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 14. The data are provided in the Appendix. 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.

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[32] Japan was missing data 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.

The Start of the Baby Boom and a Country's Income: Likewise, one would expect that the baby boom should have started earlier in richer countries. This appears to be true. Figure 15 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.

4 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. 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, 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 *one-and-one-half-fold* increase estimated here is much smaller than the documented *seven-fold* improvements in market productivity. The last hundred years witnessed an enormous increase in female labor-force participation. Undoubtedly, part of the secular decline in fertility is related to the rise in female labor-force participation. Working women have always had less kids than homemakers. Somewhat surprisingly, however, it was working women who had the biggest percentage rise in fertility during the baby boom. What would motivate a significant number of women *both* to work in market and to have more kids? The argument here is that technological progress in the household sector freed up enough time to allow women both to have more children and to work.[35] An interesting extension of

[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 impact that technological innovation in household sector has had on female labor-force participation is analyzed in Greenwood et al (2002).

the current analysis would be to develop a model that can simultaneously account for the historical observations on female labor-force participation and fertility.

5 Appendix

Transformation to a Stationary Representation: Consider a situation of balanced growth where there is no technological progress. Over time the size of the population will be increasing, provided that each parent has more than one child. Given this some variables, such as the aggregate capital stock and employment, will grow along a balanced growth path at the same rate as the population. To render the model stationary, define the transformed variables $\widetilde{k}_{t+1} = k_{t+1}/s^1_{t+1}$ and $\widetilde{e}_{t+1} = e_{t+1}/s^1_{t+1}$. The analysis can be cast in terms of these transformed variables.

5.1 The Difference Equation System, $I = 2$, $J = 4$

Given the assumption of constant returns to scale, it is possible to write the wage rate in period t as a function of the period-t interest rate and the market technological shock, which is a function of time, so that $w_t = W(r_t, t)$. The generic period-t solution to an age-1 adult's optimization problem will have the form $b^{j+2}_{t+j+1} = B^{j+2}_{t+j+1}(r_t, r_{t+1}, r_{t+2}, r_{t+3}, t)$, $c^{j+1}_{t+j} = C^{j+1}_{t+j}(r_t, r_{t+1}, r_{t+2}, r_{t+3}, t)$, and $n^{j+1}_{t+j} = N^{j+1}_{t+j}(r_t, r_{t+1}, r_{t+2}, r_{t+3}, t)$ for $j = 0, \cdots, 3$.

Asset Market Clearing Condition: The transformed period-t asset market clearing condition is

$$b^2_{t+1} + (s^2_t/s^1_t)b^3_{t+1} + (s^3_t/s^1_t)b^4_{t+1} = (s^1_{t+1}/s^1_t)\widetilde{k}_{t+1}. \tag{16}$$

The lefthand side of the above equation represents period-t savings while the righthand side gives period-t investment. Neglecting the s's for the moment, it is easy to see that period-t savings depends upon $r_{t+3}, r_{t+2}, \cdots, r_{t-2}$. This fact is evident from substituting the decision rules for the b's into the lefthand side of (16). Next, note that the period-$(t+1)$ goods market condition states that

$$c_{t+1}^1 + (s_{t+1}^2/s_{t+1}^1)c_{t+1}^2 + (s_{t+1}^3/s_{t+1}^1)c_{t+1}^3 + (s_{t+1}^4/s_{t+1}^1)c_{t+1}^4 + (s_{t+2}^1/s_{t+1}^1)\widetilde{k}_{t+2} - \delta\widetilde{k}_{t+1} = \widetilde{k}_{t+1}O(1, \widetilde{e}_{t+1}/\widetilde{k}_{t+1}, t+1),$$

so that the period-t demand for investment can be written as

$$\widetilde{k}_{t+1} = \frac{c_{t+1}^1 + (s_{t+1}^2/s_{t+1}^1)c_{t+1}^2 + (s_{t+1}^3/s_{t+1}^1)c_{t+1}^3 + (s_{t+1}^4/s_{t+1}^1)c_{t+1}^4 + (s_{t+2}^1/s_{t+1}^1)\widetilde{k}_{t+2}}{O(1, \widetilde{e}_{t+1}/\widetilde{k}_{t+1}, t+1) + \delta}. \quad (17)$$

