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Source: *The Review of Economics and Statistics*, Vol. 54, No. 4 (Nov., 1972), pp. 374-380
Published by: The MIT Press
Stable URL: http://www.jstor.org/stable/1924564
Accessed: 25/06/2014 09:50

A SIMULTANEOUS EQUATION MODEL OF BIRTH RATES IN THE UNITED STATES

Paul R. Gregory, John M. Campbell and Benjamin S. Cheng *

I Introduction

IN a recent paper on population policy, Glen G. Cain concludes that the "... feasibility of attaining a benign rate of population growth ... rests on limited scientific evidence." [1]

In this paper, we attempt to add to our store of knowledge concerning population growth by estimating a simultaneous equation model of birth rates in the United States. Our model is based on time-series data for the United States covering the 1910 to 1968 period and consists of four separate equations: a birth rate equation, a permanent income equation, an infant mortality equation, and a female labor participation rate equation. Two variants of the total model are reported; the first is based on the two-stage regression procedure and the second variant is based on three-stage least squares. In both cases, elasticity multipliers are computed as a guide to policy decision making. In general, the two approaches yield quite similar results; nevertheless, there are some differences — therefore, the dual approach. Our data are generally unadjusted and should therefore reflect both secular and cyclical patterns. The major exception to this rule is our use of permanent rather than measured income for reasons outlined below.

II The Importance of Simultaneous Systems

The impact of economic variables upon birth rates has been a controversial issue ever since the classical economists postulated a positive relationship between per capita income and fertility. Past empirical evidence, based largely upon cross-section evidence, fails to deal adequately with some crucial issues concerning the fertility equation. We have reviewed this past empirical research elsewhere,[2] and the reader is also referred to Simon's excellent survey article on the subject.[3] Instead, we shall concentrate in this section on the problems involved in developing a simultaneous equation model of fertility from time-series evidence. The rationale for the use of a simultaneous system has already been discussed elsewhere,[4] but we would like to reemphasize the reasons for the simultaneous equation approach when dealing with fertility determination.

As Simon suggests in his survey article,[5] impacts of selected economic variables on birth rates can only be gauged by taking into account both the direct and indirect effects of these variables. For example, in our model we suggest that the level of education will have a negative effect on the birth rate; yet education itself affects other variables which themselves influence fertility decisions. Thus, the level of education will affect the rate of infant mortality, and changes in the rate of infant mortality influence the birth rate. Therefore, to determine the total impact of education on fertility, both its direct and indirect effects must be measured. This is accomplished by dealing with the entire system of interrelationships rather than with a single relationship.

III The Model

1) *The Fertility Equation*

Our postulated four-equation model follows past research, to a great extent. Let us begin with the crucial fertility equation: We postulate that the United States birth rate is a function of the following explanatory variables: (a) per capita permanent income (b) the female

Received for publication December 3, 1971. Revision accepted for publication May 12, 1972.

* The authors thank the Department of Economics and the Bureau for Business and Economic Research of the University of Oklahoma for assistance, and also thank Dr. C. K. Liew for his comments on an earlier draft.

[1] Glen G. Cain, "Issues in the Economic Theory of a Population Policy for the United States," *American Economic Review*, Papers and Proceedings, May 1971, p. 416.

[2] Paul Gregory, John Campbell, Benjamin Cheng, "A Cost-Inclusive Simultaneous Equation Model of Birth Rates, *Econometrica* (forthcoming, 1972).

[3] Julian Simon, "The Effect of Income on Fertility," *Population Studies*, 23 (Nov. 1969).

[4] B. Okun, "The Birth Rate and Economic Development: A Comment," *Econometrica*, 33 (Jan. 1965), p. 245.

[5] Julian Simon, op. cit., p. 329.

labor participation rate (c) infant mortality (d) education (e) the unemployment rate and (f) the percentage of non-white population. Thus, our fertility equation is

$$X_0 = F_0 (X_1, X_2, X_3, X_4, X_5, X_6) \quad (1)$$

where

- X_0 refers to the crude birth rate, which is defined as the number of live births per 1000 population in the United States.
- X_1 refers to per capita permanent income in 1958 United States dollars.
- X_2 refers to the female labor participation rate in the United States, which is defined in detail in the appendix.
- X_3 refers to infant mortality in the United States, which is defined as the number of deaths under one year of age per 1000 live births.
- X_4 refers to the education of the United States population, which is measured by the median number of school years of United States population.
- X_5 refers to the national unemployment rate, defined according to Department of Commerce definitions.
- X_6 refers to the percentage of non-white population in the United States.

