U.S. FERTILITY TRENDS: WHAT BIRTH RATES SPECIFIC FOR AGE AND PARITY OF WOMEN TELL US

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This paper continues a line of inquiry of U. S. fertility patterns in terms of the most detailed index available in this country on an annual basis, namely birth rates specific for age and parity of women, [1] also referred to as conditional birth probabilities or annual parity progression ratios. A previous paper developed a model, summarized below, that characterizes the major dimensions of the statistical relations among schedules of these rates for cohorts of American women.[2] In this paper we examine trends in U. S. fertility since 1917 in terms of the model, and we explore some of the implications for fertility projections of these highly detailed measures.

Nature and Uses of the Rate. Birth rates specific for age and parity of women b(x,n) describe the proportion of women in a specific age group (x) and parity class (n) who had children in a particular year, as illustrated in Figure 1. A matrix (B) of such values representing rates for women in the same calendar year (t) is identified as a 'period' matrix B(x,n,t); it is distinguished from the matrix of rates for a cohort of women born in the same year (T), which is called a 'cohort' matrix B(x,n,T).

One can view the matrix B, with either its period or cohort time referent, as describing the reproductive experience of a group of women moving deterministically through successive ages and stochastically from one parity class to the next. This suggests a non-homogeneous Markov process with which one can generate expected parity distribution for women of any age (x). The mean of parity distributions so generated represents the average number of children born per woman by that age. And the mean for women age approximately 49 years, taken as the age of termination of childbearing, is equivalent to the average completed family size, a concept that we identify with the symbol $\bar{P}(T)$, when the parity distribution was generated by a cohort-specific matrix B(T); or with $\bar{P}(t)$ when the distribution was generated by a period matrix B(t).

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In a previous paper we constructed a model that characterizes the principle features of an entire schedule of birth rates specific for age and parity of women, that is, a cohort-specific matrix B(x,n,T) based on rates recorded for American women born between 1877-1954. The model, which is restricted to rates for women in the age range 22-47 years, takes the following form:

$$b(x,n,T)=\begin{cases} 1, & x-\lambda n < m_1+(m_2-m_1)e^{-1/A(n,T)} \\ -A(n,T)\ln\left[\dfrac{x-m_1-\lambda n}{m_2-m_1}\right], \text{ where} & m_1+(m_2-m_1)e^{-1/A(n,T)} \leq x-\lambda n \leq m_2 \\ 0, & x-\lambda n > m_2 \end{cases} \qquad (1)$$

When fit to observed rates, parameters of the model took on the following values: m_1 =8.58; $m_2 - m_1$ = 30.83; and λ =1.83. The parameter A(n,T) represents a cohort-specific 'scale factor'; it is an index of the cohort's parity-specific birth rates, irrespective of the age of the woman. In that sense, A-values resemble parity progression ratios (Figure 1) which are not specific for age either. The age-parity model in equation (1), then, summarizes the major features of matrix B(x,n,T), which can be seen as a series of monotonically decreasing birth rates by age of woman, one set for women in each parity class of a cohort; and each series of rates is higher than the previous series as one moves from lower to higher parity classes. An interpretation of the model parameters m_1, m_2 , and λ is discussed in the previous paper.

With the age-parity model and a complete set of A(n,T) values, we can generate matrices of fitted or expected birth rates B(x,n,T) for each cohort which can be compared with the observed rates from which the model was constructed. Differences between the expected and observed rates, $\hat{B}(x,n,T)-B(x,n,T)$, for individual cohorts are interpreted below as representing a combination of fertility 'timing' phenomena as well as random movements.

It should be noted, moreover, that birth rates specific for age and parity of women can be identified with either a specific cohort of women (T) or with a calendar year (t). The relation between a cohort's year of birth (T) and any calendar year (t) is expressed in the simple identity:

$$t=x+T \qquad (2)$$

Thus, birth rates of women born in 1940, now aged 35 years, can be referenced with respect to either the year of their birth (T=1940), or with respect to a recent calendar year (t=1975). Accordingly, entire matrices of age-parity specific birth rates can be referenced in terms of the year of birth to the cohorts, in which case they are described by cohort matrices, B(x,n,T). In contrast,with information from many different cohorts, one can construct calendar-year or 'period' matrices of age-parity specific birth rates B(x,n,t). Cohort matrices convey information about fertility trends different from period matrices. The former are the rates of actual, individual cohorts; while the latter, for any calendar year, combine in one array birth rates for a number of co-existing cohorts of women, of different ages.

