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A DYNAMIC MODEL OF CONTRACEPTIVE CHOICE OF SPANISH COUPLES

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SUMMARY

We propose a simple dynamic stochastic model of sterilization and contraceptive use and we estimate its structural parameters using a sample of married couples from the 1995 Spanish Family and Fertility Survey. The estimated structural model improves on previous studies in terms of its ability to rationalize observed behaviour. Allowing for simple forms of permanent unobserved heterogeneity across couples in their ability to conceive has important implications for estimates of utility and cost parameters. Estimates of child valuation parameters imply that most Spanish couples would have two children, but significant deviations from this goal are brought about by imperfect and costly fertility control. We perform simulations to quantify the impact on fertility of the availability of sterilization and other technologies which improve fertility control.

1. INTRODUCTION

The analysis of fertility within the framework of modern economic theory goes back to Becker (1960, 1991). Since then, the literature known as the 'New Family Economics' has developed considerably. During the last 20 years researchers have developed new methods for the estimation of structural dynamic models of discrete choice.[1] These models are an attractive framework for the analysis of fertility decisions since they can explicitly accommodate several important features which were neglected in earlier static models, such as: (1) the dynamic dimension of fertility choices which are made in a life-cycle context; (2) the stochastic nature of human reproduction, whereby parents make contraceptive choices and respond to the (irreversible) realizations of the birth process. Furthermore, structural methods allow us to obtain estimates of parameters which can be interpreted directly in the context of the maintained behavioural model. The large computational burden of empirical work has constrained the number of applications in economic demography. Wolpin (1984), Montgomery (1988), Hotz and Miller (1993) and Ahn (1995) are a few exceptions. In this paper we propose a simple model of sterilization and contraceptive use over the life-cycle and we estimate its structural parameters using data from the 1995 Spanish Family and Fertility Survey. Our main goal is to investigate whether the main features of the data can be rationalized in a dynamic stochastic optimization framework. During the last two decades there was a large and rapid decline in fertility rates in Spain. In 1975 the Total Fertility Rate (TFR) was still 2.8 but by 1995 it was only 1.2, the lowest in the world.[2] In contrast, during the same period in the USA the TFR increased slightly from 1.8 to 2.1. Although many other OECD countries have

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[1] See Eckstein and Wolpin (1989) and Rust (1994) for surveys of this field.
[2] The Total Fertility Rate is the average number of children per woman in a synthetic cohort obtained from cross-sectional age-specific fertility rates. In a stationary environment 2.1 is the replacement level.

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experienced below-replacement fertility rates, nowhere was the decline so precipitous as in Spain. The beginning of this trend coincided with important changes in the availability of contraceptive technology: contraceptives became legal in 1978, and sterilization in 1983. We are not suggesting that these changes were the main cause of the rapid fertility decline, but we believe the analysis of contraceptive behaviour and the consequences of imperfect fertility control is of interest in this context.[3]

Dynamic models of contraceptive behaviour were first studied in Heckman and Willis (1976) and Newman (1988). To our knowledge, Montgomery (1988) and Hotz and Miller (1993) are the only earlier attempts to implement structural econometric versions, and our work shares several features with each of them. Children are modelled as an irreversible durable good, and the 'stock' of children is a controlled discrete-state stochastic process with transition probabilities determined by contraceptive choices. Montgomery used a sample of American households from the CASH data set to estimate a model in which women choose between four different contraceptive options, including no use of contraceptives, and have preferences defined in terms of a 'target' number of children. His model fits the data reasonably well. However, it overpredicted the use of contraceptives in the early stages of the life-cycle and its treatment of sterilization—an important aspect of US and Spanish data—was not very successful. Our model is very similar to Hotz and Miller's. However, unlike ours their NFS survey of US households included income information. This allowed them to identify a richer structure, but many of their parameter estimates were highly implausible and all three of their specifications were strongly rejected by the data. Hotz and Miller's study illustrated the use of the Conditional Choice Probability (CCP) estimator, an innovative method which does not require repeated solutions of the dynamic programming problem and thus significantly reduces the computational burden of estimation. Unfortunately, the CCP estimator is hard to implement in models with permanent sources of unobserved heterogeneity. In our empirical work, allowing for permanent unobserved heterogeneity in fecundity across couples has turned out to be important. The estimated structural model fits the Spanish FFS data quite well and offers a more plausible rationalization of observed behaviour. The use of contraceptives produces disutility but 'precautionary' behaviour can help explain the large fraction of couples using them at parity 0. We perform counterfactual exercises which simulate the effect of the introduction of sterilization and of improvements in reversible contraceptive methods.

The paper is organized as follows: in Section 2 we present the model of sterilization and contraceptive use of married couples, in Section 3 we describe and summarize the data and in Section 4 we describe the econometric implementation of the model. In Section 5 we present structural parameter estimates, analyse how the estimated model rationalizes the data and show the results of counterfactual exercises. Section 6 summarizes and concludes.

2. A MODEL OF CONTRACEPTIVE CHOICE

We analyse a couple's decisions regarding sterilization and the use of contraceptives over the life-cycle within the framework of a dynamic stochastic discrete choice model as in Hotz and Miller (1993). We assume that couples face no uncertainty about the maximum potential duration

[3] For a detailed study of the use of contraceptive methods, sterilization, abortion and the treatment of infertility in Spain during the last 25 years, see Ruiz-Salguero (2002).

of their fertile life (T) and that they ignore the risks of their own and their children's mortality.[4] The timing of marriage is exogenous; couples who marry at different ages are identical except for the length of the decision horizon. We abstract from divorce, separation and adoption decisions and from fertility outside marriage.

Every period from the time of marriage ($t = 1$) to the stopping period ($t = \tau$), the couple chooses one of three mutually exclusive actions: not to contracept ($j = 1$), to use temporary contraceptive methods ($j = 2$) or to sterilize ($j = 3$). Define $d_{tj} = 1$ if action j is chosen in period t, and 0 otherwise. Then, $\sum_{j=1}^{3} d_{tj} = 1$. Let b_t denote an indicator variable for a period t birth, and S_t the state vector which contains all variables known to the couple at t which have an impact on their current and future choices. For instance, the state vector may include current parity and the recent history of contraceptive choices. Let $F_j(b_{t+1} = 1|S_t)$ or F_{jt} denote the probability that a birth will occur at $t + 1$ conditional on the state and on the choice of action j in period t. We assume that $0 < F_{jt} < 1$ for $j = 1, 2$, i.e., fertility control is imperfect if either of the first two actions are chosen. If $d_{t3} = 1$ then $F_{3t} = 0$ and t is the stopping period. That is, sterilization is irreversible. Couples know the probabilities F_{jt} and they become infecund after the stopping period. For couples who never sterilize, the stopping period is T, the moment when menopause occurs.[5]

Period t contraceptive plans are chosen to maximize the intertemporal utility function

$$E_t\left(\sum_{s=t}^{\tau}\beta^{s-t}\sum_{j=1}^{3}d_{sj}u_{sj}(S_s)\right) + \beta^{\tau+1-t}E_t(W(\tau, S_{\tau+1})) \tag{1}$$

subject to the laws of motion of the state and, in particular, to birth control 'technology' $\{F_{jt}\}$. In equation (1) β is the discount factor, $W()$ is the terminal value function, E_t is the expectation operator conditional on the state and $u_{tj}()$ is the period-by-period utility function which aggregates utility flows from the stock of children and the cost or disutility of the current contraceptive action. Thus children in the model are an irreversible durable good. The stock of this durable is controlled through contraceptive choices but control is costly and imperfect. The detailed specification of $u()$ and $W()$ is found in Section 4, and a discussion of its behavioural implications is deferred to Section 5.

3. DATA

Our data are drawn from the Spanish Fertility and Family Survey which was carried out by the Centro de Investigaciones Sociológicas (CIS). The survey interviewed 1992 men and 4021 women who were Spanish citizens between the ages of 18 and 49 in 1994–5. The information obtained for each interview refers to the household's current characteristics, partnership history, current partner characteristics, pregnancies and children, contraceptive history, views on having children, values and beliefs, education and occupational history.

We screened out couples with missing information and couples facing situations which did not conform to the stylized model described in Section 2. Our sample consists of observations from

[4] Given low mortality rates in Spain from birth to age 44, this seems a reasonable assumption.
[5] We take age 44 as the end of a woman's fertile life.

2923 couples in unbroken first marriages.[6] We set the length of a period to one year and for each couple we included observations for every (calendar) year that the couple was married and the wife was under age 45, beginning in 1983 which is when sterilization became legal in Spain. This resulted in 21 254 couple-year observations. For each observation we obtain values of the model's birth and contraceptive action indicators as follows.[7] The birth indicator b_t was set to 1 if any births occurred during calendar year t. If a birth occurred during year $t+1$, information about the couple's behaviour at the time of conception was used to assign the year t action. This information included answers to a question on the reasons why the couple stopped using contraceptive methods. Respondents were asked to be specific about contraceptive failures which resulted in conceptions and about decisions to stop contracepting in order to conceive. If $b_{t+1} = 0$ a couple was classified as 'contracepting' at t if they used *any* contraceptive methods for more than half the year. If a birth occurred during year t we applied the same criterion to the interval beginning one month after the birth and ending in December of that year. We do the same in the year the couple married. Sterilization is the year t action if any one of the spouses underwent it at any time during the year.