Further definitional details and data sources are outlined in the appendix for these and other variables used in this study.

The inclusion of most of these variables in the birth rate equation has been justified elsewhere.[6] Nevertheless, we briefly outline the rationale for each: Per capita income is included because changes in income will alter the family's budget constraint and thus create an income effect on fertility, which is assumed to be positive. We opt for per capita *permanent income* rather than measured income for the same reasons that permanent rather than measured income is included as an argument in the aggregate consumption function,[7] i.e., a family's fertility decisions will be based more on its estimate of average income over a period of time rather than on current income. Thus, we assume that a family with low-measured but relatively high permanent income will exhibit a fertility pattern which differs from a family with both low-measured and permanent income.

We have argued for the inclusion of the female labor participation rate elsewhere,[8] and we find added support in the recent literature. Thus, Cain [9] argues that the "single most important price associated with children appears to be the price of the mother's time." A significant cost of fertility is the resulting lowering of female labor participation. The new mother must withdraw from the labor force in order to deliver and care for the new family member, and her loss of earnings will be a significant factor in the fertility decision. This is not the sole cost (price) of fertility, but it is a significant one and one which can be measured empirically. Other costs such as the cost of child care, child raising, and education are difficult to measure,[10] especially over time, and will not be included in our model, perhaps at the expense of some specification error.

The argument in favor of the inclusion of infant mortality is that infant mortality will reflect the replacement needs of the family for children. A high infant mortality rate will cause the family to attempt to have more children to replace those lost. It is our view that this effect would be more prominent in a more traditional agriculture-oriented society than in a mature industrial economy like that of the United States where the extended family system is not operative and the child cannot be employed as an agricultural worker. We include it, nevertheless, but we expect its impact to be small.

The inclusion of education is justified on the grounds that education will affect not only the family's utility function concerning additions to the family but also will affect the family's ability to enforce such decisions insofar as some education is generally required to acquaint oneself with and practice birth con-

[6] Gregory, Campbell, Cheng, op. cit., Robert Weintraub, "The Birth Rate and Economic Development," *Econometrica* (Oct. 1962), pp. 812–817. Irma Adelman, "An Econometric Analysis of Population Growth," *American Economic Review*, 53 (June 1963), pp. 315–339.

[7] Milton Friedman, *A Theory of the Consumption Function* (Princeton: Princeton University Press, 1957).

[8] Gregory, Campbell, Cheng, op. cit.

[9] Cain, op. cit., p. 412.

[10] Cain estimates that the total cost of one child in the United States including opportunity costs is around $31,000. Cain, op. cit., p. 412.

trol techniques, especially in the absence of government sponsored educational programs.

The unemployment rate is included as an indicator of the degree of uncertainty in the economy. It is postulated that a high level of unemployment will cause the family to give up plans to have children insofar as the family's ability to support and maintain such children is in question. As far as we are aware, the available literature on fertility has yet to consider the uncertainty factor.

Finally, the percentage of non-white population is included because of the observed higher birth rates among the non-white population than the white.[11] In including this variable, we are assuming that the reasons for the higher non-white fertility rates will not be fully found through the impact of lower non-white income and education and higher non-white infant mortality on the aggregate income, education and infant mortality figures.

2) *The Permanent Income Equation*

To specify the per capita permanent income equation for the United States, we follow the standard permanent income hypothesis [12] that a family's evaluation of its permanent income will depend upon its current income and its expectations concerning its future earning capacity. We suggest that the average wage rate and the female labor participation rate will serve as indicators of current earning capacity. The latter is included as an indicator of the degree to which there is more than one income earner per family. Expectations concerning the family's future earning capacity will be reflected in the level of education and by uncertainty concerning future employment opportunities, which, we suggest, is best indicated by the national unemployment rate. Thus, our per capita permanent income equation is

$$X_1 = F_1\,(X_2, X_4, X_5, X_9) \qquad (2)$$

where

X_9 refers to the average wage rate, defined as the average wage rate in manufacturing. The other variables are identified above and in the data appendix.