TIME-SERIES ANALYSIS-CONSIDERATIONS. The time-series analysis, using the age-parity model, proceeds from the assumption that changes in period, or calendar-year, fertility measures can be conceived in terms of several theoretically specifiable components. Some of these are best understood from a cohort perspective and accordingly require that rates b(x,n,t) be examined using B(x,n,T), while other components are meaningful in terms of calendar year changes and thus would be isolated using information contained in B(x,n,t). Annual changes in fertility, then, are seen as an admixture or what Ryder called an 'interpenetration' of cohort and period effects.[3]

The most 'basic' component of the fertility time-series, viewed on a calendar basis, represents cohorts' more or less stable notions of their 'expected' family size goals, a behavioral concept underlying surveys designed to elicit the childbearing ideals and expectations of women now having children.[4] Our analysis, below, indicates that there is a close concordance between such stated expectations and actual trends in cohort-specific fertility. In relation to the age-parity model, the family size 'goals' component is embodied in trends of the parity-specific scale factor A(n,T). The model implies that childbearing intentions of cohorts express themselves early in the reproductive history of cohorts' actual fertility performance, generally subject to only 'timing' adjustments. Were the family size component to be removed from fertility time series, what would remain would be a combination of fertility timing effects as well as random variation. 'Timing' is how couples space their children, not how many they have.

The second component of fertility change represents short-term fertility responses to outside, or exogenous, influences. Studies have shown for example, that economic conditions have been associated with fertility rates on both a short-term and a long-term basis.[5] In relation to the model, the presence and magnitude of fertility changes associated with short-term exogenous influences would be evident in sets of residual rates. These residuals would be the difference between rates fitted to the age-parity model and referenced to calendar years, $\hat{B}(x,n,t)$ and rates observed in those years B(x,n,t).

The third component represents fertility changes due to 'compensatory' fertility behavior on the part of cohorts. These are changes in the timing of births set in motion by earlier deviations from an average trajectory toward the family size goals. Evidence for the third component would be found in matrices of residuals referenced to cohorts, or $\hat{B}(x,n,T)$ -B(x,n,T).

In summary, the three components of the model of fertility change are respectively, a goals-related component, meaningful in cohort terms; a short-term timing component that embodies the impact of calendar-year influences on childbearing patterns; and another timing component that reflects endogenous cohort-specific corrections to prior timing adjustments.

This conceptual model of fertility change implies a high degree of reproductive rationality, that is, preferences on the part of couples as to approximately how many children they intend to have as well as a high degree of consistency, in the aggregate, between such fertility goals and their realization.[6]

TIME-SERIES ANALYSIS-- APPLICATIONS. Trends in parameter A(n,T) for women born during the period 1896-1945, shown in Table 1, exhibit three distinct patterns:

(1) Among low parity women, namely those with no children, one or two, the trends in A-values show a single cycle of change with a trough for Cohort 1906 (C.1906) and a subsequent peak for C.1930-1940.

(2)For women in parity classes of intermediate family size, the propensity to have a next child, despite year-to-year fluctuations, exhibits a general trend of stability until sharp declines that occurred beginning with recent cohorts.

(3) For women with the largest families, those with five children or more, the time-series shows fairly sustained reductions beginning with the earliest cohorts for which we have information on their likelihood of having yet another child. There have been periods in which the reduction accelerated, such as the current period.

The time-series analysis of A-values, in summary, shows parity selectivity in which trends in birth rates specific for parity of women have not followed parallel paths. Women with small families or those with no children have shown a high degree of reproductive responsiveness to exogenous factors, a point noted by Ryder.[7] Until recently, those women with families of moderate size showed relatively little variation over time in their birth rates. Women in the largest family size classes continue to exhibit vestiges of the 'demographic transition,' namely monotonically decreasing birth rates.

