

## THE ECONOMICS OF FERTILITY IN DEVELOPED COUNTRIES

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## 1. Introduction

In this chapter we survey the intellectual development and empirical implications of the literature on the economics of fertility as it applies to fertility behavior in developed economies. The now commonly held view that fertility behavior can be analyzed within the choice-theoretic framework of neoclassical economics originated in the pioneering paper by Becker (1960).<sup>1</sup> Therein, Becker attempted to reconcile “the neo-Malthusian proposition that increases in income tend to stimulate fertility”, with “the facts that income growth has been accompanied by secular decline of fertility and that family income is inversely associated with cross-section differentials in the industrialized countries”.<sup>2</sup> Becker sought to address this apparent puzzle by applying

the theory of the consumer to show that these secular changes and cross-sectional differences in the completed family sizes of households in developed countries were the result of variations in family incomes and the “prices”, or opportunity costs of children.

In surveying the literature which followed Becker’s pioneering work, we have two primary objectives. First, we seek to review the important theoretical developments, or model features, spawned by the attempts to explain household fertility behavior within a neoclassical framework. In the process we characterize how the development of the theory of the allocation of time, the concepts of household production theory, and human capital investment theory, among others, helped improve our understanding of the fertility decisions of households in developed societies.

Second, we attempt to characterize the implications that these models provide for empirical assessments of the determinants of fertility behavior. As is true in many other subfields of economics, strategies for identifying the effects of relationships implied by neoclassical economic models of consumer choice, even those as straightforward as the effect of a price change on a household’s demand for a good, are often controversial. Assessing the validity of implications of economic models of fertility is no exception to this pattern. Below, we characterize the identification problems as they arise in this context, and we highlight several studies which, in our view, follow exemplary strategies for obtaining estimates of causal relationships, especially with respect to their credibility.

The balance of the chapter proceeds in four sections. The next section lays out some stylized facts. It provides a brief description of the key trends in fertility for developed economies. We consider those dimensions of fertility which have been emphasized in the static and dynamic theoretical and empirical literature considered in

<sup>1</sup> Another influential, slightly earlier model of fertility was presented by Leibenstein (1957). In it, Leibenstein stressed the importance intergenerational transfers such as old age security as a motivation for fertility in developing countries.

<sup>2</sup> Willis (1973).

the remainder of the chapter. While our depiction relies primarily on data for the US, many of these trends appear to hold in all countries which are characterized by market-based economies and relatively high standards of living.

The third section, following much of the extant literature, takes a static perspective to the modeling. Applying the neoclassical theory of consumer choice to household fertility, the section applies several developments of the neoclassical framework to the salient features of fertility. We begin by considering standard price effects and consider generalizations to include marital status and the use of “costly” methods (contraception and abortion) to control a woman’s fertility. Adopting the conventions of the literature, we then consider pure income effects (identified with male earnings and the literature on quantity–quality) and the effects of changes in the value of women’s time (incorporating both income and substitution/price effects).

In Section 4, we review the literature on dynamic models of fertility behavior over the parents’ life cycle. We outline the ways in which these models extend the static models and examine what implications they provide for dimensions of fertility behavior which cannot be addressed with the earlier models, namely, the timing of first births, spacing of children, and contraceptive behavior.

After this review of the theoretical models of fertility, we discuss, in Section 5, the broad issues in estimating the implications of the theory for observed fertility behavior. We discuss various solutions to the fundamental identification problems which arise in assessing the impact of prices and income on both lifetime and life-cycle fertility behavior. Throughout this discussion we use several key empirical studies in the literature which we think best illustrate both the strengths and weaknesses of the various strategies for identifying price and income effects on household-level fertility behavior. We devote special attention to the empirical strategies (econometric approaches) used to analyze fertility behavior within a life-cycle (or dynamic) context in the estimation of dynamic models. We review the analysis of aggregate time-series data, hazard models, and estimable structural models derived from the optimal solutions to the intertemporal dynamic programming problems faced by parents.

The paper concludes with a short summary.

## **2. Fertility in the US: data, trends and the stylized facts**

In this section we provide an overview of the important trends and patterns in fertility and fertility-related behavior over the twentieth century for developed countries. More precisely, we focus on the trends for the United States, although we note where the US experience differs from that of other developed economies. While not intended to be a comprehensive discussion, we attempt to develop what we see as the key “stylized” facts that existing neoclassical economic models have attempted to explain and/or must confront in the future.

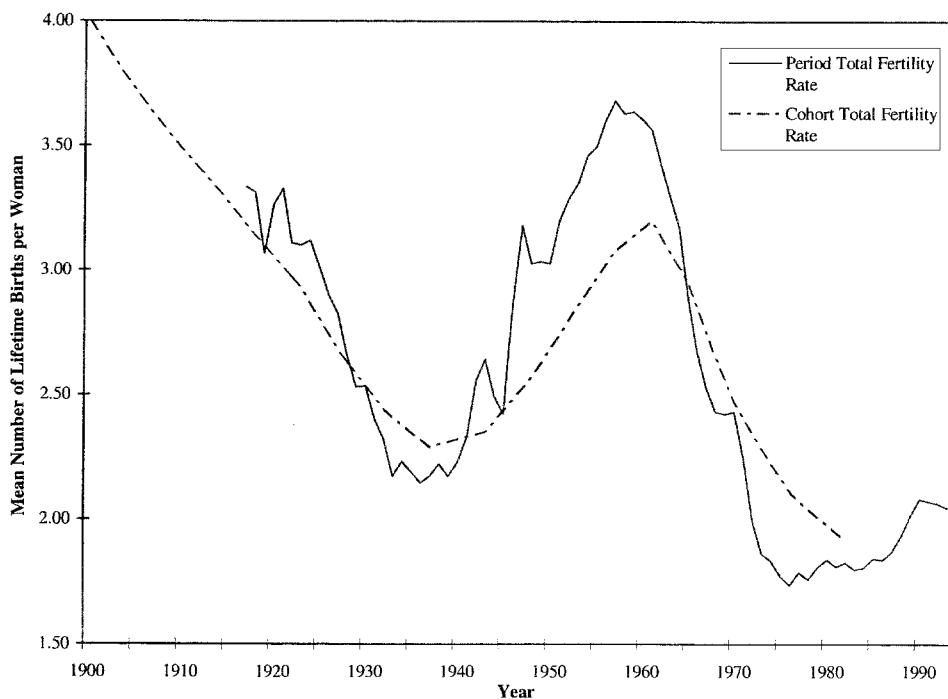


Fig. 1. Period and cohort total fertility rates in the US, 1900–1993. Source: NCHS, *Vital Statistics for the US*, selected years.

## 2.1. Completed family size

Given the focus of static economic models of fertility on explaining differences in the lifetime fertility of families, we begin by examining the trends in the total number of children born to women (and their mates) over their lifetimes. Fig. 1 displays annual measures of total fertility rates (TFRs) for the US over the twentieth century. TFRs are the sum of age-specific birth rates over those ages (15–44) during which women are fertile; the figure contains both *period* and *cohort* TFRs. The period TFRs displayed in Fig. 1 measure the total lifetime number of births that would be predicted if a representative woman realized the age-specific fertility rates that prevailed in particular years.<sup>3</sup> Cohort TFRs measure the average number of children born to women of a par-

<sup>3</sup> The *period total fertility rate* for year  $t$  is given by

$$TFR_t = \sum_{a=15}^{44} BR_{t,a} \times 1000.$$

ticular birth cohort<sup>4</sup> and each birth cohort's TFR is displayed in the year in which that cohort attained its mean age of fertility.<sup>5</sup>

Regardless of the measure used, it is clear that the US has experienced a substantial decline in the lifetime fertility of women and their mates from the beginning to the end of the twentieth century. At the turn of the century, the typical woman bore four children over her lifetime (based on cohort TFRs) while women who reached the age of 45 in recent years bore, on average, only 1.9 children; at the latter level of lifetime fertility, the US population would not even replace itself from one generation to the next if it did not experience net in-migration. As noted in the Introduction, the negative association between economic development and completed family size was one of the empirical puzzles which Becker sought to reconcile with a neoclassical economic model of consumer choice. While the exact timing of the decline and the fluctuations around the long-run trend vary, all other developed countries experienced this same sort of long-run decline as their per capita incomes and standard of living rose.<sup>6</sup> Since the 1960s, the total fertility rates of almost all developed countries have converged to total fertility rates just below rates at which a country's population would be replaced by births.

The long-run decline in the lifetime fertility of American women was temporarily interrupted by the post-war baby boom when the women, whose fertility fueled the boom, experienced total lifetime fertility of 3.2 births. While explaining the post-war baby boom and subsequent baby bust in the US has been the focus of much numerous economic studies,<sup>7</sup> it is important to note that the magnitude of this "boom and bust" cycle in US fertility is unprecedented; no other developed country experienced the fertility increase after World War II that the US did.<sup>8</sup>

We next examine what has happened to other aspects of fertility behavior over the twentieth century which contribute to the trends in period TFRs. In particular, we ex-

<sup>4</sup> The *total fertility rate* for women in birth cohort  $c$  (i.e., women born in year  $c$ ) is given by

$$TFR_C = \sum_{i=14}^{44} BR_{c+i,a+i} \times 1000,$$

where the age-specific fertility rate,  $FR_{t,a} = (\text{Number of births in year } t \text{ to women of age } a / \text{Population of women of age } a \text{ in year } t) \times 1000$ .

<sup>5</sup> The *mean age of fertility* for the  $c$ th birth cohort is given by

$$A_c = \sum_{a=15}^{44} \frac{a \cdot FR_{c+a,a}}{\sum_a FR_{c+a,a}}.$$

<sup>6</sup> For example, the period TFR in Sweden was 4.0 in 1905 and declined to 1.6 by the mid-1980s. See Walker (1995).

<sup>7</sup> Many of these studies are reviewed in Macunovich (1994).

<sup>8</sup> For example, the peak in Sweden's post-war period TFR was 2.5 which occurred in 1964. See Walker (1995).

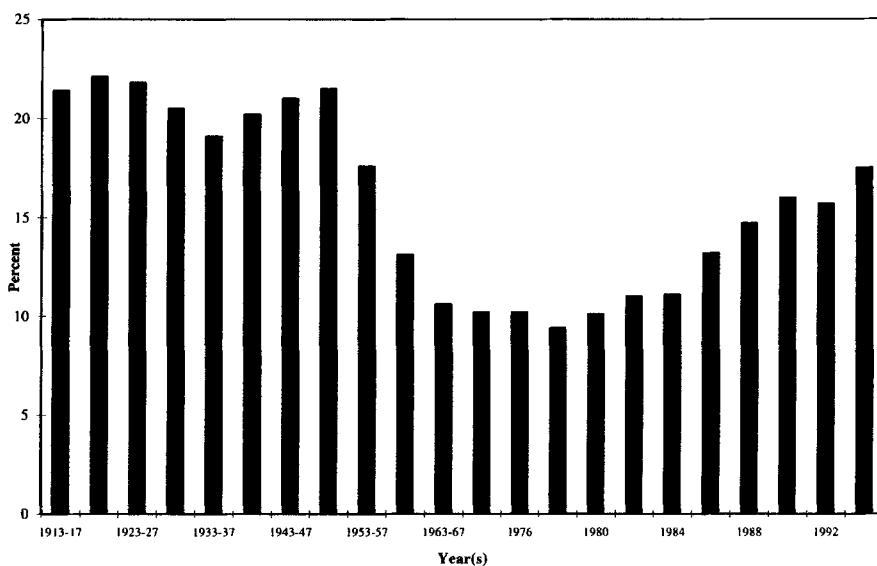


Fig. 2. Percent of women in US who are childless by age 40–44: 1913–1994. Source: NCHS, *Vital Statistics for the US*, selected years.

amine the trends in childlessness, the age at first birth and the incidence and tempo of childbearing after the first. Below, we treat each in turn.

## 2.2. Childlessness

While the vast majority of women in developed countries become mothers, a sizable fraction of them bear no children and, as can be seen in Fig. 2, the incidence of childlessness has fluctuated a great deal over the twentieth century. For example, over the last 20 years, the incidence of childlessness in the US has almost doubled, going from 9% of women who reached age 40–44 in 1978 to 18% for comparably aged women in 1994. (We note that while childlessness has increased among white women in the US, it has declined among non-white women, more or less continuously, since the mid-1940s.<sup>9</sup>) Some of this increase reflects the decline in the fraction of women who are married over this same period.<sup>10</sup> But the incidence of childlessness has risen among

<sup>9</sup> See Chen and Morgan (1991).

<sup>10</sup> For example, the percentage of women in the US who were ever married by ages 30–34 declined from 86.1% in 1970 to 72.8% in 1988. See Olsen (1994).

married women as well.<sup>11</sup> While this recent increase in childlessness in the US has drawn a great deal of attention by demographers,<sup>12</sup> Fig. 2 makes clear that the current rates of childlessness are not unprecedented. Cohorts who reached maturity early in the century had extremely high rates of non-marriage and, of those who married, many remained childless. In fact, what Fig. 2 suggests is that the nearly universal marriage and motherhood of cohorts of women who participated in the baby boom was atypical.<sup>13</sup>

### *2.3. The mother's age at first birth and the pacing of subsequent births*

Trends in a country's fertility rates depend, in part, on women's timing of childbearing over their reproductive careers. In addition to changes in the total number of births to women, the measured fertility rates over the post-war baby boom and bust cycle for the US also reflected changes in the life-cycle timing of childbearing by women who were of childbearing age during this era. To see this, compare the trends in cohort and period fertility rates after 1940 that are displayed in Fig. 1. Recall that the period TFR in a particular year is a synthetic characterization of what completed fertility would be if a woman who bore children at the age-specific rates that prevailed in that year; in contrast, cohort TFRs represent the total childbearing of women in the same birth cohort. As one can see, during the baby boom, period TFRs exceeded the cohort rates and, over the subsequent baby bust, the cohort rates were higher. These discrepancies reflect changes in the timing of births by women who were of childbearing age over this period. As shown in Fig. 3, fertility rates for younger women rose and fell over the course of the baby boom and bust. In essence, the baby boom was fueled by women shifting their childbearing to earlier ages and the subsequent bust was largely the result of the tendency for childbearing to be delayed. Thus, explaining the baby boom and bust rests heavily on explaining why there was a shift in timing of births as much as explaining what caused the completed fertility of women to change.

A common way of characterizing the timing of births is in terms of the probability of a woman's first birth at different ages and spacing between subsequent birth parities. In Fig. 4, we present the trends in first birth probabilities at ages 20 and 35, separately for white and non-white women in the US. Among whites, there is clear evidence that childbearing shifted to later ages; first birth probabilities, as of age 20, have declined since the early 1960s while the probability of having a first birth at age 35 has increased. Among non-white women, first birth probabilities at age 20 have declined since 1970 – although at a slower rate than was the case for whites – and

<sup>11</sup> See Morgan and Chen (1992).

<sup>12</sup> See, for example, Bloom (1982), Rindfuss et al. (1988), Chen and Morgan (1991).

<sup>13</sup> See Goldin (1992) for an interesting historical analysis of the relationship between childless and educational attainment during the twentieth century among women in the US.

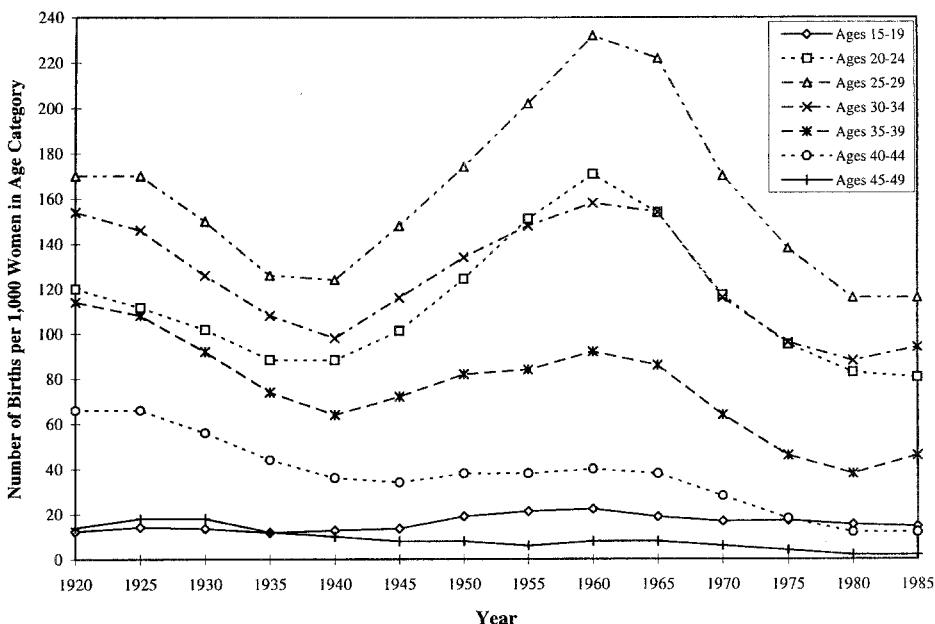


Fig. 3. Age-specific fertility rates for women in the US: 1920–1985. Source: NCHS, *Vital Statistics for the United States*, selected years.

have increased at age 35 at a rate substantially higher than whites. Beginning in the late 1980s, the first birth probabilities for 20-year-olds began to rise among whites and non-white women in the US. While not pictured here, a similar trend was observed among teenage women.<sup>14</sup> Finally, we note that the recent trend toward women delaying their childbearing is not unique to the US; women residing in other developed countries, such as Sweden, increasingly have tended to delay their childbearing until they are older.<sup>15</sup>

There have also been decided trends in the spacing of births as well. In Figs. 5 and 6, we display the probability of second and third births, respectively, *conditional* on reaching the beginning of each subsequent interval without having had a birth of the next parity, i.e., the hazard rate associated with the parents' decision to progress to the next parity. Each figure displays these probabilities for three different *parity-cohorts*, representing different years at which the first (or second) birth occurred. Both figures indicate that the spacing of intervals between first and second and second and third births has *lengthened* over time (i.e., for more recent parity-cohorts). What is especially noticeable is that probability of short interbirth intervals (e.g., those at intervals

<sup>14</sup> This recent trend toward higher rates of motherhood among teenagers has fueled much of the recent social concern about the teenage childbearing "problem" in the US.

<sup>15</sup> See Walker (1995).