[11] *Statistical Abstract of the United States* (selected years).

[12] Friedman, op. cit.

3) *The Female Labor Participation Rate Equation*

We include four explanatory variables in the female labor participation equation. The birth rate is included in line with arguments made above: As the birth rate increases, new mothers must withdraw from the labor force to devote themselves to child care and child raising. Thus, we postulate a negative (*ceteris paribus*) relationship between the birth rate and the female labor participation rate in the United States. We stress the *ceteris paribus* nature of this relationship because other factors account for variations in female labor participation as well. In particular, a higher wage rate can both attract females into the labor force and lead them to limit family size.[13] Thus, in the United States, we have experienced periods of rapid increases in the female labor force during periods of rising birth rates as women were attracted into the labor force by rising wage rates. A further factor in female labor participation is the percentage of non-white population. Empirical studies of the United States labor force have shown that the levels of participation among black wives are higher than among the white population and that children are less of a deterrent to entering the labor force among the black female population.[14] Finally, the age structure of the female population is suggested as an explanatory factor because an age structure skewed in the direction of prime working ages will lead, *ceteris paribus*, to a higher participation rate in the labor force. Thus, our model of the female participation equation is

$$X_2 = F_2\,(X_0, X_6, X_7, X_9) \qquad (3)$$

where

X_7 refers to the age structure of the female population of the United States, which is defined as the percentage of female population between 14 and 44 years of age.

The other variables are defined above and in the data appendix.

4) *The Infant Mortality Equation*

Our infant mortality model includes four explanatory factors. We postulate that the rate

[13] Jacob Mincer, "Labor Force Participation of Married Women," *Aspects of Labor Economics* (Princeton: Princeton University Press, 1962).

[14] Glen G. Cain, *Married Women in the Labor Force*, (Chicago: Chicago University Press, 1966), pp. 119–120.

of infant mortality depends on the family's financial ability to purchase health care, which is reflected by its permanent income, by its knowledge concerning hygiene techniques and health care within the family, which is reflected by the level of education of the parents, and finally by the availability of health care. A further factor in explaining infant mortality in the United States is the percentage of non-white population, owing to the markedly higher infant mortality rates among the black population. Our model of infant mortality therefore is

$$X_3 = F_3\ (X_1, X_4, X_6, X_8) \tag{4}$$

where

X_8 refers to the availability of health care service. Our proxy for health care services is the number of hospital beds per 1000 population. The other variables are identified above and in the data appendix.

III The Regression Results

The simultaneous equation system described above was estimated from annual data for the United States encompassing the 1910 to 1968 period. In the case of the female participation rate, it was necessary to extrapolate between 10 year benchmarks up to 1920 assuming exponential change. In all four equations, linear functional forms were assumed. Two of the four equations — the infant mortality equation and the permanent income equation — are subject to significant time trends; therefore the estimated regression equations yield high coefficients of multiple determination in the second stage.[15] The other two — the birth rate equation and the female participation equation — are not subject to definite secular time trends, although the female participation rate does rise steadily during the postwar period. Thus, the coefficients of multiple determination (see previous note) tend to be lower.

We relate our regression results in two ways: First, we present the estimated models in the traditional manner by detailing the estimated coefficients and their standard deviations and t values. In the text, we relate the second-stage regression results in which the coefficients are estimated by entering the predicted values of the endogenous variables as independent variables in the second stage. As outlined in the equation system above, the *exogenous* variables are: Education, percentage of non-white population, the wage rate, the unemployment rate, the age structure, and the supply of health services.[16]

The *endogenous* variables are: the birth rate, per capita permanent income, the female labor participation rate, and infant mortality. In the table notes we present the third stage "efficient" estimators.[17] We stress the second stage over the third stage results because the latter tend to be more heavily affected by specification error and will be unbiased only if all equations are adequately specified. In most cases, however, the differences between second and third stage results are minimal however.