A significant departure from the historic pattern of parity selectivity occurred among women born around the mid-1930's. For those women and for subsequent cohorts, birth rates declined simultaneously among all parity classes of women. The reductions among all these women occurred at about the time that oral contraceptives were licensed and their wide-spread use began.[8]

Matrices of residuals were examined for evidence of timing effects of the two kinds postulated earlier, which are distinguished by being exogenous and related to events occurring in calendar years on the one hand, and by being endogenous and cohort-specific on the other. Both types of timing effects were evident in the analysis.

On a calendar-year basis, matrices of residuals $\hat{B}(x,n,t)-B(x,n,t)$ moved sharply upward and downward during certain periods. In those years, deviations from average rates consistent with the age-parity model were evident for almost the entire age-parity matrix. Thus, in 1955 about 85-percent of the residuals were positive suggesting an acceleration of childbearing coincident with high A-values among low parity women. In 1968, about the same proportion of residuals were negative, coinciding with a trend--this time downward-- in A-values.

When residuals are arrayed by cohort $\hat{B}(x,n,T)-B(x,n,T)$, they provide a clear indication of compensatory changes in fertility. The evidence is in the form of parity-specific 'runs' of excess and deficit births from averages expected on the basis of cohort-specific A-values. These represent respectively acceleration and reduction of birth rates around some average expected tempo of childbearing, consistent with cohort family size goals. Compensatory timing patterns of American women, according to the analysis, show considerable variation with respect to which parity classes of women are involved, how long a run will last, and its magnitude. A common pattern is one in which birth rates are elevated or depressed for a period of about ten years around the expected values, consistent with A(n,T). Deviations sustained at a level of 20-30 percent above or below the average, before dampening, are not at all unusual.

FERTILITY PROJECTIONS. The age-parity model provides a straight-foward approach to the projection of fertility, using the relation:

$$b(x+1,n,T)= -\hat{A}(n,T)\ln\left(\frac{x+1-m_1-\lambda n}{m_2-m_1}\right) \qquad (3)$$

in which the value of $\hat{A}(n,T)$ is estimated from the partial experience of a cohort subject to variation associated with timing effects. It can also be extrapolated from fertility trends in A-values of previous cohorts of women.

For example, women of C.1936, with three children (parity 3), had A-values of 0.223, 0.230, 0.234, 0.219, and 0.210 in the years 1958-1962, when they were aged respectively 22,23,24,25, and 26 years. This implied a downard trend in age-parity specific birth rates as well as continuation in the long-term downward trend in A-values that began with approximately C.1930. Using this series of A-values, we examined a number of ways in which to estimate a single A(3) suitable for projecting the age-parity specific birth rate for women aged 27 years in the 'projection' year 1963. Alternative tests included simple averaging and extrapolation with or without least squares. The best results in this instance of rapidly falling birth rates, were achieved by a simple averaging of the A-values for the two most recent years of the series. The projected value b(27,3,1936) was 0.175; the actual value was 0.171, a difference of about 2-percent. By this procedure, an entire matrix B(t), B(t+1),B(t+2),..., can be projected for women now in the childbearing ages. By extrapolating A(n,T) from the experience of young women, matrices can also be projected for women below the age of childbearing.

DISCUSSION. We believe that our understanding of fertility trends in the United States is facilitated by examining rates of childbearing specific for both age and parity of women. By doing so, one can partially isolate those components of change that seem to comprise fundamental shifts in family size goals from more temporary timing variations.

Demographers often disagree on the significance or interpretation of year-to-year changes in fertility rates. Some argue, for example, that the present decline in calendar-year rates to below 'replacement' levels adumbrate smaller families eventually. Others take exception to such interpretations.[9] Time-series analysis of fertility in terms of age-parity specific rates throws some light on the significance of these changes. It does this by making the distinction between trends in A-values which are most likely to eventuate in changes in completed family size and trends in the residuals which, as timing effects, are seen as being of much less consequence for eventual completed family size.