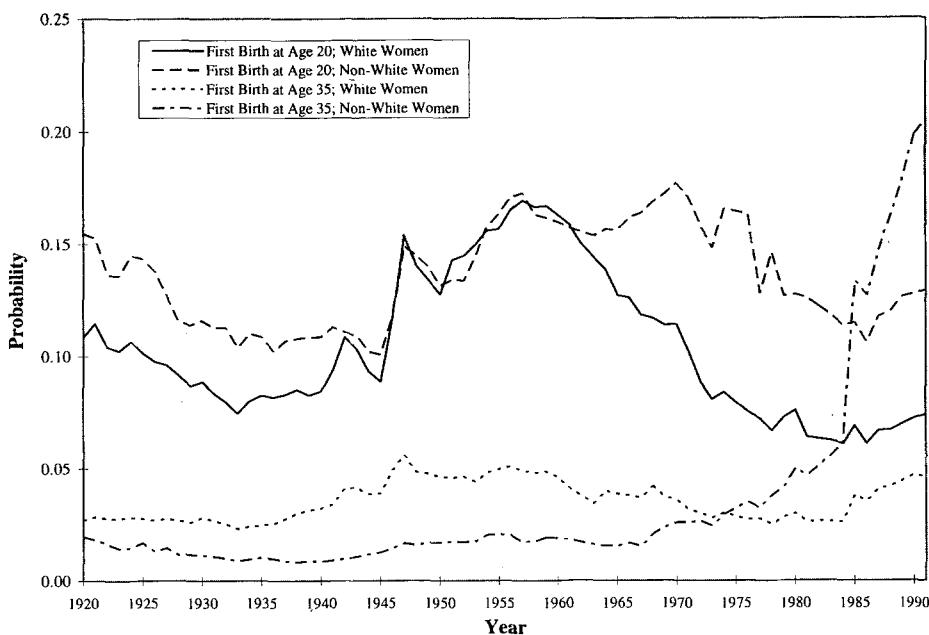


Fig. 4. First birth probabilities in US by race and for various ages: 1917–1991. Source: NCHS, *Vital Statistics for the United States*, selected years.

of 12–17 and 18–23 months) declined rapidly over time. Consistent with the decline in completed fertility since the peak of the baby boom, the hazard rates for both second and third births have declined at all durations over time. By five years after the first birth, these conditional probabilities imply that 80%, 72% and 63% of women who had a first birth would have had second births in the three succeeding parity-cohorts (1950–1959, 1965–1969, 1975–1989, respectively).<sup>16</sup> The corresponding percentages for having a third birth within five years after the second birth are 64%, 45% and 35%, respectively.

#### 2.4. Marital and nonmarital childbearing

At the beginning of the 1960, marriage was a virtual pre-condition for childbearing in most developed societies in that less than 10% of all births occurred out-of-wedlock in

<sup>16</sup> These calculations are taken from Morgan (1995).

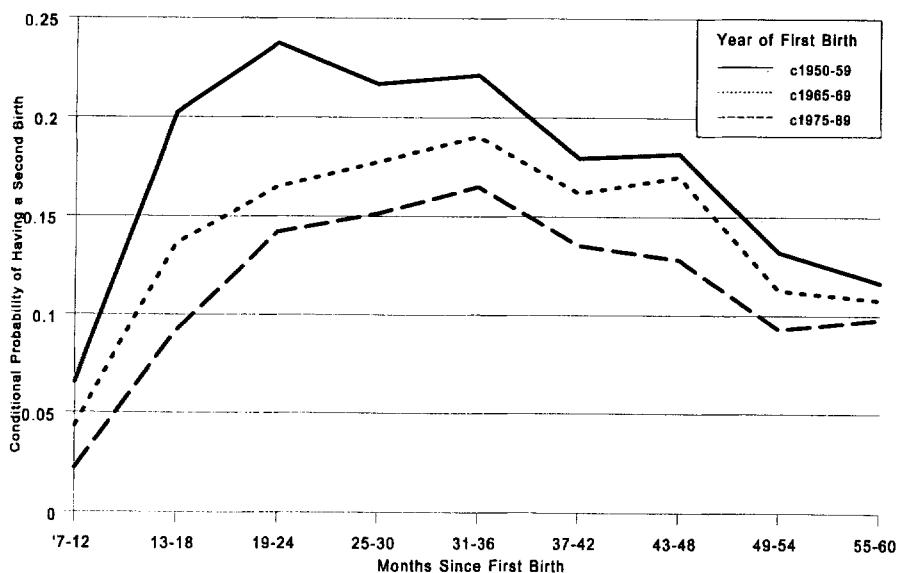


Fig. 5. Trends in the timing of second births in US; 1950–1989 (Morgan, 1995).

the countries of Western Europe and in the US.<sup>17</sup> During the next 35 years, this fraction steadily increased in these countries. In Panel A of Table 1 we display the trends in out-of-wedlock childbearing in the US from 1963 to 1992. In 1963, less than 6% of births were out-of-wedlock; by 1992, out-of-wedlock births accounted for 30% of all births. Among whites, the ratio of out-of-wedlock births was 3% in 1963 and it rose to 23% in 1992, a 642% increase over this 30-year period. Among blacks, who have historically had higher rates of out-of-wedlock childbearing, out-of-wedlock births rose from 45% of all births in 1973 to 68% in 1992. As recorded in Panel A of Table 1, the proportions of births occurring out-of-wedlock have become exceptionally high among teenagers in the US. Among all races, the percentage of births occurring out-of-wedlock among women, age 15–19, increased from 17% in 1963 to 70% in 1992. These rates are even higher among black teenage women, where 93% of this demographic group's births occurred out of wedlock in 1992.

The trends for Western Europe in nonmarital fertility since 1960 mirror those for the US. By the late 1980s, the fraction of births born to unmarried women had also increased throughout Western Europe, albeit at radically different rates in different countries. In the Netherlands, to take one extreme, out-of-wedlock childbearing was virtually unknown until the mid-1970s, then began to increase substantially, but as late

<sup>17</sup> See Ermisch (1991) for data on trends in Western Europe and DaVanzo and Rahman (1993) for those in the US.

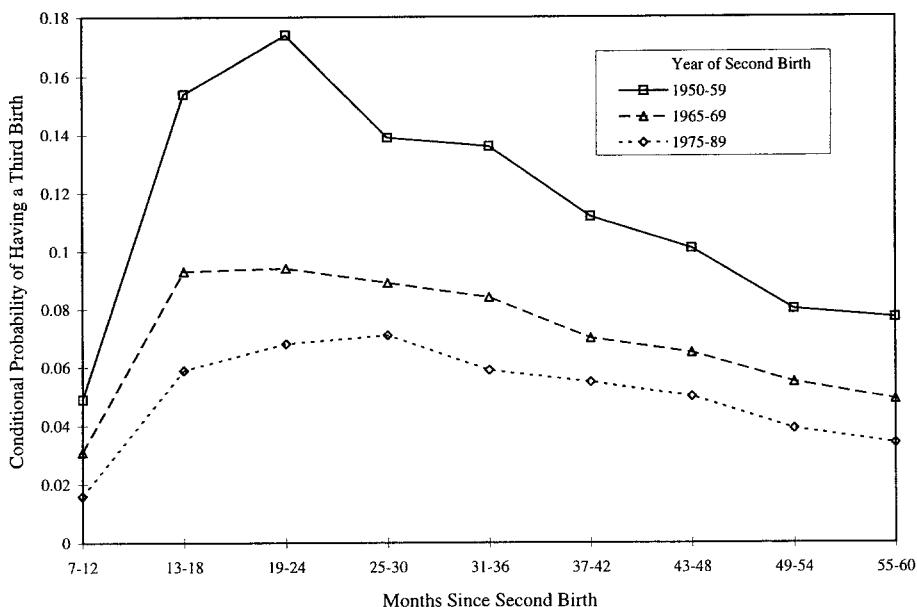


Fig. 6. Trends in the timing of third births in US; 1950–1989 (Morgan, 1995).

as 1988 only 8% of births were nonmarital, a rate similar to that of West Germany. At the other extreme, rates of out-of-wedlock childbearing had increased to over 50% in Sweden and nearly as high elsewhere in Scandinavia. Moreover, the growth of non-marital fertility began accelerating elsewhere in Europe in the mid-1970s, reaching a level of more than 25% by 1988 in England and France, similar to levels in the US at that time.

The increasing proportion of births occurring out of wedlock in advanced countries reflects three important changes over the last three decades. First, the rate of childbearing among unmarried women has increased. In the US, for example, the birth rate of unmarried women, age 15–44, went from 23 to 45 births per 1000 women over the period 1963 to 1992. While the rates of childbearing among unmarried women were higher and increased among black women, the rate of childbearing among white women actually increased more rapidly over this period, going from 11 to 35 births per 1000 women over this 30-year interval. Second, the rate of childbearing among married women has declined over this period. In 1963, the height of the baby boom in the US, the rate of childbearing among women of all races who were married was 146 births per 1000 women; the corresponding rate was 90 births per 1000 women in 1992. Third, the proportion of women of childbearing ages who were married declined over the last three decades. Olsen (1994) notes that from 1960 to 1988, the percentage of women, age 14–44, who were married went from 72% in 1960 to

Table 1  
US trends in nonmarital childbearing by race and age: 1963–1992

Ages	Ratio of births to unmarried women to all births							Births per 1000 unmarried women							Births per 1000 married women						
	1963	1968	1973	1978	1983	1988	1992	1963	1968	1973	1978	1983	1988	1992	1963	1968	1973	1978	1983	1988	1992
<i>All races:</i>																					
15–19	0.17	0.27	0.34	0.44	0.53	0.65	0.70	15	20	23	25	30	36	45	487	436	340	323	348	371	410
20–24	0.06	0.08	0.11	0.16	0.23	0.33	0.41	40	37	32	35	42	56	69	321	243	181	188	203	209	213
25–29	0.03	0.04	0.05	0.07	0.11	0.16	0.20	49	38	30	29	36	49	57	206	157	131	137	146	154	160
30–34	0.03	0.04	0.05	0.06	0.09	0.12	0.14	33	28	20	17	22	32	38	114	80	61	68	79	91	97
35–39	0.03	0.05	0.06	0.07	0.10	0.13	0.15	16	15	11	8	10	15	19	57	38	24	21	25	32	37
40–44	0.04	0.05	0.08	0.10	0.13	0.16	0.18	4	4	3	2	3	4	16	11	6	5	4	6	6	6
15–44	0.06	0.10	0.13	0.16	0.20	0.26	0.30	23	24	24	26	30	39	45	146	117	95	94	94	91	90
<i>Whites:</i>																					
15–19	0.09	0.16	0.19	0.29	0.39	0.54	0.66	7	10	11	14	19	25	33	473	422	328	318	339	356	393
20–24	0.03	0.05	0.05	0.08	0.14	0.23	0.32	21	23	16	18	27	39	53	319	240	179	184	199	206	207
25–29	0.01	0.02	0.02	0.03	0.07	0.10	0.14	23	22	16	15	24	36	45	204	158	132	137	146	154	159
30–34	0.01	0.02	0.02	0.03	0.05	0.08	0.10	15	15	11	9	16	24	32	113	79	61	67	79	91	96
35–39	0.02	0.02	0.03	0.04	0.07	0.09	0.11	5	5	6	5	8	12	16	35	23	23	20	24	31	36
40–44	0.02	0.03	0.04	0.06	0.07	0.13	0.15	5	5	2	1	2	3	4	35	23	6	4	4	5	6
15–44	0.03	0.05	0.06	0.09	0.13	0.18	0.23	11	13	12	14	20	27	35	143	115	94	93	93	90	90
<i>Blacks:</i>																					
15–19	0.71	0.83	0.89	0.91	0.93	0.95	0.98	86	86	95	88	106	134	144	116	111	107	134	144	192	227
20–24	0.39	0.53	0.61	0.69	0.75	0.85	0.80	80	97	85	80	97	98	98	113	124	127	132	144	V.J. Hotz et al.	
25–29	0.26	0.32	0.41	0.49	0.55	0.58	0.44	44	44	58	44	57	58	58	58	66	70	74	74	83	
30–34	0.23	0.26	0.33	0.41	0.47	0.31	0.38	0.45	0.45	28	19	19	24	26	28	30	28	27	29	34	
35–39	0.23	0.26	0.31	0.38	0.45	0.23	0.32	0.37	0.42	8	6	5	5	5	8	10	7	6	6	7	
40–44	0.23	0.28	0.32	0.37	0.42	0.23	0.32	0.37	0.42	89	81	77	87	87	89	98	94	88	83	86	
15–44	0.45	0.53	0.58	0.63	0.68	0.53	0.60	0.68	0.73	100	95	98	100	100	100	100	100	100	100	100	

Source: NCHS, Vital Statistics and Health Statistics, "Births to Unmarried Mothers: United States, 1980–92," Series 21, No. 53, June 1995 and NCHS, *Vital Statistics for the US*, Vol. 1 – Natality, 1995.

54% in 1988. Among women, age 20–24 – the age category which had the highest rates of childbearing at the peak of the baby boom – marriage rates fell from 69.5% in 1960 to 35.7% in 1988.<sup>18</sup> (We note that these declines in marriage rates in the US reflect both an increasing tendency to delay the entry into marriage as well as increasing rates of divorce.<sup>19</sup>) While the causal links between marriage and fertility cannot be inferred from these trends, it is clear that the close tie between marriage and childbearing no longer reflects the contemporary scene in the developed countries of the world.

## 2.5. Contraceptive practices

Since the beginning of the 1960s, the world has experienced a “revolution” in the technology of methods available to control fertility. At the outset of this decade, the Pill and the Intrauterine Device (IUD) were introduced in most developed economies, as well as developing countries, and both methods, especially the Pill, experienced a high rate of adoption by women of childbearing ages. By the mid-1960s, over one-third of all married women in the US, age 15–44, reported using either the Pill or an IUD.<sup>20</sup> Over the subsequent three decades, the rates of utilization for both methods have declined, especially that for the IUD, and other methods of contraception have increased.

In Table 2, we provide a more detailed picture of the changing pattern of contraceptive utilization of the various contraceptive methods used by women of childbearing ages in the US from 1982 to 1990. Therein, we display how these utilization rates varied across a variety of different socioeconomic characteristics of women in the US. There have been several important trends, or lack of them, over the last 15 years. First, there has been remarkably little change over time in the proportion of women of childbearing age who use some form of contraception while engaged in sexual activity. The only exception to this pattern is among never married women, where the percentage using some form of contraception has increased from 1982 to 1990 by eight percentage points. Second, there has been a precipitous increase in the use of condoms. This is especially true among those who are young and unmarried, where rates of condom utilization have doubled since 1982. This increase in the rates of condom use for these groups appears to reflect the desire for increased protection against contracting the HIV virus.<sup>21</sup> Third, there has been a slight increase, over the last 12 years,

<sup>18</sup> See Olsen (1994) for more on the relationship between trends in marriage and fertility in the US.

<sup>19</sup> See DaVanzo and Rahman (1993) and Weiss (this volume) for a more complete discussion of trends in marriage and divorce in the US.

<sup>20</sup> The early trends in contraceptive utilization are discussed in Ryder and Westoff (1973).

<sup>21</sup> See Ahituv et al. (1996).

Table 2  
Incidence and utilization patterns for various contraceptive methods for women, age 15–44, in US: 1982, 1988 and 1990

	% of women using any method			% of women using particular method, given using some method					
				Female sterilization			Male sterilization		
	1982	1988	1990	1982	1988	1990	1982	1988	1990
<i>Age</i>									
15–24	40.8	45.7	43.9	3.2	3.1	4.2	2.7	1.0	0.9
25–34	66.7	66.3	63.2	22.1	24.8	25.2	10.1	10.0	9.1
35–44	61.6	68.3	68.9	43.5	47.7	47.9	19.9	20.8	22.9
<i>Race</i>									
Hispanic		50.4	52.2		31.7	33.1		4.3	6.4
White, non-Hispanic	52.0	62.9	60.5	22.1	25.6	27.3	12.2	14.3	15.5
Black, non-Hispanic	56.7	56.8	58.7	30.0	37.8	41.0	1.4	0.9	1.3
<i>Marital status</i>									
Currently married	69.7	74.3	70.7	26.9	31.4	33.5	15.5	17.3	19.2
Divorced, separated, widowed	55.5	57.6	57.3	39.2	50.7	52.1	3.4	3.6	2.8
Never married	35.3	41.9	43.0	3.7	6.4	9.6	1.8	1.8	1.1
<i>Woman's educational attainment</i>									
0–11		60.2	60.6		51.9	58.0		6.9	6.8
12		67.5	66.3		34.3	38.4		15.0	15.7
13 and over		65.8	63.1		20.7	22.3		12.6	13.7
<i>Income (% of poverty level)</i>									
0–149		60.2	59.4		42.8	47.2		5.2	6.2
150–299		67.1	66.2		34.5	38.5		13.1	11.8
300 and over		67.0	64.0		23.5	25.1		15.1	16.5

Source: National Surveys of Family Growth, 1982, 1988, 1990.

in the proportion of women who have elected to become surgically sterilized and, thus, cease their childbearing completely. It is interesting to note that while sterilization has increased among married women by 24% over this period, it has increased more among divorced, separated or widowed women (33%) and among those who have never married (159%).

Over the last 20 years, the US and other developed countries have seen important changes in the incidence of another method for preventing births, namely induced abortions. Abortions first became legal in the US in 1967 when the State of Colorado enacted legislation which legalized the right of women to abort their fetuses during the early stages of their pregnancies. Abortions during the first trimester of a pregnancy became legal in all of the US as a result of the highly controversial Supreme Court

Pill			IUD			Diaphragm			Condom			Other methods					
1982	1988	1990	1982	1988	1990	1982	1988	1990	1982	1988	1990	1982	1988	1990			
57.6	63.6	53.8	3.4	0.2	0.4	9.0	2.4	0.3	13.5	23.5	34.3	10.6	6.3	6.1			
24.7	32.9	35.4	9.7	2.1	0.7	10.3	7.2	3.5	11.4	13.8	17.4	10.7	9.1	8.8			
3.7	4.3	6.7	6.9	3.2	2.6	4.0	6.0	3.5	11.3	11.2	9.8	10.8	6.9	6.7			
			33.4	31.4		5.0	1.9		2.4	1.5		13.6	17.1		9.6	8.8	
26.7	29.5	28.5	6.9	1.5	1.3	8.8	6.6	3.9	12.7	16.2	17.0	10.7	7.3	7.4			
38.0	38.1	28.5	9.1	3.2	1.4	3.5	2.0	1.6	6.2	10.1	19.4	11.7	8.0	6.8			
			19.3	20.4	20.6	6.9	2.0	1.4	6.5	6.2	4.1	14.1	14.3	14.0	10.8	8.4	7.3
28.4	25.3	22.4	11.5	3.6	2.5	6.7	5.3	0.9	1.5	5.0	9.7	9.2	5.7	9.6			
53.0	59.0	50.5	5.4	1.3	0.8	13.4	4.9	0.6	11.6	19.6	30.1	11.1	7.0	7.3			
			22.6	18.4		3.8	1.7		1.3	0.2		6.4	11.7		7.2	3.3	
29.4	26.8					1.7	1.1		2.8	1.7		10.7	11.0		6.1	5.3	
28.7	28.0					2.2	1.7		10.0	4.6		16.4	19.3		9.5	10.4	
			31.3	24.8		3.3	1.1		2.3	0.6		10.2	14.9		5.0	5.3	
26.6	26.6					2.4	2.5		5.0	1.9		11.4	12.9		7.0	5.8	
27.8	27.3					1.7	1.0		8.0	4.2		14.5	16.8		9.3	9.2	

decision in the case of Roe v. Wade in 1973.<sup>22</sup> We present, in Table 3, statistics on annual abortion rates in the US subsequent to this decision. The proportion of pregnancies which ended in abortions increased after the Roe v. Wade decision, peaking in 1981 when 30% of pregnancies were terminated by an abortion. Since the early 1980s abortion rates have leveled off and fallen slightly in the US. We also provide, in Table 3, abortion rates for a number of developed countries in selective years. While rates of abortion have been relatively high in countries in Eastern and Central Europe – coun-

<sup>22</sup> See Merz et al. (1995, 1996) for more on the judicial and legislative history of abortions in the US.

