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A MICROECONOMIC ANALYSIS OF THE TIMING OF BIRTHS

Alessandro CIGNO

University of Pisa, 56100 Pisa, Italy

John ERMISCH

NIESR, London SW1P 3HE, UK

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The effects of personal characteristics, wage rates and career structures on the time-profile of childbearing among married couples are examined theoretically, through an intertemporal microeconomic model of family decisions, and empirically, by an econometric analysis of British women's childbearing and work histories. The effects of the mother's age on the 'quality' of the child, and the financial implications of interrupting the mother's career to care for a child are taken explicitly into account. The demographic consequences of economic policies are also examined.

1. Introduction

The focus of economic analyses of fertility is beginning to shift from the study of 'completed fertility' (the total number of children born to a woman) to that of the 'tempo of fertility' (the distribution of births over a woman's lifetime). The main reason for this change of emphasis is that, at the very low levels of completed fertility now reached by most western countries, fluctuations in the 'period' birth rate (births per unit of time) are overwhelmingly associated with changes of tempo.[1] Any attempt at explaining these, often very marked, fluctuations and the way in which they might be affected by government policy must thus begin with a dynamic theory of parental decisions.

Another reason for being interested in a dynamic theory of family decisions is that a large proportion of the available micro-data on employment, fertility and expenditure concern families which have not yet completed their reproductive cycle. In other words, only a fraction of the available data gives information about completed fertility. It is thus desirable to have a theory which predicts how many children a family will have *at any point in its life cycle*, because only such a theory can actually explain the available data. That, however, is far from easy to accomplish, because both the

[1] See, for example, Hopflinger (1984), Muñoz-Perez (1986).

marginal cost and the marginal utility that parents derive from an extra child depend on the dates of birth of *all* their children, as well as on the timing of saving and labour participation decisions. Further complications arise from 'technological' uncertainty about the effectiveness of fertility controls and the personal characteristics of the child to be born, as well as 'market' uncertainty about future prices, wages, taxes, etc. For these reasons, truly dynamic analyses of birth timing have been late coming.

Earlier studies have tried to capture aspects of the timing decision within an essentially static model: Razin (1980) postulates that parents-to-be simultaneously choose the number and the average interval between births, under the assumption that the 'quality'[2] of the average child is an increasing function of the length of that interval; Schultz (1976) and Lee (1980) use a stock-adjustment model in which the speed of adjustment to the desired number of children is not derived from intertemporal optimisation. Explicitly dynamic theoretical models, on the other hand, have tended to make drastic simplifications to the decision framework. Cigno (1983) assumes that timing decisions are taken entirely on the basis of financial considerations. Happel et al. (1984) restrict their attention to the timing of the first birth, taking the time-profile of subsequent births as given. Similarly, econometric analyses such as Moffitt (1984) or Rosenzweig and Schultz (1985) assume that the birth profile by woman's age or by marriage duration is independent of economic variables. Others, such as Newman and McCulloch (1984), concentrate on the stochastic aspects of the problem at the expense of almost any other consideration.

A richer set of dynamic interrelations is analysed in a recent theoretical study, Cigno (1988). While not attempting to model uncertainty, the paper in question allows for the quality of a child or, more generally, for the utility that parents derive from a child to depend on both the age of the mother at the date of birth of the child and the amount of resources expended on the same. Furthermore, it takes account of the interrelations between the time-patterns of childbearing and maternal earnings, and explicitly recognises the simultaneous nature of the parents' lifetime consumption, employment and reproduction plans. In the present paper, we discuss the assumptions on which the theory is based, and compare its predictions with family-building and work patterns observed among British women.

2. Theoretical analysis

2.1. The decision framework

The economic model of the family describes the demand for children as the

[2]The term 'quality' is used here in the New Home Economics sense of parental perception of the quality of life awaiting the child.

outcome of the optimising decisions of parents, whose objective is to maximise a utility function,

$$U=U(C,B), \tag{1}$$

where C is an index of parental consumption of market goods and B a quality-weighted index of the number of children.[3] The quality of a child is, in general, a function of the quantities of time and financial resources expended on the child by the parents, and may be interpreted as the parental perception of the child's lifetime utility. If this interpretation is followed, the function $U(\ )$ can be read as a family welfare function.

Cigno (1988) introduces timing considerations in the model by defining

$$C=\sum_{t=a}^{T} u_t(C_t), \qquad \text{and} \tag{2}$$

$$B=\sum_{t=a}^{T} v_t(I_t)B_t, \tag{3}$$

where C_t and B_t denote, respectively, parental consumption and the rate of birth at t, while I_t is the present value at t of the optimally timed stream of voluntary parental expenditures (including any bequests) on a child born at date t, a is the exogenously given date of mariage, and T is the date of death (also exogenous and assumed to be the same for both parents). The functions $u_t(\cdot)$, assumed to be increasing and concave, and dated to allow for possible time-preference, are 'instantaneous' utility functions. The functions $v_t(\cdot)$, also increasing, concave and dated to allow for lifecycle variations in the parents' willingness and ability to have children, represent parental perceptions of their children's (indirect) utility functions. Thus, $v_t(I_t)$ is the parent's assessment of the lifetime utility of a child born at t, given that the child has been allocated a lump-sum (or equivalent payment stream) I_t.

A simplifying assumption implied by the absence of parental time from among the arguments of $v_t(\cdot)$, is that a certain minimum amount of specifically maternal time is absolutely required over the first period of a child's life (suitably extended to include an appropriate portion of the pregnancy period), but that income expenditure is a perfect substitute for maternal and paternal time in all subsequent periods. The length of this crucial first period is taken as the unit of time of the analysis and conventionally referred to as the year. Taking leisure as given, as is common

[3] See Willis (1973). More general formulations, e.g. Becker (1981) or Cigno (1986), have quality and quantity entering the utility function as separate arguments.

practice in the fertility literature, the father's labour supply is then simply equal to his work capacity, while the mother's is given by

$$L_t = m - B_t, \tag{4}$$

where m is her annual work capacity, expressed as a multiple of the minimum amount of time required for each child.

The woman's wage rate in year t is given by

$$W_t = K_t w, \tag{5}$$

where K_t is her stock of human capital at t, and w is the (real) market rate of return to human capital. Human capital is supposed to accumulate with work experience, so that

$$K_t = K_a + \beta \sum_{\tau=a}^{t-1} L_\tau, \tag{6}$$

where β is a positive constant. K_a will depend on the woman's natural talent, education and premarital work experience. The husband's wage rate will be determined by a similar mechanism, the only difference being that his work experience is independent of the number and time-distribution of births, while hers depends crucially on both.