A number of observations emerge from the age-parity rate time-series analysis. The first is that the demographic transition in the United States has not run its course if by "post-transition" we mean that there are no significant trends in fertility in the U.S.[10] Reductions in A-values of high parity women show no evidence of slowing from their historic pattern. It is even possible that such reductions could eventually extend into lower reaches of the parity distribution.

Second, the age-parity model is not consistent with the interpretation that couples now respond to varying social and economic conditions in terms only of the timing of children.[11] Rather, trends in the A-values particularly of low parity women indicate no diminution in their cyclical behavior. It is, moreover, the level of the A-values of women with zero, one, or two children that contribute most to the eventual size of the completed families $\bar{P}(T)$. Evidence for the modification of family size associated with outside factors is clear in relation to both the depressed levels resulting from the Great Depression as well as the recoveries in family size coincident with the prosperity following the Second World War.

Trends in A-values also indicate the growing pervasiveness of the small family in this country. There has been a sharp reduction in the proportion of women with no children at all as well as the sustained decrease in the proportion of mothers with more than three children, a phenomenon noted by others.[12]

What are the implications of present fertility patterns for the eventual family size of women still having children? The logic of the age-parity model stresses that their completed family size goals are implicit in the early reproductive performance of cohorts of women. A basic pattern is established in early age-parity transition rates to which subsequent modification, constituting timing patterns, are made. Timing changes are of either an immediate sort, coincident with sharply impinging social and economic factors, or they are subsequent adjustments,lasting several years,to earlier deviations.

On this basis, then, trends in A-values, or more generally parity progression ratios, point unequivocally toward smaller families for women now having children. The current downturn in the fertility rates of American women appears to be on the order of past declines that also resulted in real reductions in the number of children per family.

The current decline in age-specific or age-parity specific rates does not represent merely a "negative distortion" in the tempo of current fertility, an interpretation offered earlier.[13] Additional evidence that the low and decreasing levels of the age-parity scale factors indicates a strong cyclical downturn in cohort fertility is provided by recent sample survey data on the birth expectations of young women.[14] Reported reductions in the total number of expected births to successive cohorts of wives aged 25-29 year, shown below, parallel actual declines in parity transition probabilities for these women:

Cohort Interviewed	Expected Total Number of Births	Cohort	Scale Factor
1938-42	3.04	1940	1.85
1942-46	2.62	1944	1.61
1945-49	2.34	1945*	1.51

* Most recent data available

The model of birth rates specific for age and parity of women may throw light on a further question, methodological in nature: this is the relation between period and cohort measures of fertility or what has been called the "translation" problem. The analysis indicates that measures of importance for understanding long-term trends in fertility have the cohort signature (T) rather than the period time referent (t). For projecting trends, period rates are less suitable than cohort rates. It is true that the cohort fertility experience is conditioned by and initiated within the context of a period time frame; but the analysis indicates that it proceeds thereafter largely as a cohort-parity specific process from which calendar-year rates can be extrapolated. The reverse is not true.

In conclusion, we believe that much can be gained from systematic analysis of birth rates specific for both age and parity of women. The present paper has shown how time-series analysis couched in these terms can contribute to an understanding of U.S. fertility trends and can provide an additional tool for projecting birth rates.

FOOTNOTES

1/ Parity refers to the number of children a woman has had. Zero parity women have had no children; one parity women, one child, etc.

2/ Harry M. Rosenberg and Ralph E. Thomas, "A Model of Birth Probabilities Specific for Age and Parity of Women," Proceedings of the American Statistical Association, Social Statistics Section, 1974, pp. 412-415.

3/ Norman B. Ryder,"The Recent Decline in the American Birth Rate," in E. Pohlman, editor, Population: A Clash of Prophets, New York: New American Library, 1973, condensed from a manuscript, August 1970, p. 22.

4/ U.S. Bureau of the Census, Current Population Reports, Series P-20, No. 277,"Fertility Expectations of American Women, June 1974," February 1975.