Table 3

Proportion of abortions to pregnancies ending in abortion or live birth; rate of abortions per 1000 women aged 15–44; and number of reported abortions (in thousands): United States, selected years 1973–1992 and other countries (year in parentheses).

Country, year	Proportion	Rate	Abortions
<i>United States</i>			
1973	0.193	16.3	744.6
1975	0.249	21.7	1034.2
1977	0.286	26.4	1316.7
1979	0.296	28.8	1497.7
1981	0.301	29.3	1577.3
1983	(0.304)	(28.5)	(1575.0)
1985	0.297	28.0	1588.6
1988	0.286	27.3	1590.8
1991	0.274	26.3	1556.5
1992	0.275	25.9	1528.9
<i>Eastern and Central Europe</i>			
Soviet Union (1987) <sup>a</sup>	0.549	111.9	6818000
Czechoslovakia (1987)	0.422	46.7	156600
Hungary (1987)	0.402	38.2	84500
German Dem. Rep. (1984)	0.297	26.6	96200
<i>Selected other countries</i>			
Australia (1988)	0.204	16.6	63200
Belgium (1985)	0.122	7.5	15900
Canada (1985)	0.166	12.1	74800
Denmark (1987)	0.270	18.3	20800
England and Wales (1987)	0.186	14.2	156200
France (1987) <sup>a</sup>	0.173	13.3	161000
German Fed. Rep. (1986) <sup>a</sup>	0.128	7.0	88500
Italy (1987) <sup>a</sup>	0.257	15.3	191500
Japan (1987) <sup>a</sup>	0.270	18.6	497800
Netherlands (1986)	0.090	5.3	18300
New Zealand (1987)	0.136	11.4	8800
Singapore (1987)	0.327	30.1	21200
Sweden (1987)	0.249	19.8	34700

<sup>a</sup>Based on statistics that are incomplete.

Sources: US data: Henshaw and Van Vort (1994). US data in parentheses are estimated by interpolating the numbers of abortions. International data: Henshaw (1990: Table 3, p. 86).

tries which were members of the former Communist bloc – abortion rates in other developed countries have tended to be lower than those in the US.

These trends in contraceptive practices among women in the US, including abortions, reflect, in part, the constellation of factors which have changed the incentives to bear children by men and women of childbearing ages in the US. We return to discuss

Table 4  
Labor force participation rates for wives, husband present, by age of own youngest child in US: 1975–1994

Presence and age of child	1975	1980	1985	1990	1994
All wives	44.4	50.2	54.2	58.2	60.6
No children under age 18	43.8	46.0	48.2	51.1	53.2
With children under age 18	44.9	54.3	60.8	66.3	69.0
Under 6, total	36.7	45.3	53.4	58.9	61.7
Under 3	32.7	41.5	50.5	55.5	59.7
1 year or under	30.8	39.0	49.4	53.9	58.8
2 years	37.1	48.1	54.0	60.9	64.5
3–5 years	42.2	51.7	58.4	64.1	64.6
3 years	41.2	51.5	55.1	63.1	62.9
4 years	41.2	51.4	59.7	65.1	63.9
5 years	44.4	52.4	62.1	64.5	67.1
6–13 years	51.8	62.6	68.2	73.0	75.5
14–17 years	53.5	60.5	67.0	75.1	77.2

Source: Current Population Surveys, 1975, 1980, 1985, 1990, 1994.

what hypotheses from economic models of fertility might be used to explain these patterns.

## 2.6. Relationship between fertility and female labor force participation

One of the important social trends in developed countries has been the rise, over time, in labor force participation of women in both developed and developing countries.<sup>23</sup> The relationship between this trend, and its causes, and that of fertility has been an important focus of the economic models of fertility to be discussed below. One of the most noticeable trends, at least in the US, has been the precipitous rise in the labor force participation rates of mothers with young children. These trends are displayed in Table 4. While the labor force participation rates of all wives increased by 36% over the last 20 years, the rates increased by 83% for women with children under the age of three and by 91% for women with children one year old or younger. As of 1994, there is virtually no difference in the labor force participation rates of married women with children of different ages. It appears that it is no longer the case that mothers with young children curb their labor force participation to the same extent that women did even 20 years ago. There are a number of possible explanations for this reduction in the negative association between the presence of young children and the mother's attachment to the labor force. These include the increase in the availability of market

<sup>23</sup> See Heckman and Killingsworth (1996).

substitutes (i.e., child care) for the mother's time and the fact that more recent cohorts of women have higher levels of educational attainment which may increase the opportunity cost of remaining out of the labor force to care for their children.<sup>24</sup> Below, we offer some possible explanations for the breaking of this association, based on the economic models of fertility and women's time allocation decisions.

### 3. Static models of fertility behavior

In one sense, the economic approach to explaining fertility behavior is nothing more than an application of neoclassical models of consumer demand. Such models view parents as consumers who choose that quantity, or number, of children which maximizes their utility subject to the price of children and the budget constraint they face. In this simple setting, we assume that the relevant unit of time for these choices is the parents' lifetime. We use the term "static" to characterize this one period lifetime perspective. In this section, we ignore such issues as the possibility that the constraints that parents face, in terms of prices and budget constraints, may vary over the parents' life cycle, the potential uncertainty that parents may have at any point in time about these constraints in future periods, or the apparent fact that fertility outcomes unfold over time as well. Admitting these possibilities and addressing their implications will be considered when we consider dynamic models of fertility behavior below. Finally, we assume that, aside from their budget constraint, there are no obstacles to the ability of parents to choose their family size.

More formally, we assume that parents maximize a utility function,

$$U = U(n, s), \quad (1)$$

which depends on the outcome of interest, the number of children, which is denoted by  $n$ , and a good,  $s$ , which characterizes all other consumption. (We assume that that utility function has all the conventional properties, i.e., increasing and concave in both arguments.) In this simplified model, parents are assumed to choose  $n$  and  $s$  so as to maximize Eq. (1) subject to the following (conventional) budget constraint:

$$I = \pi_s s + p_n n, \quad (2)$$

where  $I$  is the household's income,  $p_n$  is the per unit "price" of children, and  $\pi_s$ , is the per unit price of the composite commodity. Taking the price of the composite good as numeraire, this simple model yields a relatively simplistic, but standard, demand-for-children function,

<sup>24</sup> See Leibowitz and Klerman (1995).

$$n = N(p_n, I), \quad (3)$$

which depends upon the price of children and parental income. The effect of changes in the price of children on completed fertility are characterized by the standard income and substitution effects of consumer theory and changes in parental income give rise to income effects with respect to the "purchase" of children.

Given data on households who are subjected to exogenous variations in this price and parental income and a parametric specification of Eq. (3), estimation of  $\partial n / \partial p_n$  and  $\partial n / \partial I$  would constitute the focus of an econometric investigation of the economic model. Without substantial deviation from this simple model, one can envision investigations of the price responsiveness of the demand for children due to exogenous changes in the cost of rearing children or changes in governmental policies which affect the cost of children (e.g., changes in tax deductions for dependents or public assistance benefits). The simple neoclassical approach to fertility yields unambiguous predictions about price effects, assuming that children are not Giffen goods. The empirical challenge is to find proxies for the price of children. As is well known, neoclassical theory does not yield unambiguous predictions about income effects, although there has been a presumption in the literature that they are positive, i.e., children are not inferior goods. Nonetheless, determining the direction and magnitudes of the effect of income on the demand for children is an important objective for econometric studies of fertility. Again, the essential question is how does one obtain exogenous variation in income facing households with which to identify such income effects. In our discussion below of the estimation of the empirical implications of static models of fertility, we discuss these challenges in some detail and describe what one might call "best practice" examples in the empirical literature for economic models of fertility behavior.

While a generic model of consumer choice generates a limited set of potentially testable predictions, such a model fails to capture the special features of fertility choices. As noted in the Introduction, the challenge of adapting neoclassical economic models to fertility behavior has given impetus a number of important extensions of this simple model. These extensions not only attempt to address the distinctive aspects of this set of behavior but also represent important adaptations of the application of economics to human behavior. In the following sections, we describe several of the key adaptations of the model of consumer demand which have a prominent role in the intellectual development of the static theory of fertility behavior.

We begin by examining two important contributions to the early literature on the economics of fertility. The first, the quality–quantity model of fertility, acknowledged that parents not only demanded numbers of children but also children with certain qualities. The second contribution was to acknowledge the important of parental time, especially the mother's in the rearing development of children. Elements of these two model features are found in Becker (1960) and Mincer (1963) and are synthesized within the Becker (1965) household production framework by Willis

(1973), with some further implications of the quality–quantity model developed in Becker and Lewis (1973).<sup>25</sup> We then survey a recent line of research which addresses the relationship between fertility and marriage. The initial models of fertility presumed that childbearing took place within marriage. As is clear from the trends noted in Section 2, this is an increasingly less accurate description of childbearing within developed countries. We discuss recent models which attempt to provide an explanation for why the link between fertility and marriage may be changing over time.

### *3.1. The quality–quantity model*

Recall from the Introduction that Becker's seminal paper on applying neoclassical economic theory to fertility began with the puzzle that fertility tends to be negatively related to income both in time series and cross section. Becker (1960) rejected explanations for this relationship which assert that children are inferior goods or that high income families, who spend more on their children, have lower fertility because they face higher prices of children. Instead, he argued that the puzzle could be resolved within a model of stable preferences in which children are a superior good by recognizing that the demand for children involves, in addition to the quantitative dimension represented by the number of children, a qualitative dimension associated with the choice of expenditures per child. Adapting a model introduced by Theil (1952) and Houthakker (1952) for the study of consumer budget data, Becker proposed a simple model of fertility behavior in which parents had preferences both for the number of children and the quality per child. This static, lifetime model is an adaptation of the simple model outlined above.

In particular, a newly married couple is considered to act as a unitary household with a single decision maker with preferences given by the utility function

$$U = U(n, q, s), \quad (4)$$

where  $n$  continues to denote the number of children,  $s$  the parents' standard of living,

<sup>25</sup> These two papers were published in March/April of 1973 and 1974 as part of two special issues of the *Journal of Political Economy* which were reprinted in T.W. Schultz (1974). Willis (1987) suggests that this collection of papers marks the emergence of the economics of the family as a distinct subfield in economics. In addition to the Willis and Becker–Lewis papers, the collection includes other papers on the economics of fertility (Ben-Porath, 1973; DeTray, 1973; Hashimoto, 1973; Michael, 1973), investment in children (Leibowitz, 1974), investment in human capital by women (Mincer and Polachek, 1974), the economic analysis of child care (Heckman, 1974b), and the theory of marriage (Becker, 1973, 1974). In this paper, we reference papers in this collection by their *Journal of Political Economy* citation but sometimes refer to the collection itself as the “Schultz volume”.

and  $q$  is the quality per child.<sup>26</sup> In place of Eq. (2), the household's lifetime budget is now given by

$$I = \pi_c nq + \pi_s s, \quad (5)$$

where  $I$  continues to denote total family lifetime income,  $\pi_c$  is a price index of goods and services devoted to children and  $\pi_s$  is a price index of goods and services consumed by adults. The unusual feature of this problem is that the budget constraint is nonlinear because quantity and quality enter multiplicatively. It is this quality–quantity interaction that leads to certain distinction features of the demand for children that we will describe shortly and to which we will return at several later points in this paper.

One immediate implication of the model of Eqs. (4) and (5) that was stressed by Becker (1960) is that the income elasticities of demand for  $n$ ,  $q$  and  $s$  must satisfy the relationship

$$\alpha(\varepsilon_n + \varepsilon_q) + (1 - \alpha)\varepsilon_s = 1, \quad (6)$$

where  $\alpha$  is the share of family income devoted to children and the  $\varepsilon$ 's denote income elasticities. If children are normal goods in the sense that total expenditures on children are an increasing function of income, then the *sum* of the income elasticities of the number and quality of children must be positive (i.e.,  $\varepsilon_n + \varepsilon_q > 0$ ), but it is still possible that the income elasticity of demand for the number of children is negative (i.e.,  $\varepsilon_n < 0$ ) if the income elasticity of quality is large enough. Although he was unable to cite estimates of the demand for other goods in which the income elasticity of demand for quantity was negative, Becker did cite studies showing that quality elasticities tended to be larger than quantity elasticities. He ended up arguing that income is likely to have a small positive effect on fertility, but believed that a negative correlation between birth control knowledge and income might change the overall sign of the income–fertility relationship to negative.<sup>27</sup>

The quality–quantity model did not receive much attention again until the two above mentioned papers by Willis (1973) and Becker and Lewis (1973). These papers provide a formal analysis of the model in which the implications of the nonlinearity in the budget constraint in Eq. (5) are explored. Maximizing household utility in Eq. (4)

<sup>26</sup> The term “unitary model of the household” was introduced by Chiappori et al. (1993) to distinguish traditional theories of household behavior in which all members of the household act as if they were a single decision maker from newer “collective” theories in which the separate interests of individuals within a household are considered. Later in this chapter, we consider some implications of the collective approach for fertility behavior. (See also the chapters by Bergstrom and Weiss in this volume for further discussion of this point.)

<sup>27</sup> Becker (1960) attempted to show empirically that a positive relationship between income and fertility exists when birth control knowledge is held constant, but the data used in the empirical analysis (e.g., data from subscribers of *Consumer Reports*) would not meet current standards for data quality.

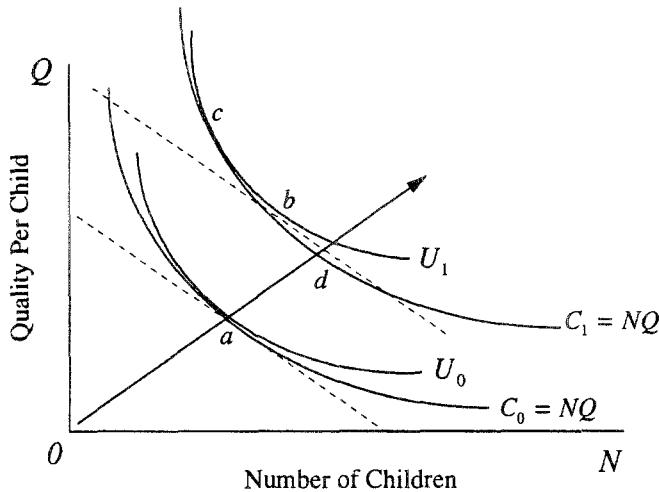


Fig. 7. Interaction of the demand for quality and quantity of children.

subject to the family budget constraint in Eq. (5) yields the following first-order conditions:

$$MU_n = \lambda q \pi_c = \lambda p_n, \quad MU_q = \lambda n \pi_c = \lambda p_q, \quad (7)$$

where the  $MU$ 's are marginal utilities and the  $p$ 's are marginal costs or shadow prices of the number of children and quality per child, respectively, and  $\lambda$  is the marginal utility of income. These conditions imply that the shadow price of the number of children is an increasing function of child quality and, similarly, that the shadow price of child quality is an increasing function of the number of children. Additionally, since  $n$  and  $q$  are chosen by the household, the shadow prices are endogenous. It is ironic that the same model Becker (1960) used to demonstrate why rich and poor households really face the same prices of children despite evidence that the rich spend more per child is used by Becker and Lewis (1973) to show that the shadow price of the number of children is higher under these circumstances.

The household's optimal choice of number and quality of children is illustrated by the indifference curve diagram in Fig. 7. Equilibrium occurs at point  $a$ . At this point, the indifference curve  $U_0$  is tangent to the budget constraint,  $c_0 = nq = (I - \pi_s s(\pi_c, \pi_s, I)) / \pi_c$ , where  $c_0$  is the household's real expenditure on children and  $s(\pi_c, \pi_s, I)$  is the demand function for parents' standard of living. The assumption that this tangency point corresponds to maximum utility implies that the indifference curve must be more concave than the budget constraint,  $c_0 = nq$ , which is a rectangular

hyperbola. Thus, quality and quantity cannot be too closely substitutable in consumer preferences if second-order conditions for utility maximization are to be satisfied.

The nonlinearity of this budget constraint causes a quality–quantity interaction as income increases that results in an induced substitution effect against the number of children and in favor of quality per child if the income elasticity of demand for quality exceeds the income elasticity of demand for number of children, an assumption that both Becker and Lewis (1973) and Willis (1973) believed to be empirically plausible. To see this, note that Eq. (6) implies that the marginal rate of substitution between the quantity and quality of children is  $MU_n/MU_q = p_n/p_q = q/n$  so that the relative cost of the number of children tends to increase as the ratio of quality to quantity increases, as it will if  $\varepsilon_n > \varepsilon_q$ .

This quality–quantity interaction is illustrated diagrammatically in Fig. 7. If the income elasticities for quality and quantity were equal, the income-expansion path would be given by ray *Oad* and the ratio of quality to quantity and the marginal rate of substitution between quality and quantity both remain constant. If  $\varepsilon_n > \varepsilon_q$ , the total effect of an increase in income that raises total expenditures on children from  $c_0$  to  $c_1$  is to move optimal consumption from point *a* to point *c*. This total effect may be decomposed into a “pure income effect”, holding  $p_n/p_q$  constant, from point *a* to point *b*, and an “induced substitution effect” from point *b* to point *c*. As drawn in Fig. 7, the total effect of an increase in income leaves the number of children unchanged because the pure income effect, which tends to increase desired fertility, is offset by a substitution effect against fertility induced by the increased expense per child associated with higher desired quality.

The budget in Eq. (6) was generalized by Becker and Lewis (1973) to incorporate costs of the number of children that are not dependent on quality and costs of quality that are not dependent on the number of children. This generalized budget may be written

$$I = \pi_n n + \pi_q q + \pi_c nq + \pi_s s, \quad (8)$$

where  $\pi_n$  and  $\pi_q$ , represent these independent cost components so that the marginal costs of numbers and quality become, respectively,  $p_n = \pi_n + \pi_c q$  and  $p_q = \pi_n + \pi_c n$ . As an application, they consider a case in which  $\pi_q = 0$  and  $\pi_n$  represents the opportunity cost of fertility control. The introduction of a new contraceptive method such as the oral contraceptive pill, which does not interfere with sexual pleasure, will reduce the cost of averting births and, therefore, *increase* the marginal cost of a birth without affecting the marginal cost of child quality.<sup>28</sup> The increase in  $p_n$  leads to a substitution effect against fertility which increases  $q/n$ , thereby inducing a further substitution effect against fertility and in favor of quality. Their analysis suggests that the elasticity

<sup>28</sup> See Michael (1973), Michael and Willis (1975) and Heckman and Willis (1975) for economic analyses of the relationship between contraception and fertility behavior.

of demand for number of children is likely to be more negative with respect to variables such as contraception or maternity costs, which affect  $\pi_n$ , than it is with respect to variables such as the female wage which, as we shall show shortly, affect  $\pi_c$ . A parallel analysis suggests that a decrease in  $\pi_q$  due to, say, an increase in parents' education, may have a negative effect on fertility because the direct substitution effect which increases  $q$  causes an increase in  $p_n$ . Other examples of factors affecting  $\pi_q$  might include the quality of a neighborhood, school quality and cultural factors.