Keeping in mind that any bequests made to a child born at t are included in I_t, and assuming that the family can borrow or lend any amount they wish at the real interest rate r, we can then write the parents' lifetime budget constraint as

$$\sum_{t=a}^{T} \{B_t(q+I_t)+C_t\}(1+r)^{a-t} = A_a + \sum_{t=a}^{T} L_t W_t (1+r)^{a-t}, \tag{7}$$

where q is the fixed cost of a child, defined as the sum of all unavoidable expenditures associated with childbirth, plus the minimum cost of supporting the child, and A_a is the couple's stock of wealth at marriage, defined as financial assets, plus the present value at marriage of the husband's lifetime earnings.

2.2. *Intertemporal efficiency*

A sequence of birth and expenditure rates $\{B_t, C_t, I_t\}$ which maximises (1) subject to (7)[4] will satisfy the dynamic conditions

[4]In addition to the budget constraint, there are nonnegativity restrictions on all the choice variables and on L_t, plus the condition that B_t must be an integer and cannot exceed some physiological maximum. However, like most of its predecessors, this model seeks to explain the average experience of a large number of couples with common characteristics *as if* it were the outcome of a single optimising decision by the group as a whole. It thus seems legitimate to assume that, on average, these additional constraints are not binding.

$$(u'_t - u'_{t+1})/u'_{t+1} = r, \tag{8}$$

$$(v'_t - v'_{t+1})/v'_{t+1} = r, \quad \text{and} \tag{9}$$

$$\{(P_{t+1}/v_{t+1}) - (P_t/v_t)\}/(P_t/v_t) = r, \quad \text{where} \tag{10}$$

$$P_t \equiv q + I_t + W_t + \beta w \sum_{\tau=t+1}^{T} L_\tau (1+r)^{t-\tau}. \tag{11}$$

Being the sum of the three costs associated with the birth of a child in year t,

(i) an actual disbursement, $(q+I_t)$,
(ii) a loss of earnings, as the mother becomes temporarily unavailable for employment, W_t,
(iii) a loss of future earning potential (evaluated at date t), as the mother has to forego an increment in her stock of human capital,

$$\beta w \sum_{\tau=t+1}^{T} L_\tau (1+r)^{t-\tau},$$

the endogenously determined variable P_t represents the 'price' that parents must pay in order to have a baby at t. But, since B_t is equal to the amount of time expended on child-raising activities in year t, we can also interpret P_t as the full opportunity cost of a unit of time spent at home by the woman in year t.

Eqs. (8) and (9) are applications of the familiar *Ramsey–Keynes Rule* that the marginal utility of expenditure must decline at the rate of interest. Eq. (10) is easily recognisable as the *Hotelling Rule*, according to which a natural resource must be extracted at such a rate, that its price will grow at the rate of interest. The resource being 'extracted', in the present case, is the mother's time supplied to the labour market and, therefore, diverted from child raising activities where it would attract the quality-adjusted price P_t/v_t.

It should be noted that the rules in question do not hinge on a particular form of the utility function. Rather, they are efficiency criteria flowing from the assumption of free access to capital markets. Subject to that assumption, some such set of rules will apply to any couple, irrespectively of tastes and personal circumstances. If, on the other hand, parents were not able to borrow and lend, (7) would break into a sequence of annual budget constraints, as in Happel et al. (1984), and the solution could be quite different.

2.3. Efficient fertility and expenditure profiles

The properties of efficient expenditure profiles can be easily inferred from eqs. (8) and (9). If the marginal utility of adult consumption is isoelastic, parental consumption will increase or decrease monotonically over time, according to whether the real interest rate is higher or lower than the rate of time-preference implicit in eq. (2); otherwise, there may be fluctuations. The same is true of parental expenditure on successive children, with the implication that it may be inefficient on the part of parents to spend the same for each child.[5] It may turn out that it is better to spend more on the first-born, less on the second and so on, or the other way round. It could even turn out that, as folklore has it, the middle child comes off worse.

The properties of efficient fertility profiles, determined by eqs. (9)–(10), are rather more complicated because the value of each P_t depends on the entire profile of births, before and after t. In particular, the current-wage element of P_t increases with t if births are concentrated in the earlier part of married life, while the opposite is true of the future-earning-potential element. With constant child quality, the rule that the quality-adjusted 'price' of a birth must rise with r would thus yield a downward or upward sloping fertility profile if the current or the future wage element predominated throughout, a fluctuating one if neither of them did. Child quality, however, is generally not a constant: it varies with expenditure and the date of birth of the child. Depending on whether and how fast I_t is growing, $v_t(I_t)$ would either grow or decline at first, but it must eventually decline and fall to zero by the end of the woman's fertile span. In general, therefore, we can only say that the birth rate is likely to fluctuate over the woman's fertile span, and that it will fall to zero towards the end of it.

Let us consider a specific parameterisation.

$$v_t(I_t)=I_t^{\alpha}(1+\phi)^{-t}, \qquad 0<\alpha<1, \tag{12}$$

where t is now measured from the beginning of the woman's fertile span (assumed to be not later than that of marriage). To reflect the fact that parents do not plan to have children beyond the end of the fertile span, the parameter ϕ must be positive and large enough to make v_t virtually zero, whatever the value I_t, beyond a certain t. Given that the number of fertile years after the date of marriage cannot be more than 40, at the very most, the value ϕ must be well in excess of 0.1.

Given eqs. (9)–(10), and assuming eq. (12), Cigno (1988) shows that the number of children born by date t, denoted by

[5]That is so because eq. (3) is, in effect, a Benthamite welfare function. A more general formulation would be required to allow for the possibility that parents might want to treat all their chldren equally come what may.

$$N_t = \sum_{\tau=a}^{t-1} B_\tau, \tag{13}$$

is governed by a second-order difference equation,

$$N_{t+2} - 2N_{t+1} + (1+r)N_t$$
$$= \frac{1-\alpha}{\alpha}\frac{I_a}{\beta w}(\pi - r)(1+\pi)^{t-a} + r\left\{\frac{K_a w + q}{\beta w} + m(t-a)\right\}, \quad \text{where} \tag{14}$$

$$\cos x = (1+r)^{-\frac{1}{2}}, \tag{15}$$

$$\pi \equiv \{(1-r)/(1+\phi)\}^{1/(1-\alpha)} - 1, \quad \text{and} \tag{16}$$

$$n \equiv \frac{1-\alpha}{\alpha\beta w}\frac{\pi(\pi - r)}{r+\pi^2}. \tag{17}$$

From the solution to this equation for $N_a = 0$, we find the efficient time-distribution of births for any given B_a and I_a,

$$B_t = m + nI_a(1+\pi)^{t-a} - (m + nI_a - B_a)(\sqrt{1+r})^{t-a}\frac{\sin tx}{\sin ax}. \tag{18}$$

It is clear from eq. (18) that the efficient timing of childbirth depends crucially on the values of ϕ and r. The latter can be safely taken to be nonnegative but smaller than ϕ, because real interest rates cannot be less than zero for too long and, on the other hand, have never been as high as 10 per cent for any length of time. Since ϕ must be greater than 10 per cent, it then follows that

$$0 < 1 + \pi < 1. \tag{19}$$

Thus, if the real interest rate were zero, the birth rate would decline over married life in geometric progression. But, so long as credit is costly, the birth rate will fluctuate around a downward trend.