Second, we present the reduced form of the equation system. Rather than presenting the reduced form "static multipliers" directly, we compute what we call the "elasticity multipliers" of the reduced form. The elasticity multipliers indicate the percentage change in the endogenous variable caused by a given percentage change in an exogenous variable when both the *direct* and *indirect* effects of the exogenous variable are considered.

For example, the elasticity multiplier of the birth rate (X_0) with respect to the percentage of non-white population (X_6) in table 2 is 1.575. This is defined as $\partial X_0/\partial X_6 \cdot X'_6/X'_0$ where X'_0 and X'_6 refer to the sample average values. Thus, a one per cent increase in the ratio of the non-white population to the total population would be expected to increase the birth rate by 1.575 per cent if both the direct and indirect effects of X_6 are considered. Let us now turn to the empirical results. The second-stage regression results are given in table

[15] The second stage coefficients of multiple determination are estimated using instrumental variables. There is considerable question as to how meaningful such measures are. We thus pay little attention to them.

[16] The choice of exogenous variables is a difficult and crucial one in such a model. In this case, a crucial choice was made to consider education as an exogenous rather than endogenous variable. Simon (1969) argues that education is actually a function of income. We argue, however, that education (as we measure it by median number of years of education) is essentially a policy variable controlled by government.

[17] A discussion of the second and third stage estimation procedures used in this study is found in C. Liew and D. Kahng, *Computerized Econometric Models*, Bureau for Business and Economic Research, University of Oklahoma (Aug. 1971).

1 and the third-stage results are recorded in the accompanying footnote.

TABLE 1. — ESTIMATED REGRESSION MODEL [a]

(1) Birth Rate

$$X_0 = 0.8905 + 0.0206\ X_1 - 0.7407\ X_2 - 0.0378\ X_3 - 3.4130\ X_4 - 0.0738\ X_5 + 4.8700\ X_6$$
$$\quad (8.8180)\ (0.0159)\ (0.4009)\ (0.0583)\ (1.6070)\ (0.1852)\ (1.5330)$$

$R^2 = 0.7423$ (based on instruments)

(2) Per Capita Permanent Income

$$X_1 = -264.9000 + 14.7900\ X_2 + 92.6600\ X_4 - 11.1600\ X_5 + 8.5940\ X_9$$
$$\quad (57.1400)\ (5.8970)\ (16.7800)\ (1.6250)\ (5.6270)$$

$R^2 = 0.9604$ (based on instruments)

(3) Female Labor Participation Rate

$$X_2 = -0.1067 - 0.6399\ X_0 + 4.9810\ X_6 - 0.4224\ X_7 + 0.5363\ X_9$$
$$\quad (23.6800)\ (0.1643)\ (1.4310)\ (0.2770)\ (0.2948)$$

$R^2 = 0.6961$ (based on instruments)

(4) Infant Mortality

$$X_3 = 67.1300 - 0.0044\ X_1 - 13.2400\ X_4 + 11.5300\ X_6 - 3.8630\ X_8$$
$$\quad (28.7300)\ (0.0094)\ (1.1970)\ (2.4470)\ (0.6691)$$

$R^2 = 0.9688$ (based on instruments)

[a] The third-stage results are given below:

(1) $$X_0 = -7.0480 + 0.0371\ X_1 - 1.3070\ X_2 - 0.0420\ X_3 - 3.073\ X_4 + 0.1660\ X_5 + 4.929\ X_6$$
$$\quad (8.1220)\ (0.0135)\ (0.3413)\ (0.0532)\ (1.3920)\ (0.1532)\ (1.3740)$$

(2) $$X_1 = -276.9000 + 16.7900\ X_2 + 85.4900\ X_4 - 8.9240\ X_5 + 8.7810\ X_9$$
$$\quad (55.0900)\ (5.4830)\ (15.6200)\ (1.5230)\ (5.1890)$$

(3) $$X_2 = -5.8220 - 0.69400\ X_0 + 5.4370\ X_6 - 0.3739\ X_7 + 0.3973\ X_9$$
$$\quad (22.4400)\ (0.1606)\ (1.3680)\ (0.2593)\ (0.2584)$$