Using the information available in the survey it would have been possible to construct contraceptive choice indicators for shorter time intervals, e.g. one month, and for different methods, e.g. pill, condoms, etc. Annualizing the data and aggregating reversible methods is less realistic, but our focus is on rationalizing the overall patterns of sterilization and contraceptive use over the life-cycle and the computational burden of estimation increases with the number of periods and methods.[8] We have defined yearly indicators carefully so as to minimize potential errors arising from annualizing. In particular, note that all intervals beginning nine months before a birth and ending one month after it were not used to construct the choice indicators. Therefore, choice indicators for calendar years during which a birth occurred are based on shorter decision intervals, and the specification of conditional birth probabilities allows for the fact that the interval at risk is shorter. Furthermore, if a birth occurred in November or December of year t, year t was not considered a decision period. As for aggregating methods, it may pose a problem if the failure rates and utility costs of the methods that are actually used differ from one another greatly. Panel A of Table III shows that at the time of the interview 84% of all couples using contraceptives were using 'safe' methods (condoms, the pill or IUD), which lends some support to our approximation. Panel B gives sample means of birth and contraceptive use indicators by year. Notice the sharp decline in sample birth rates, which dropped from 13% in 1984–5 to 8% in 1992–3. There was a slight upward trend in the choice of contraception; by 1993 more than 75% of the couples in the sample were contracepting. Note that these patterns may reflect changes in the sample distribution of ages and parities as much as an actual trend in behaviour. Ruiz-Salguero (2002) has compared the prevalence of different methods of contraception across three fertility surveys fielded in Spain in 1977, 1985 and 1995. The most salient trends are an increase in the proportion of couples that are protected in some way, and in particular the growth in the prevalence of sterilization and the use of condoms.

We constructed categorical variables for the wife's and the husband's education and for the couple's religious beliefs. Definitions of these variables, as well as their sample means and cross

[6] Also excluded were couples who adopted a child or experienced the death of a child and those who sterilized for medical or other reasons unrelated to the choice of family size.
[7] Our criteria are similar to Hotz and Miller's (1993).
[8] Furthermore, using retrospective histories, recall error is likely to be more important the more disaggregated the data.

Table I. Descriptive summary statistics by categories

	Variable	Obs.	Mean	Std dev.
All couples	Age at marriage	2923	22.8	3.52
	Religious	2923	0.088	0.284
	Year of birth	2923	59.4	6.61
Primary or less	Age at marriage	673	22.0	3.49
	Religious	673	0.113	0.317
	Year of birth	673	56.3	7.15
Secondary	Age at marriage	1479	22.5	3.41
	Religious	1479	0.066	0.248
	Year of birth	1479	60.1	6.47
High school	Age at marriage	400	23.2	3.18
	Religious	400	0.080	0.271
	Year of birth	400	61.4	5.61
College	Age at marriage	371	25.2	3.27
	Religious	371	0.143	0.350
	Year of birth	371	60.2	5.14
Non-religious	Age at marriage	2665	22.7	3.48
	Year of birth	2665	59.7	6.48
Religious	Age at marriage	258	23.7	3.85
	Year of birth	258	56.2	7.02

All characteristics but 'religious' refer to the wife.

Table II. Sample joint and marginal distributions of the couple's education (%)

Wife's education level	Husband's education level							
	(0)	(1)	(2)	(3)	(4)	(5)	(6)	Total
(0) No schooling	1.16	0.27	3.08	0.21	0	0.1	0	4.82
(1) Primary	0.68	1.33	13.68	2.09	0.17	0.21	0.03	18.2
(2) Secondary	1.13	4.65	31.2	9.89	1.33	2.26	0.14	50.6
(3) High school	0.07	0.86	5.1	4.62	0.82	2.22	0	13.68
(4) 3-year college	0.03	0.14	1.51	1.4	1.3	2.33	0.07	6.77
(5) 5-year college	0	0.1	0.65	1.09	0.68	2.63	0.34	5.51
(6) Postgraduate	0	0	0	0.1	0.03	0.17	0.1	0.41
Total	3.08	7.36	55.22	19.4	4.34	9.92	0.68	100
No. observations	90	215	1614	567	127	290	20	2923

tabulations, can be found in the Appendix and in Tables I and II. On average men have slightly more schooling than women in this sample, but the modal education category is 'secondary' (with less than a high school degree) for both men and women, and the education of husbands and wives is highly correlated. The mean age at marriage is 23 years and it increases with the woman's education.

Table IV tabulates birth outcomes conditional on the previous year's action and other covariates. The frequency of births conditional on no use of contraceptives is around 40%, but it falls to 8.9% if another birth has just occurred.[9] There are significant differences across age and education

[9] A lower birth hazard in the period following a birth is the consequence of post-partum amenorrhea and a shorter time to conceive.

Table III.

Panel A: contraceptive methods used at the time of the interview

Contraceptive method	Proportion (%)
Condom	42.35
Pill	27.94
IUD	13.34
Withdrawal	12.13
Rhythm	2.66
Others	1.58

Panel B: age, parity, birth rate and contraceptive use; time series of sample means

Year	# Obs.	Age: mean(sd)	Parity: mean(sd)	Birth rate: births/obs.	Contracept	Sterilize
1983	325	24.84(4.62)	1.19(1.16)	0.662	53.54%	1.85%
1984	1618	28.58(5.11)	1.49(1.05)	0.124	67.86%	1.11%
1985	1788	28.96(5.34)	1.52(1.08)	0.130	69.30%	1.62%
1986	1891	29.48(5.46)	1.54(1.07)	0.123	72.13%	1.53%
1987	1997	30.00(5.60)	1.55(1.05)	0.105	72.25%	1.95%
1988	2102	30.44(5.82)	1.53(1.05)	0.098	72.74%	1.76%
1989	2209	30.90(6.02)	1.53(1.05)	0.102	73.11%	2.13%
1990	2314	31.32(6.21)	1.52(1.03)	0.095	74.29%	1.86%
1991	2329	31.67(6.13)	1.51(1.01)	0.082	74.97%	1.89%
1992	2343	31.92(5.98)	1.51(1.01)	0.082	74.47%	2.26%
1993	2338	32.30(5.97)	1.49(0.97)	0.098	76.26%	2.01%

Table IV. Sample birth frequencies by wife's age and education (%)

Age	Not contracept		Contracept	Education	Not contracept	Contracept
	$b_{t-1} = 0$	$b_{t-1} = 1$				
≤25	60.42	10.79	5.39	Primary or less	28.94	2.63
26–30	56.30	9.24	2.86	Secondary	39.44	2.41
31–35	36.52	5.26	2.08	High school	43.64	3.19
36–44	6.92	2.78	0.71	3-years college	43.47	1.62
				5+-year college	44.62	4.51
All	43.75	8.90	2.61	All	38.02	2.61

b_{t-1} is lagged birth indicator.

categories; the birth hazard decreases monotonically with the mother's age and it is higher for more educated women. The frequency of births conditional on using contraceptives (i.e., 'failure' rates) is between 2% and 4% on average. It also declines with age, but there are no significant education effects.

The columns of Table V show the distribution of the couple's choices by parity and wife's age, excluding period-observations of sterilized couples. Figure 1 displays an important aspect of this data, the age profiles of the probability of using contraceptives by parity. The essential patterns of contraceptive behaviour are the following. The use of contraceptives increases as couples move from parity 0 to parity 2, but it declines slightly for women in parities 3 and higher. Overall, the proportion of women choosing to contracept is very high, around 50% at parity 0 and higher than