The simple analytics of child quality described above proceeded without an explicit discussion of what is meant by child quality. There are several alternative concepts of child quality in the literature. In Becker (1960), children are treated as a durable consumption good and child quality is indexed by expenditures per child in much the same way that quality might be judged by price in markets for automobiles in a world of well-informed consumers.<sup>29</sup> The linkage between expenditures per unit and quality that is implicit in this approach was made explicit in the "new consumer theory" of Lancaster (1966) in which, for example, an automobile is viewed as a bundle of "characteristics" such as power, comfort, safety, and so forth which enter the consumer's utility function.<sup>30</sup> With the exception of studies of the effect of sex preference on fertility,<sup>31</sup> the characteristics approach has not been widely used in economic models of fertility. The dominant view of child quality in the literature on fertility behavior and family economics is based on the theory of human capital form, envisioned as a model of human development.<sup>32</sup>

### *3.2. Time allocation and the demand for children*

A second major reason for a negative relationship between income and fertility, in

<sup>29</sup> For a variety of reasons, it is extremely difficult to disentangle expenditures on children from expenditures on other persons within a household. A number of indirect approaches have been suggested to estimate the "cost of children" based upon equivalency scales which depend upon how observed household consumption patterns (e.g., proportion of income spent on food) vary as income and household consumption vary. See Browning (1992) for a survey of this literature. This literature is not helpful in understanding fertility behavior because (a) estimates of child costs are derived under the assumption that variations in household composition, including the number of children, are exogenous and (b) total expenditures on children are not decomposed into an endogenous part reflecting child quality and an exogenous part measuring the price index of children faced by the household.

<sup>30</sup> When goods are traded, implicit prices for these characteristics may be established in "hedonic markets" (Rosen, 1974). Since children are not traded, at least openly, this feature of hedonic theories is of little use in attempting to measure the costs of children of given characteristics.

<sup>31</sup> See Ben-Porath and Welch (1976) and Sah (1991).

<sup>32</sup> This appeal to human capital theory as a way of characterizing child quality was first explicitly introduced by Leibowitz (1974) and is formally developed in the seminal paper by Becker and Tomes (1976). In that paper, parents, who care about the lifetime economic well-being of their children, influence their children's well-being either through the direct transfer of money or by investing in the child's human capital.

addition to quality–quantity interaction, is the hypothesis that higher income is associated with a higher cost of female time, either because of increased female wage rates or because higher household income raises the value of female time in nonmarket activities. Given the assumption that childrearing is a relatively time intensive activity, especially for mothers, the opportunity cost of children tends to increase relative to sources of satisfaction not related to children, leading to a substitution effect against children. As noted earlier, the cost of time hypothesis was first advanced by Mincer (1963) and, following Becker's (1965) development of the household production model, the relationship between fertility and female labor supply has become a standard feature of models of household behavior.

A simple framework for analyzing the interplay between time allocation, labor supply and fertility behavior was introduced by Willis (1973). He assumes that household decisions are made jointly by a married couple who derive utility from adult standard of living and from the number and quality of children as given by the utility function in Eq. (4). Following Becker (1965), it is assumed that these basic commodities, satisfaction from children and adult standard of living, cannot be purchased directly in the market. Rather, the household uses the nonmarket time of household members and purchased goods as inputs into household production processes whose outputs enter into the utility function. The analysis takes place within a static, lifetime framework in which choices concerning the number of children, the fraction of wife's time supplied to the labor market and so forth are assumed to be made at the beginning of marriage and are not subject to revision. Extension of the model to a dynamic life-cycle context are treated later in the paper.

Several simplifying assumptions are made which allow the model to be analyzed using the simple two-good, two-factor general equilibrium model familiar to students of international trade theory. First, it is assumed that only the wife participates in the production of household commodities while the husband is fully specialized in market work and his income,  $H$ , is treated as exogenous. Total family income is  $I = H + wL$  where  $w$  is the wife's real wage and  $L$  is her labor supply. Second, satisfaction from children is measured by "child services",  $c = nq$ , and the determination of the division of  $c$  between the number and quality of children is left aside for the moment. Third, household production takes place according to constant returns production functions,  $s = g(t_s, x_s)$  and  $c = f(t_c, x_c)$ , where  $t_s$  and  $t_c$  are the wife's time inputs  $x_s$  and  $x_c$  are purchased goods devoted, respectively, to the production of adult standard of living and child services. A key assumption of the model is that the production technology for children is time intensive relative to the technology for parents' standard of living. The total time of the wife,  $T$ , is allocated between home and market work; that is  $T = t_c + t_s + L$ . Similarly, purchases of market goods are constrained by total household income so that  $I = H + wL = x_c + x_s$ .

The solution of this model is illustrated diagrammatically in Fig. 8. Household production is depicted in Panel A with an Edgeworth Box diagram in which the horizontal dimension of the box measures the total amount of wife's time that is devoted to

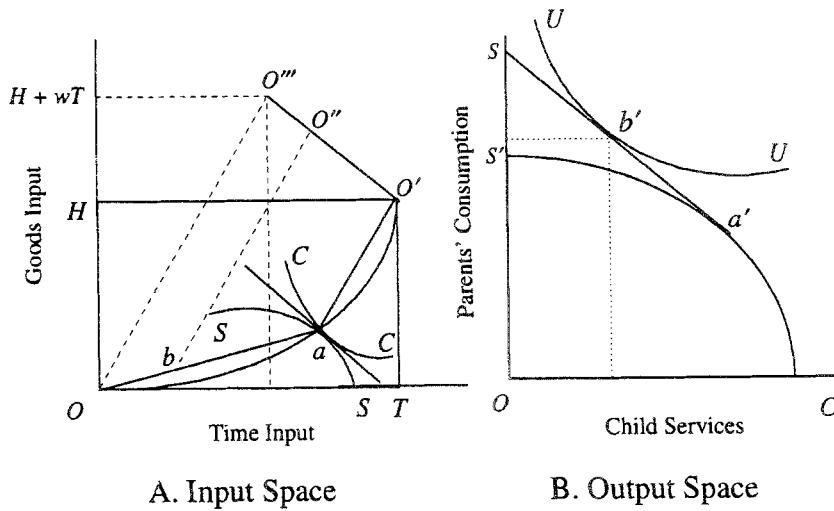


Fig. 8. Time allocation and fertility decisions.

household production (i.e.,  $t_c + t_s = T - L$ ) and the vertical dimension measures the total expenditure on goods (i.e.,  $x_c + x_s = T + wL$ ). When the wife does no work, the diagonal corners of the Edgeworth box are  $OO'$ ; as the fraction of the wife's lifetime which is devoted to market work increases, the northeast corner of the box moves to points such as or  $O'''$  where the slope of the line  $O'O'''$  is determined by the wife's market wage,  $w$ .

Assuming that the wife does no market work, all possible efficient allocations of time and goods occur along the contract curve,  $OO'$ . Within the box, isoquants corresponding to increasing outputs of child services such as  $CC$  emanate from the origin at  $O$  while isoquants for parents standard of living such as  $SS$  originate at  $O'$ . The assumption that children are relatively time intensive implies that the contract curve lies below the diagonal of the box. The (absolute value of the) common slope at the tangency between  $CC$  and  $SS$  at point  $a$  is equal to the shadow price of the wife's time,  $\hat{w}$ , given by the ratio of the marginal products of time and goods in each activity (i.e.,  $\hat{w} = f_t/f_x = g_t/g_x$ ). As drawn, the shadow price of time at point  $a$  is equal to the value to wife's market wage given by the slope of  $OO''$ . The corresponding outputs of  $c$  and  $s$  are indicated at point  $a'$  on the production possibility frontier in Panel B of Fig. 8.

If the output of child services is increased by moving along the contract curve to the northeast of point  $a$  in Panel A, the shadow price of time increases because ratio of goods to time in the production of both  $c$  and  $s$  must increase, as is seen geometrically by the fact that rays to the origin from both origins become steeper as points to the northeast of  $a$  are selected. Given that children are relatively time intensive, an in-

crease in the price of the time input leads to an increase in the relative cost of the time intensive output. Thus, the relative shadow price of children,  $\pi_c/\pi_s$ , which is equal to the (absolute value of the) slope of the production possibility frontier in Panel B, tends to increase as the output of children rises above the level indicated at point  $a'$ . Conversely, as the output of  $s$  is increased and input allocations occur to the southwest of point  $a$ , the shadow price of the wife's time falls below the market wage, implying that it is inefficient for her to spend all of her time in household production. As the wife enters the labor market, thereby increasing household money income and decreasing the supply of nonmarket time, the shadow price of her time can be increased to equality with her market wage and household output can be increased beyond the boundaries of the production frontier associated with full-time housework. For example, the time intensities of  $c$  and  $s$  production at point  $b$  along the contract curve  $OO'$ , which is associated with a positive amount of market labor by the wife, are the same as the intensities at point  $a$  along the contract curve  $OO'$ , but the output of  $c$  is smaller and of  $s$  is larger at point  $b$ . Given constant returns technology, the ratios of the marginal products of inputs remain constant if factor intensities remain constant. In addition, constancy of the shadow prices of inputs implies that the relative marginal cost of outputs remains constant. Hence, point  $b'$  on the production frontier in Panel B, which corresponds to point  $b$  in Panel A, must lie along the tangent at point  $a'$  on bowed-out production possibility curve that constrains the household when the wife does not participate in the labor market.<sup>33</sup> The fact that points such as  $b'$  along  $a'b'$  lie outside that frontier illustrates the efficiency gain to the household of adjusting the total supplies of time and goods through variations in the wife's labor supply. Since the wife cannot supply negative amounts of labor, these adjustments are not possible for outputs of child services greater than the output at point  $a'$  so that the household is constrained over this range by the bowed-out frontier.<sup>34</sup>

The household's fertility decision is determined by maximization of its utility subject to the production possibility frontier. In Panel B of Fig. 8, this optimum is shown at the tangency between the household's indifference curve and the linear segment of the production frontier at point  $b'$ . The associated allocations indicated by point  $b$  in Panel A show that the wife is supplying a positive amount of market labor and the shadow price of her time is equal to her market wage (i.e.,  $w = \hat{w}$ ) corresponding to an Edgeworth box whose northeast corner is at point  $O''$ . If the household had a stronger preference for children relative to adult commodities such that its optimal choice oc-

<sup>33</sup> The straight line segment  $a'b'$  is the envelope of production frontiers defined by Edgeworth boxes associated with different positive values of wife's labor supply. For example, the frontier determined by the Edgeworth box whose corner is at point  $O''$  in Panel A of Fig. 8 is tangent to  $a'b'$  at point  $b'$ .

<sup>34</sup> The analysis would be modified if purchased child care is introduced into the model. See Heckman (1974b) for an early analysis of child care and see Gustafsson and Stafford (1992) for a recent application to subsidized day care in Sweden. Macunovich (1994) points out that the relationship between a given woman's wage rate and the shadow price of children is broken if, at the margin, the cost of child services is determined by the market cost of child care rather than by the mother's wage rate.

curs on the production frontier to the right of point  $a'$ , the wife would do no market work and the shadow price of time would exceed the market wage.

More generally, imagine a large population made up of households with identical resources but heterogeneous preferences for children such that some households choose every point along the production frontier  $Ca'S$  in Panel B. In this population, we would observe some fraction of the population made up of high fertility women who never work during their marriage consisting of households who choose points to the right of point  $a'$  on the production frontier in Panel B and who choose an Edgeworth box whose northeast corner is at point  $O'$  in Panel A. We would also observe some fraction of the population consisting of childless women who devote a substantial fraction of their married lives to market work consisting of households whose optimal choice of fertility is a corner solution at point  $S$  in Panel B with a corresponding choice of market labor implied by the Edgeworth box whose corner is at  $O''$  in Panel B. Note that even these childless women may devote a considerable fraction of their married lives to nonmarket work.<sup>35</sup> Finally, we would observe some fraction of the population made up of households in which wives combine motherhood and market work such as, for example, households whose preferences are depicted in Panel B. In this group, there would tend to be a negative correlation between completed fertility and fraction of married life devoted to market work. We return to this point in our discussion of empirical models of completed fertility below.

The major empirical hypotheses of this static model are developed from comparative static analysis of the effects of exogenous variations in husband's income and female wage rates on fertility choices and related labor supply decisions by the wife. These results are presented diagrammatically in Fig. 9 for an increase in the wife's market wage,  $w$ , and for an increase in the husband's income,  $H$ , in Fig. 10. (See Willis (1973) for mathematical derivations.)

An increase in  $w$  causes the point at which it is efficient for the wife to enter the labor market to shift from point  $a$  to point  $c$  on the production frontier in Fig. 9 so that the linear portion of the new frontier, corresponding to  $L > 0$ , is both outside of and steeper than the linear portion of the old frontier, implying that the increase in  $w$  increases the household's real income and increases the opportunity cost of children. Given a household with preferences indicated by the indifference curves in the diagram, the increase in  $w$  causes the household to move its optimal choice from point  $b$  to point  $d$ . The total effect of the increase in  $w$  on  $c$  is ambiguous because the substitution effect against  $c$  be more than offset by a positive income effect in favor of  $c$ . Even if the income effect dominates so that  $c = nq$  increases, it is possible that fertility decreases while child quality increases. Indeed, Willis (1973) argues that this may be

<sup>35</sup> To keep the diagrams in two dimensions, the model has ignored the contributions of husbands to household production. Evidence on household time allocation from a broad sample of countries suggests that this is not a very unrealistic simplifying assumption. See Juster and Stafford (1991).

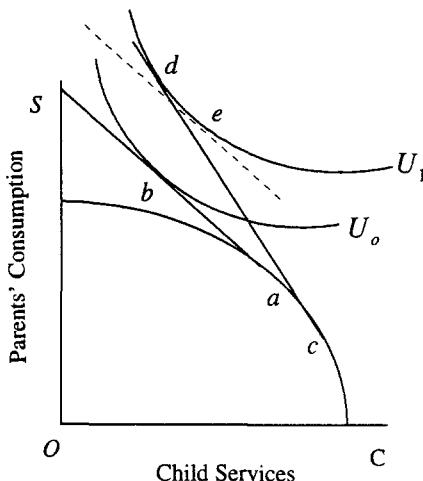


Fig. 9. Effect of an increase in the female wage.

the probable outcome because it seems unlikely that child quality would decrease while parents' standard of living increases sharply.<sup>36</sup>

Although the income effect associated with increasing female wages may push women away from childlessness toward married lives in which they combine motherhood and work, this effect may be offset by increasing returns to human capital investments in labor market careers caused by the fact that the returns to a given investment in human capital are proportional to its rate of utilization. To the extent that rising female wages lead women to devote a larger fraction of their lives to market work, there is a larger return to investments for women in market-related skills and reinforcing effects on their incentive to supply market labor and on the shadow price of time.<sup>37</sup> As shown by Willis (1973), investment in wife's human capital leads to a non-convex production possibility frontier which decreases the likelihood that a mix

<sup>36</sup> We note that the weight of the income effect relative to the substitution effect caused by an increase in the wife's wage is smallest in the neighborhood of point *a* in Fig. 10 where women have high fertility and spend a small fraction of married life in the labor force and largest in the vicinity of point *S* where women are childless and spend a relatively large fraction of their lives in the labor force. This suggests that a general increase in the price of female time might help to explain the decline in the variance of cohort TFR in the US since the mid-1930s first noted by Ryder (1986). Specifically, the substitution effects against fertility are not offset by income effects for households with strong tastes for children while only income effects are possible for childless households. Thus, increases in the female wage might tend to attract increasing numbers of women into the labor force and reduce fertility at high parities while, at the same time, it reduces the incidence of childlessness among women who have the lowest levels of fertility.

<sup>37</sup> The enormous literature on investments in human capital by women originates with Mincer and Polacheck (1974) and the emphasis of the effects of increasing returns on the sexual division of labor is found in Becker (1981).

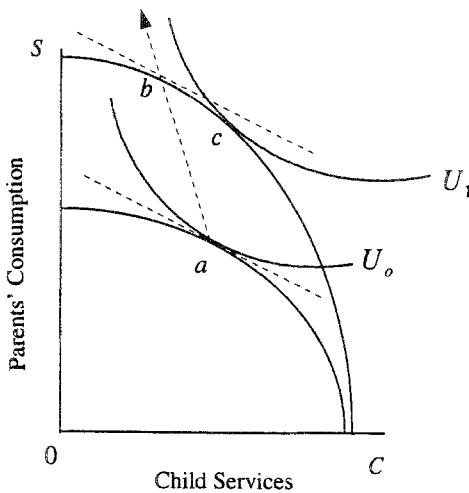


Fig. 10. Effect of an increase in the husband's income.

of motherhood and market work will dominate corner solutions involving either high fertility and specialization in home work or childlessness and an emphasis on the wife's labor market career.<sup>38</sup>

Finally, we note that Pollak and Wachter (1975) express concern about the robustness of the predictions concerning price and income effects that have been generated in the household production or time allocation literature, of which the Willis model is a special case. In particular, Pollak and Wachter point out that the close correspondence between market prices and shadow prices (i.e., the  $\pi$ 's) is lost when assumptions of constant returns to scale and exclude joint production are relaxed. However, Sanderson (1980) shows that the property of a positive relationship between the

<sup>38</sup> Increases in husbands' income may also lead to reduced variance in cohort total fertility discussed in the previous footnote. Given that children are relatively time-intensive, an increase in husband's income tends to have an asymmetric effect on the household's production frontier, increasing the potential output of adult commodities by more than it increases the potential for child-related commodities, when the wife's supply of time is held constant. This is illustrated in Fig. 10. If the household's preferences for children are relatively weak and the wife supplies a positive amount of market labor when husband's income is low, an increase in income will cause her to reduce her supply of labor. As long as she continues work at a constant wage, her price of time remains constant and, consequently, the opportunity cost of children also remains constant. Thus, in this case, the increase in  $H$  leads to a pure income effect which presumably increases the demand for  $c$ , and, because of quality-quantity interactions, has an ambiguous effect on the demand for number of children. For households with the same initial resources and a demand for  $c$  which is sufficiently strong that the wife does not work, the income effect resulting from an increase in  $H$  tends to be offset by a substitution effect against children, as illustrated by the movement from point  $a$  to point  $c$  in Fig. 10. Because of this negative substitution effect, it is more likely that increases in husband's income will reduce fertility among households with relatively strong preferences for children.

shadow price of children and the wife's wage rate carries over to more general models when it is assumed that children are *marginally* more intensive than alternative household production activities.