It is also clear that an increase in B_a would raise the whole birth profile. By contrast, an increase in nI_a would lower B_t at each t, but more at later ones. Therefore, the total number of children (*completed fertility*) is an increasing function of B_a and a decreasing one of nI_a, while the speed with which this total is approached (the *tempo of fertility*) is increasing in nI_a. We are thus interested in how the choice of B_a and I_a is affected by differences in personal characteristics or changes in the exogenous variables.

Table 1
Effects of exogenous variables.

	Completed fertility		Tempo of fertility		
	Theory	Data	Theory	Data	
a	−	−	+	?	wife's marriage age
A_a	?	+	+	−	husband's lifetime earnings
		[+]		[+]	[male earnings after tax]
K_a	−	−	+	+	wife's work experience at marriage
		+		+	post-compulsory education
q	−	[−]	+	[−]	[−child benefits]
β	?	−	−	−	wife's type of occupation
w	?	[−]	−	[−]	female wage rate after tax

2.4. Comparative dynamics and policy implications

Using eq. (18), it is possible to sign the effects of a, A_a, K_a and q on the number and time-distribution of births, under the assumption that income-effects are positive but small (relative to substitution and cross-substitution effects), and that the marginal utility of B does not fall too quickly as B increases (U_{BB} small in size relative to U_B). Cigno (1988) shows that, under these particular conditions, B_a is increasing in A_a, but decreasing in a, K_a and q, while I_a is increasing in all four exogenous variables. Consequently, the tempo of fertility increases with all these exogenous variables, while completed fertility decreases with a, K_a and q, and may increase or decrease as A_a increases depending on the relative size of the income-effects on B_a and I_a. By contrast, the responses of B_a and I_a to changes in β or w cannot be signed under any plausible set of assumptions. It may be surmised, however, that these responses are inelastic. Since n is inversely proportional to β and w, we can then conclude that nI_a and, therefore, the tempo of fertility decreases as β or w increase. The predictions of the model are summarised in the first and third columns of table 1.

According to this model, women with greater financial assets at marriage, or married to men with higher incomes, may thus be expected to have their children earlier in married life – but not necessarily to have more children, because they will also spend more on each child. The same is predicted for women who marry late or are endowed with more human capital (greater earning ability) at the time of marriage, except that these women will definitely have fewer children. On the other hand, women in occupations characterised by steeper earning profiles will tend to have their children later. Therefore, if women with greater initial human capital, or women who marry late, tend to be in professions where the wage rate rises sharply with seniority of service, that could offset the tendency to earlier motherhood.

Paradoxically, a rise in q would raise the amount that parents spend voluntarily for each child in addition to q and thus raise the tempo of fertility, but it would reduce completed fertility. A general rise in married men's wages (higher A_a) would also raise expenditure per child and the tempo of fertility, but it is not clear what would happen to completed fertility – possibly little. By contrast, a general rise in married women's wage rates (higher w) would lower the tempo of fertility.

The model also tells us something about the demographic consequences of various economic policies. Higher taxes on married women's earnings – equivalent to a fall in w – would raise the tempo of childbearing, probably without any noticeable consequence for the quality and number of children. By contrast, higher taxes on married men's earnings – equivalent to a fall in A_a – would delay childbirth and lower the quality of children, possibly without much change in number. And finally, a rise in child benefits – equivalent to a fall in q – or a policy resulting in lower ages of marriage would increase completed fertility, but the tempo of fertility and the amount spent on each child would fall.

3. Empirical analysis

3.1. Data

Although we cannot estimate the structural parameters of the theoretical model, we can compare its predictions with observed fertility patterns. The data are from the *Women and Employment Survey*, which provides complete marital, childbearing and work histories for a nationally representative sample of British women aged 16–59 in 1980. The analyses reported below are restricted to women whose first marriage lasted at least 10 years and who did *not* have a premarital pregnancy (identified by births less than 8 months after marriage).

The data are summarised in figs. 1 to 3, which show the average profiles of fertility by duration of marriage for different groups of women who survived at least 10 years of marriage. The first thing to be noted about these profiles is that, consistent with the theory, the birth rate fluctuates around a downward trend. The second is that the timing and number of births differ for women with different levels of education, different jobs before child-

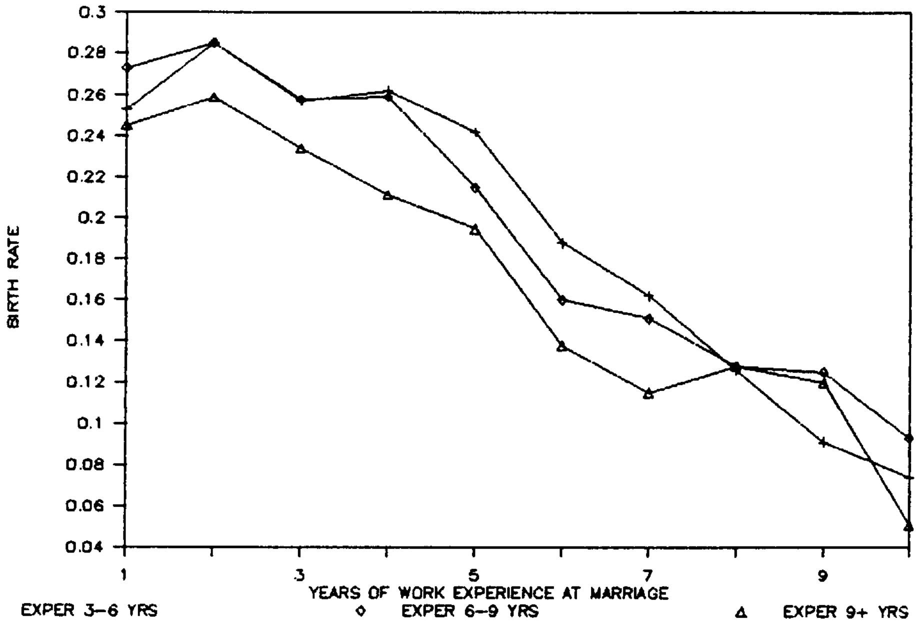

Fig. 1. Birth rate by marriage duration and years or work experience at marriage (women with no post-compulsory education).