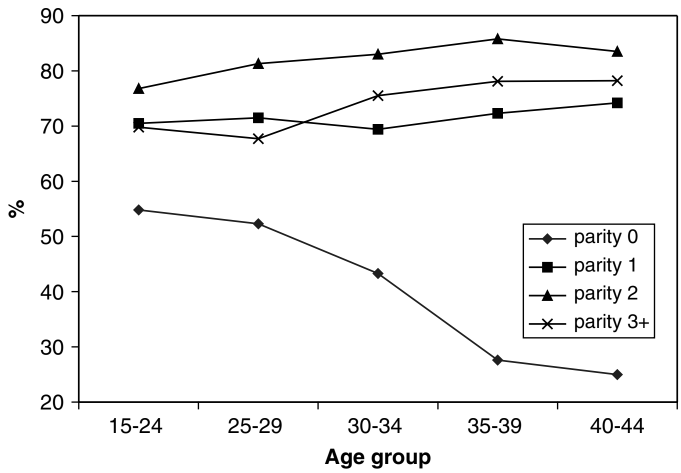

Figure 1. Proportion of non-sterilized couples contracepting, by age and parity

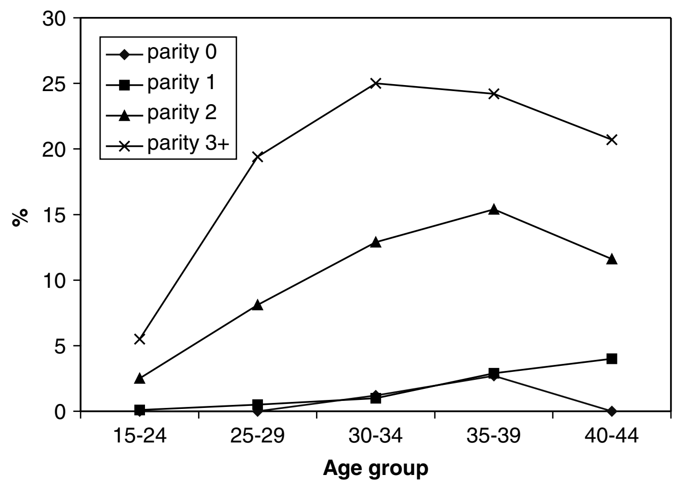

Figure 2. Proportion of all couples sterilized, by age and parity

70% at every other parity. At parity 0 the proportion using contraceptives is clearly decreasing in the mother's age, but not at higher parities. Sterilization almost never occurs at parities 0 and 1 but it is quite common at parities 2 and higher. The age profile of sterilization rates is hump-shaped, with its peak around 30. Couples are a lot more likely to sterilize immediately after a birth: 8.5% choose to do so when their second child is born, as well as 20% of those who experience a birth at higher parities (see Table VI).[10] Figure 2 shows the cumulated proportion of sterilized couples, by age and parity. By age 30, one in every eight couples who have reached parity 2 and one in

[10] Sterilization rates are even higher when a birth follows contraceptive failure, but sample sizes are small and these differences are only marginally significant.

Table V. Contraceptive actions by age and parity (%)

Parity	Age group	No contraception		Contracept		Sterilize	
		S	P	S	P	S	P
0	15–24	45.2	49.0	54.8	51.0	0.0	0.0
	25–29	47.7	45.5	52.3	54.3	0.0	0.1
	30–34	56.5	57.3	43.3	42.3	0.2	0.4
	35–39	71.7	68.1	27.6	31.1	0.7	0.8
	40–44*	75.0	70.6	25.0	28.9	0.0	0.4
1	15–24	29.5	27.4	70.5	72.3	0.0	0.2
	25–29	28.4	25.9	71.5	73.6	0.1	0.4
	30–34	30.2	32.5	69.4	66.7	0.4	0.8
	35–39	27.3	30.5	72.3	67.8	0.4	1.7
	40–44	25.5	25.9	74.2	73.1	0.3	0.9
2	15–24	21.6	20.7	76.8	77.1	1.6	2.1
	25–29	15.5	14.8	81.3	82.1	3.2	3.2
	30–34	13.2	14.2	83.0	82.1	3.8	3.7
	35–39	12.1	12.5	85.8	84.6	2.1	2.9
	40–44	15.3	15.0	83.5	83.8	1.2	1.1
3+	15–24*	28.3	22.8	69.8	73.3	1.9	3.9
	25–29	23.8	19.7	67.7	75.3	8.5	4.9
	30–34	16.3	16.0	75.5	78.4	8.2	5.6
	35–39	17.0	16.4	78.1	80.2	4.9	3.4
	40–44	20.1	19.4	78.2	79.4	1.7	1.2

* Group with less than 100 observations.
S = sample; P = predicted.

Table VI. Sterilization rates by age, parity and current birth outcome (%)

Parity	1		2		3	
	$b_t = 0$	$b_t = 1$	$b_t = 0$	$b_t = 1$	$b_t = 0$	$b_t = 1$
Sample proportions						
15–25	0.1	0	1.1	2.8	2.0*	5.4**
26–30	0.1	0	2.5	8.1	4.6	17.9
31–35	0.5	0*	2.6	13.0	5.7	19.4
36–44	0.6	0**	1.5	15.8**	1.8	28.8*
Predicted probabilities						
15–25	0.2	0.5	1.4	4.1	2.7*	6.8**
26–30	0.3	1.3	2.3	8.1	3.3	9.5
31–35	0.8	3.3*	2.9	11.3	3.7	13.3
36–44	1.4	6.3**	2.1	9.6**	1.9	9.3*

** Group with less than 40 observations.
* Group with less than 100 observations.
b_t is birth indicator.

every four couples who have reached parity 3 are protected by sterilization. These proportions are somewhat higher for couples who married after sterilization became legal in 1983.

An important feature of the data is the persistence in the couples' choices. This is illustrated in Table VII, which shows transition probabilities between actions within a birth interval. For

Table VII. Contraceptive choices, transition probabilities

Parity zero at t and $t+1$

Action at t	Action at $t+1$			
		No contraception	Contracept	Sterilize
No contraception	Sample	0.8056	0.1905	0.0040
	Predicted	0.8100	0.1896	0.0003
Contracept	Sample	0.3328	0.6672	0
	Predicted	0.2525	0.7469	0.0006

Parity one at t and $t+1$

Action at t	Action at $t+1$			
		No contraception	Contracept	Sterilize
No contraception	Sample	0.9242	0.0720	0.0038
	Predicted	0.8342	0.1638	0.0021
Contracept	Sample	0.1604	0.8365	0.0031
	Predicted	0.1506	0.8437	0.0057

Parity two at t and $t+1$

Action at t	Action at $t+1$			
		No contraception	Contracept	Sterilize
No contraception	Sample	0.9128	0.0780	0.0092
	Predicted	0.8744	0.1194	0.0062
Contracept	Sample	0.0192	0.9573	0.0236
	Predicted	0.0351	0.9408	0.0242

Parity three or more at t and $t+1$

Action at t	Action at $t+1$			
		No contraception	Contracept	Sterilize
No contraception	Sample	0.9167	0.0500	0.0333
	Predicted	0.8210	0.1715	0.0076
Contracept	Sample	0.0204	0.9593	0.0204
	Predicted	0.0257	0.9498	0.0245

Note: These sample statistics are calculated for couples whose education level is less than high school (both husband and wife); the couple has $R = 0$ (not religious) and married when the wife was between 20 and 24 years old. Periods t with a birth ($b_t = 1$) are excluded.

instance, 81% of couples in parity 0 who choose not to contracept in any given year will choose the same action the following year, provided a birth has not occurred. The degree of persistence is larger at higher parities, reaching 96% for couples who are contracepting in parities 2 and higher. Figure 3 shows, for the population of couples who attain a given parity, the proportion who are still contracepting at each duration of the subsequent birth interval. Duration 0 is the period that initiates the interval. With the exception of durations 0 to 1, the proportion keeps

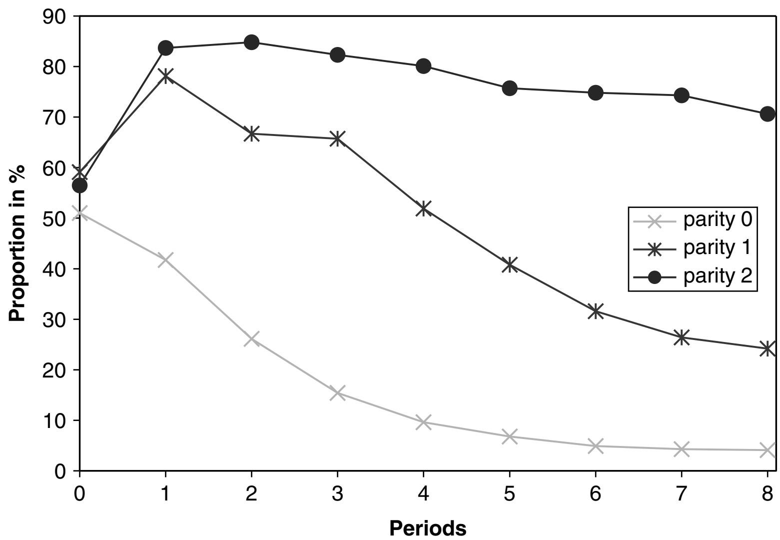

Figure 3. Sample proportion of couples still contracepting, by duration of birth interval

falling as couples switch to no contraception and/or experience a birth and move to the next parity.[11] That is, the proportion of couples contracepting is at a relative low immediately after a birth, increases sharply the following year and then declines monotonically. The decline is steeper at lower parities, reflecting the smaller degree of persistence of those who are contracepting as seen in Table VII. As a result the proportion contracepting three years into the interval is only 15% at parity 0, still over a half at parity 1 and more than 80% at parity 2.

In summary, a large fraction of couples are contracepting right after marriage but the transition to no use of contraceptives and the first birth tends to be short. Most couples contracept for at least two years after the first birth and then gradually switch to no contraception and a second birth. A non-negligible number of couples choose to sterilize immediately after reaching parities 2 or higher. Almost all other couples at those parities contracept continuously; exits occur slowly and are the result of contraceptive failures and the decision by a few couples to stop contracepting.

The main difference in contraceptive behaviour across education categories is that more educated women are more likely to contracept at parity 0 (see Table VIII). Furthermore, educated couples are more likely to sterilize at parities 2 and higher and religious couples are less likely to contracept and to sterilize.