### *3.3. Marriage, fertility and out-of-wedlock childbearing*

As documented in Section 2, the incidence of nonmarital fertility has grown since World War II in almost all developed countries. This fact, coupled with greatly increased divorce rates and an increased proportion of children living in female-headed households, has provoked considerable alarm about the demise of the traditional family and concern about its potentially harmful effects on the well-being of women and children. While there have been a number of recent studies which attempt to describe the socioeconomic correlates of out-of-wedlock childbearing or attempt to determine empirically whether potential harmful effects are real,<sup>39</sup> only recently have there been attempts to develop a coherent theoretical framework for understanding the causes and consequences of out-of-wedlock childbearing. On the one hand, economic theories of fertility of the sort that we have described so far treat fertility as a "household decision", made jointly by a husband and wife who can be treated as a unitary decision maker. On the other hand, economic theories of marriage<sup>40</sup> note that childbearing is a leading reason for marriage but do not explicitly incorporate fertility decisions into the analysis.

A recent attempt to integrate economic theories of fertility and marriage in order to understand the growth of out-of-wedlock childbearing is presented in Willis (1995). In order to understand the interaction between marital decisions and fertility decisions, he considers a very simple model in which women and men are treated as separate decision makers. The model represents a blend of Becker's theory of marriage (Becker, 1981) and Weiss and Willis' (1985) theory of children as a collective good.<sup>41</sup> Under certain circumstances, the model produces results similar to those emphasized by William J. Wilson's theory of out-of-wedlock childbearing among the underclass (Wilson, 1987). Specifically, if women's resources are sufficiently great, both absolutely and relative to men's, and women are also more numerous, there may be equilibria in which men, drawn from the lower tail of the income distribution, father as many children as possible and women, also low income, voluntarily bear and rear these children out of wedlock using only their own resources or AFDC transfers. In such an equilibrium, expenditures on children are lower than in an alternative "traditional" equilibrium in which all available men marry and father children, the

<sup>39</sup> DaVanzo and Rahman (1993) provide citations to many of these studies.

<sup>40</sup> See Becker (1973, 1974, 1981).

<sup>41</sup> See Weiss (this volume) and Bergstrom (this volume) for more detailed discussion of models of marriage and household behavior in which the interests of male and female partners are considered separately.

mother and father share in the costs of childrearing, and unmarried women remain childless. "Underclass equilibria" of the latter type occur when men are relatively scarce and women's incomes are both absolutely and relatively higher.

Following Weiss and Willis (1985), assume that children are collective goods from the point of view of the parents in the sense that both parents value their children's welfare. Given that children are collective goods, there are potential gains to both parents from coordinating the allocation of their resources to their children and, arguably, this coordination is best accomplished within the context of marriage because repeated interaction between the parents reduces tendencies for free riding. Moreover, the efficient allocation of resources within marriage also benefits the children because, by sharing in their costs, both parents face lower prices of child quality. Conversely, if one parent has custody and the other parent can only influence the children's welfare by transferring money to the custodian, Weiss and Willis (1985) show that the couple will reach a Stackelberg equilibrium in which (a) the expenditure on child quality will be lower than it would be within marriage, (b) the allocation of the couple's joint resources is not Pareto optimal so that both parents could be made better off by increasing expenditures on children, and (c) the amount of money the non-custodial parent is willing to transfer to the custodian decreases as the custodian's income increases and, if the custodian's income is sufficiently high, the non-custodial parent will voluntarily contribute nothing toward the upbringing of his or her child. In a world with one woman and one man, this implies that Eve would never choose to become a single mother, nor would Adam choose to be a single father, because both parties can be made better off through marriage.

Despite these gains to marriage, Willis (1995) argues that out-of-wedlock childbearing and single parenthood may arise as an equilibrium outcome in a competitive marriage market if: (a) most women have incomes exceeding a threshold  $\bar{I}$  such that they are willing to bear and rear children using only their own resources;<sup>42</sup> (b) men in the lower portion of the income distribution have relatively low incomes so that the gains to coordinating parental resources are relatively small; and (c) women are more numerous than men in the marriage market. Conversely, when these conditions fail to hold, he argues that there will be a "traditional equilibrium" in which all childbearing takes place within marriage and unmarried persons remain childless.

To summarize the argument, first consider a traditional marriage market equilibrium in a world in which there are equal numbers of men and women. Within each sex, assume that persons have identical preferences but vary in income. Given the

<sup>42</sup> For simplicity, assume the couple's utility functions satisfy the conditions for transferable utility such that the efficient quantity of a public good is independent of the distribution of income (Bergstrom and Cornes, 1983). In this case there is a given threshold level of income,  $\bar{I}$ , such that a married couple would desire to have children if their joint resources exceed this threshold (i.e.,  $I_m + I_f > \bar{I}$ ) and, similarly, such that a single mother would desire to have children if her income exceeds the same threshold (i.e.,  $I_f > \bar{I}$ ) where  $I_m$  and  $I_f$  refer to male and female incomes.

existence of a household public good such as children, Lam (1988) proves that the equilibrium assignment in a Beckerian marriage market involves positive assortative mating. That is, assuming that their joint income exceeds  $\bar{I}$ , the highest income man will marry and have a child with the highest income woman, the next highest income couple will marry and bear a child and so on until a point is reached at which joint incomes of highest income unmarried man and highest income unmarried woman are less than or equal to  $\bar{I}$ . In the absence of other reasons to marry, assume that all persons with incomes below this level remain unmarried and childless.

A traditional equilibrium would also hold if there is a numerical excess supply of men even if the lowest income man has an income that exceeds  $\bar{I}$ . In this case, all women would marry and bear children with men drawn from the upper portion of the income distribution. The remaining men in the lower tail of the income distribution will remain unmarried and childless because no such man can make any married woman better off by leaving her marriage to bear his child. A traditional equilibrium will also occur if women are in excess supply but they have incomes that are much too low to support a child on their own. In this case, a married man might wish to father children by unmarried women but he will not be able to do so without incurring costs that outweigh the benefit of maintaining a traditional marriage.

If women have incomes that are sufficiently high, however, they will desire to have children even if they must rear children entirely with their own resources where resources are interpreted to include either the woman's own labor income or AFDC transfers she is eligible to receive. From a man's point of view, this means that he may enjoy the benefits of fatherhood (or the joy of sex) at zero economic cost to himself if he decides to father children by a woman who is willing to bear all the costs of rearing them. As we have seen, both the father and the mother could always attain a still greater level of utility within marriage by making a higher expenditure on their children financed with some of the father's income. However, it is possible that a man might find it advantageous to forgo this gain if he could father children at zero cost by enough different women. Because their incomes exceed  $\bar{I}$ , women gain by becoming mothers rather than by remaining childless.

If women outnumber men, there may exist an "underclass equilibrium" under these circumstances such that, while high income men and women continue to bear children within marriage, some fraction of men drawn from the lower part of the income distribution father children out-of-wedlock by women who also have low incomes. Suppose, for example, that each man would prefer to forgo marriage if he could father children out-of-wedlock by two different partners and assume that the overall sex ratio is 110 males per 100 females in a large population. Marriage will still tend to take place among couples in the upper end of the income distribution because there are too few available female partners to entice males to eschew marriage. However, as the number of marriages increases, the ratio of unmarried females to unmarried males tends to increase without bound. A little arithmetic shows that each unmarried male can have two partners when 90% of men marry and 10% of men father children by the

18% of women who fail to find a marriage partner. Although these women would prefer to become married, given their low incomes they are unable to offer more utility to any married man than he obtains in partnership with a higher income woman. Similarly, no married man would find it advantageous to exchange places with a lower income unmarried man with two partners because the gains to the efficient coordination of joint resources is higher for him precisely because he has more resources.

This analysis has a variety of empirical implications, although few have yet been explored systematically. One is that a reduction in the number of partners that a man requires in order to be willing to forgo marriage may have a large effect on the fraction of births born out of wedlock. For instance, if the required number of partners per unmarried man falls from 2 to 1.2, the equilibrium fraction of men who will father children out-of-wedlock increases from 10% to 50% and the fraction of nonmarital births increases from 18% to 58%. What would cause such a shift? One cause would be a growth in the resources of women, particularly growth in the lower portions of the income distribution due to increased labor market opportunities or AFDC. Another would be a decline in the income of men in the lower portions of the income distribution. Still another would be an increase in the ratio of females to males in the marriage market caused by differential mortality or incarceration. Such factors have been emphasized by Wilson (1987) in his analysis of the high prevalence of out-of-wedlock childbearing among underclass blacks. Rapid growth of the fraction of nonmarital births among non-blacks during the past two decades coincides with growing female labor force attachment and some reduction in the male-female wage ratio that partly reflects gains for women and partly reduced earnings of men in the lower half of the wage distribution. These co-movements appear to be broadly consistent with the theory, but formal tests of the theory's capacity to explain the trends await future research. Yet another implication is that stronger enforcement of child support laws (i.e., identification of paternity, establishment of child support awards, collection of obligations) would tend to reduce the attractiveness of nonmarital childbearing by eliminating the capacity of men and women to make a private deal in which the man fathers a child but takes no financial responsibility for it.

Finally, the empirical implications of the economic model of out-of-wedlock childbearing can be enriched by bringing in some of the factors that were assumed away in the interest of simplicity. For example, it would be useful to attempt to extend the theory of out-of-wedlock childbearing presented here to include the effect of the growth of divorce and remarriage on fertility decisions using more dynamic models along the lines of those described later in this paper. Another useful extension is to incorporate the desire for sexual pleasure and imperfect fertility control into the model. In an interesting and provocative paper, Akerlof et al. (1994) argue that the growing capacity of women to control their reproduction through abortion has the paradoxical effect of increasing the likelihood of nonmarital childbearing and Kane and Staiger (1995) present empirical evidence that improved access to abortion clinics tends to increase out-of-wedlock births.

#### 4. Life-cycle models of fertility

In this section, we describe the essential features of the dynamic, or life-cycle, models of fertility that have been developed in the literature. As has been noted in the study of labor supply behavior within labor economics, developing models which are explicitly dynamic and embedded within a life-cycle setting is important for several reasons. Introducing decision making within a life-cycle framework makes explicit the existence of additional margins over which parents may choose to substitute their fertility, namely, childbearing at different ages over the life cycle. As such, changes in prices and income over the life cycle may result in changes in the *timing* of fertility demand, even if they do not cause *lifetime* fertility to change. The life-cycle context is also the appropriate setting within which to consider the consequences of the stochastic nature of human reproduction, including the choice of contraceptive practices and responses of parents to the realizations of this stochastic process. Finally, the dynamic setting provides a more appropriate context within which to examine the relationships between women's labor supply, investment in human capital and childbearing decisions that were alluded to in Section 3.2.

In what follows, we provide an overview of the structure of the nascent literature on dynamic models of fertility. We begin by outlining a taxonomy of the model "features" which have been incorporated into the theoretical literature to date, indicating how they correspond to those contained in the static models considered above. We then briefly discuss the mathematical structure of the solution to the parents' optimal childbearing (or contraceptive method) decisions over their life cycle. As that discussion makes clear, these solutions do not lead to straightforward and robust implications about what life-cycle patterns of fertility behavior should be observed and how they vary as prices and income vary.<sup>43</sup> Finally, we summarize the implications that these models have for the dimensions of intertemporal fertility behavior whose empirical trends we surveyed earlier: namely, trends in the timing of first births, the spacing between births, total childbearing, contraceptive practices and contraceptive failures; and "unwanted" children in the US and other developed countries during the twentieth century.

##### 4.1. Features of life-cycle models of fertility and the optimal solution

Existing economic theories of fertility in a life-cycle setting blend features of static models of fertility with those from at least four different strands of dynamic models of behavior: (i) models of optimal life-cycle consumption,<sup>44</sup> (ii) models of life-cycle la-

<sup>43</sup> As we shall discuss in Section 5, the solutions to these programs do not lend themselves to simple econometric specifications, either.

<sup>44</sup> See Friedman (1957).

bor supply decisions,<sup>45</sup> (iii) models of human capital investment and accumulation,<sup>46</sup> and (iv) stochastic models of human reproduction.<sup>47</sup> While no one model incorporates all of these strands, it is pedagogically useful to characterize the features of a comprehensive model in order to delineate those model elements which have been considered in the existing literature.<sup>48</sup> We consider a prototypical household which, at the outset, consists of a woman and her spouse<sup>49</sup> who are assumed to act in unison to make fertility and time and resource allocation decisions over a finite lifetime.<sup>50</sup> We characterize their lifetime in discrete time units,  $t$ , that index the "age" of the household unit and their lifetime runs from zero to  $T$ . In our comprehensive model, we assume that the couple make their choices so as to maximize a well-defined *set of preferences*, subject to *time* and (*financial*) *budget constraints*, to technological constraints which govern the (*re)production* and *rearing of children* and to constraints on the *production* of the woman's *stock of human capital* which determines the value of her time in the labor market at each age. The couple will make these decisions either in a *certain* (perfect foresight) or an *uncertain* setting, where the uncertainty they may face can arise either from the stochastic nature of the reproductive process or of the future income, prices or wage rates they may face. We now briefly describe the specifications of these model features which have been considered in the literature.

#### 4.1.1. Preference structures and the production of child services

Following the structure of preferences considered in static models, the most general specification of lifetime parental preferences considered in the literature takes the following form:

$$U = \sum_{t=0}^T \beta^t u(c_t, \ell_t, s_t), \quad (9)$$

where  $\ell_t$  is the amount of time the mother consumes in leisure activities at age  $t$ ,  $s_t$  is

<sup>45</sup> See MaCurdy (1980) and Heckman and MaCurdy (1980).

<sup>46</sup> Ben-Porath (1967).

<sup>47</sup> See Perrin and Sheps (1964).

<sup>48</sup> While hardly exhaustive, the following studies develop life cycle models of fertility behavior from an economic, or rational choice, perspective: Heckman and Willis (1976), Razin (1980), Hotz (1980), Cigno (1983), Happel et al. (1984), Moffitt (1984a), Vijverberg (1984), Hotz and Miller (1986), David and Mroz (1986), Newman (1988), Cigno and Ermisch (1989), Montgomery (1989), Cigno (1991), Hotz and Miller (1993), Rosenzweig and Wolpin (1993), and Walker (1995). Some of these models are surveyed in Montgomery and Trussell (1986).

<sup>49</sup> To date, no dynamic models have been developed which incorporate marriage decisions within a life cycle fertility model.

<sup>50</sup> Hotz and Miller (1986) actually develop a model in which, for analytic convenience, couples are assumed to be infinitely-lived.

parental consumption,  $\beta$  is the couple's rate of time preference ( $0 \leq \beta \leq 1$ ), and  $c_t$ , the flow of child services parents receive at age  $t$  from their stock of children, is governed by the following production process:

$$c_t = (b_0, b_1, \dots, b_{t-1}, t_{ct}, x_{ct}), \quad (10)$$

where  $b_\tau = 1$  if the parents gave birth to a child when they were age  $\tau$  ( $\tau = 0, \dots, t-1$ ) and  $b_\tau = 0$  otherwise; and  $t_{ct}$  and  $x_{ct}$  denote, respectively, the mother's time and a vector of market inputs used in the production of child services. The latter inputs may include non-parental child-care services.<sup>51</sup> Assuming that children do not die before their parents do,<sup>52</sup> it follows that the couple's stock of children at age  $t$  is given by

$$n_t = \sum_{\tau=0}^{t-1} b_\tau.$$

The life-cycle models of fertility found in the literature are based on several specializations of this general specification of preferences. The simplest specification in the literature, considered by Happel et al. (1984), assumes that  $U$  in Eq. (9) does not depend on  $\ell_t$  at any age and does not depend on  $c_t$  except at age  $T$ , when child services are assumed to be proportional to  $n_T$ , the couple's completed family size (i.e.,  $c_T = n_T$ ). The latter specification closely mimics the specification of static models in that parental utility is not affected by the timing of births; all they care about is their completed family size. In many of the life-cycle models developed to date, child services,  $c_t(\cdot)$ , vary with the parents' age but are restricted to be proportional to the accumulated number of children,  $n_t$ .<sup>53</sup> The exceptions are the papers by Moffitt (1984b), Vijverberg (1984), Hotz and Miller (1986, 1993), which consider more general forms of  $c_t(\cdot)$ . For example, both Moffitt (1984b) and Hotz and Miller (1986) evaluate specifications of Eq. (10) in which parental time inputs,  $t_{ct}$ , and market inputs,  $x_{ct}$ , vary as a function of the ages of children, with young children "requiring" more maternal time and older children more market inputs.<sup>54</sup>

<sup>51</sup> Moffitt (1984b) explicitly considers the substitution possibilities between parental time and market-based child care inputs.

<sup>52</sup> Wolpin (1984) and Newman (1988) consider models in which the survival of children is governed by a stochastic mortality process.

<sup>53</sup> This is true of Wolpin (1984).

<sup>54</sup> Hotz and Miller (1993) also allow children to have an age-dependent effect on  $c_t$ , over and above the impact that children of different ages have via age-varying requirements of parental time and market inputs in the production of  $c_t$ .

#### 4.1.2. *Maternal time constraints*

To the extent that the allocation of maternal time is explicitly incorporated, existing life-cycle models include period-by-period constraints on the mother's time of the form

$$\ell_t + h_t + t_{ct} = 1, \quad (11)$$

where we normalize the per-period amount of time available to the mother to one and where  $h_t$  is the (normalized) amount of time she spends in the labor market. None of the existing life-cycle models consider the time allocation decisions of fathers; they are assumed only to provide for the rearing of children through the income they generate.

#### 4.1.3. *The production of children and control of fertility*

The static models of fertility discussed in Section 3 presumed that parents could control their fertility perfectly and costlessly. Several of the life-cycle models in the literature maintain this assumption, allowing parents complete and costless control over their ability to have or not have a birth at each age.<sup>55</sup> However, controlling a woman's fertility is not likely to be either perfect or without costs, be they monetary or psychic. In fact, producing (or avoiding) births is an uncertain process which is intimately linked with the sexual activity and gratification of women and their mates. Modeling human reproduction as a stochastic process has a long tradition in population biology and formal demography.<sup>56</sup> In this literature, a couple's childbearing behavior is viewed as realizations of a stochastic process governing conception and pregnancy resolution events which are largely beyond the control of parents. Thus, in contrast to the emphasis on the demand for fertility found in the early, largely static, economic models, the demographic and biological literature has stressed the "supply" side of human fertility.

The models in the economics literature which allow for stochastic reproduction in their modeling of life-cycle fertility<sup>57</sup> assume that a couple's fertility is stochastic but controllable, in part, by the contraceptive strategies they choose. As such, we can view the couple's fertility as being governed by their "reproduction" function, which takes the form

<sup>55</sup> This is true of the models by Hotz (1980), Wolpin (1984), Moffitt (1984b), Happel et al. (1984), Vijverberg (1984), and Cigno and Ermisch (1989).

<sup>56</sup> See Perrin and Sheps (1964) and Sheps and Menken (1973).