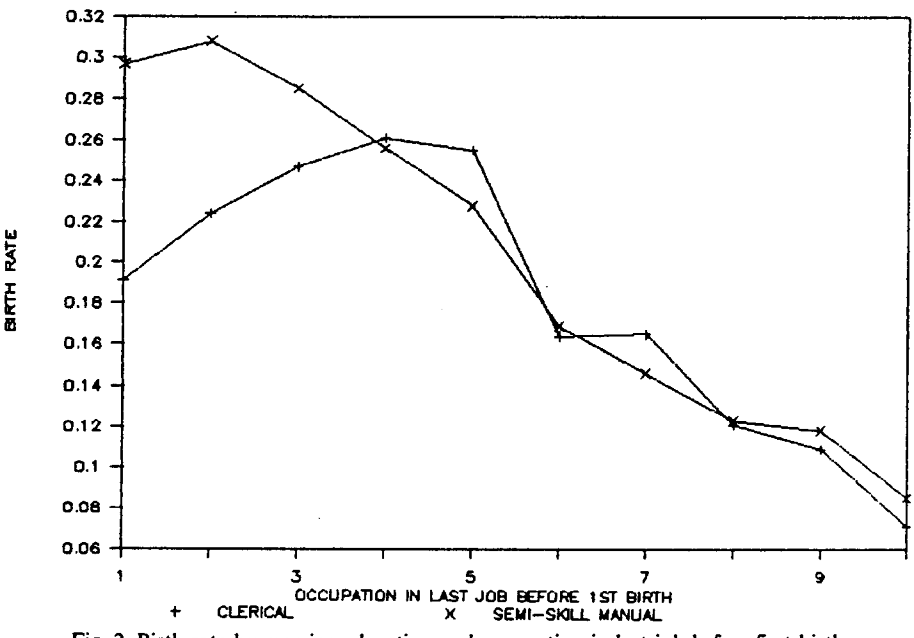

Fig. 2. Birth rate by marriage duration and occupation in last job before first birth.

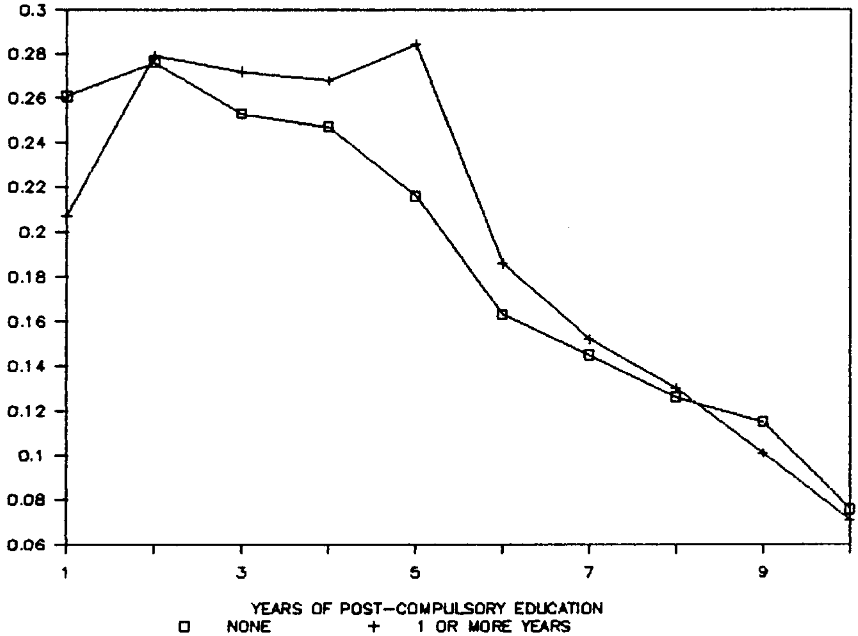

Fig. 3. Birth rate by marriage duration and years of post-compulsory education).

bearing and different amounts of work experience at marriage. Are these behavioural differences consistent with the theoretical predictions?

3.2. Definition of explanatory variables

A number of observable characteristics of a woman are either parameters of the model, like her age at marriage denoted by a, or likely to be related to parameters of the theoretical model. In particular, a woman's endowment of human capital at marriage, K_a, is likely to be directly related to her educational attainments, measured here as years of full-time education beyond the minimum school-leaving age ('post-compulsory education'), and to her work experience at marriage. The steepness of a woman's career profile, β, is likely to depend on her occupation. This could change over her lifetime, but the one she had when the childbearing plan was formulated is probably the most relevant to the choice of plan. Her occupation in her last job before her first birth – or her top occupation if she has remained childless – is, therefore, taken as the occupation to which β corresponds. Because of potential occupational mobility, this occupation may not be exogenous with respect to the fertility profile. For instance, women who decide to start childbearing later may progress further up the career ladder.

The potential bias resulting from this should, however, be substantially mitigated by the grouping of occupations into five broad categories, between which mobility is likely to be limited during the period from marriage to motherhood. While occupational group is taken as the primary indicator of β, this could also be positively correlated with the amount of human capital at marriage, and therefore with educational attainment and work experience at marriage.

One component of A_a is husband's lifetime earnings. These are not directly observable in our data, but gross earnings of a woman's husband in 1980 are recorded. In order to ensure that the husband is the same as the one who was present at the time of childbearing, the sample was further restricted to women married in 1980 who were married only once. Gross earnings in 1980 are not likely to be a good measure of lifetime earnings because they reflect the husband's age in 1980. For instance, earlier cohorts of men, who are older in 1980, would tend to have higher earnings in 1980. In addition, earnings in a particular year reflect transitory fluctuations in earnings. To reduce these problems, we constructed a measure of lifetime earnings from an earnings function estimated in 1980.[6] Evaluating the function at 25 years after the husband leaves school (approximately the husband's 40th birthday) and at the actual values of the other variables yields a measure of predicted husband's annual earnings that is proportional to the lifetime earnings predicted by the function. This is our measure of husband's lifetime earnings, which is an important component of A_a.

There are three important shortcomings of this measure, two of which arise because the earnings function is estimated from a cross-section. First, the effect on earnings of being from a particular birth cohort cannot be separated from the effect of age. Thus, the earnings measure treats all men as being from the same cohort. This would be acceptable if relative earnings within a cohort, rather than the absolute level of lifetime earnings, were important for decisions about the number and timing of children. If, however, absolute earnings are important, as the theoretical model suggests, then the lifetime earnings of earlier cohorts of men (older in 1980) are overstated because wages at each age tend to be lower as a result of secular growth in earnings. Inclusion of a set of dichotomous variables for 5-year birth cohorts of women in the fertility equations below control for this trend

[6]The earnings function was estimated from a regression equation in which the logarithm of the husband's gross annual earnings in 1980 is expressed as a function of the following variables: (a) husband's age in 1980 minus the age at which he left full-time education, and the square of this variable; these variables are continuous, while the following are sets of dichotomous categorical variables: (b) the highest qualification that the husband attained; (c) husband's years of post-compulsory education; (d) social class group of husband; (e) region of residence (standard English regions plus Scotland and Wales); (f) whether residing in a rural area. Twenty-two per cent of the variation in the logarithm of annual earnings is explained by the estimated function.

in lifetime earnings to some extent. Second, unmeasured personal traits of a man which affect his lifetime earnings also cannot be identified from cross-section data. Thus, this important source of variation in lifetime earnings is not measured. The third shortcoming is due to the lack of tax information in our data. Because of non-linearities in the income tax schedule, gross lifetime earnings may in fact be a poor indicator of net lifetime earnings. Indeed, we shall find below that one of the effects changes sign when taxes are deducted.