Finally, of the 2923 women in the sample, we have complete histories for 629 and 1285 are observed through age 36 or sterilization. Table IX shows the distribution of final parity for these subsamples. Few births occur beyond age 36. Approximately half of women stay at parity 2, at least a third move to parities 3 or higher and only 1–2% stay at parity 0. On average, completed parity is lower for couples with more educated wives.

[11] Some couples move from 'not contracepting' to 'contracepting' and thus partly offset the flow out of the pool of contracepting couples. However, this offsetting flow is very small, first because the birth hazard is high and second because of the persistence in contraceptive behaviour.

Table VIII. Contraceptive actions by parity and wife's education (%)

Parity	Wife's education	No contraception		Contracept		Sterilize	
		S	P	S	P	S	P
0	Primary or less	67.7	62.6	32.3	37.3	0.0	0.0
	Secondary	52.0	52.2	47.9	47.8	0.1	0.1
	High school	40.1	43.4	59.9	56.6	0.0	0.1
	College	40.4	41.9	59.5	57.6	0.1	0.5
1	Primary or less	27.9	27.7	72.0	71.5	0.1	0.8
	Secondary	29.3	27.9	70.4	71.5	0.2	0.6
	High school	26.9	29.1	72.8	70.3	0.3	0.6
	College	31.0	30.7	68.7	68.6	0.3	0.7
2	Primary or less	14.3	14.7	83.2	82.7	2.5	2.5
	Secondary	14.5	14.6	82.5	82.4	2.9	3.0
	High school	10.5	11.6	86.4	84.8	3.1	3.7
	College	15.2	14.5	81.8	81.4	3.0	4.1
3+	Primary or less	22.1	20.7	74.1	76.2	3.8	3.1
	Secondary	14.9	14.4	78.6	81.6	6.6	4.0
	High school	11.2	11.4	79.3	83.7	9.5	4.9
	College	22.9	18.7	70.9	76.6	6.3	4.8

S = sample; P = predicted.

Table IX. Sample distributions of parity (%)

	Number of children				
	0	1	2	3+	Mean
Full sample >35	2.9	13.0	54.4	29.7	2.2
Full sample >39	2.4	10.3	52.4	34.9	2.4
Full sample >43	1.3	7.5	52.8	38.5	2.5
Non-religious	2.6	13.0	55.4	29.0	2.2
Religious	5.0	13.2	47.2	34.6	2.3
Primary or less	0.9	12.4	48.9	37.8	2.4
Secondary	3.1	11.0	57.9	28.0	2.2
High school	4.5	19.6	59.8	16.1	1.9
College	7.4	19.0	52.1	14.1	1.7

Note: The first three rows show the distribution of parity at a couple's last observation for all women who are then older than 35, 39 and 43, respectively. In each case we also included those who had sterilized before that age since that is their stopping period. The other rows are calculated using the last observation of women who are older than 35 and those who have sterilized. Age and education levels refer to the wife.

4. ECONOMETRIC IMPLEMENTATION

4.1. Likelihood

Following Rust (1988), we assume the state vector can be partitioned as follows: $S_t = (X_t, \varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t})$, where ε_{jt} is a random variable which determines the utility of action j in period t. It is known to the couple at t but it is not observed by the econometrician, whereas X_t is observed by the econometrician. The ε_{tj}'s satisfy the conditional independence assumption, i.e., they are independent across choices, couples and periods with distribution $G()$. The utility function is additively separable in observables and unobservables:

$$u_{tj} = \tilde{u}_{tj}(X_t) + \varepsilon_{tj}$$

Let $d^*_{tj}(S_t)$ denote the choice indicators when optimal actions are chosen and τ^* the optimal stopping period. Then $d^*_{tk}(S_t) = 1$ if and only if

$$k = \arg \max_{j\in\{1,2,3\}} [v_{tj}(X_t) + \varepsilon_{tj}] \tag{2}$$

and

$$P_{tk}(X_t) = \int I(k = \arg \max_j [v_{tj}(X_t) + \varepsilon_{tj}])\, \mathrm{d}G(\varepsilon_{tj}) \tag{3}$$

where $P_{tk}(X_t)$ is the probability of choosing action k at t conditional on X_t and $v_{tj}(X_t)$ is a valuation function giving the expected flow of current and future utilities conditional on the choice of j at t and on optimal choices in the future. The valuation function satisfies the following Bellman equation:

$$v_{tj}(X_t) = \tilde{u}_{tj}(X_t) + \beta E[\max_k \{v_{t+1k}(X_{t+1}) + \varepsilon_{t+1,k}\}|X_t, d_{tj} = 1] \tag{4}$$

for $j = 1, 2$ and $t \leq T - 1$, and $v_{tj}(X_t) = \tilde{u}_{tj}(X_t) + \beta E[W(t + 1, X_{t+1})|X_t, d_{tj} = 1]$ if $j = 3$ or $t = T$. Note that the conditional independence assumption implies that in order to compute valuation functions and the conditional choice probabilities it is not necessary to perform multiple integration over lagged values of the unobservables. In our specification below, the birth outcome is the only source of uncertainty about X_{t+1} so the expectation on the right-hand side of equation (4) is taken over conditional distributions of the birth outcome and of next period's values of the unobservables.

Suppose $\tilde{u}_{tj}()$, $W()$, $F_j()$ and $G()$ are known up to a vector of parameters θ. In order to allow for permanent unobserved heterogeneity we assume that some of the parameters in θ may vary across a finite number of 'types' in the population. Let θ_k denote the value of the parameters for type k and π_k the proportion of the population of that type. A couple's type is known to the couple but it is not observed by the econometrician. Since sterilization was not legal before 1983 we decided to drop all couple-year observations corresponding to that period. Our data consists of an unbalanced panel $\{d_{itj}, X_{it}, b_{it}\}_{i=1,\ldots,n}^{t=\underline{t}_i,\ldots,\bar{t}_i}$. A household's history may be right-censored ($\bar{t}_i < \tau^*_i$) if the woman was under 45 at the time of the interview, or left-censored ($\underline{t}_i > 1$) if the couple married before 1983, or both. Therefore, even if distributions of type $\{\pi_k\}$ are assumed independent of the couple's observable characteristics at the time of marriage X_{i1}, we have to consider the possibility that initial conditions $X_{\underline{t}_i}$ might be correlated with the unobservable type for couples with left-censored observations. We deal with this problem by allowing the probability that those couples are of each type to vary with initial conditions. A couple's contribution to the likelihood conditional on the unobserved type combines conditional choice probabilities and the probabilities of birth outcomes conditional on contraceptive actions:

$$\mathcal{L}_i(\theta_k) = \prod_t \prod_j \{P_j(X_{it};\theta)[b_{it+1}F_{jt}(\theta) + (1 - b_{it+1})(1 - F_{jt}(\theta))]\}^{d_{itj}}$$

The sample log-likelihood is then $L(\theta) = \sum_i \ln \sum_k \mathcal{L}_i(\theta_k)\Pr(k|X_{\underline{t}_i})$. In order to evaluate the likelihood we need the valuation functions v_{jt}. A full solution of the model is required to compute

v_{jt} for $j = 1, 2$. Solving the model by backward induction for each θ is straightforward but computationally expensive. Under the assumption that the unobserved state variables ε_{tj} are drawn from an extreme value distribution, the conditional choice probabilities and the recursions in (3) and (4) have convenient (logistic) closed forms.[12]

4.2. Specification

The per-period utility function is

$$\begin{aligned} u_{tj}() = {} & \eta_1 I_{1t} + \eta_{2k} N_t + \eta_3 N_t^2 \\ & + (\gamma_1 E_1 + \alpha_1 E_2) I_{1t} + (\gamma_2 E_1 + \alpha_2 E_2) I_{2t} + (\gamma_3 E_1 + \alpha_3 E_2) \sum_{n>2} I_{nt} \\ & + \mu_0 d_{t-1,1} d_{t2} + \mu_{j1} + \mu_{j2} R + \mu_{33} \tilde{t} d_{t3} \\ & + \psi_0 (t - 35) 1(t \geq 36) b_t + (\psi_1 dur_{t1} + \psi_2 dur_{t2} + \psi_3 dur_{t3}) b_t \end{aligned} \quad (5a)$$