(4) $$X_3 = 74.7200 + 0.0036\ X_1 - 14.2900\ X_4 + 10.9000\ X_6 - 3.6550\ X_8$$
$$\quad (27.4500)\ (0.0092)\ (1.1790)\ (2.3370)\ (0.6273)$$

The estimated model (table 1) conforms well to our a priori expectations. Adopting a 10 per cent significance level, we note that the female labor participation rate coefficient, the education coefficient, and the non-white ratio coefficient are all statistically significant, and their signs tend to confirm the theoretical arguments made above. The same is true of the third-stage results in the footnote. The infant mortality and unemployment rate coefficients are highly insignificant. The insignificance of the former is not unexpected as was explained above. The per capita permanent income coefficient exceeds its standard deviation yet fails to meet the 10 per cent significance test in the second stage. In the third stage, it becomes significant at the 10 per cent level. It should be noted that the sign of the income coefficient is positive, which is in keeping with the theory of consumer choice outlined above.

We will not discuss in detail the other three estimated equations. We only point out that the signs and significance levels of the estimated coefficients all conform to a priori expectations with the possible exception of age structure, which is insignificant at the 10 per cent significance level. We feel that we have succeeded well in specifying both the infant mortality equation and the per capita permanent income equation. The significant non-white ratio coefficient in both the female participation and infant mortality equations should be accorded special attention. Another point worthy of note is the significant impact of education and the supply of health services (hospital beds) on infant mortality.

We turn now to the elasticity multipliers (table 2), which include both the direct and indirect impacts of the exogenous variables upon the endogenous variables:

TABLE 2 [a]. — ELASTICITY-MULTIPLIER COEFFICIENTS (SECOND STAGE)

	Ratio Non-white (X_6)	Unemployment Rate (X_5)	Wage Rate (X_9)	Education (X_4)	Age Structure (X_7)	Hospital Beds (X_8)
Birth Rate (X_0)	1.575	−0.125	−0.004	−0.496	0.395	0.071
Permanent Income (X_1)	0.583	−0.056	0.025	1.018	−0.359	−0.017
Female Participation (X_2)	1.218	0.065	0.026	0.260	−0.749	−0.037
Infant Mortality (X_3)	2.489	0.004	−0.001	−2.180	0.026	−0.597

[a] Elasticity-multiplier Coefficients (third stage).

	(X_6)	(X_5)	(X_9)	(X_4)	(X_7)	(X_8)
X_0	1.577443	−0.0953504	0.005931	−0.318988	0.755489	−0.098540
X_1	0.726087	−0.041308	0.021007	0.923520	−0.494894	0.030537
X_2	1.334317	0.053249	0.014746	0.181659	−0.909458	0.056117
X_3	2.436299	−0.002453	0.001247	−2.219225	−0.029391	−0.564884

Looking first at the elasticity-multipliers in the birth rate equation, we find that the non-white ratio (X_6), education (X_4) and age structure (X_7) have the largest direct and indirect impacts on the birth rate. The only elastic elasticity-multiplier is the non-white ratio (1.575). The education elasticity-multiplier of -0.496 indicates that a one per cent increase in the education variable will cause a 0.5 per cent reduction in the birth rate. We concentrate on the education variable because we feel it is a true policy variable subject to government control. The unemployment elasticity-multiplier is small and negative (-0.125). The other elasticity-multipliers in the birth rate equation are negligible.

In the other equations (which are not discussed in detail), we note the significant direct and indirect impacts of both education and the non-white ratio. As an example, we single out the very large negative education elasticity-multiplier in the infant mortality equation. Also the provision of health services (hospital beds) seems to have an important negative effect on infant mortality.

We would also like to gauge the impact of the endogenous variables upon the birth rate. To do so, we compute what we call "intercept-elasticities,"[18] which are computed from the reduced form. Thus the intercept-elasticity of the birth rate with respect to per capita permanent income would be interpreted as the percentage change in the birth rate caused by a given percentage change in the intercept of the income function. We relate the intercept-multipliers of the endogenous variables in table 3:

TABLE 3. — INTERCEPT-MULTIPLIERS: BIRTH RATE WITH RESPECT TO:

	Second Stage	Third Stage
Per Capita Permanent Income	0.792	1.431
Female Labor Participation Rate	−0.684	−0.828
Infant Mortality	−0.086	0.095

[18] Gregory, Campbell, Cheng, op. cit.