(Again, note that the market technology shock is a function of time. Hence, with some abuse of notation, replace z_t with t in the function O.) Now, note that $\widetilde{k}_{t+2}$ can be substituted out for by using an updated expression for (16). Again neglecting the s's for the moment, it is easy to see that period-t investment demand depends upon $r_{t+4}, r_{t+3}, \cdots, r_{t-2}$. The fact obtains from substituting the decision rules for the c's and b's into the righthand side of (17) – after eliminating $\widetilde{k}_{t+2}$. Also, note that given the constant-returns-to-scale assumption that $\widetilde{e}_{t+1}/\widetilde{k}_{t+1}$ will depend solely on r_{t+1}. Therefore, the period-t asset market clearing condition represents a nonlinear difference equation in $r_{t+4}, r_{t+3}, \cdots, r_{t-2}$, when abstracting from the s's.

Population Dynamics: The s's need to be taken into account. To this end, define

$$\theta_{t+1} \equiv s_{t+1}^1/s_t^1.$$

It's simple to deduce that

$$\theta_{t+2} \equiv s_{t+2}^1/s_{t+1}^1 = n_t^1 s_t^1/s_{t+1}^1 = n_t^1/\theta_{t+1}. \quad (18)$$

Likewise, it follows that

$$s_t^2/s_t^1 = s_{t-1}^1/s_t^1 = 1/\theta_t = \theta_{t+1}/n_{t-1}^1,$$

$$s_t^3/s_t^1 = s_{t-2}^1/s_t^1 = s_{t-2}^1/(n_{t-2}^1 s_{t-2}^1) = 1/n_{t-2}^1,$$

and

$$s_{t+1}^2/s_{t+1}^1 = s_t^1/s_{t+1}^1 = 1/\theta_{t+1}, s_{t+1}^3/s_{t+1}^1 = 1/n_{t-1}^1, s_{t+1}^4/s_{t+1}^1 = s_t^3/s_{t+1}^1 = 1/(n_{t-2}^1\theta_{t+1}).$$

Therefore, θ_{t+2} and the s's depend on $r_{t+4}, r_{t+3}, \cdots, r_{t-2}$, when given θ_{t+1}. Thus, (16) and (18) together implicitly define a nonlinear difference equation system of the form

$$D(r_{t+4}, r_{t+3}, \cdots, r_{t-2}, \theta_{t+2}, \theta_{t+1}, t) = 0.$$

This nonlinear difference equation system is used to compute the time path for fertility shown in Figure 6. The solution to the system will have the form $n_t^1 = F(t; \phi, \mathfrak{c}, \nu, x_{1800}, x_{1950}, x_{1960})$; that is, fertility will be a function of time and parameter values (where only the estimated ones are included for notational simplicity).

The Linearized System: Assume that there is no technological progress. Let $x_{t+1} \equiv (r_{t+4}, r_{t+3}, \cdots, r_{t-1}, \theta_{t+2})^T$ and define x^* to be the steady-state value of this vector. Then, the above system can be linearized around the final steady state and put in the form

$$(x_{t+1} - x^*) = A(x_t - x^*).$$

The dynamic properties of the model in a neighborhood around the steady state can be deduced by examining the eigenvalues that are associated with the matrix A. This linearized system is used only to check whether or not the model is locally stable.

5.2 International Data

Below is the data used in Figure 14. The sources for the data are given in Section 3.5.