The terms in the first two lines determine the utility derived from the stock of children as a function of parity, the couple's unobserved type and schooling and the parameters (η, γ, α). N_t is parity at the end of period t, the indicator I_{nt} is 1 if the wife has reached parity n or greater, k is unobserved type and E_1 and E_2 are the wife's and the husband's education. Our specification combines a quadratic-in-children baseline utility, parity-specific effects of the mother's and the father's education and an additional utility of leaving the state of childlessness. Thus the marginal value of the first child is $\eta_1 + \eta_{2k} + \eta_3 + \gamma_1 E_1 + \alpha_1 E_2$, the marginal value of the second child is $\eta_{2k} + 3\eta_3 + \gamma_2 E_1 + \alpha_2 E_2$ and the marginal value of the Nth child for $N > 2$ is $\eta_{2k} + (2N - 1)\eta_3 + \gamma_3 E_1 + \alpha_3 E_2$. In the third line, parameters (μ_{j1}, μ_{j2}) for $j = 1, 2, 3$ characterize the couple's preferences over contraceptive actions. Since only the differences in the utilities associated with each action are identified we use $\mu_{11} = \mu_{12} = 0$ as an identifying restriction; i.e., the disutility of taking no contraceptive action is set to zero. Note that separate identification of child valuation and contraceptive cost parameters relies on sample variation in the probabilities of conception.[13] We assume that a fixed disutility cost μ_0 is incurred whenever a couple initiates a spell of contraception. Once a couple is already contracepting, each year of protection involves an additional cost which depends on the couple's religious beliefs: R is an indicator equal to 1 if the couple attends religious services every week. The fixed cost/variable cost structure will help us fit the strong persistence in the use of contraceptives which is a feature of the data. The fixed cost μ_0 may be interpreted in terms of habit formation, as a cost of 'switching' to contraception for couples who are currently not contracepting.[14] The parameter μ_{33} introduces age variation in the cost of sterilization. A potentially important component of the cost of sterilization is the possibility of regret, i.e., because the method is irreversible a couple who uses it will be unable to adjust family size in the future if

[12] See Appendix for more details.
[13] A couple's choice determines the current period's contraceptive costs with certainty, while the utility flow from children is uncertain because it depends on whether another birth occurs. Therefore contraceptive cost parameters μ enter utility differences directly, whereas child valuation parameters are multiplied by differences in conditional birth probabilities. Furthermore, as in probit and logit models, utility and cost parameters are identified only up to scale.
[14] As pointed out by a referee, one drawback of this interpretation is that our single contraceptive choice aggregates methods which would seem to involve different 'fixed' and 'variable' costs, e.g. condoms and IUD.

their preferences for children were to change unexpectedly. Anticipating regret, some couples may substitute reversible contraceptive methods for sterilization. The risk of regret is smaller for older couples, so the contribution of regret to the cost of sterilization should fall with the age of the woman. Making the cost of sterilization a linear function of age allows us to test for sterilization regret in a simple fashion.[15] Finally, the terms in the last line of equation (5a) capture birth timing and birth spacing effects. We assume that every year beyond the age of 35 the cost of giving birth increases by ψ_0. The indicators dur_{th} for $h = 1, 2, 3$ describe the duration of the current birth interval. Specifically, $dur_{th} = 1$ if the last birth occurred h periods ago. Positive values of the parameters ψ_1, ψ_2, ψ_3 reflect a couple's preference for spacing births.

We set the discount factor to 0.95 and in line with our treatment of children as an irreversible durable, we assume that the terminal value function is the discounted sum of utility flows from the stock of children between the stopping period and the end of life at age 76.[16,17]

The conditional birth probabilities F_{jt} are logistic functions of the couple's unobserved type, education and age as well as of the current period birth indicator b_t. That is, $F_{jt} = \exp(z_{jt})/[1 + \exp(z_{jt})]$ with

$$z_{jt} = \theta_{j0} + \theta_k + \theta_{j1}\tilde{t} + \theta_{j2}\tilde{t}^2 + \theta_{j3}\tilde{t}^3 + \theta_{j4}1(E_1 = 2) + \theta_{j5}1(E_1 = 3) + \theta_{j6}1(E_1 = 4) + \theta_{j7}1(E_1 > 4) + \theta_{j8}b_t$$

Based on our analysis of the raw data we set $\theta_{24} = \theta_{25} = \theta_{26} = \theta_{27} = \theta_{28} = 0$; i.e., the effects of education and lagged births on the probability of conception are negligible whenever contraceptives are used.

The number of unobserved types is fixed at three. We have allowed the parameters η_2 and θ_{j0} to vary across unobserved types, shifting the profile of marginal values of children and the log odds ratio of births. For couples with left-censored histories we use a multinomial logit to model the distribution of unobserved types conditional on the couple's characteristics and initial conditions. All other couples draw their unobserved type at marriage from a fixed distribution, i.e., observable characteristics are exogenous with respect to type.

5. RESULTS

5.1. Parameter Estimates

Estimates of the multinomial logits giving the distributions of unobserved types can be found in Table XI, while full information maximum likelihood estimates of the model's structural parameters are in Table X. Panels A and B show estimates of the utility function and conditional birth probability parameters, respectively. The (quadratic) baseline utility is concave in the number

[15] The model lacks any other explicit mechanism for sterilization regret. Introducing one (e.g., permanent shocks to the marginal utility of children) would add considerable complexity in estimation as well as in identification in the absence of additional information such as a time-varying measure of desired family size. See Montgomery (1989) for a discussion of sterilization regret and dynamic behavioural models of contraceptive choice.

[16] In preliminary estimation rounds the model was also estimated with a discount factor of 0.90 and 0.99, resulting in a smaller value of the maximized likelihood.

[17] If a couple sterilizes and the stopping period is less than age 45, we include in the terminal value function the expected discounted value of the unobservable components of contraceptive costs between the stopping period and age 45. We do this because unobservables have non-zero means and their variances may be large relative to the choice-specific valuation functions and we do not want the comparison between sterilization and other choices to be dominated by the absence of unobservables.

Table X. Estimates of structural parameters

(A) Per-period utility function

Parameter and variables		Estimate	Standard error	z-ratio
Contraceptive costs				
μ_0	$d_{t-1,1}d_{t2}$ Fixed contraceptive cost	−1.6900	0.04896	−34.51
μ_{21}	Contraceptive cost per year	0.1225	0.09940	1.23
μ_{22}	$R = 1$ diff., religious couple	−0.1675	0.05836	−2.87
μ_{31}	Sterilization cost, fixed	−31.7841	2.89417	−10.98
μ_{32}	$R = 1$ diff., religious couple	−1.9728	0.55304	−3.57
μ_{33}	Sterilization cost, age/10	6.1302	0.61134	10.03
Value of children				
η_1	$N_t \geq 1$ at least 1 child	0.1344	0.04670	2.88
η_2	N_t stock of children, baseline	0.1504	0.02684	5.60
	Unobserved type 2, diff.	7.6915	1.66527	4.62
	Unobserved type 3, diff.	0.2388	0.03289	7.26
η_3	N_t^2	−0.0399	0.00537	−7.43
Effect of wife's education on				
γ_1	Value of first child	−0.0636	0.01190	−5.34
γ_2	Value of second child	0.0052	0.06186	0.85
γ_3	Value of third and successive	−0.0115	0.00627	−1.84
Effect of husband's education on				
α_1	Value of first child	0.0075	0.01232	0.61
α_2	Value of second child	0.0140	0.00607	2.30
α_3	Value of third and successive	−0.0211	0.00553	−3.81
Birth spacing effects				
ψ_1	one period	−7.9454	1.58457	−5.01
ψ_2	two periods	−1.5418	0.14470	−10.65
ψ_3	three periods	0.0418	0.13216	0.32
Birth timing effects				
ψ_0	birth cost beyond age 35	−0.7245	0.06214	−11.66

(B) Conditional birth probabilities, log-odds regression

Parameter and variables		Estimate	Standard error	z-ratio
Not contracepting				
θ_{10}		7.1376	2.40996	2.96
θ_{11}	$Age/10$	−6.9329	2.52594	−2.74
θ_{12}	$(Age/10)^2$	2.6910	0.86032	3.13
θ_{13}	$(Age/10)^3$	−0.3357	0.09542	−3.52
θ_{14}	Secondary education	−0.0709	0.07584	−0.94
θ_{15}	High school	0.0087	0.10513	0.08
θ_{16}	3 years college	−0.1051	0.14224	−0.74
θ_{17}	5+ years college	−0.4202	0.14654	−2.87
θ_{18}	birth at t	−3.3009	0.11986	−27.54
Contracepting				
θ_{20}		9.3316	3.79033	2.46
θ_{21}	$Age/10$	−11.9613	4.16221	−2.87
θ_{22}	$(Age/10)^2$	3.9046	1.49040	2.62
θ_{23}	$(Age/10)^3$	−0.4518	0.17417	−2.59
Unobserved type effect (θ_k)				
type 2		−4.3855	0.17702	−24.77
type 3		−2.6617	0.10257	−25.94

Log-likelihood = −13 455.

Table XI. Parameters of the auxiliary multinomial logit model of the distribution of unobserved types (reference category is type 1)

Parameter		Estimate	Standard error	z-ratio
	Couples married before 1983			
Type 2				
χ_{20}		−2.6217	0.48330	−5.42
χ_{21}	Number of children in 1983	−0.4895	0.10394	−4.71
χ_{22}	Number of periods since marriage	0.1189	0.02652	4.48
χ_{23}	Wife's education	−0.0886	0.10301	−0.86
χ_{24}	Husband's education	−0.1166	0.08467	−1.38
χ_{25}	Religious couple	0.8280	0.25546	3.24
Type 3				
χ_{30}		−3.8627	0.57709	−6.69
χ_{31}	Number of children in 1983	0.3637	0.13253	2.74
χ_{32}	Number of periods since marriage	−0.0365	0.03618	−1.01
χ_{33}	Wife's education	0.0554	0.13509	0.41
χ_{34}	Husband's education	0.2044	0.11933	1.71
χ_{35}	Religious couple	0.2067	0.36252	0.57
Couples married after 1982				
χ_{2}	Type 2	−4.8418	0.82600	−5.86
χ_{3}	Type 3	−2.1159	0.13129	−16.12

Note: Distribution conditional on couple's characteristics and initial conditions for couples with left-censored histories, i.e. couples married before 1983.

of children. Several education effects are significant. Of these the largest is the negative effect of the mother's schooling on the marginal utility of the first child. Furthermore, the marginal utility of the second child increases with the father's education, while increases in both the mother's and the father's schooling reduce the marginal utility of the third and all subsequent children.