The initial endowment of non-human capital at marriage is another important component of A_a. As was the case for husband's lifetime earnings, it is also likely to be higher for later generations of women. The real rate of return to human capital, w, also tends to rise over time with general productivity growth. The dummy variables for 5-year cohorts of women mentioned earlier would reflect these developments, although they clearly also pick up other trends influencing fertility. The implications of the absence of a measure of non-human capital at marriage from the empirical analysis and of the shortcomings of the measure of husband's lifetime earnings for the measured impacts of the other variables are explored later in this section.

3.3. Estimation procedure

We define a continuous latent 'family size indicator' variable, N^*_{t-a}, for each yearly marriage duration $t-a$, and we postulate that

$$N^*_{t-a}=X\xi_{t-a}+\varepsilon_{t-a}, \tag{20}$$

where X is a vector of explanatory variables associated with a woman, ξ_{t-a} are their corresponding parameters at marriage duration $(t-a)$, and ε_{t-a} is a standard normal random variable. This random variable might have a woman-specific component which is constant over the first ten years of marriage, measuring unobserved characteristics (e.g. her physiological capacity to have children, or *fecundity*) which continue to affect her fertility. No attempt has been made to fully utilise the panel element of the data by estimating a model with such a fixed component. The econometric procedure does, however, take account of the discrete nature of family size.

Define a set of parameters μ_0, μ_1, μ_2, μ_3 such that

$$\begin{aligned}&\text{if } N_{t-a}=0,\ N^*_{t-a}<\mu_0,\\ &\text{if } N_{t-a}=j,\ \mu_{j-1}\leqq N^*_{t-a}<\mu_j, \qquad j=1,2,3,\\ &\text{if } N_{t-a}=4,\ \mu_3\leqq N^*_{t-a}.\end{aligned} \tag{21}$$

The survey does not date births above the fourth.

The probability that a couple has a particular family size at $t-a$ is calculated easily from the standard normal distribution; for instance,

$$Pr(N_{t-a}=2)=F(\mu_2-\xi_{t-a}X)-F(\mu_1-\xi_{t-a}X), \tag{22}$$

where $Pr(\cdot)$ denotes the probability of the bracketed statement and $F(\cdot)$ is the standard normal distribution function. Expected family size at marriage duration $t-a$ is, therefore,

$$E(N_{t-a})=\sum_{j=0}^{4} j\cdot Pr(N_{t-a}=j). \tag{23}$$

As one of the μs is not identified, $\mu_0=0$ is imposed in order to remove the indeterminacy.

An econometric model with the structure thus described is generally called an 'ordered probit model'. Estimates of the parameters ε_{t-a} and μ_j are obtained by maximising its likelihood function, given in Maddala (1983, p. 48). Table 2 shows the estimated parameters for 10 years marriage duration, which should be a good indicator of the effect of the explanatory variables on completed fertility. The expected birth rate at marriage duration $(t-a)$ is given by

$$E(B_{t-a})=E(N_{t+1-a})-E(N_{t-a}). \tag{24}$$

The birth rate profiles predicted by this last equation are shown in figs. 4 to 8.

These profiles give full information about the effects of the explanatory variables on the number and time-distribution of births. In particular, they tell us whether births are likely to occur closer together or further apart, and whether they are likely to be anticipated or postponed, as a result of a change in one of the explanatory variables. Given the irregular shape of these profiles, however, it is not always easy to say whether the change has resulted in a rise or a fall of tempo.

For this reason, we supplemented the econometric analysis of the number of children born by each year of marriage with one of the proportion of children born during the first 10 years of marriage whose births occurred in the first 3 and 4 years.[7] We shall take such proportions as crude indicators of the tempo of fertility, but always keeping in mind that they are very crude

[7] Because of the concentration of observations with proportions at zero and one, we have used the 'two-limit tobit model' to estimate the relationship between the proportions of 'early' births and the variables in X. This model, based on the normal distribution, takes account of these concentrations, and is estimated by maximum likelihood methods.

Table 2
Analysis of family size at 10 years marriage duration.

	Parameter	't-value'
Constant[a]	−1.469	1.06
Post-comp. ed.		
none ϕ	–	–
1 year	0.066	0.86
2 years	0.171	1.87
3+ years	0.317	3.14
Work experience at marriage (years)	−0.0355	2.48
Age at marriage (years)	−0.0320	2.26
Log of husband's earnings	0.452	2.80
Occupation (before birth):		
Prof./int. non-man	−0.481	5.59
Clerical	−0.399	6.24
Sales	−0.302	3.91
Skilled manual	−0.249	2.38
Semi-skilled and unskilled manual ϕ	–	–
No job	−0.203	1.19
Birth cohort:		
1925–29	−0.129	1.62
1930–34	0.079	1.04
1935–39	0.100	1.28
1940–44	0.093	1.09
1945–49	−0.052	0.55
1950–54	−0.028	0.13
μ_1	0.830	25.70
μ_2	2.044	63.40
μ_3	2.948	52.11
Log likelihood		−2,973.0
Chi-square (17 d.f.)		23,691
N		2,174

[a]ϕ = Reference category.

indeed, because they take no account of the distribution of births beyond the third or fourth year of marriage (so, for example, if a planned birth were brought forward from the fourth or fifth to the third or fourth year of marriage, that would be construed as a rise in tempo, but not if a birth were brought forward from the tenth to the fourth or fifth year of marriage). Possibly because the proportion of 'early' births is such an imperfect measure of the phenomenon in question, few of the estimated effects turned out to be statistically significant. The results are shown in table 3.