TABLE 4: SIZE OF BABY BOOM AND A COUNTRY'S INCOME

Country	*GDP per Capita – 1950*	*Baby Boom*		
		Size	Begin	End
U.S.A.	8648	125.25	1936	1965
Canada	6324	153.90	1937	1965
Finland	3511	85.64	1933	1961
Norway	4319	134.85	1935	1974
Sweden	5767	63.40	1934	1960
France	4063	111.40	1942	1974
Belgium	4385	38.85	1944	1966
Denmark	5221	42.90	1933	1954
U.K.	5400	59.63	1941	1971
Ireland	2716	105.00	1940	1983
Spain	1903	0.00		
Portugal	1204	0.21	1947	1949
Italy	2756	0.00		
Netherlands	4536	66.75	1937	1965
Switzerland	6797	98.50	1937	1971
Greece	1419	7.25	1944	1948
Australia	6633	177.50	1934	1974
New Zealand	6662	255.00	1935	1977

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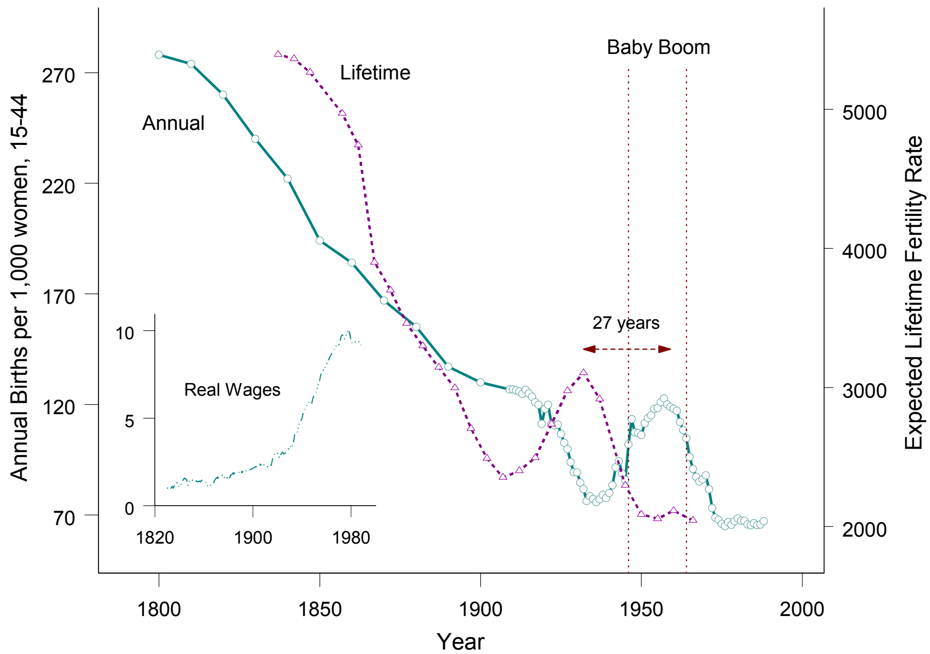

Figure 1: Fertility in the U.S., 1800-1990.

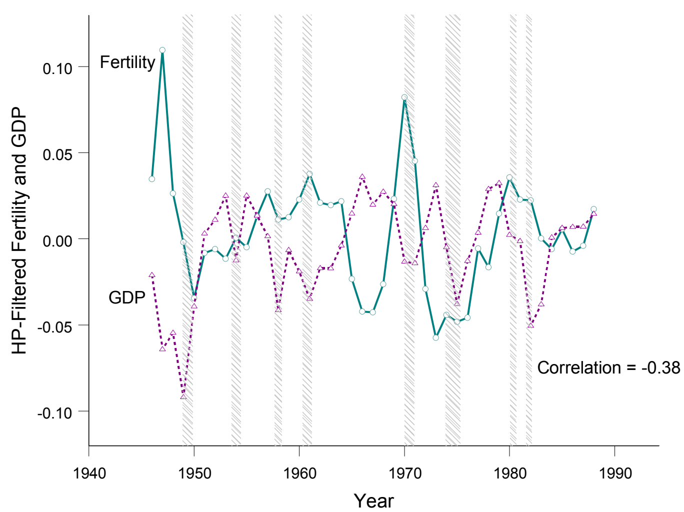

Figure 2: Hodrick-Prescott Detrended Fertility and GDP, 1946-1990.