Thus, we see that the impact of an upward shift in the income function has a fairly large impact upon the birth rate. An upward shift in the income function intercept of one per cent will cause a 0.792 (second stage) per cent increase in the birth rate. The positive impact is even larger when measured using the third-stage results. The same is true of intercept shifts in the female participation rate function where an upward shift in the intercept of one per cent will cause a 0.684 (second stage) reduction in the birth rate. The impact of changes in the infant mortality intercept is much smaller. The large positive income intercept-multipliers lend support to the positive effect of income on the birth rates.

IV Conclusions

Our simultaneous equation model of the United States birth rates is designed to account for both direct and indirect effects which selected variables have upon fertility rates. In particular, our regression results single out the important roles played by education, the female participation rate, permanent income and the ratio of non-white population in the determination of fertility. The possible uses of this model for policy purposes — in particular the reduced form multipliers — remain to be investigated, but education and female labor participation seem to qualify as likely policy variables. This four-equation model is suggested as a step forward in the area of population research, which could be improved upon in several ways in a more sophisticated model. In particular, it might prove interesting to introduce distributed lags to pinpoint the timing of impacts upon birth rates. Second, it might prove worthwhile to expand the model to include more endogenous variables. Third, in view of the importance of education on fertility determination, it would be interesting to deal with breakdowns by type of education rather than using the rather crude measures used in this model.

APPENDIX

1) Live birth rate is the number of live births per 1000 population. Sources: *Historical Statistics of the United States.* U.S. Department of Commerce, 1961 and *Statistical Abstract of the U.S.*, Various Years, U.S. Department of Commerce.
2) *Per Capita Permanent Income* (X_1): per capita permanent income in 1958 United States dollars is calculated from per capita income with trend factor ($\alpha = 0.014$) and uncertainty factor ($\beta = 0.114$) *Long-Term Economic Growth*, U.S. Department of Commerce, 1966, and *Survey of Current Business*, Jan. 1967–Jan. 1969.
3) *Female Labour Force* (X_2): the sum of the employed and unemployed women 14 years of age or over. "Employed persons comprise all women who, during that week, did any work for pay or profit, worked 15 hours or more as unpaid workers in a family enterprise; or did not work but had jobs or businesses from which they were temporarily absent. Unemployed persons comprise all persons not working during the survey week who had made specific efforts to find a job within the past four weeks and who were available for work, and persons who were on layoff from a job or waiting to report to a new job within 30 days." *Statistical Abstract of the U.S.*, 1967, p. 218. Source: *Statistical Abstract of the U.S.* (various years).
4) *Infant Mortality* (X_3): the number of deaths under one year of age per 1000 live births. Sources: *Demographic Yearbook* (various years), United Nations and *Statistical Abstract of the U.S.* (various years).
5) *Education* (X_4): median number of years of school completed by the adult population. Source: *Statistical Abstract of U.S.*, 1950–1970. *Census of Population*, 1910, 1920, 1930, 1940, remaining years by intrapolation.
6) *Ratio of non-white population* (X_6): percentage of black in total United States population. Source: *Statistical Abstract of the United States* (various years).
7) *Unemployment Rate* (X_5): see female labour force definition. Source: *Long-Term Economic Growth*, U.S. Department of Commerce, 1966, and *Statistical Abstract of U.S.*, 1967 and 1968.
8) *Age Structure* (X_7): population 14 to 44 years of age. Source: *Long Term Economic Growth*, U.S. Department of Commerce, 1966, and *Statistical Abstract of U.S.*, 1967 and 1968.
9) *Hospital Beds* (X_8): A proxy for medical care. It is measured by the number of hospital beds per 1000 population. Source: Computed from *Statistical Abstract of the U.S.* (various years).
10) *Average Wage Rate* (X_9): the average hourly wage rate in manufacturing. Source: *Historical Statistics of the United States*, *Statistical Abstract* (selected years).

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