<sup>57</sup> The initial papers to address this issue were Michael and Willis (1976) and Heckman and Willis (1976). The models developed by Rosenzweig and Schultz (1985, 1989), Hotz and Miller (1986, 1993), Newman (1988), and Montgomery (1989) also incorporate the stochastic nature of reproduction into choice based, life-cycle models of fertility.

$$b_t = R(\mathbf{e}_t, \phi_t), \quad (12)$$

where  $\mathbf{e}_t$  denotes a  $K$ -dimensional vector of whose typical element,  $e_k$ , denotes whether or not the  $k$ th contraceptive method is used,  $k = 1, \dots, K$ , and  $\phi_t$  denotes the stochastic component governing the likelihood that a birth is produced with an unprotected sexual act. It follows that  $b_t$  is a random variable and the parents' *birth probability function* is given by

$$p_{bt}(\mathbf{e}_t, \mu, \sigma_\phi^2) \equiv \Pr(b_t = 1 | t, \mathbf{e}_t, \mu, \sigma_\phi^2) = E_\phi(R(\mathbf{e}_t, \phi_t)), \quad (13)$$

where  $E_\phi(\cdot)$  denotes the expectations operator over the random variable  $\phi_t$ , and  $\mu$  and  $\sigma_\phi^2$  are the mean and variance, respectively, of  $\phi_t$ . The couple's  $\mu$  can be interpreted as a couple's *fecundity*; More fecund couples have a higher probability of conception conditional on any method used, i.e.,  $\partial p_{bt}(\mathbf{e}_t, \mu, \sigma_\phi^2)/\partial \mu \geq 0$ , holding constant any particular contraceptive method used,  $e_k$  say.<sup>58</sup> In addition to the pill, condoms, etc., three contraceptive methods are of particular analytic interest: (i) the use of no protection (which we indicate by  $e_{1t}$ ); (ii) permanent sterilization, which precludes any (further) births; and (iii) an induced abortion (which we indicate by  $e_{Kt}$ ) which, for our purposes, can be thought of as an *ex post* contraceptive method.

Most models presume that fertility control through the use of contraceptive methods, other than unprotected sex ( $e_{1t} = 1$ ), is costly – either in out-of-pocket costs, time costs in their execution (e.g., physician visits to obtain prescriptions), or psychic costs associated with the displeasure or inconvenience of their use (e.g., using a condom which reduces the pleasure of sexual intercourse).<sup>59</sup> These costs can be incorporated into the model by including  $\mathbf{e}_t$  as an argument in the parents' utility function in Eq. (9), where  $U(\cdot)$  is presumed to be decreasing in  $\mathbf{e}_t$ , and by including the out-of-pocket costs in the parental budget constraint which is to be described below.

Finally, we note that models in which the birth process is stochastic, as in Eq. (12), transform the parents' intertemporal optimization problem into one of decision making under uncertainty. The implications of this point for strategic behavior on the part of parents are discussed below.

#### 4.1.4. The household's budget constraint

The budget constraints facing parents in the existing life-cycle models of fertility vary depending upon what is assumed about their ability to save and/or their access to capital markets. All existing models assume that capital markets are either *perfect* –

<sup>58</sup> See Sheps and Menken (1973) and Rosenzweig and Schultz (1985, 1989).

<sup>59</sup> The Hotz and Miller (1986, 1993) model allows for stochastic births and contraceptive protection, but assumes that such protection is costless to the parents. The other models which incorporate stochastic reproduction explicitly acknowledge the costs of such protection.

i.e., parents are able to borrow and lend across time periods at a real interest rate,  $r_t$  – or *perfectly-imperfect*, in which case no borrowing or saving is possible.

In models which maintain the perfect capital markets (PCM) assumption,<sup>60</sup> the parents face an overall, lifetime budget constraint in which assets,  $A_t$ , can be borrowed or lent over time. For simplicity, assume that parents start with no assets, i.e.,  $A_0 = 0$ , and leave no bequests, i.e.,  $A_T = 0$ . Then defining *savings* at age  $t$  to be  $S_t$  ( $\equiv A_t - A_{t-1}$ ), the parents' age  $t$  budget constraint is given by

$$S_t = Y_{ht} + w_t h_t - s_t - \mathbf{p}'_{ct} \mathbf{x}_{ct} - \mathbf{p}'_{et} \mathbf{e}_t - \pi_n n_t, \quad (14)$$

where  $Y_{ht}$  denotes husband's income at age  $t$ ,  $w_t$  is the wife's market wage rate,  $\mathbf{p}_{ct}$  and  $\mathbf{p}_{et}$  are vectors of prices for market inputs to the production of child services and the out-of-pocket costs of contraceptives, respectively, and, as before,  $\pi_n$  denotes the per-unit, non-quality cost of children. A key feature of the PCM assumption is that savings in any period can either be positive or negative, i.e., parents are allowed to borrow against the future or *dissave*. In the case of perfectly, imperfect capital markets (PICM), parents cannot save, i.e.,  $S_t = 0$  for all  $t$ , and parental consumption is constrained by the following *period by period* constraint:<sup>61</sup>

$$Y_{ht} + w_t h_t = s_t + \mathbf{p}'_{ct} \mathbf{x}_{ct} + \mathbf{p}'_{et} \mathbf{e}_t + \pi_n n_t. \quad (15)$$

While not adopted in any of the models in the existing literature, we note that there is a third alternative for specifying the parents' budget constraint, namely the possibility of *less than perfect capital markets* (LPCM) in which parents can save for but not borrow against the future. This assumption amounts to imposing the side constraint on Eq. (14) that  $S_t \geq 0$  for all  $t$ . Despite its realism, the LPCM assumption has not been widely used in formal models of life-cycle behavior because of its mathematical intractability. Nonetheless, we speculate below as to what implications it might have for fertility behavior over the life cycle.

Finally, we note that considering parental decision making within the life-cycle context puts the possibility that they face uncertainty about future income and prices into sharper relief. Most of the existing literature on life-cycle fertility does not incorporate this form of uncertainty. The one exception is the model of Hotz and Miller (1986, 1993) in which future realizations of husband's income,  $Y_{ht}$ , and the wife's wage rate,  $w_t$ , are treated as stochastic.

<sup>60</sup> The models of Happel et al. (1984), Moffitt (1984b), Vijverberg (1984), and Walker (1995) maintain this assumption about capital markets.

<sup>61</sup> The models of Heckman and Willis (1976), Wolpin (1984), Hotz and Miller (1986, 1993), and Newman (1988) adopt this assumption about the nature of capital markets available to parents.

#### 4.1.5. Maternal investments in human capital

The final feature of life-cycle fertility models considered in the literature concerns the treatment of the mother's wages. In most of the models in which the allocation of maternal time is treated as endogenous, the mother's wages over her life cycle are treated as exogenously determined. Several papers, however, do introduce the possibility that the mother's participation in the labor force not only generate income for the family but also may enhance her future labor market skills, and thus her future wage rate possibilities.<sup>62</sup> Adding this feature also introduces a potentially important source of intertemporal variation in the opportunity cost of maternal time in the production and care of children and, thus, in the timing of births over the life cycle. We return to this point below.

The life-cycle fertility models which introduce human capital investment generally adopt a "learning-by-doing" human capital production process in which maternal wage rates are determined, in part, by the mother's past labor supply and her current work effort. More formally, this production function is given by

$$w_t = H(w_{t-1}, h_t) - \delta_1 w_{t-1} - \delta_2 w_{t-1} I[h_t = 0], \quad (16)$$

where  $H(\cdot, \cdot)$  is the human capital production function,  $\delta_1$  and  $\delta_2$  are rates of depreciation ( $0 \leq \delta_i \leq 1$ ,  $i = 1, 2$ ), and  $I[\cdot]$  is the indicator function. The depreciation component of the mother's human capital accumulation given in Eq. (16) allows for the possibility that the woman's skills – and, thus, her subsequent wage rates – depreciate either because of age-related atrophy or because they are not utilized in the labor market.<sup>63</sup>

#### 4.1.6. The structure of the solution to the parents' intertemporal optimization problem

While differing according to the particular model features incorporated, the life-cycle models in the literature all entail parents sequentially making choices over: (i) child-bearing, or contraceptive methods, (ii) parental consumption and (iii) the allocation of the mother's time across labor market and childrearing activities so as to maximize Eq. (9) subject to the constraints implied by the relationships in Eqs. (10)–(12) (if reproduction is stochastic), Eq. (14) or (15) and, possibly Eq. (16). The parents' optimization problem can be solved using techniques in the dynamic programming literature.<sup>64</sup> The structure of the solution differs somewhat depending upon whether the

<sup>62</sup> The models of Cigno (1983), Happel et al. (1984), Moffitt (1984b), Cigno and Ermisch (1989) and Walker (1995) incorporate the possibility of maternal human capital investment.

<sup>63</sup> The latter type of human capital depreciation is considered by Hotz et al. (1996).

<sup>64</sup> See, for example, Bellman (1957).

model includes uncertainty with respect to future birth, income or price realizations (the “uncertainty” case) or not (the “perfect foresight” case).

For pedagogic purposes, consider the perfect foresight case. With no uncertainty, the solution to the parents’ dynamic programming problem maps parental choice variables at each age to the life-cycle sequences of prices (including wages and interest rates), incomes (or initial assets) and the dimensions of the “technologies” which characterize the production of children, their rearing and human capital. That is, the optimal solution for the parents’ decision to have a birth at age  $t$  would be given by the following mapping:

$$b_t = b_t(\{\mathbf{p}_{ct}\}_{t=0}^T, \{\mathbf{p}_{et}\}_{t=0}^T, \{w_\tau\}_{\tau=0}^T, \{r_\tau\}_{\tau=0}^T, A_0; \theta) \quad (17)$$

under the PCM assumption and

$$b_t = b_t(\{\mathbf{p}_{ct}\}_{t=0}^T, \{\mathbf{p}_{et}\}_{t=0}^T, \{w_\tau\}_{\tau=0}^T, \{r_\tau\}_{\tau=0}^T, \{Y_{ht}\}_{t=0}^T; \theta) \quad (18)$$

under the PICM assumption, where,  $\{z_t\}_{t=0}^T$  denotes the sequences of variables,  $z_t$ , and  $\theta$  denotes a vector of the exogenous parental attributes which shape their preferences and which characterize the technologies and/or endowments governing the production functions given above. The mappings in Eqs. (17) and (18) constitute the analogue to fertility demand equations in the static context.

Several general observations can be made about the structure of the above mappings. First, they make clear that the life-cycle setting entails several alternative types of price effects (and income effects under the PICM assumption). As has been noted in the literature on life-cycle labor supply models,<sup>65</sup> changes in prices (or income) at any age (i.e., transitory price changes) will, in general, affect whether the couple want to have a birth at age  $t$ . More to the point, the effect of such price changes on contemporaneous fertility – which will generally entail income and substitution effects – may be to shift the *timing* of births over the life-cycle rather than have much, if any, effect on the number of births accumulated. (A similar conclusion applies to transitory changes in parental income.) As noted in the introduction to this section, one of the consequences of extending models of fertility to the life-cycle context is the expansion of the margins over which fertility can be shifted in response to changes. Note that this point about the potential importance of intertemporal substitution of fertility holds whether prices or incomes change over any segment of the parents’ life cycle.<sup>66</sup>

<sup>65</sup> See MaCurdy (1980) and Heckman and MaCurdy (1980).

<sup>66</sup> For example, Walker (1995) notes that changes in the “slope” of price and/or wage profiles which hold parental wealth constant – what MaCurdy (1980) refers to as “evolutionary” price changes – may change the life-cycle timing of births but not have any effect on a couple’s completed family size.

Second, while the mappings in Eqs. (17) and (18) express births at a given age as a function of sequences of prices, it is important to keep in mind that none of these individual prices correspond to the “price of children” concept, be it  $\pi_c$  or  $\pi_n$ , developed under the static theory of fertility. This is because children are “durable” goods so that the “user cost” of children is a function of the sequences of prices given in Eqs. (17) and (18).<sup>67</sup>

Finally, while the above mappings characterize the general solutions to the parents’ fertility choices, at least in the perfect foresight case, they typically cannot be expressed as closed form or particularly manageable functions. Moreover, when one extends these models to include stochastic elements, i.e., moves to the uncertainty case, these problems become even more complex. For example, the analogues to Eqs. (17) and (18) in the uncertainty setting are not, in general, obtained by simply substituting expected values in place of future prices and incomes.<sup>68</sup> In either the certainty or uncertainty setting, the solutions are derived via backward recursion methods and result in complex functions of future prices and incomes in the perfect foresight case or, in the case of uncertainty, of expected values of functions which involve their stochastic analogues. This problem arises, in large part, because of the discrete nature of many of the choice variables (e.g., births or contraceptive methods are characterized as discrete events) and/or the “corner” solutions which characterize the mother’s labor supply decisions over her life-cycle. This feature of solutions to the parents’ life-cycle choice complicates the task of devising econometric specifications of the life-cycle models developed in the existing literature.<sup>69</sup> It also has limited the ability to obtain unambiguous comparative dynamic predictions from these models. Nonetheless, several of the models developed in the literature do appear to give some general predictions about how several dimensions of life-cycle fertility respond to variations in prices and income and the alternative specifications of the model features described above. In the next several sections, we briefly discuss these implications.

#### *4.2. The optimal timing of first births*

As we noted in Section 2, the age at which women in developed countries begin their childbearing has varied substantially over the twentieth century and differs across ethnic groups. Recall that since the 1960s first births have shifted to later ages in the US and that this decline has been much more pronounced for white women compared to non-whites (see Fig. 4). The life-cycle models developed to date have suggested several factors which account for when, in the life cycle, it is optimal for couples to

<sup>67</sup> See Walker (1995) for a discussion of this point.

<sup>68</sup> Thus, the specifications of dynamic fertility demand and labor supply functions in Ward and Butz (1980), which are based on this approach, have no theoretical basis.

<sup>69</sup> As discussed below, Wolpin (1984) and Hotz and Miller (1993) do develop models which are consistent with the economic structure and, at the same time, are estimable.

begin their childbearing. What determines the optimal age at which to begin childbearing in these models primarily hinges on: (i) what one assumes about how parents value their offspring; (ii) the structure of capital markets; and (iii) how the maternal time costs of mothers vary over her life cycle. Birth timing may also be affected by contraceptive strategies to avoid having too many births.

Consider, for example, the model by Happel et al. (1984). Recall that these authors assume that parental preferences depend only on completed family size; their flow of utility from children does not depend upon how much of their life cycles they share with their children. With little loss of generality, they assume that the couple only has one child; the only choice is when to have it. Consider the case where capital markets are perfect, i.e., the PCM assumption holds. Then the timing of childbearing over the parents life cycle depends on the “costs” that childbearing imposes on parental consumption due to the loss of income that results from the mother’s labor force withdrawal to care for newborns. This loss in income depends on the rate at which earnings depreciate due to absence from the labor force (the value of  $\delta_2$  in Eq. (16)) and the initial level of earnings at the start of a couple’s life cycle ( $w_0$ ). If mothers start with little or no earning power ( $w_0$  at or near 0) and skills depreciate with absence from the market ( $\delta_2 > 0$ ), then it is optimal for women to have their children early to minimize the loss in their total lifetime earnings. If a mother has positive initial earnings ( $w_0 > 0$ ) and  $\delta_2 > 0$ , then she is better off to postpone her childbearing, minimizing the loss of lifetime earnings that result from the time she takes to rear her children. If woman’s skill does not depreciate with an absence from the market then under the PCM assumption, women are indifferent as to whether they have their children early or late as the loss of lifetime earnings to have a child is the same at whatever age they start their childbearing.

If capital markets are perfectly-imperfect (PICM holds), the time path of the father’s income – which played no role in the optimal timing of births under the PCM assumption – now matters. In particular, Happel et al. (1984) show if the mother’s skills do not deteriorate during her absence from the market ( $\delta_2 = 0$ ), the optimal time to have births is when the husband’s income is highest, i.e., when the marginal utility of income for parental consumption is the lowest. Assuming that husband’s earnings rise, this implies that the couple postpones its childbearing; in essence, children are postponed until the parents minimize the impact on their own consumption and “can afford” children. Finally, if women’s skills do depreciate ( $\delta_2 > 0$ ), then the timing of childbearing depends upon the relative importance of giving up parental consumption (i.e., the marginal utility of income in terms of parental consumption) and the marginal loss of income due to this depreciation.

While Happel et al. do not consider the case in which savings are possible but borrowing against future income is not (i.e., the LPCM assumption), one might speculate that such restriction on capital markets would still imply that childbearing would be postponed until the couple had achieved a “nest egg” to finance having the wife leave the labor market to have children. Such predictions seem to be consistent with anecdotal

tal evidence that in the early part of this century, many couples in the US, especially those in which the women were not highly skilled (i.e.,  $\delta_2 \approx 0$ ), postponed their child-bearing until they had saved enough to have their children.

Recall that Happel et al. (1984) assume that the utility parents derive from children only depends on the total number they bear. Most of the other life-cycle models of fertility relax this restriction and have parents derive utility from children as soon as they are born, i.e.,  $c_t$  enters  $U$  in Eq. (9) for ages  $t < T$ . Allowing for children to generate parental utility as soon as they are born provides another impetus for children to be born early, rather than, late in the life cycle. Nonetheless, Moffitt (1984b) shows that it still may be optimal for parents to postpone their first births. Moffitt's model, which is not dissimilar to that of Happel et al., assumes that: (i) parents receive utility from child services and the leisure time of mothers; (ii) capital markets are assumed to be perfect; (iii) children require maternal time inputs; and (iv) working in the labor force can increase a mother's future wages. Moffitt (1984b) shows that couples may choose to postpone their childbearing either because of the opportunity cost of human capital accumulation early in their life cycle exceeds the value of children or, even in the absence of the human capital investment motive, the couple's marginal utility of the first unit of the mother's time in leisure activities exceeds that of the utility achieved from having a child.

Finally, the existing theories of life-cycle fertility suggest another motive for postponing the age at first birth. This motive arises when human reproduction is assumed to be stochastic, as in Eq. (12). As first noted by Heckman and Willis (1975), imperfect fertility control and the potential for contraceptive failure may lead couples to contracept early in their life cycles, even though they would choose not to if contraception were perfectly effective and costless.<sup>70</sup> In this case, couples may find it optimal to engage in a "precautionary" contraception strategy early in their life cycles so as to reduce their risk of having more births than they would have chosen to have if their fertility were perfectly and costlessly controllable.

#### *4.3. The optimal spacing of births*

A good deal of attention has been paid in the life-cycle models of fertility to their predictions concerning the spacing of births. This attention is due, in part, to the inherent interest in obtaining predictions about the spacing of births. The ability to develop dynamic models which generate spacing between births is also an important "litmus" test of the model itself. As noted by Newman (1988), "there is a tendency in dynamic programming models for the optimal solution to involve building up a stock

<sup>70</sup> Couples always can avoid births by abstaining from sexual intercourse. In addition, couples may have access to abortions or sterilization, each of which is a "perfect" form of fertility control. However, either or both methods may be viewed as too "costly" for parents to use, especially young couples.

either at the beginning or end of the period. Since this [prediction] runs counter to observations of fertility over the childbearing period, a dynamic model must be able to generate a spacing pattern where the births do not occur all at once".<sup>71</sup> Since biological constraints would prevent most couples from having all desired births at once, Newman's point should be reformulated as a question that asks why, once the first birth occurs, couples do not choose to have all subsequent births as quickly as possible. In what follows, we briefly discuss several different mechanisms within existing models which tend to generate spacing between births and discusses what predictions these mechanisms generate about what leads to longer versus shorter birth intervals.