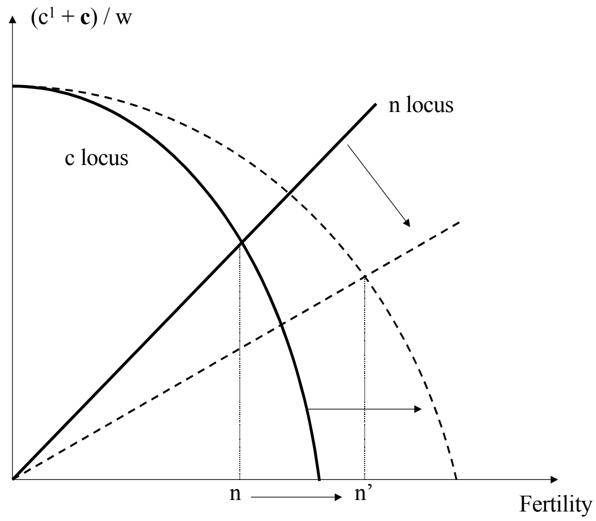

Figure 3: The Determination of Fertility and the Effect of Technological Progress in the Household Sector.

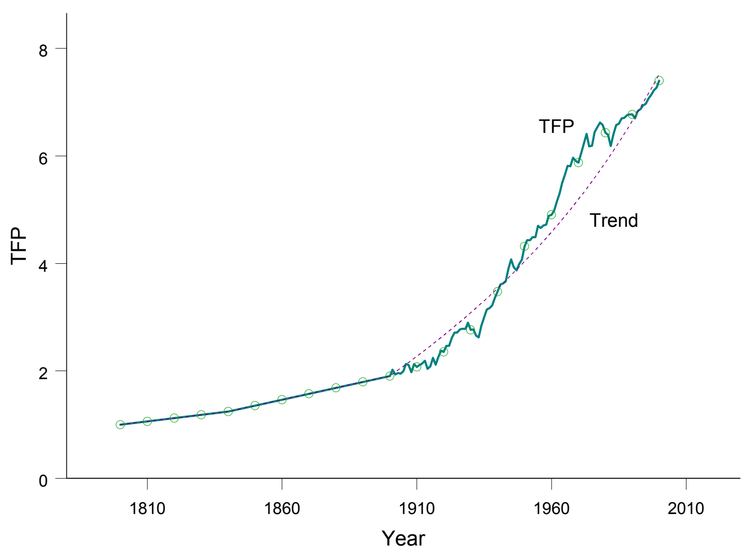

Figure 4: Total Factor Productivity, 1800-2000.

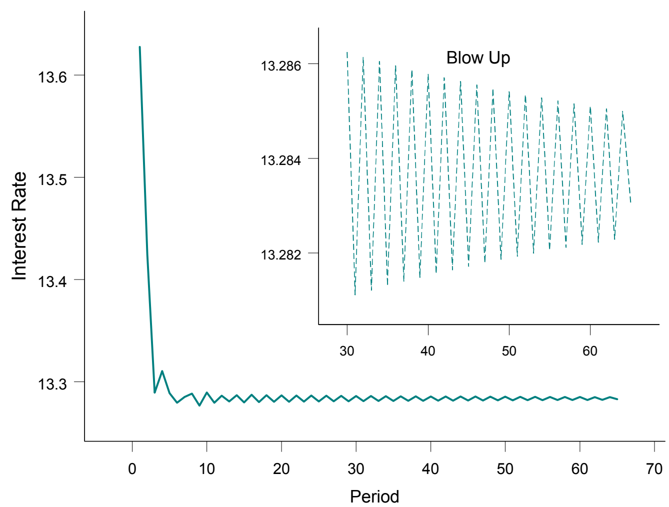

Figure 5: Local Stability, Oscillations in the Interest Rate.