5/ E.g., R.A. Easterlin, " On the Relation of Economic factors to Recent and Projected Fertility Changes," Demography 3(1), 1967, pp. 131-153.

6/ See, for example, "An Economic Framework for Fertility Analysis," Studies in Family Planning 6(3), March 1975, pp. 54-63; Krishnan Namboodiri, " Some Observations on the Economic Framework for FertilityAnalysis," Population Studies, 26(2), July 1972, pp. 185-206; and Gary S. Becker," An Economic Analysis of Fertility," in National Bureau of Enomic Research, Demographic and Economic Change in Developed Countries, Princeton: Princeton University Press, 1960, pp. 209-240.

7/ Norman B. Ryder," The Emergence of a Modern Fertility Pattern, United States, 1917-1966," in S.J. Behrman, Leslie Corsa, Jr., and Ronald Freedman, editors, Fertility and Family Planning, A World View, Ann Arbor: University of Michigan, 1969, p. 105.

8/ Norman B. Ryder and Charles F. Westoff, "The United States: The Pill and the Birth Rate, 1960-1965," Studies in Family Planning 20, June 1967, pp.1-3.

9/ Arthur A. Campbell, "Beyond The Demographic Transition," Demography 11(4), November 1974, p. 549. June Sklar and Beth Berkov, "The American Birth Rate: Evidence of a ComingRise," Science 189, August 29, 1975, pp. 693-700.

10/ Ronald Lee, " Forecasting Births in Post-Transition Populations: Stochastic Renewal with Serially Correlated Fertility," Journal of the American Statistical Association 69 (347), September 1974, p. 607.

11/ Campbell, 1974, op.cit., p. 557.

12/ Norman B. Ryder, "The Time Series of Fertility in the United States," in International Union for the Scientific Study of Population, International Population Conference, London, 1969, Volume 1, London: International Union for the Scientific Study of Population, p. 589.

13/ Ibid., p. 590.

14/ U.S. Bureau of the Census, February 1975, op.cit., Table 1.

FIGURE 1. MATRIX [B(x,n)] OF BIRTH RATES SPECIFIC FOR AGE AND PARITY OF WOMEN AND DERIVED MEASURES: AGE-SPECIFIC BIRTH RATES AND PARITY PROGRESSION RATIOS

Parity of Woman (n)

$$
\begin{array}{c|ccccc|c}
 & 0 & 1 & 2 & \cdots & 7+ & \text{TOTAL Age-specific Fertility Rates} \\
\hline
14 & b_{14,0} & b_{14,1} & b_{14,2} & \cdots & b_{14,7+} & \sum_{n=0}^{7+} b_{14,n}p_{14,n} \\
15 & b_{15,0} & b_{15,1} & b_{15,2} & \cdots & b_{15,7+} & \\
16 & b_{16,0} & b_{16,1} & b_{16,2} & \cdots & b_{16,7+} & \\
\vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\
49 & b_{49,0} & b_{49,1} & b_{49,2} & \cdots & b_{49,7+} & \sum_{n=0}^{7+} b_{49,n}p_{49,n} \\
\hline
\text{TOTAL} & \sum_{x=14}^{49} b_{x,0}p_{x,o} & & & \cdots & \sum_{x=14}^{49} b_{x,7+}p_{x,7+} &
\end{array}
$$

Age of Woman (x)

(Parity Progression Ratios)

$b_{x,n}$ = Proportion of women aged (x) and in parity class (n) giving birth

$p_{x,n}$ = Proportion of women aged (x) and in parity class (n)