As is suggested by the discussion in the previous two sections, life-cycle models of behavior imply that intertemporal variation in the timing of "consumption" of any commodity, including durable goods like children, tend to result from life-cycle variation in income, in the absence of perfect capital markets, and/or in the prices or costs associated with these goods. Consider, first, the role of life-cycle variation in income when capital markets are perfectly-imperfect (i.e., under the PICM assumption). In this setting, as discussed in Heckman and Willis (1975), Wolpin (1984), and Newman (1988), variations in the life-cycle profile of household income shapes the timing and spacing of births. As the quote by Newman (1988) suggests, models in which parents derive service flows from children, once they are born, tend, all else equal, to generate early childbearing and no (or minimal) spacing between births. But, in the absence of capital markets, spacing arises as a resolution of the tension between the desire to have children early (given discounting and a finite fertile stage) and the economic incentive to have children later when income is high. Thus, for example, rising income profiles, with an inability to save or dissave, gives rise to the incentive to space births, especially to the extent that, once born, children incur "maintenance" costs for some portion of their lives. Thus, the models of Heckman and Willis (1975), Wolpin (1984), and Newman (1988) all predict that the more rapid the rise in household (or father's) income, *ceteris paribus*, the more likely it is that parents will contracept in order to space their births.<sup>72</sup>

Another way spacing is generated within life-cycle models of fertility is due to price variation. In general, if the prices associated with rearing children vary over the parents' life cycle, spacing may also be generated. The models of Moffitt (1984b) and Hotz and Miller (1986) generate such life-cycle variation through the costs of maternal time in the care of children by imposing a technological restriction on the production function for child care services in Eq. (10). In their models, they incorporate the assumption, used by Willis (1973) in his static model of fertility, that the production of child services for young children are intensive in the mothers time. Put another way,  $t_{ct}$

<sup>71</sup> Newman (1988: p. 50).

<sup>72</sup> While allowing parents access to capital markets mitigates one of the incentives to postpone and/or space births, it does not preclude it. As Heckman and Willis (1975) note, it still may be optimal for parents to space births, even in the presence of capital markets, if the market rate of interest,  $r$ , exceeds the parents' rate of time preference  $\beta$ .

is assumed to be higher when children are young. To the extent that caring for young children is so intensive that it requires the mother to withdraw from the labor force, the shadow price of the mother's time rise, exceeding her market wage, as in the Willis (1973) model. In the face of the temporary price rise, postponing the next birth, until this "price" declines, generates the incentive to space births.

#### *4.4. Contraceptive choice and the efficacy of contraceptive methods*

An important feature found in many of the life-cycle models of fertility is the explicit incorporation of stochastic reproduction. Such models have focused the attention on the contraceptive strategies that parents follow over their life cycles in an attempt to control their reproduction. Incorporating the strategic dimension of contraceptive practices has generated several new insights on issues related to the failure rates of contraceptive methods.

Much of the family planning literature has taken the perspective that various methods have inherent rates of failure to prevent births.<sup>73</sup> While it is true that methods differ in the technology by which births are prevented and may produce different failure rates in practice, it is not true that the failure rate of any given method is independent of choices made by a woman and/or her partner about trade-offs between, say, activities that bring sexual pleasure and ways of using a given method to minimize the probability of pregnancy. Beginning with Michael and Willis (1975) and Heckman and Willis (1975), forward looking economic models of fertility have treated contraception as imperfect and costly and have assumed that couples choose methods and use them in ways that reflect a balance between the "costs" of contraception and the benefit of preventing a birth temporarily or permanently. For instance, Michael and Willis (1975) suggest that a couple who wish to terminate their childbearing is more likely to incur the fixed costs of learning about and paying for a contraceptive such as the Pill which is highly effective and has a low marginal cost because it does not interfere with sexual pleasure than is a similar couple that is just attempting to space births. Similarly, a teenager who engages in sex sporadically may not be willing to invest in contraceptive methods with high fixed costs and low marginal costs while a more sexually active teenager might make such investments. The point that contraceptive efficacy is a matter of choice is also featured in the more recent work of Rosenzweig and Schultz (1985, 1989) and Hotz and Miller (1993). For example, Rosenzweig and Schultz (1989) note that an optimizing model suggests that there is likely to be a systematic relationship between the efficacy of methods with the levels of educational attainment of the couple. In particular, they show that more educated parents can use less "costly" methods, i.e., ones which allow for greater "pleasure" during sexual intercourse, and still achieve high levels of production because of their greater ability to produce "protection".

<sup>73</sup> See Trussell and Kost (1987) for a survey of the contraceptive effectiveness literature.

## 5. Empirical implications of models of fertility: identification issues, econometric approaches and empirical examples

The previous two sections outlined several of the unique intellectual contributions of static and dynamic economic models of parental fertility decisions. These models all imply that parents' demand for children depend on the price(s) of children, the prices of other goods and services, including child quality, the mother's market wage rate(s) and levels of household income. However, as our discussion of these models made clear, the exact nature of these relationships and, thus, the predictions of how variation in prices, wages and income will affect parental demands depend on which model features one considers. As such, determination of the appropriateness of the predictions of these theories is an empirical question. Furthermore, even when the comparative static or dynamic predictions are clear, the magnitudes of the effects are often of considerable intrinsic interest.

In this section, we discuss the issues involved in estimating the sign and magnitude of the price and income effects implied by these theories. Our discussion begins with a detailed discussion of the issues involved in estimating reduced-form price and income effects for the demand for children. There many of the issues are closely related to parallel issues in the larger labor supply literature. We then turn to the issues which are raised in estimating the parameters of quantity-quality models.

### 5.1. Strategies for identifying price and income effects for parental fertility choices

All of the models of fertility discussed in the previous two sections imply that the demand for children depends on various types of "prices" – including prices of children, their quality, the price of mothers' time, the prices of contraceptive practices, etc. – and household income. In this section, we consider the issues associated with obtaining unbiased (or consistent) estimates of the "reduced-form" effects of "exogenous" changes in various prices which are related to children and their production and in household income on the number of children demanded (and borne) by parents over their lifetimes or over some specified period of their life cycles. To illustrate the estimation issues, we focus on the implications of static models for a couple's demand for children. All of the models outlined in Section 3 imply a mapping between the number of children born and a set of prices (the  $\pi$ 's) and family income ( $I$ ). Let this mapping be denoted by

$$n = N(\pi_n, w, \pi_e, I; \pi_o, \theta), \quad (19)$$

where  $\pi_n$ ,  $w$ ,  $\pi_e$ , and  $I$  have been defined above and  $\pi_o$  denotes a vector of all other prices which, either directly or indirectly, affect parents' demand for children and  $\theta$  denotes a vector of other household-specific attributes which affect  $n$ , including traits

which characterize parental preferences, technologies which influence the production of children and services related to children, and endowments of fixed-factors – such as parental fecundity – which affect these production processes.

Much of the empirical literature on fertility, either consciously or de facto, has sought to obtain estimates of the own-price effect of fertility,  $\partial n/\partial \pi_n$ , the effect of exogenous variation in the mother's market wage (or market-based opportunity cost of her time) on fertility,  $\partial n/\partial w$ , and of the effect of changes in the "price" of contraceptive methods on fertility,  $\partial n/\partial \pi_e$ . Furthermore, as we have already noted, explaining the sign and magnitude of the effect of exogenous changes in family income on fertility,  $\partial n/\partial I$ , was one of the primary motivations for the early applications of neoclassical economic models to fertility. Obtaining estimates of such effects is of interest for several reasons. First, such effects address questions of how fertility behavior responds to exogenous variations in the constraints which parents face when making the fertility decisions. Second, knowledge of such effects may provide good approximations to the consequences of policy interventions, especially in contexts in which the intervention is a marginal change and in which one otherwise expects the preferences and technologies facing households to remain constant. Third, such estimates provide important benchmarks against which to compare estimates of the "structural" relationships suggested by the theoretical models discussed in Sections 3 and 4. In the final analysis, such structural models must accord with those which purport to characterize the mechanisms by variations in prices and income affect behavior. A fourth reason, related to the third, is that the identification of reduced-form price and income effects is typically less demanding than is the identification of more structural effects.

Nonetheless, estimating the sign and magnitude of the effects corresponding to this theory is a non-trivial challenge. The major issue is the standard problem of econometric identification. Our economic theory has predictions about the effect of an exogenous change in prices or income holding all else constant. The variation in income and prices recorded in the data does not necessarily reflect such exogenous variation. Thus, simple regressions of fertility on observed income and prices will not recover the concepts corresponding to the economic theory of fertility. The challenge is to extract estimates of the effect of such exogenous variation in prices and income from observational data.

In considering approaches to estimation, it is useful to consider two particular reasons why the variation recorded in the data may not correspond to the exogenous variation considered in the economic theory of fertility – one at the individual level, the other at the market level. At the individual level, fertility regressions are subject to the standard unobserved individual characteristics concern of the labor supply literature. Cross-sectional data on households record variation in observed fertility, income, and some prices (in particular women's wages and the cost of child care). While some of this variation in prices undoubtedly reflects exogenous variation (e.g., in the demand for labor), it seems likely that much of the observed correlation is due to a corre-

lation between the woman's wage or the husband's income and the household's preferences for children.

In particular, consider a simple linear approximation to the general demand for children equation given above (ignoring any issues related to the limited dependent variable nature of the number of children):

$$n = N(\pi_n, w, \pi_e, I; \pi_o, \theta). \quad (20)$$

Note that human capital accumulation considerations imply that  $w$  and  $I$  reflect earlier choices of the household. Similarly, quantity-quality theory implies that many components of the cost of children (e.g., type of child care) also reflect household choices. Denoting this vector of household choices generically by  $X$ , the equivalent reduced-form demand functions would be

$$X = \gamma_0 + \gamma_n \pi_n + \gamma_w w + \gamma_e \pi_e + \gamma_I I + \gamma'_{\pi} \pi_o \gamma'_{\theta} \theta. \quad (21)$$

Thus, in general, any omitted (or imperfectly measured) prices or any taste variation (i.e., in  $\theta$ ) will induce simultaneous equations bias and inconsistent estimates of the parameters of interest.

In particular the standard theory of human capital accumulation<sup>74</sup> suggests that such simultaneous equations bias is likely. Fertility decisions are among the most central life-style decisions for women and couples. Since child rearing has historically been intensive in women's time, and in particular negatively correlated with women's labor force participation, women with preferences for larger numbers of children are likely to spend more time not working.<sup>75</sup> Less time working implies less time to earn returns on accumulated human capital, and thus a smaller optimal investment. This relation between expected labor supply and the optimal human capital investment is reinforced if time out of the labor force for childrearing may require the forfeiting of firm-specific human capital and the depreciation of general human capital. Thus, unobserved variation in preferences for the number of children will induce a spurious negative correlation between observed wages and fertility.

A similar critique applies when considering variation in the price of children. The theory suggests that exogenous variation in the cost of raising children should lower fertility. Below, we discuss the literature on estimating the structural effects implied by quantity-quality models. Here, we consider more reduced-form approaches relating the "price of children" to the quantity dimension of fertility. One large component of the cost of children is child care. There is considerable variation in the price of an hour of child care. Some of that price variation is undoubtedly due to variation in the price of a constant quality child care, but much of it is induced by variation in the

<sup>74</sup> See, for example, Mincer (1963).

<sup>75</sup> See Rosenzweig and Schultz (1985).

quality of the child care provided. In the previous section, we discussed the theoretical literature which has developed to explain the lack of a strong positive effect of family income on the number of children.<sup>76</sup> Nevertheless, since the quality of child care is clearly a normal good – unless the included regressors perfectly control for the appropriate lifetime income concept – there will be a spurious correlation between observed prices paid for child care and the omitted components of the appropriate income concept. Therefore, using observed variation in the price of children (e.g., the cost per hour of child care) will induce omitted variable bias in the estimated effect of exogenous changes in the price of children on the demand for (the quantity of) children.<sup>77</sup>

This critique suggests using household data which spans multiple markets. Differences across markets in the characteristics of those supplying labor, endowments of natural resources, and available technology will induce exogenous variation in equilibrium prices of quality adjusted labor. Furthermore for some prices (e.g., welfare benefits, abortion regulations, tax policies), only inter-market variation exists (either across governmental jurisdictions or in different time periods).

While such multiple-market data provides variation in prices, there is reason to believe that such aggregate price variation may also be endogenous. For market prices (e.g., male and female wages and the price of child care), such endogeneity might arise from standard market equilibrium considerations. Market clearing prices equalize market supply for the good (the sum over the individual supplies) and market demand for the good (the sum over the individual demanders). Adopting linear approximations, we have:

$$\begin{aligned} X^S &= a_0^S + a_\pi^S \pi + a_Z^S Z^S + a_\theta^S \theta, \\ X^D &= a_0^D + a_\pi^D \pi + a_Z^D Z^D + a_\theta^D \tau, \end{aligned} \tag{22}$$

where  $Z^S$  and  $Z^D$  summarize the characteristics of the individual supplies of the good (labor, child care) and those demanding it (households),  $\theta$  represents the sum of taste

<sup>76</sup> See Becker and Lewis (1973) and Willis (1973).

<sup>77</sup> This discussion of variation in women's wages and child care prices is in addition to the standard problem that the observed prices are a censored sample of all prices (Heckman and Killingsworth, 1986). In most standard datasets, wages are recorded only for workers. Similarly, child care prices are recorded only for those who purchase child care. Thus, estimating models of the effect of women's wages or child care costs on fertility will usually require imputing a wage or price for those women for whom no wage/price is recorded in the data. Since the standard theory of labor supply suggests that women with lower market wages (relative to their reservation wages) are less likely to work and that women facing higher child care costs are less likely to purchase market child care, simply using average observed wages/prices is not in general appropriate. On average women facing higher child care costs are less likely to purchase market child care. See Heckman (1974a), Heckman and MacCurdy (1984), and Heckman and Killingsworth (1986) for surveys of the problem of selection bias in the estimation of female wage functions. For a discussion of the implications of this problem for analyzing the demand for children, see Schultz (this volume).

parameters over the households supplying the good and  $\tau$  represents the sum of the technology-specific factors shifting the demand for the good. The reduced-form for market clearing prices, therefore, is a function of the individual taste parameters. In as much as tastes (or more generally anything which enters the individual household supply functions) are not distributed independently across markets (e.g., geographically or through time), market prices are potentially subject to the same simultaneous equations bias as are individual level regressions (Rosenzweig and Evenson, 1977; Schultz, 1985).<sup>78</sup> In particular, if in some markets women have stronger preferences for children, we would expect to see more fertility, smaller investments in human capital, and less work, and therefore higher prices for female labor (after adjusting for differences in measured human capital and experience).

A similar critique applies to public policies. Government policies (e.g., welfare payments, regulations on abortion) can be viewed as inducing price variation. That variation exists only at the market level (either across places or through time). But, at least in a democracy, public policies should be expected to respond to the distribution of tastes in the population – in particular, among voters.<sup>79</sup>

Similarly, while there have been major time-series changes in government policies, there have also clearly been major time-series changes in social mores with respect to fertility behavior. Some of these changes may be due to the variables included in our models, but it seems likely that the preferences of succeeding cohorts also differ. This preference variation would also be reflected in changes in elected governments through time. Thus, variation in governmental policies across states or through time are not necessarily exogenous.

The empirical literature uses three approaches to control for the potential endogeneity of the variation in prices and income: *social experiments*, *instrumental variables*, and *fixed effects* methods. We discuss each of these approaches in turn. For each approach, we begin with a general methodological discussion. We then present in detail at least one “best practice” paper applying each approach to the empirical study of fertility.

<sup>78</sup> This critique raises questions about the empirical results in the much cited work by Butz and Ward (1979) and Ward and Butz (1980). They attempt to estimate Willis's (1973) model of the effects of variation in male and female wages; in particular that as female labor force participation rates rise the negative substitution effect of pro-cyclical wages might overcome the positive income effect of male wages. Their empirical results are consistent with this theory and appear to predict fertility changes through 1980 quite closely. Their treatment of the endogeneity of male and female wages, however, is not convincing. Noting that current wages are endogenous, they instrument current wages with lagged wages. Given strong serial correlation in wages, it is not clear why lagged wages are a valid exclusion restriction, if current wages are not. See also Macunovich (1995) who shows that the Butz and Ward model does not predict well out of sample.

<sup>79</sup> See Ellwood and Bane (1985) for this line of argument.

### 5.1.1. Random assignment/social experiments

Treatments in social experiments can often be viewed as varying prices (or income). By construction in properly conducted social experiments, the random assignment of participants to different treatment or control groups provides exogenous variation in prices (or income). Thus random assignment guarantees that the variation in prices is independent of any taste variation or unobserved prices. Comparing subsequent fertility of those randomly assigned to different treatments (including the control group) will thus provide consistent estimates of the relative effects of the different treatments on fertility.<sup>80</sup>

Such use of social experiments to identify the effect of exogenous variation of prices on fertility is subject to the standard critiques of experiments in the social sciences.<sup>81</sup> The experiments are not always properly conducted. General equilibrium effects (or the effects on attitudes) of wide implementation are not estimated. The effect is only estimated for the subset of the population who chose to participate. Finally, the duration of the experiment is quite limited, so only the effects of short-term variation in prices can be estimated.

Maynard and Rangarajan (1994) exploit the random assignment in the Teenage Parent Demonstration to evaluate the ability of enhanced case management to prevent repeat pregnancies among welfare dependent teenage mothers. From late-1987 to mid-1991, 5297 first-time teenage mothers receiving welfare in Chicago, Illinois and Newark and Camden, New Jersey were randomly assigned either to an “enhanced services” program or to the regular AFDC program. The enhanced services were similar to those later mandated by the Family Support Act of 1988. Groups of 50 to 60 young women were assigned to a case manager. These case managers counseled the young mothers as to “what types of education and training to pursue and found appropriate programs; they coaxed and pressured them to stick to their plans; and they counseled them when crises arose”. The young women were required to attend workshops to “promote personal and parenting skills; increase awareness of contraceptive methods and sexually transmitted diseases (STDs); and prepare them for later education, training, and employment”. Finally, the program provided child care and transportation services to allow the women to attend school, training, or work.

Maynard and Rangarajan evaluated the program by building logistic regression models of the probability of use of any contraceptive, use of an effective contraceptive, ever subsequently pregnant, and the outcome of the most recent repeat pregnancy (live birth, abortion, or miscarriage/still birth) as of two years after the beginning of the program. The logistic regression models include controls for heterogeneity of the women (age, race-ethnicity, family background, living situation, family size, reading

<sup>80</sup> Burtless (1995) makes this argument.