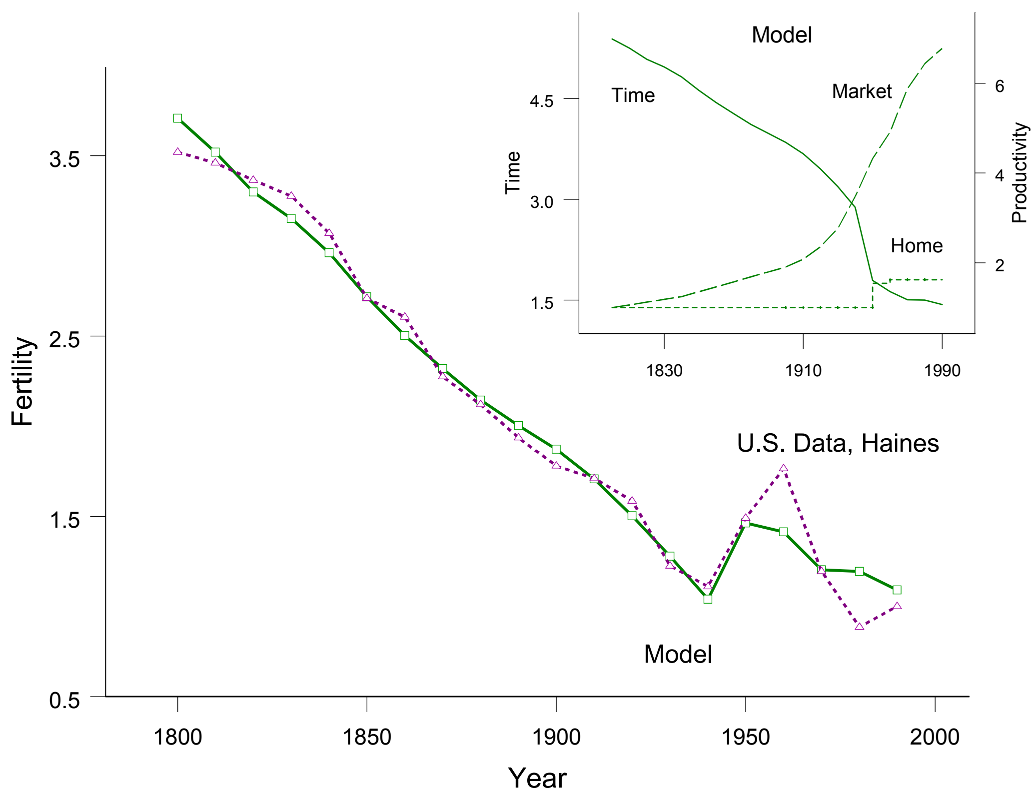

Figure 6: Fertility, 1800-1990 – U.S. Data and Model.

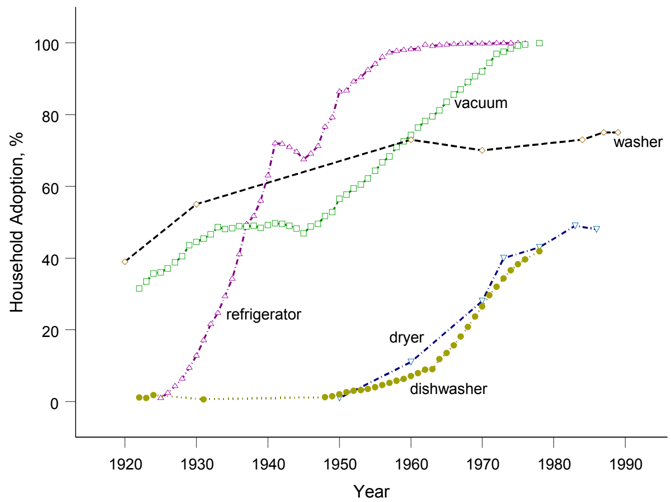

Figure 7: The Diffusion of Some Household Appliances in the U.S., 1920-1990.