As we might expect given the low yearly rates of sterilization, the estimated disutility of sterilization relative to the reference action (no contraception) is very large at all ages (and decreases with age). Overall, the estimated disutility of using contraceptives is much smaller but still significantly different from zero. However, the fixed cost accounts for almost all the disutility of a contraceptive spell. Variable costs per year of contraception were not significantly different from zero, and for non-religious couples the point estimate was actually negative. The point estimate for religious couples was positive, and the difference between the variable cost for religious and non-religious couples is significant. Two of the birth spacing parameters are significant and induce a preference for birth intervals of at least 3 years. The disutility of giving birth beyond age 35 is strongly significant. All contraceptive cost and birth spacing parameters are very large when compared to the point estimate of the lifetime utility from the first child, which is 2.48 for a couple with modal education.

Table XII shows the distribution of the unobserved types and a description of preferences and birth probabilities of each type. In order to characterize preferences for children we show the 'marginal child', i.e., the last child that contributes positive marginal utility. The second child is the marginal one for couples of type 1, the 'baseline' type. Most of the sample, 89% of couples who married in 1983 or later and 83% of couples who married before 1983, are of the baseline type. The marginal child is the third or the fourth, depending on the couple's education, for couples of type 3 (7.8% of couples married before 1983, 10.7% of those married after 1983). The

Table XII. Distributions and description of unobserved types

	Type		
	1	2	3
Type distributions (%)			
Couples married before 1983	82.8	9.5	7.8
Couples married after 1983	88.6	0.7	10.7
Marginal child	2	98	3–4
Birth probabilities (%)*			
Not contracepting, age 25	79.9	4.7	21.7
Contracepting, age 25	3.8	0.0	0.3

* See age profiles in Figure 4.

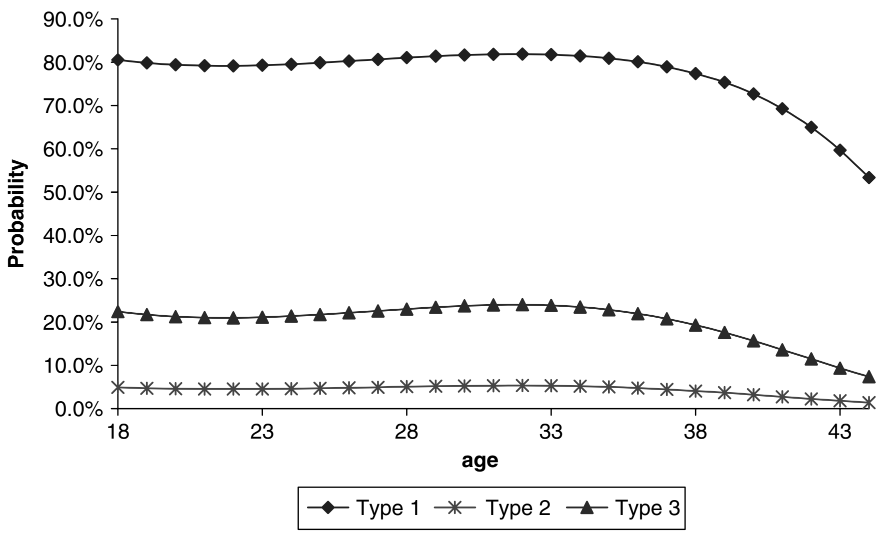

Figure 4. Birth probabilities, conditional on not contracepting, by age and unobserved type

least common type is type 2, with 9.5% and 0.7% of pre-1983 and post-1983 marriage couples, respectively. For this type children have a very high value and all children have positive marginal utility in the relevant range.[18] As a measure of fecundity we compute the probability of a birth conditional on no use of contraceptives and show its age profile for all three unobserved types in Figure 4. For most women who are of the baseline type the probability of giving birth in a year is high up to the age of 35, around 80%.[19] Birth probabilities are much lower for the other unobserved types, only 5% for type 2 and around 25% for type 3 under the age of 35. A

[18] Point estimates of the marginal child are very large and imprecise.
[19] Compared to other measures of natural fertility, such as estimates of age-specific fertility rates of fecund hutterite women (see Bongaarts and Potter, 1983, p. 13), our estimated profile has a similar shape but it is higher in levels. This difference may reflect lack of controls for unobserved heterogeneity as well as different behaviour. Although we use the term fecundity as a shorthand for 'birth probabilities conditional on not contracepting', the probabilities we (and others)

comparison with the raw data in Table IV reveals that a model with no unobserved heterogeneity would grossly underpredict the birth probability for most women who are not using contraceptives. If birth hazards were so much lower there would be less use for contraception, and the only way the model could rationalize the high proportion of women contracepting at all parities would be by assigning a positive utility to the use of contraceptives. Thus, allowing for permanent unobserved heterogeneity had very important implications for estimates of utility parameters.[20] Furthermore, our estimates also suggest that the large education and age effects on fecundity in the raw data are mostly spurious. For instance, the probability of a birth appears to decline sharply between ages 25 and 35 because the proportion of the less fecund type 2 and type 3 women among those that are still 'stuck' at parity 0 and not contracepting increases with age. The probability of a birth declines gradually by about one-third between ages 35 and 44, and is much lower at all ages for those who have just given birth. Failure rates (i.e., the probability of a birth when contraceptives are used) for the baseline type are around 4% at age 25, 2% at age 35 and even lower for older women.

5.2. Within-Sample Fit Discussion

The model's within-sample predictions of contraceptive actions by parity and age, and the transition probabilities between actions, are shown in Tables V and VII, respectively.[21] A comparison with the corresponding sample statistics in the same tables reveals that the model does very well in replicating the main patterns of behaviour described in Section 3. We now discuss how the model rationalizes the main features of the data and we comment on a few remaining discrepancies between model predictions and data.

For most couples the marginal utility of the first two children is positive and the third and all subsequent children have negative value. If fertility control were perfect and costless, most couples would stop at parity 2. However, for the less educated couples the marginal utility of children is monotonically decreasing, whereas for the more educated couples the second child actually has higher value than the first. This pattern of marginal utilities rationalizes the observation that while the use of contraceptive methods increases between parities 0 and 2, the increase is much less marked for the more educated couples whose waiting time to the first birth is longer. This delay probably reflects higher labour force participation rates of more educated women and the difficulties involved in simultaneously building a successful career and a family.

Given that couples value two children, why is the proportion of them using contraceptives so high at parities 0 and 1? Why does a sizable proportion move on to parity 3 and why is the proportion of women contracepting at parity 3 slightly smaller than at parity 2? At parity 0 the model's explanation is partly based on 'precautionary contraception'. Since fertility control is imperfect, a couple who reaches parity 1 early is at high risk of 'overshooting'; for instance, the cumulated failure rate for a woman who is continuously using contraceptives between ages 26 and 35 is 23%. It may therefore be rational for many couples at low parities to contracept and delay births.[22] At parity 1 the precautionary motive is still present, together with the desire to space

estimate depend not only on fecundity but also on other more obviously behavioural aspects such as the frequency of intercourse.

[20] A conjecture that this would be the case can be found in Heckman and Willis (1976).

[21] A description of the computation of predicted probabilities can be found in the Appendix.

[22] The notion of precautionary contraception was introduced in Heckman and Willis (1976).

births, and for some couples the benefit of not contracepting (i.e., a second child) is not large enough relative to the switching cost that will have to be borne once contraception is resumed at parity 2. The reasons why many couples move to parity 3 are contraceptive failures which result in unplanned births combined with a large variance of choice-specific utility shocks. In some decision periods, the random component of contraceptive costs can make the disutility of too many births smaller than the cost of preventing them. Likewise, the large variance of the random components of choice-specific utilities also contributes to explain the high proportion of couples contracepting at low parities. Finally, the small decline in the use of contraceptives at parity 3 is explained by the higher proportion of women with religious beliefs and of unobserved type 3 among those who attain that parity.

An implication of the precautionary motive for contraception is that at every parity the age profile of contraceptive use should be decreasing. On the other hand, there is a large disutility of late births and increasing the mother's age for fixed parity produces selected samples (by religion and education) of couples who are more likely to use contraceptives, and selected samples by unobserved type of couples who are less likely to use them. It is the interaction of these opposing effects that enables the model to fit the sample age profiles by parity.