3.4. *The effects of marriage age*

Fig. 4 shows the predicted birth profiles for women marrying at ages 19

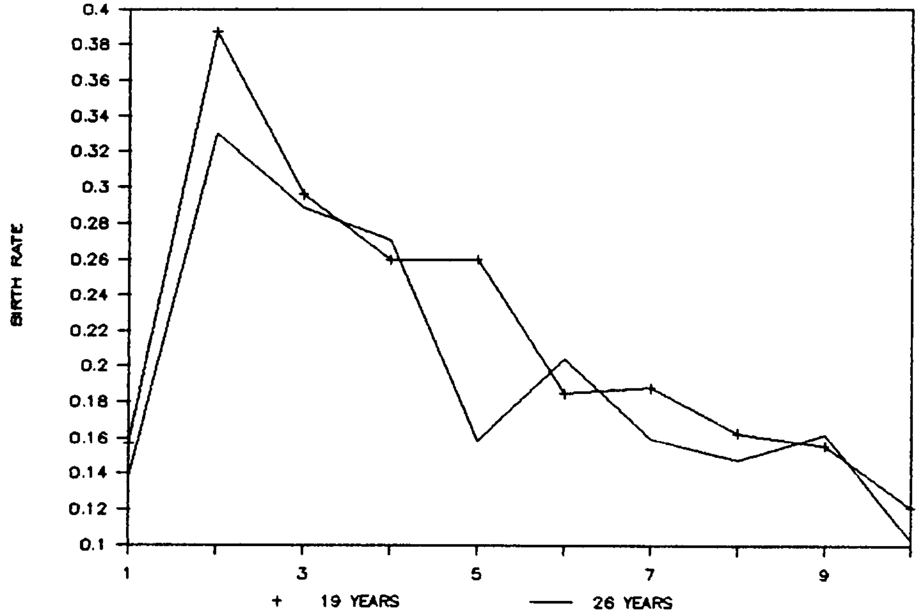

Fig. 4. Effect of age of marriage.

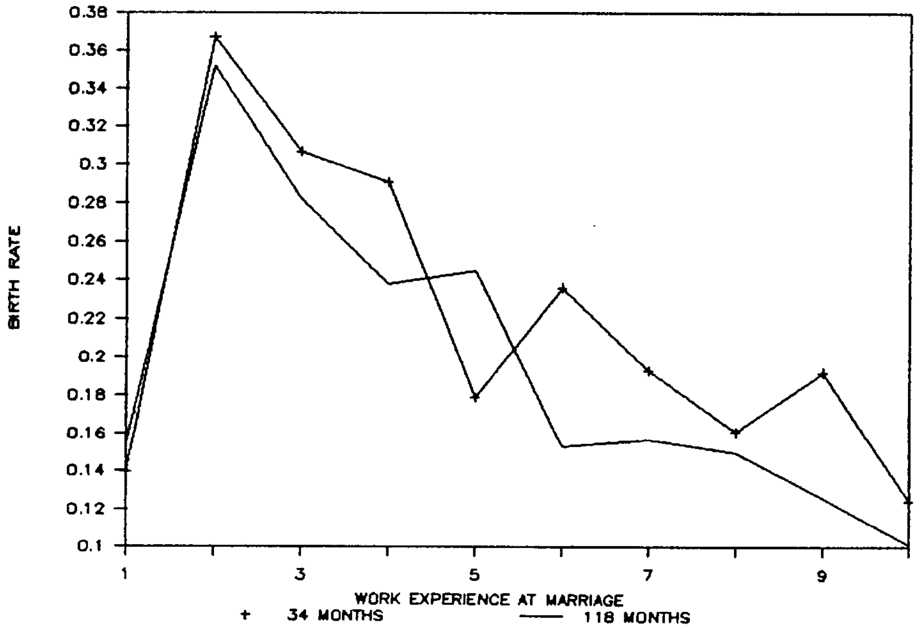

Fig. 5. Effect of work experience at marriage.

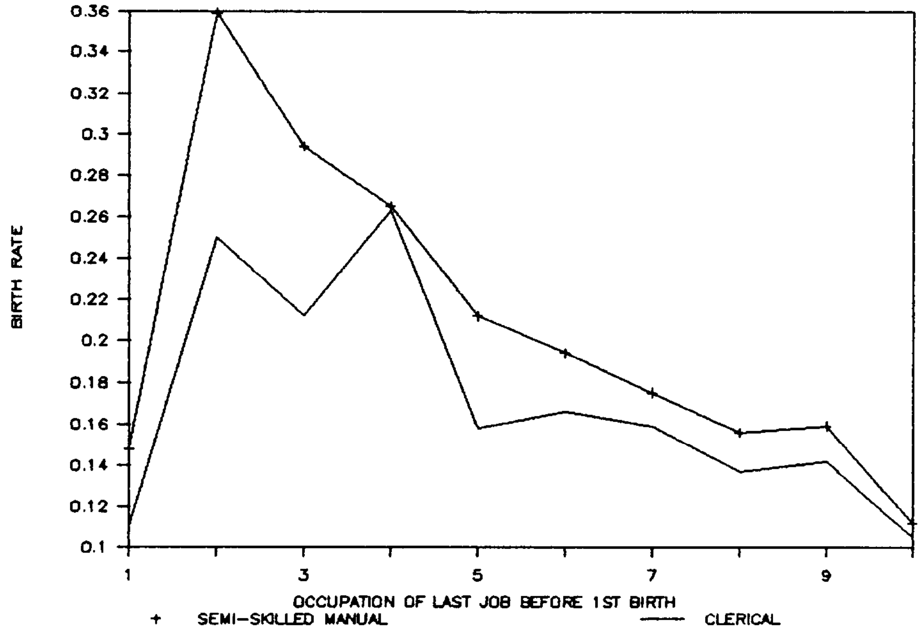

Fig. 6. Effect of type of occupation before first birth.

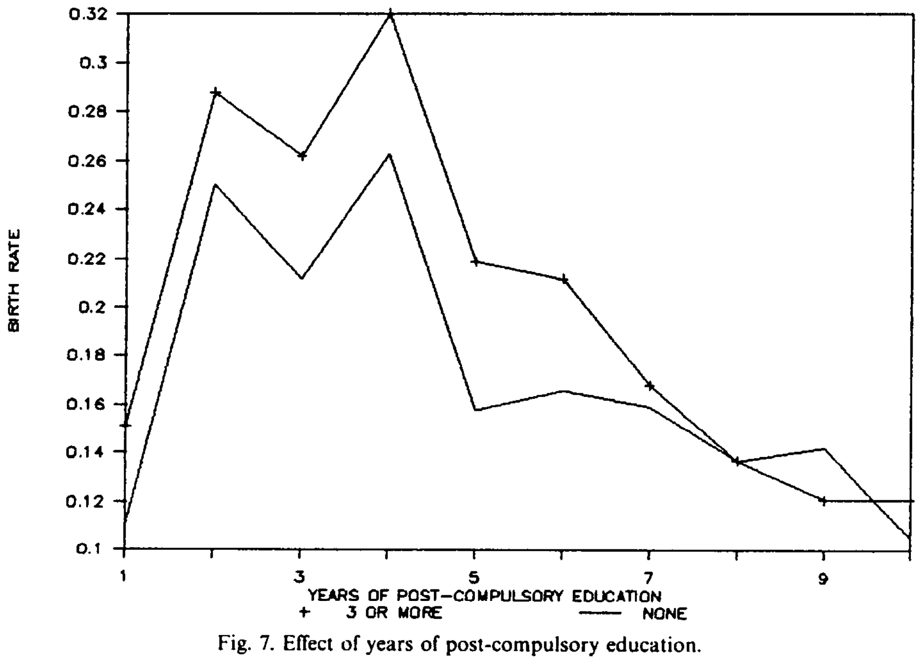

Fig. 7. Effect of years of post-compulsory education.