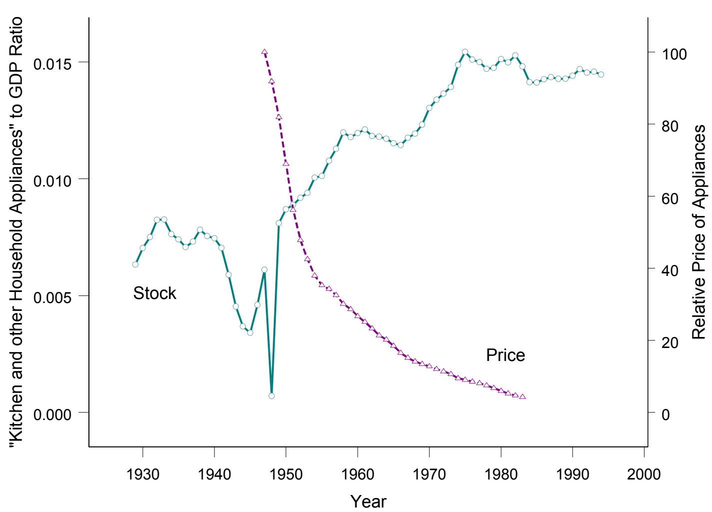

Figure 8: Price and Quantity of Household Appliances

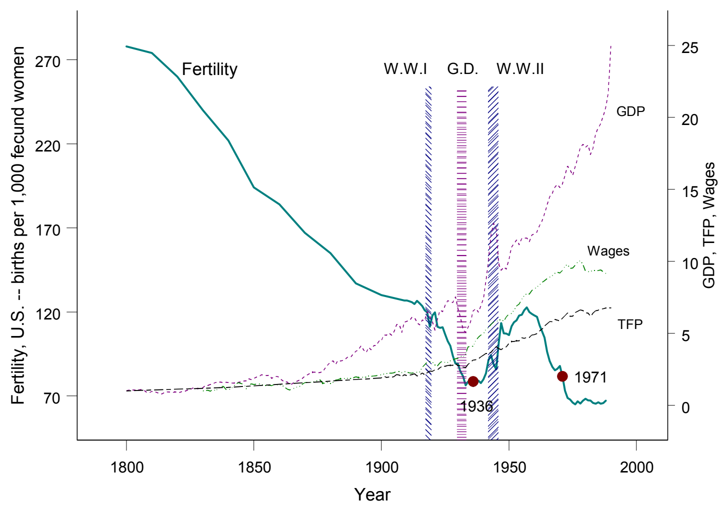

Figure 9: U.S. Fertility, 1800-1990.

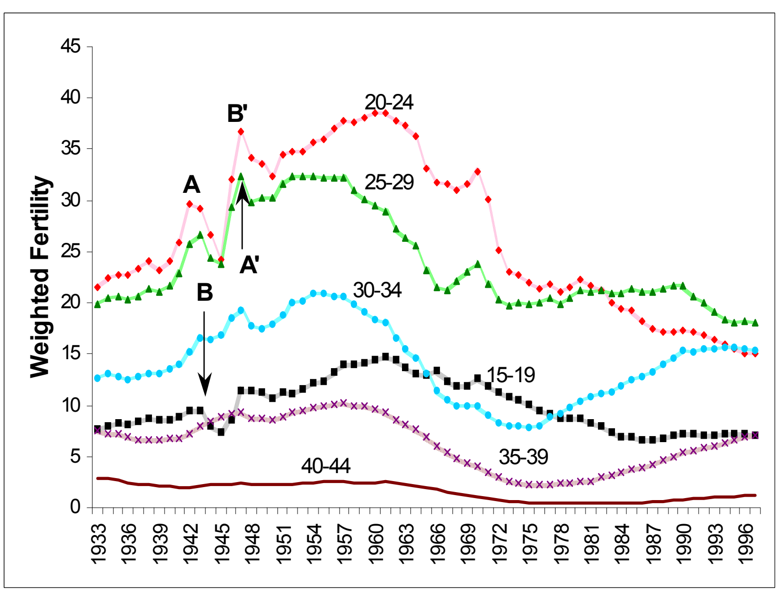

Figure 10: Fertility by Age Group, 1933-1997.