TABLE 1. SCALE FACTORS A(n,T) FOR BIRTH COHORTS OF AMERICAN WOMEN, 1896-1945

Cohort (Year of Birth)	Parity of Women							
	0	1	2	3	4	5	6	ABAR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1945	0.181	0.257	0.156	0.152	0.145	0.144	0.135	0.151
1944	0.191	0.268	0.159	0.147	0.142	0.164	0.151	0.161
1943	0.202	0.289	0.168	0.152	0.149	0.151	0.153	0.163
1942	0.221	0.304	0.181	0.160	0.158	0.156	0.152	0.169
1941	0.234	0.321	0.197	0.166	0.168	0.170	0.156	0.178
1940	0.238	0.333	0.211	0.180	0.179	0.171	0.162	0.185
1939	0.241	0.344	0.217	0.189	0.180	0.185	0.168	0.193
1938	0.252	0.352	0.226	0.198	0.192	0.192	0.184	0.204
1937	0.254	C.357	0.230	0.204	0.197	0.190	0.197	0.210
1936	0.263	0.359	0.231	0.205	0.203	0.200	0.178	0.208
1935	0.265	0.362	0.234	0.206	0.202	0.204	0.202	0.217
1934	0.267	0.363	0.233	0.209	0.204	0.208	0.192	0.215
1933	0.262	0.365	0.231	0.208	0.206	0.207	0.198	0.217
1932	0.242	0.362	0.227	0.210	0.208	0.209	0.211	0.221
1931	0.230	0.357	0.227	0.206	0.216	0.207	0.210	0.220
1930	0.236	0.352	0.224	0.211	0.211	0.212	0.227	0.227
1929	0.229	0.334	0.221	0.210	0.207	0.207	0.191	0.212
1928	0.226	0.325	0.219	0.210	0.218	0.215	0.218	0.223
1927	0.218	0.316	0.215	0.214	0.221	0.228	0.205	0.221
1926	0.226	0.302	0.212	0.211	0.223	0.226	0.239	0.231
1925	0.236	0.296	0.208	0.210	0.216	0.230	0.237	0.230
1924	0.236	0.289	0.204	0.205	0.214	0.221	0.236	0.226
1923	0.222	0.280	0.196	0.200	0.205	0.222	0.238	0.223
1922	0.223	0.261	0.192	0.202	0.211	0.221	0.229	0.220
1921	0.218	0.255	0.193	0.204	0.215	0.239	0.230	0.225
1920	0.221	0.252	0.195	0.206	0.222	0.238	0.214	0.221
1919	0.199	0.251	0.197	0.209	0.220	0.247	0.222	0.225
1918	0.175	0.244	0.198	0.215	0.224	0.244	0.254	0.235
1917	0.165	0.238	0.196	0.212	0.217	0.235	0.194	0.210
1916	0.157	0.230	0.193	0.214	0.217	0.338	0.267	0.233
1915	0.150	0.223	0.192	0.209	0.215	0.227	0.262	0.229
1914	0.150	0.217	0.189	0.209	0.210	0.233	0.213	0.213
1913	0.148	0.209	0.184	0.210	0.217	0.218	0.229	0.215
1912	0.142	0.204	0.185	0.208	0.206	0.227	0.232	0.215
1911	0.133	0.202	0.185	0.205	0.208	0.236	0.187	0.202
1910	0.129	0.198	0.184	0.207	0.207	0.230	0.177	0.197
1909	0.126	0.190	0.180	0.204	0.200	0.246	0.206	0.208
1908	0.132	0.190	0.179	0.205	0.205	0.229	0.203	0.204
1907	0.132	0.186	0.180	0.205	0.208	0.230	0.203	0.205
1906	0.133	0.186	0.184	0.207	0.210	0.237	0.201	0.207
1905	0.138	0.189	0.185	0.212	0.210	0.234	0.202	0.207
1904	0.143	0.197	0.189	0.209	0.205	0.233	0.232	0.217
1903	0.147	0.201	0.195	0.211	0.205	0.245	0.228	0.219
1902	0.146	0.204	0.205	0.215	0.192	0.255	0.245	0.227
1901	0.145	0.216	0.216	0.224	0.203	0.264	0.251	0.235
1900	0.147	0.226	0.221	0.232	0.205	0.267	0.293	0.252
1899	0.154	0.229	0.223	0.235	0.201	0.272	0.308	0.258
1898	0.161	0.223	0.220	0.232	0.208	0.268	0.340	0.269
1897	0.158	0.229	0.227	0.233	0.210	0.274	0.345	0.273
1896	0.161	0.239	0.233	0.234	0.213	0.273	0.354	0.277