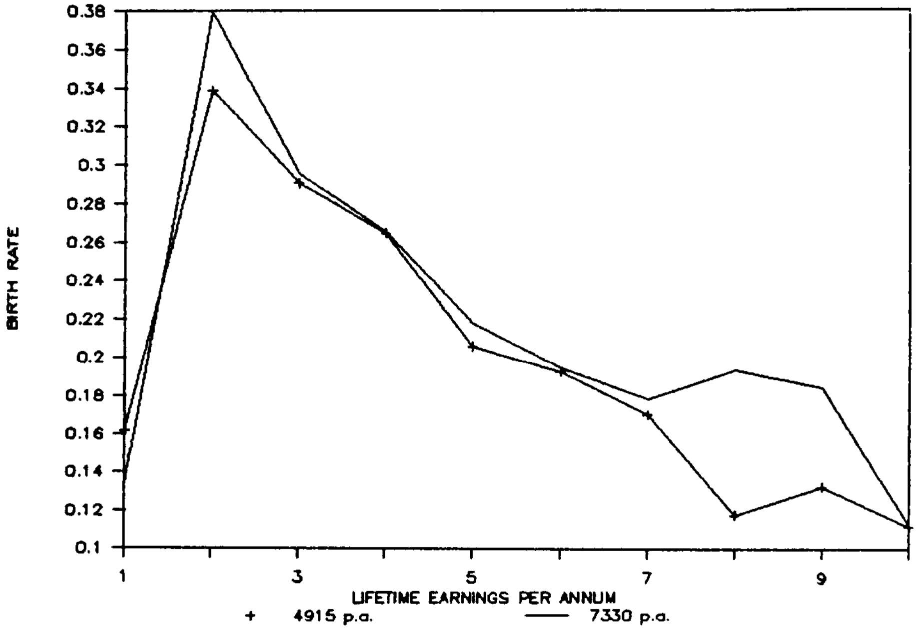

Fig. 8. Effect of husband's lifetime earnings.

and 26, which are roughly one standard deviation on each side of the mean age of 22. In each case, the woman is assumed to have been born during 1920–24 and to have work experience at marriage and husband's earnings equal to their mean values. Each woman is assumed to have no post-compulsory education and to be in a semi-skilled manual occupation (both of these categories are the dominant ones in the sample).

At almost all durations of marriage, a woman marrying later has a lower birth rate. Because this pattern clearly results in fewer children after 10 years of marriage for women marrying later (see table 2), one prediction of the theoretical model is confirmed. But it is difficult to determine whether the data are consistent with the theoretical prediction that the tempo of fertility increases with the age of marriage: while the proportion of children born in the first 4 years of marriage increases with the age of marriage, the proportion born in the first 3 years does not, and neither effect is statistically significant.

3.5. The effects of length and type of employment

Fig. 5 illustrates the impact of work experience at marriage on the birth rate profile, holding other variables constant. Experience of 34 and 118 months at marriage represent the range of one standard deviation on each

Table 3
Analysis of proportion of births occurring 'early' in marriage.[a]

	Proportion of family size at 10 years born during first[b]	
	3 years	4 years
Constant[c]	2.197*	2.547*
Post-comp. ed.		
none ϕ	–	–
1 year	−0.006	0.002
2 years	0.071	−0.002
3+ years	0.096	0.055
Work experience at marriage (years)	0.0168	0.0127
Age at marriage (years)	−0.0055	0.0074
Log of husband's earnings	−0.2080*	−0.2505*
Occupation (before birth):		
Prof./int. non-man	−0.091	−0.001
Clerical	−0.132*	−0.064*
Sales	−0.011	−0.015
Skilled manual	−0.083	−0.116*
Semi-skilled and unskilled manual ϕ	–	–
No job	0.220	0.118
Birth cohort:		
1925–29	−0.004	−0.057
1930–34	−0.036	−0.093*
1935–39	−0.032	−0.063
1940–44	−0.014	−0.009
1945–49	−0.008	0.003
1950–54	0.269*	0.146
$\hat{\sigma}$	0.574*	0.580*
Log likelihood	−1,791.5	−1,838.3
N	1,965	1,965

[a]Only women who were mothers in first 10 years of marriage.
[b]* indicates that the absolute value of the t-statistic exceeds 1.65.
[c]ϕ = Reference category.

side of the mean of 76 months. Women with more work experience at marriage generally have a lower birth rate, particularly after the first 2 years of marriage, thereby producing smaller families, as table 2 confirms. Since work experience at marriage is directly related to human capital at marriage, the lower completed fertility of women with more work experience at marriage is consistent with the theoretical model. Another prediction of the model, namely that their tempo would be faster, receives some support from the empirical analysis in table 3, although the positive impact of work experience on the proportion of births early in marriage is not statistically significant. As explained below, however, the absence of important components of A_a from X may bias the coefficient of work experience toward zero.

Women in clerical jobs (a third of all women sampled) are likely to receive a higher return in earnings from additional experience than women in semi-skilled manual jobs (another third of the sample). Thus, comparison of the birth rate profiles of these two major groups of occupations should provide a test of the effect of the steepness of the earnings profile β on the timing of births. As the theoretical model predicts, fig. 6 shows that the clerical group starts childbearing much more slowly than the manual group, and this tendency for women in clerical jobs to have their children comparatively late in marriage is confirmed by table 3. Table 2 and fig. 6 also help us to resolve empirically the question, left open by the theoretical model, of whether a higher β is associated with higher or lower completed fertility. As is clear from fig. 6, women in clerical occupations produce fewer children over the first 10 years of marriage. Indeed, as table 2 shows, there is a clear gradient in completed fertility, with women in higher status occupations before motherhood having fewer children. Since this ranking of occupations tends to correspond to a ranking according to the value of β, it may thus be inferred that women in occupations with steeper career profiles (higher β) have lower completed fertility.

3.6. The effects of education

Fig. 7 examines the impact of different educational attainments on the birth rate profile, all else equal. Women with 3 or more years of post-compulsory education are compared with women who stopped their education at the minimum age. Because members of the former group are unlikely to be in semi-skilled manual jobs, women from either educational group are assumed to be in a clerical job. The more educated group has a higher birth rate and produces a significantly larger family. Indeed table 2 shows a clear positive gradient in the relationship between years of education and family size.