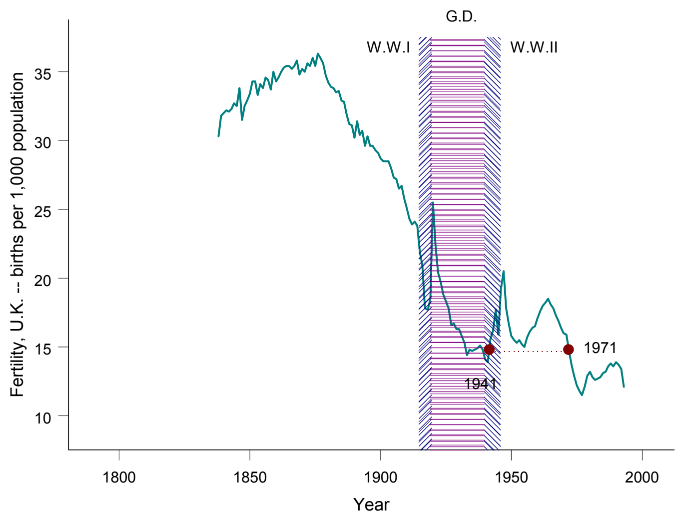

Figure 11: U.K. Fertility, 1838-1993.

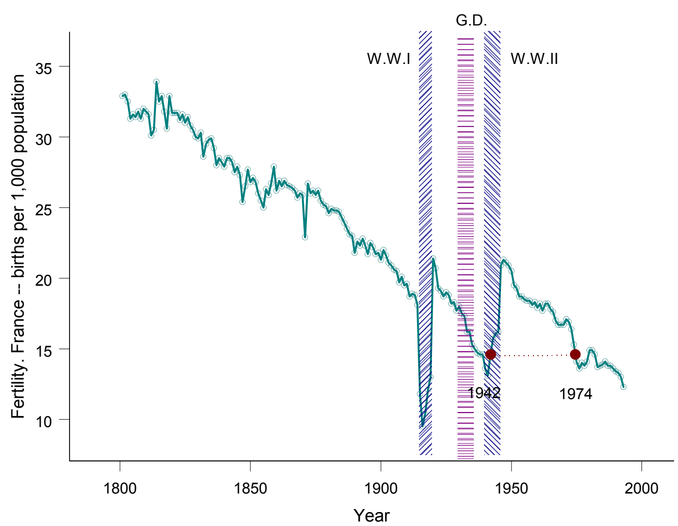

Figure 12: French Fertility, 1801-1993.