The model predicts the marked increase in sterilization rates at parities 2 and higher and their hump-shaped age profile at any given parity. The decline in the hazard of conception and the reduced number of periods at risk beyond age 35 explain the lower rates of sterilization predicted in that age group. The model also fits the lower rates of sterilization under the age of 30, but without the estimated additional cost of sterilization in that age group it would overpredict sterilization rates. This result lends support to the hypothesis of sterilization regret. Furthermore, the model also rationalizes the observation that sterilization is a lot more likely immediately after a birth (see Table VI). When a birth occurs which makes the marginal utility of the next child negative, sterilization or contraception are needed in order to avoid another birth. If sterilization is optimal, a forward-looking couple would rather do it now than in the future, since postponing it involves additional switching and contraceptive costs and temporary exposure to the hazard of conception.[23]

The model also matches a large part of observed persistence in contraceptive actions. Endogenous sample selection in the couple's observable and unobservable characteristics contributes to persistence in both actions at all parities. If a couple is contracepting this period it is more likely to have characteristics which make contracepting the optimal choice both this period and the next. At parities 0 and 1 preferences for spacing and precautionary contraception contribute to persistence in the use of contraceptives, whereas the positive marginal utility of the next child contributes to persistence in 'not contracepting'. At parities 2 and higher no more children are wanted, which explains the very high degree of persistence in the use of contraceptives. A feature of the model that contributes to persistence in 'no use of contraceptives' is the large value of the fixed component of contraceptive costs introduced in our specification. Furthermore, only couples who did not contracept and did not have a birth are used to compute the corresponding transition probability.

[23] As pointed out by a referee, another possible explanation for this fact which is not built into our model is that the costs of sterilization are lower at the time of birth, especially following a C-section. C-sections are less common in Spain than in the USA. Ruiz Salguero (2002) reports that in the Spanish survey the median interval between the last birth and sterilization is 3 months for women and 11 months for men in ages 25–34, and 17 and 33 months for men and women over the age of 35. However, note that we do underpredict sterilization rates immediately after births in the 35–44 age group.

Therefore, the relevant subsample is selected to include more couples of the less fecund types and this should generate some persistence in that action.[24]

Our discussion was based on behaviour of the 'baseline' type. As noted above, child valuations and fecundability are very different for couples of unobserved types 2 and 3, and so is their predicted behaviour. Only one of every six couples belongs to one of these types, and in particular type 2 is almost non-existent in the subsample of women who married after 1983. However, likelihood ratio tests rejected simpler models with only one or two types in fecundability and/or preferences for children. In order to better understand the role of permanent unobserved heterogeneity we used the estimated model to compute posterior distributions of type for each couple in the sample given their observed histories. It turns out that this clearly 'identifies' type 2 and type 3 couples, i.e., the model assigns very high posterior probability of belonging to types 2 and 3 to small subsamples of couples with distinct behaviour and fertility outcomes. For instance, the number of couples that belong to type 2 or type 3 with probability greater than 80% is 133 and 154, respectively. In the data, the couples thus identified as 'type 2' have very low fertility but they almost never use contraceptives; the model rationalizes this behaviour by inferring an extremely high valuation of children together with a very low probability of conception. Type 3 couples use contraceptives occasionally, e.g. to space births, and the distribution of their final parity has the same mean as for the full sample but the variance is higher.

Finally, in order to assess the contribution of forward-looking behaviour to the model's ability to rationalize the data we estimated a restricted version of the model with $\beta = 0$. The restricted model does not match the patterns of sterilization rates by parity, age and birth indicator. Point estimates are different in general and overall they seem less plausible: using contraceptives yields higher utility than not using them, and the probability of births for older women conditional on not using contraceptives is much higher.

5.3. Out-of-Sample Fit

Our estimation sample did not include the pre-1983 observations for couples who married before 1983 because, although the use of contraceptives was made legal in 1978, sterilization was not legal until 1983. For the subsample of couples married between 1978 and 1982, we can use the estimated model to predict parity in 1983 under the assumption that sterilization was not available, i.e., we restrict the choice set but we keep every other feature of the model the same and we assume that couples correctly anticipate the availability of sterilization starting in 1983. For each couple, we compute the predicted mixture distribution of parity in 1983 given the couple's observed date of marriage and the distribution of unobserved types obtained from the auxiliary multinomial logit. Table XIII compares the average of predicted distributions to the actual distribution of parity in the data. This out-of-sample comparison with a regime change provides a much more stringent test of the model's ability to predict behaviour than within-sample forecasts, a test that would be hard to implement within a less structured approach. The model's predictions are reasonable but it does underpredict the proportion of couples who attain parity 3 and expected parity.[25] Note that since contraceptives had just become legal in the period considered in our test, to the extent

[24] In spite of this, the model falls a bit short in its predictions of the degree of persistence in no use of contraceptives.

[25] We repeated the simulation under the assumption that couples did not anticipate the availability of sterilization in 1983. Expected parity is slightly lower (0.98) in this case, as the model predicts that couples would engage in a little bit more precautionary contraception.

that the cost of acquiring them was still higher than in our sample period, our simulation design would not fully capture the difference in regimes and we would expect the model to underpredict fertility. We explored this issue further by increasing the fixed costs of contraceptive spells, and we found that if we had assumed that fixed costs were still twice as large between 1978 and 1982 as they were in the sample period, we would have predicted the distribution of parity in 1983 almost perfectly, as shown in the last row of Table XIII.

5.4. Counterfactual Experiments

Table XIV shows summary statistics for simulations which illustrate the importance of imperfect fertility control. The simulations are obtained from a model with the estimated parameter values. We first compute the distribution of final parity for a population of identical couples with the modal characteristics in the sample (the baseline population). We then repeat the calculations for alternative hypothetical scenarios. In the first one we assume that a new contraceptive method

Table XIII. Out-of-sample fit. Distributions of parity in 1983 (%)

	Number of children				
	0	1	2	3+	Mean
Sample distribution of parity	22.3	57.7	18.7	1.4	0.99
Mean predicted distributions					
Using estimated parameters	32.6	56.6	10.3	0.5	0.79
Doubling fixed contraceptive costs	22.2	61.8	15.1	0.9	0.95

Note: Actual and predicted distributions are for the subsample of couples married between 1978 and 1982. This corresponds to the period when sterilization was not yet legal.

Table XIV. Predicted distributions of parity at the end of fertile life (%)

	Number of children				
	0	1	2	3+	Mean
Modal couple	0.4	15.0	63.3	21.3	2.08
Counterfactual experiments for modal couple					
Zero failure rate in contraception	0.3	14.4	72.2	13.1	1.99
Sterilization not available	0.3	13.9	61.0	24.8	2.14
Fertility treatment	0.4	13.0	63.1	23.5	2.13
Fertility treatment, unobserved type 3	0.4	4.3	8.0	87.3	3.5
Couple characteristics different from modal values					
Unobserved type 2	41.0	39.0	15.9	4.1	0.84
Unobserved type 3	3.2	18.0	39.9	38.9	2.27
Age at marriage: 27	1.1	25.1	61.2	12.6	1.86
Religious	0.3	11.9	62.8	25.0	2.16
Age at marriage 27, 5+ years in college	10.0	15.9	64.9	9.2	1.74
Age at marriage 30	2.5	38.0	52.5	7.0	1.65
Age at marriage 34	9.5	66.0	22.9	1.6	1.16

Modal characteristics: wife and husband have secondary education; they got married when the wife was 23 years old, they aren't religious and they are of unobserved type 1.

is introduced which has the same utility cost as the existing one but never fails; couples know that the failure rate is zero but the population is otherwise identical to the baseline case. In the baseline population the expected number of births is 2.08, and 21% of the population attains parity 3 or higher. In the zero failure rate scenario the precautionary motive which induces couples to use contraceptives at parity zero is not present. For instance, the fraction of couples using contraceptives the first period after marriage is 34% as opposed to 39% in the baseline population. As a result, couples build their 'stock' of children slightly faster, which can partly offset the reduction in fertility brought about by eliminating contraceptive failures. Overall, the proportion of couples moving to parity 3 drops from 21% to only 13% and the expected number of births per married couple from 2.08 to 1.99. This experiment suggests that the precautionary motive is present but not very strong, and that contraceptive failures account for about half the couples who reach parity 3, while the other half correspond to couples who draw large contraceptive costs and stop contracepting.[26] In our second experiment we assume that sterilization is not available. The probability of moving to parity 3 increases by about 10% relative to the baseline and expected final parity rises to 2.14. In spite of its far from negligible incidence in couple's choices, sterilization does not have a large impact on completed fertility because couples can substitute for it by using contraceptives. In our third experiment which we label 'fertility treatment', we explore the effect of new technologies which assist couples in conceiving children. We extend the couple's choice set to include a fourth option which results in a birth with probability one and we assume that the cost of this option is the same as the fixed cost of initiating a contraceptive spell.[27] The impact of this new technology is small for the modal unobserved type but it is large for couples of unobserved type 3 who have a much lower birth probability. In particular, completed fertility of type 3 couples increases by 50% from 2.13 to 3.50; since type 3 couples are approximately 10% of the population, overall expected fertility would increase by 0.18 children per couple.