The tendency for women who continue their education longer to have more children appears to contradict the prediction of the theoretical model that women with more human capital at marriage have smaller families. However, the direct association between family size and women's education may reflect the operation of positive assortative mating, in conjunction with a positive impact of husband's lifetime earnings and material wealth at marriage (A_a) on family size. According to Becker's (1981) theory of marriage, wealth would in fact be positively sorted with educational attainments.[8] If family size is increasing in A_a, as the effect of our imperfect measure of husband's lifetime earnings suggests (see table 2), then, in the

[8]Thus, a woman's education would tend to be positively correlated with A_a, and evidence from the survey used in the analysis here indeed shows that British women continuing their education longer married a husband with higher earnings; see Ermisch (1987b).

absence of material wealth at marriage from X and in the light of the unmeasured personal characteristics of the husband influencing his lifetime earnings, the direct association between a woman's educational attainment and family size may be consistent with the theoretical model.

The economic theory of marriage also suggests that ignoring these important components of A_a reinforces the negative impacts of work experience and occupational status on family size and biases the effect of age at marriage on family size upward.[9] For these same reasons, the effects of age at marriage and occupational status on the proportion of children born 'early' in marriage are reinforced, but the effect of work experience on this proportion is biased toward zero. Such a bias may help explain the statistical insignificance of the impact of work experience in table 3.

The positive impact of longer education on the proportion of children born in the first 3 years of marriage (shown in table 3) supports the theoretical model, but is not statistically significant. It is noteworthy, however, that even when broad occupational group is controlled, as it is in this analysis, it is likely that women with more human capital at marriage will be in jobs with steeper career profiles within that broad occupational group. This may help account for the statistical insignificance of educational attainments and work experience at marriage in accounting for variation in the tempo of childbearing.

3.7. *Effects of husband's earnings*

In fig. 8, we show the expected birth profiles of two women, one of whom has husband's predicted annual earnings one standard deviation below and the other one standard deviation above the (geometric) mean, but who are alike in other respects. Beyond the first year of marriage, the couple with higher husband's earnings has a higher birth rate, but not significantly so until after the 7th year of marriage. Thus, the higher income couple has a significantly larger family after 10 years of marriage (as shown also in table 2), but has children proportionately later in marriage (as table 3 confirms). The first of these findings is consistent with the predictions of the theoretical model if the income effect on B_a is large compared with that on I_a. The second, on the other hand, contradicts the model, but given the uncertainties surrounding our measurement of both the dependent and the independent variables, we should perhaps not make too much of it. Indeed, Ermisch

[9]This is because personal traits that affect productivity in the labour market are negatively sorted in marriage, and women who search for a partner longer (have a higher age at marriage) tend to marry a wealthier husband; see Becker (1981) and Ermisch (1987b) for evidence of this in the present survey. Thus, A_a tends to be negatively correlated with a woman's work experience and occupational status and positively correlated with age at marriage.

(1987a), discussed below, reports positive effects of male after-tax earnings on both completed fertility and the tempo thereof.

3.8. Time effects

An important prediction of the theoretical model is that births are more likely to occur in the earlier part of marriage, with a tendency to fluctuate around a downward trend with duration of marriage. The consistency of this prediction with the data is apparent in all the figures.

Finally, with the possible exception of the 1925–29 generation, none of the cohort effects in tables 2 and 3 is statistically significant. This suggests that we have captured many of the important differences between cohorts in our explanatory variables.

3.9. Policy effects

The effects of the policy variables cannot be tested directly on the present data, but a recent econometric analysis of the time series of birth rates defined by the order of the birth and women's age, Ermisch (1987a), broadly supports the theory. The time-series analysis does in fact show that increases in women's hourly earnings *net of tax* reduce birth rates of all orders at all ages and lower the tempo of fertility (measured by the steady-state proportion of the average completed fertility realised by the age of 25), while increases in men's weekly earnings *after tax* generally increase birth rates throughout the life cycle and the tempo of fertility. Furthermore, higher child benefits raise completed fertility, but, contrary to the theory, they also raise the tempo of fertility. This last finding suggests that the model's assumption of access to the capital markets may not apply to young couples, and that child benefits raise the tempo of childbearing because they relax the liquidity constraint on early parenthood.

4. Conclusions

In the present paper we have outlined a theory of the number and timing of births (and concomitant expenditure decisions) and attempted to test the predictions of the theory against the personal histories of a sample of British women. The predictions fall into two categories: one concerning the general characteristics of birth and associated expenditure profiles, the other concerning the way in which the specific characteristics of such profiles are determined by personal characteristics and exogenous variables.

The main prediction in the first category is that, irrespectively of the date of birth of the mother and of other personal characteristics, the birth rate tends to fluctuate over married life around a downward trend. This implies that births tend to occur predominantly in the earlier part of marriage and that, as the marriage age goes up, they tend to be increasingly concentrated in a short time span. It also means that, if several births are planned, they will not be evenly spaced, but typically grouped into one or more clusters. This complex pattern – arising from the interaction between physiological and financial considerations, and in particular from the complicated way in which the time distribution of births affects the mother's earnings – is clearly supported by the data (see figures).

The second category of predictions is less firm, because special assumptions are needed in order to sign the various comparative-dynamics effects. Where the data contradict the predictions, it is therefore not clear whether the special assumptions or something more fundamental within the model is at fault. For the most part, however, these predictions have been confirmed (see table 1 for a comparison of the empirical results with their theoretical counterpart). Estimation of an econometric model which allows for the discrete family size and for variation in birth timing (see tables 2 and 3), demonstrates significant systematic differences in family-building patterns associated with the explanatory variables suggested by the theoretical model. In particular, there is empirical support for the theoretical proposition that women in occupations characterised by steeper career profiles (careers where remuneration is strongly dependent on seniority) tend to have children later in marriage, and that more human capital (accumulated through education or work experience) at the date of marriage is likely to result in fewer children and a faster tempo of fertility. In light of the many, virtually unmeasurable factors affecting a couple's fertility pattern, including their own preferences and fecundity, and of economic and other shocks over their lifetime, only a small proportion of variation in family building patterns could be expected to be accounted for by our econometric model, but the systematic differences in family formation patterns are striking.

The model also has implications for the effects of a number of policy variables. Although not testable against the cross-sectional data used in the empirical part of the present study, these policy implications are consistent with time-series evidence reported in another study by one of the present authors, on which we have drawn. In particular, there is empirical support for the propositions that a less generous tax treatment of women's earnings, or a more generous treatment of men's earnings, would raise the tempo of fertility. There is also support for the proposition that child benefits raise completed fertility, but not for the one that they lower the tempo of fertility, which suggests that a liquidity constraint may be in place in the early years of marriage.

As pointed out in the Introduction, an understanding of the factors determing the timing of childbirth is important in explaining fluctuations of the period birth rate and designing policy packages to deal with them. To our knowledge, the present paper contains the fullest analysis so far of the issues in question.

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