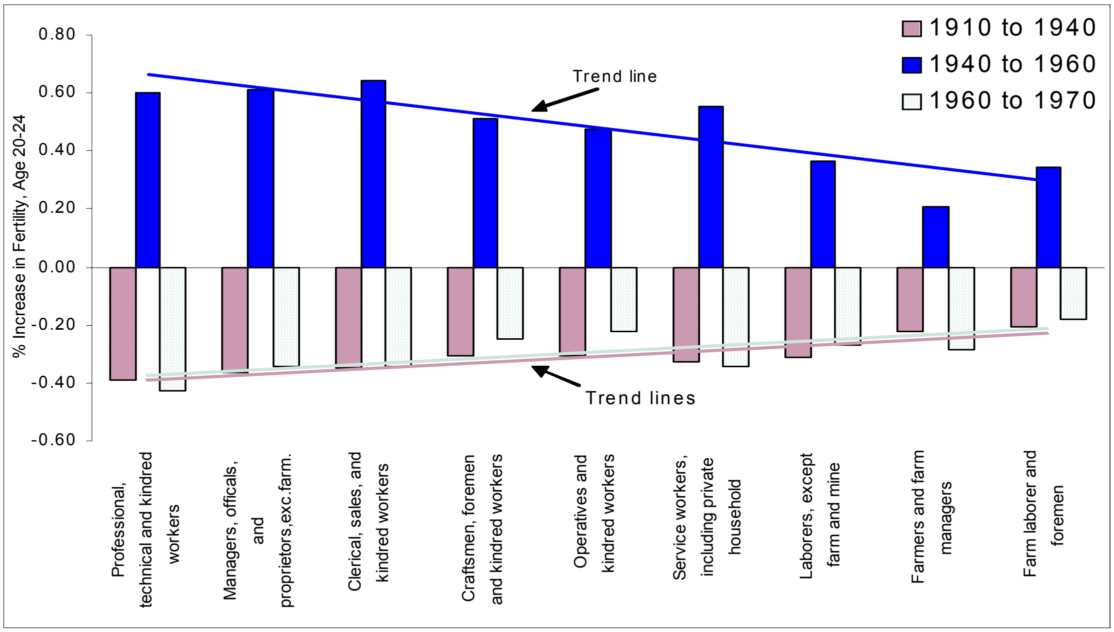

Figure 13: Fertility and Husband's Occupation, 1910 to 1970.

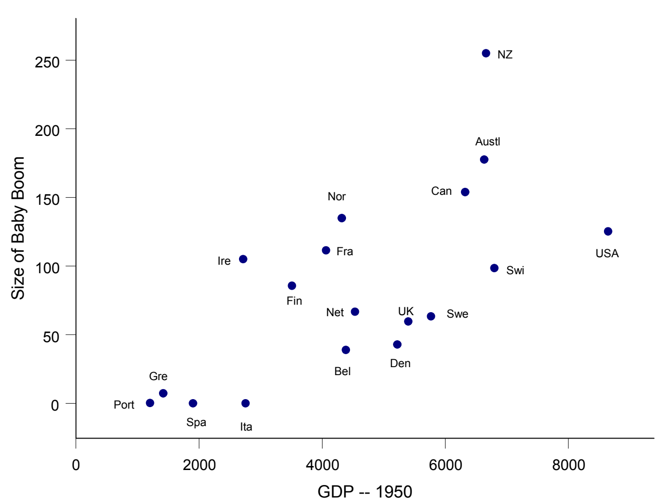

Figure 14: The Cross-Country Relationship between the Size of the Baby Boom and Income.

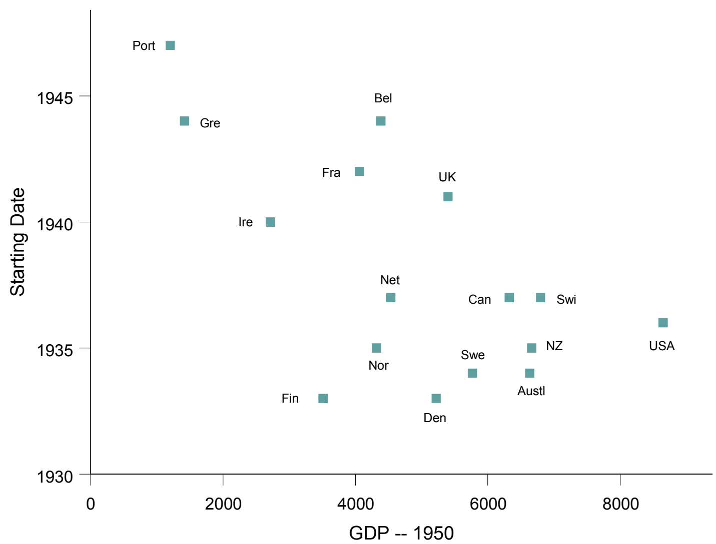

Figure 15: The Cross-Country Relationship between the Start of the Baby Boom and Income.