Other simulations reported in Table XIV show the predicted effect on the number of births of changes in the couple's characteristics. Particularly noteworthy is the large estimated impact of increases in the age at marriage, such as have been observed in Spain over the last two decades. In our simulations, an exogenous increase in the age at marriage from age 23 to ages 27, 30 or 34 reduces the expected number of births from 2.08 to 1.86, 1.65 and 1.16, respectively.

6. CONCLUSIONS

In this paper we proposed a simple dynamic stochastic model of sterilization and contraceptive use over the life-cycle and we estimated its structural parameters using the 1995 Spanish Family and Fertility Survey. The estimated structural model improves on previous studies of US data in its ability to rationalize observed behaviour, in terms of fit and the plausibility of parameter estimates. Allowing for simple forms of permanent unobserved heterogeneity across couples in their ability to conceive and in their preferences for children has important implications for estimates of utility and cost parameters. The fit of the model improved when we introduced preferences for birth spacing, a fixed cost of initiating a spell of contraception, and age variation in the cost of sterilization. Estimates of the utility function parameters imply that the couples in our sample value the first

[26] We also simulated the effect of the introduction of a costless contraceptive method with the same failure rate as the current (costly) method. In this case there would be a lot more precautionary contraception: the proportion of couples contracepting at marriage would reach 65%.

[27] Since our estimates do not have a monetary interpretation our assumption has to be somewhat arbitrary.

two children, but significant deviations from this goal are brought about by imperfect and costly fertility control. Our simulations suggest that the introduction of sterilization has reduced fertility of Spanish couples by an average of only 0.1 children per couple, and that the availability of failure-proof reversible contraceptive methods and of better technologies which assist couples in conceiving children would have fairly small additional impacts (negative and positive, respectively) on completed fertility.

APPENDIX

Expressions for emaxes and CCPs

From equation (4), the value function for $t < T$ and $j = 1, 2$ is:

$$\begin{aligned} v_{jt}(X_t) &= \tilde{u}_{tj}(X_t) \\ &+ \beta F_{jt}(X_t) E_\varepsilon[\max_k \{v_{t+1k}(X_{t+1}) + \varepsilon_{t+1,k}\} | X_t, b_{t+1} = 1, d_{tj} = 1] \\ &+ \beta(1 - F_{jt}(X_t)) E_\varepsilon[\max_k \{v_{t+1k}(X_{t+1}) + \varepsilon_{t+1,k}\} | X_t, b_{t+1} = 0, d_{tj} = 1] \end{aligned}$$

The expectations on the right-hand side are taken over the conditional distributions of next period's unobservable utility shocks. Given the assumptions that $\varepsilon_{t+1,k}$ is drawn from an extreme value distribution and conditional independence:

$$E_\varepsilon[\max_k \{v_{t+1k}(X_{t+1}) + \varepsilon_{t+1,k}\} | X_{t+1}] = \gamma + \ln\left(\sum_{k=1}^{3} \exp(v_{kt+1}(X_{t+1}))\right)$$

where $X_{t+1} = (X_t, b_{t+1}, d_{tj} = 1)$ and γ is the Euler constant (0.577 216).

If $t = T$, there is no more future uncertainty and the value function is:

$$\begin{aligned} v_{jT}(X_T) = \tilde{u}_{Tj}(X_T) &+ \beta F_{jT}(X_T) W(T+1, (X_T, b_{T+1} = 1)) \\ &+ \beta(1 - F_{jT}(X_T)) W(T+1, (X_T, b_{T+1} = 0)) \end{aligned}$$

where $W(T+1, X_{T+1}) = \sum_{t=45}^{76} \beta^{t-45} \tilde{u}_{t.}(X_{T+1})$ and $\tilde{u}_{t.}()$ is $\tilde{u}_{tj}()$ without any contraceptive action cost. The value functions for each t are calculated recursively from period $t = T$, backwards.

If $j = 3$, $F_{3t} = 0$ and

$$v_{jt}(X_t) = \tilde{u}_{tj}(X_t) + \beta E_\varepsilon[W(t+1, X_{t+1}) | X_t, b_{t+1} = 0]$$

where

$$\begin{aligned} E_\varepsilon[W(t+1, X_{t+1}) | X_t, b_{t+1} = 0] = &\sum_{h=t+1}^{T} \beta^{h-(t+1)} (\tilde{u}_{h.}(X_{t+1}) \\ &+ E_\varepsilon[\max_k \{\varepsilon_{h,k}\} | X_{t+1}]) + \beta^{T+1-(t+1)} W(T+1, X_{t+1}) \end{aligned}$$

Conditional choice probabilities take the form:

$$P_{kt}(X_t) = \frac{\exp(v_{jt}(X_t))}{\sum_{k=1}^{3} \exp(v_{kt}(X_t))}$$

Analytical derivatives with respect to the parameters are computed in a straightforward manner from these expressions.

Sample and Variable Definitions

We select our sample among the 6013 people (1992 men and 4021 women) interviewed in the survey. We drop interviews with incomplete information about the variables we require for estimation. Out of 6013 individuals, 3549 were in unbroken first marriages and living with their spouse at the time of the interview. Our sample includes 2923 of those 3549 couples. The rest were excluded for any of the reasons listed here and in the Data section. Each interview contains information about both members of the couple, the interviewed person and his or her spouse. For each couple we construct the following variables:

- Wife's and husband's education are categorical variables that take values between 0 and 6. Each category has its counterpart in the International Standard Classification of Education. The categories are:

0 no schooling or less than primary
1 primary school, starting around the age of 6 and lasting for five years
2 secondary school, lasting for about three years after primary
3 high school or professional education, lasting for about three years
4 three years in college
5 four or five years in college
6 graduate studies.

- The binary variable R describing a couple's religious beliefs is set to 1 if both members of the couple attend religious services at least once a week. We refer to these couples as 'religious'.

For each couple we construct observations for every calendar year using retrospective information. Each couple-year observation or period has the following variables:

- Contraceptive action indicators, $d_{jt},\ j = 1, 2, 3$. The values of these variables are obtained as described in the Data section. If a birth occurred during the last two months of a calendar year, that year is not considered a decision period since the action that originated the birth is assigned to the previous year and there is no time left in the (birth) calendar year for any relevant contraceptive choices. Therefore, we account for the birth but we drop that couple-year observation.
- Current birth indicator: $b_t = 1$ if a birth occurred during calendar year t.

- Next period birth indicator: $b_{t+1} = 1$ if a birth occurred during calendar year $t + 1$. The probability of this birth is determined by the contraceptive choice made in period $t(d_{jt}, j = 1, 2, 3)$. We exclude the last observation of all couples with right-censored histories because for that year we observe the contraceptive choice they made but we do not observe b_{t+1}.
- The number of children N_t is the stock of children at the beginning of decision period t. Therefore, it includes any birth occurring at period t.
- Previous contraceptive action indicator: if marriage or a birth occurred during period t, the period t 'previous contraceptive action indicator' is set to 1, i.e., not contracepting. Otherwise, it is equal to d_{jt-1}. For couples whose histories are left-censored in 1983, we drop the 1983 observation since the 'previous contraceptive action' indicator would correspond to 1982, which is censored. We have 1469 couples with left-censored histories, with an average left-censoring of 6.5 periods per couple.
- Periods from the last birth.
- Wife's age in years.

The histories of couples who have twins are right-censored at the period they have twins because that outcome is not considered in our model.

Computation of Predicted Probabilities

Predicted conditional choice probabilities for each couple-year observation are computed as the weighted average of conditional choice probabilities for each unobserved type, with weights given by the *ex post* probability that the couple is of each type conditional on the couple's full history. That is:

$$
\begin{aligned}
P_{itj} &= \sum_{k=1}^{2} P_{itjk} \Pr(k|X_i, X_{\underline{t}_i}) \\
\Pr(k|X_i, X_{\underline{t}_i}) &= \frac{\Pr(k, X_i|X_{\underline{t}_i})}{\Pr(X_i|X_{\underline{t}_i})} \\
\Pr(k, X_i|X_{\underline{t}_i}) &= \Pr(X_i|k, X_{\underline{t}_i}) \Pr(k|X_{\underline{t}_i}) \\
&= \left(\prod_{t=\underline{t}_i}^{\bar{t}_i} \sum_j d_{itj} P_{itjk} [b_{it+1} F_{ijtk} + (1 - b_{it+1})(1 - F_{ijtk})] \right) \Pr(k|X_{\underline{t}_i}) \\
\Pr(X_i|X_{\underline{t}_i}) &= \sum_{k=1}^{2} \Pr(X_i|k, X_{\underline{t}_i}) \Pr(k|X_{\underline{t}_i})
\end{aligned}
$$

where P_{itjk} is the probability that couple i chooses action j at period t if it is of unobserved type k, conditional on the state variables observed at t; F_{ijtk} is the probability that couple i experiences a birth at $t + 1$ if it is of unobserved type k, conditional on the state and on the choice of action j at period t; $X_i = \{X_t\}_{t=\underline{t}_i,\ldots,\bar{t}_i}$ is the history of the couple's choices and parity transitions; P_{itjk}, F_{ijtk} and $\Pr(k|X_{\underline{t}_i})$ are obtained from the model given parameter estimates.

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