<sup>81</sup> See Heckman and Smith (1995) and Burtless (1995).

level, educational status, contraceptive use at baseline), site, and a dummy for whether the young woman was eligible for enhanced services (whether she actually participated in the “enhanced services” offered is potentially endogenous). The randomization ensures that program eligibility was independent of background characteristics. The included regressors control for random variation in the characteristics of women assigned to enhanced services, and thus increases the precision of the estimates.

Pooling over all of the sites, the results show little effect of case management/enhanced services in reducing subsequent fertility. Use of any contraceptive method or a more effective method are unchanged (at  $P$ -value of 0.10), use of a less effective contraceptive method declines marginally (significant at  $P$ -value of 0.10, but not of 0.05). There is no effect on the probability of a repeat pregnancy (even at  $P$ -value of 0.10). Against expectations, the point estimate is positive. Conditional on pregnancy, there is weak evidence that women participating in the program were more likely to give birth, rather than to abort. Rough tabulations from the reported results suggest that about 41% of the women in the experimental group had a subsequent birth, but only 36% of women in the control group did; a difference of five percentage points.

These results are disappointing to those who had hoped that enhanced counseling and services to young welfare mothers would lower their probability of a repeat birth. Such a result would have been plausible under two economic theories. First, it would follow if these women became pregnant due to lack of knowledge of or access to contraceptives. The program lowered the cost of acquiring the knowledge and the access. Second, it would follow if the substitution effects of higher women’s wages dominate the income effects. Then, if the program improved earnings opportunities, fertility would decline. One interpretation of the positive effect of the program on fertility is that, in this welfare population, the program raised earnings opportunities, but the income effect dominated the substitution effect. The weak statistical significance of the results does not, however, provide strong support for that interpretation.

### *5.1.2. Instrumental variables*

The standard econometric approach to the endogeneity of regressors is instrumental variables. Ordinary least squares (OLS) is potentially inconsistent because the endogenous variables (e.g., women’s and men’s earnings opportunities, government policies) are potentially correlated with the unmodeled components of tastes. Formally, in the linear regression model for fertility in terms of observed covariates,  $X$ , i.e.,

$$n = X\beta + \varepsilon, \quad (23)$$

OLS will be consistent if  $X$  is uncorrelated with the unobservables,  $\varepsilon$ . We argued earlier that unobserved preference variation is likely to be correlated with observed in-

come of men and women and with government policies, so that OLS will in general be inconsistent.

The instrumental variables (IV) estimator posits a set of variables  $Z$  which are correlated with  $n$ , but uncorrelated with  $\varepsilon$ . Given the existence of (a sufficient number of) such variables, the IV estimator is consistent: The challenge is to identify a sufficient number of identifying instruments (elements of  $Z$  not in  $X$ ). For most government policies, or distance to abortion clinics, it is difficult to conceive of plausible identifying instruments

For labor market variables, our simple supply and demand model for labor suggests a potential source of identifying instruments. In that model, anything which exogenously shifts the labor demand curve without directly shifting the labor supply curve could serve as an identifying instrument. Two candidates for such labor demand shifters are relative world prices for output and changes in production technology. Changes over time in prices and technology will induce time-series variation in market clearing earnings opportunities for men and women. As long as there is some geographic specificity to different industries (either because of natural resource endowments or because of immobile capital investments), such changes will also induce variation across regions. Such world prices and technological proxies (and their interactions with measures of natural resource endowments or immobile capital) are plausibly correlated with wages and thus with fertility (as long as wages affect fertility), but are plausibly uncorrelated with variation in tastes (across time or place).

Schultz (1985) provides a convincing example of this approach. For Sweden from 1860 to 1910, he specifies major changes in world prices (grain and butter) and technological changes (improved breeds of livestock, refrigerated transport) which shifted the demand curves for male and female labor. He notes that some Swedish industries were intensive in male labor (grain and root crops, forestry and saw mills), while other industries were intensive in female labor (dairying and milk processing, textiles and food processing). He estimates the effects of male and female labor market opportunities on fertility using time-series data on fertility for the 28 Swedish counties. Output market prices, the industrial distribution of employment (measured in the middle of the period, 1896 and 1910) and the percentage of the population urban are used as instruments to identify the male wage rate and the female-to-male wage rate. He concludes that the observed 10% increase in the female-to-male wage ratio explains a quarter of the decline in fertility. The doubling of real male wages had no effect on completed family size, but it did induce earlier marriage and a shift of fertility from women over age 30 to women under age 30.

Black et al. (1996) apply a similar approach to fertility in Kentucky. Their approach exploits wide variation in the world price of energy (induced by OPEC and the oil embargoes) and for different types of coal (induced by the Clean Air Act) and the variation in the endowments of Kentucky counties in different types of coal. They use the world prices for energy and different types of coal interacted with county coal reserves as instruments for male and female wages. Coal prices have strong effects on

male wages, but weaker effects on female wages. They find a strong positive effect of higher male wages on fertility.

There are two interpretation problems with the Black et al. (1996) results. First, since they are using year-to-year variation in market prices and technology over a relatively short period of time (under two decades), there is ambiguity as to whether these effects are due to timing or whether they will lead to differences in completed family size. This seems to be a generic problem with using time-series variation in the modern period to explore the effects of economic conditions on completed fertility. It is, however, attractive for the study of the timing of fertility with respect to transitory shock to labor market opportunities. This interpretation, however, suggests the importance of incorporating the effects of, not only current labor market opportunities, but also past and future labor market opportunities. (See the discussion of estimating dynamic economic models of fertility below.)

Second, there appears to be considerable in-migration in response to coal booms. Such labor mobility is, however, problematic. In the extreme, if labor is perfectly mobile, there will be no cross-sectional variation in earnings opportunities. Black et al. (1996) do find wage variation, though it is difficult to know how much of it is a compensating differential for the conditions of coal mining.) In the less extreme case, migration may be correlated with unobserved taste variation for fertility. If so, then fertility rates by place of occurrence will be correlated with exogenous shifts in world prices and technology. In that case, these variables are not valid instruments.

### 5.1.3. Fixed effects

A third possible approach to the potential endogeneity of the prices, wages, and income in observed data is group fixed effects. In the more recent applied literature in economics, this approach is often referred to as the *difference-of-differences* (DoD) method.<sup>82</sup> In contrast to the instrumental variables approach which requires exclusion restrictions, fixed-effects methods attempt to include regressors to approximately control for the omitted variables inducing the endogeneity bias. If the unobserved taste variation for a group of people is (approximately) constant through time for a given geographic area, then fixed effects for that region will control for the omitted variables, and fixed-effects regressions on grouped data would consistently estimate the exogenous effects of interest.

Plausibly there are also nationwide secular trends in preferences (at least across cohorts). Assuming that the two effects are additive, we have the standard double

<sup>82</sup> Some authors argue that this method is applicable because of the fact that variation is generated by so-called *natural experiments* in which the variation is generated as a result of largely exogenous events or changes in policies.

fixed-effects DoD<sup>83</sup> approach to the estimation of price effects in the fertility literature:

$$n_{st} = \alpha\pi_{st} + X_{st}\beta + \gamma_s + \gamma_t + \varepsilon_{st}, \quad (24)$$

i.e., it regresses fertility in a state (or more generally some geographical unit),  $s$ , and time-period,  $t$ , on the price of interest,  $\pi$ , other covariates which vary across state and year,  $X$ , fixed effects for the state,  $\gamma_s$ , and years  $\gamma_t$ , where  $\varepsilon_{st}$  is an idiosyncratic stochastic error. The included dummy variables directly control for the first-order sources of endogeneity, time-invariant state-specific variation and national secular trends. The included regressors are assumed to control for all other within state variation not controlled for by the common national year dummies; the remaining variation is assumed to be due to the price/policy of interest.

In as much as correlation between the prices/policies and the state and year effects is important, this double fixed-effects strategy will yield improved estimates compared to OLS. In as much as the changes in prices/policies within states – not correlated with the year effects – is correlated with the regression residual, the double fixed effects will not be a sufficient control and the estimates will be inconsistent. Exploring both of these issues has been a major focus of this line of research.<sup>84</sup>

Two papers on the determinants of abortion demonstrate the application of this fixed-effects approach. The economic theory of fertility suggests a derived demand for abortion as a method of contraception. Increased demand for children should lower the demand for abortions. Increased cost of abortion should lower the demand for abortion. Much of the literature on the determinants of abortion has focused on two government policies that make abortions more expensive: whether a state's Medicaid program treats abortion like any other medical procedure; and whether doctors require parental notification or consent before performing an abortion on a non-adult.

For both of these policies there is considerable variation in policy. In response to a sequence of Supreme Court decisions, most states changed their policy from funding

<sup>83</sup> This regression approach derives its name “difference-of-differences” from the equivalent operation on means in the evaluation literature. Consider the case where one group of, the “control states”, never (or always) had the policy in place and another group of states, “the experimental states”, did not have the policy in place in time 0, but did have it in place in time 1. Then, denoting the mean fertility rate in the four cells by  $m$  (with an appropriate subscript), the difference-of-difference estimator for the effect of the binary policy is

$$\alpha = (m_{e1} - m_{e0}) - (m_{c1} - m_{c0}).$$

The first term is the change, in fertility in the experimental states when the policy is imposed. This difference controls for time-invariant state-specific effects. The second term is the change in fertility in the control states. The difference controls for national secular change. The “difference-in-differences” thus controls for both effects. The previous equation is the regression generalization.

<sup>84</sup> Meyer (1995) provides a discussion of the methodological issues in a general context.

to not funding abortions and from not requiring parental involvement in abortions to minors to requiring such involvement. The timing of these changes varied widely across the states and some states never changed their policies. The empirical literature exploits this variation, while attempting to control for the potential endogeneity of government policy.

Blank et al. (1994) estimate these policy effects using time-series cross-section data on state abortion rates for 1974–1988. Their main data source is the Alan Guttmacher Institute's (AGI) survey of abortion providers. As a survey of providers, it records the total number of abortions by state of occurrence, but includes no demographic information. Using Census Bureau population estimates, they estimate linear regression models for the log of the abortion rate (abortions per woman aged 15–44). Their model includes policy variables (Medicaid funding, parental involvement, AFDC payment levels), political climate variables, the number of abortion providers in the state, and demographic variables (marriage rate, summary measures of age distribution of women, race of women, urban), and economic conditions (female labor force participation rate, log per capita income, unemployment rate). Because of concerns about the endogeneity of the number of abortion providers, they instrument for it using the number of hospitals and the number of physicians in the state as identifying variables (most of their results are robust to whether or not they instrument).

The estimated results are sensitive to the inclusion of double fixed-effects. Without the fixed effects, enforced parental involvement laws significantly lower abortions (at the 0.01 level), but the effect of Medicaid funding restrictions is insignificant (even at the 0.05 level, though the point estimate is negative). Adding fixed effects for state and year causes the parental involvement effect to turn positive (the “wrong sign”) and insignificant. The Medicaid funding effect, however, triples in magnitude and becomes significant at the 0.01 level of significance.

Their specification includes a strong specification test of whether the estimated effect of Medicaid funding is causal or due to omitted taste variables which vary within a state over time and not perfectly correlated with the national time effects. The extensive litigation of the Medicaid funding issue implies that there were many states which had laws (or administrative actions) forbidding the reimbursement of abortions by Medicaid, but which nevertheless paid for abortions pending the final judicial decision. While the legislative decisions are likely to have some correlation to shifts in within-state public sentiment, the timing of the judicial decisions is likely to have a much weaker correlation.

To use this information, in addition, to the variable for not funding abortions through Medicaid, they include a variable describing whether there is an unenforced Medicaid funding restriction. In the fixed-effects model, the unenforced restriction dummy is negative, significant (at the 0.05 level), and nearly half the magnitude of the effect of funding itself. This result suggests both that changes in attitudes towards abortion shift both abortion rates and state policies (whether or not they are enforced)

and that the double fixed-effects strategy alone is not sufficient to eliminate all of the endogeneity of state policies.

Joyce and Kaestner (1995) consider the effect of parental involvement laws in more detail. They note that the parental involvement laws only affect minors. Therefore, with data which records the number of abortions to adults and minors separately, they can apply a triple fixed-effects or difference-of-differences approach to the abortion ratio,  $r$ , the fraction of pregnancies (computed as abortions plus live births) which are aborted<sup>85</sup>:

$$r_{stg} = \alpha\pi_{stg} + \gamma_{sg} + \gamma_{tg} + \gamma_{st} + X_{stg}\beta + \varepsilon_{stg}. \quad (25)$$

The policy effect,  $\pi$ , is set to one only in state–year combinations in which there was an enforced parental involvement law and then only for minors. This additional level of data allows them to include demographic group-specific (i.e., adults vs. minors) for state and year, and to include dummy variables for each state–year combination. Thus, rather than relying on observed covariates (state economic and political conditions) to control for within state variation, they can take a non-parametric approach, including a dummy variable for each state–year combination.

Since the AGI data do not separately tabulate abortions by demographic group, Joyce and Kaestner analyze data from three states: Tennessee, South Carolina, and Virginia. These three states require that all abortions be reported to the state health department. For these three states the data appears to be of high quality and relatively complete, and the states appear to have good reciprocal reporting arrangements with neighboring states such that out-of-state abortions are also recorded.<sup>86</sup>

Joyce and Kaestner use these data to explore the effect of the enforcement of parental involvement laws on the abortion ratio. Including double fixed effects and using Virginia as a control, they find a significant effect. Parental involvement laws lower the abortion rate. In the triple fixed effects, however, the point estimate remains negative, but falls to a quarter of its earlier value and is not statistically significant. Additional analyses show some evidence (the associated  $P$ -value is 0.05) of an effect on the abortion rates of both white and black 16-year-olds (about 5%), but not for any other age group.

## 5.2. Identifying the key implications of the quantity–quality models of fertility: the use of twins

Until now, we have focused on the identification of the reduced-form effects of prices and income on fertility that are suggested by the static models discussed in Section 3. While

<sup>85</sup> By modeling the abortion ratio, rather than the abortion rate (abortions per woman, as in Blank et al. (1994)), they miss any effect of parental involvement laws on contraceptive practice (or coital frequency).

<sup>86</sup> Most states do not have any such reporting requirement. Among those that do, much of the data appears to be of poor quality. The counts of abortions are considerably below the AGI estimates.

informative and of substantive interest, identifying such effects does not enable one to distinguish the unique predictions generated by the quantity–quality model of fertility. That model implied a fundamental interaction between the shadow price of the quantity of children with that for the quality of children. In particular, the key feature of the quantity–quality model is the fact that  $\pi_c$ , the shadow price of a one unit increase in child quality for one child, is not equal to zero. As discussed in Section 3.1,  $\pi_c \neq 0$  implies that the price of children depends on the quality parents choose to provide their children and that the price of parents' increasing the quality of their children depends on the number of children. Moreover, it is this feature of the quantity–quality model which gives rise to the possibility that household income and numbers of children will be negatively correlated.

In an influential paper, Rosenzweig and Wolpin (1980a) – see also Rosenzweig and Wolpin (1980b) – consider the conditions required to identify (or test) this implication of the quantity–quality theory. They show that distinguishing the presence of a non-zero  $\pi_c$  requires independent variation in  $\pi_n$  or  $\pi_q$  as well as restrictions on the cofactors of the system of demand equations for fertility ( $n$ ), child quality ( $q$ ) and parental consumption goods ( $s$ ). As we have argued above, the ability to identify the effect of exogenous variation in  $\pi_n$  (or, for that matter, in  $\pi_q$ ) is inherently difficult to obtain. However, Rosenzweig and Wolpin show that knowledge of the effect of an exogenous change in  $n$  on  $q$ , i.e.,  $\partial q / \partial \bar{n}$ , is equal to

$$\frac{\partial q}{\partial \bar{n}} = \left( \frac{\partial q}{\partial \pi_n} \right)_{\bar{u}} \left( \frac{\partial n}{\partial \pi_n} \right)^{-1}_{\bar{u}}, \quad (26)$$

where  $(\partial q / \partial \pi_n)_{\bar{u}}$  is the compensated cross-price effect of  $\pi_n$  on  $q$  and  $(\partial q / \partial \pi_n)_{\bar{u}}$  is the own-price of  $\pi_n$  on  $n$ . Rosenzweig and Wolpin exploit the natural experiment generated by the occurrence of twins at a couple's first birth event to identify Eq. (26), the exogenous impact of a fertility change on the quality of children.

As noted above, identification of  $\partial q / \partial \bar{n}$  is not sufficient to test for the quantity–quality implication that  $\pi_c \neq 0$ . Additional restrictions on the structure of the parental utility function is required. In their empirical application, where  $q$  denotes the amount of education chosen by parents, the authors find that  $(\partial q / \partial \pi_n)_{\bar{u}}$  is sufficiently negative that for plausible restrictions on parental preferences, the quantity–quality model would be rejected by their data.

More generally, the use of the exogenous variation in fertility generated by the use of the occurrence of twins to identify the exogenous impact of fertility on parental demand for other goods on quality<sup>87</sup> represents a creative use of randomly-occurring

<sup>87</sup> In Rosenzweig and Wolpin (1980b), they utilize the twins-as-a-natural-experiment to identify the exogenous impact of fertility on the mother's labor supply decision. In a related but distinct approach, Rosenzweig and Schultz (1985) show that one can exploit the exclusion-of-prices restrictions from the reproduction function in Eq. (9) that are implied by optimizing behavior on the part of parents to identify the exogenous impact of fertility on the labor supply and contraceptive choices of parents. See Schultz (this volume) for a discussion of this model.

biological phenomena to identify structural relationships. More recently, this type of strategy has been followed to identify the effects of early childbearing on the subsequent choices of young mothers using the random occurrences of twins<sup>88</sup> and the random occurrences of miscarriages.<sup>89</sup>

### 5.3. Econometric approaches to life-cycle models of fertility

Two considerations suggest exploring explicitly dynamic econometric approaches: the inherent multi-period nature of the data and our intrinsic interest in the dynamic characteristics of fertility discussed in the previous section. Corresponding to each of these considerations there is a simple, natural, basically static econometric approach which is incomplete. We begin this section by discussing more thoroughly each of these considerations and the corresponding natural approaches. We then discuss in detail two other, more explicitly dynamic – econometric approaches: systems of *hazard models* and *estimable dynamic programming* models.

#### 5.3.1. Applying the econometric approaches of static models to life-cycle fertility behavior

The first consideration pushing analysis towards an explicitly dynamic econometric approach is the inherently multi-period nature of the data. Our static theory is a one-period formulation of the choice of completed family size. The direct empirical implementation of such models would analyze completed family size for women of an appropriate age, where the end of childbearing is by convention usually set at 44.<sup>90</sup> This approach has the twin problems that the standard data does not come in that form<sup>91</sup> and that doing so would imply analyzing data for which most fertility occurred two decades earlier (in the woman's mid-twenties).

Instead, the standard approach in the static empirical literature has been to apply the static models directly to age-specific fertility rates. Current period fertility is regressed on current period covariates. As is noted in the labor supply literature,<sup>92</sup> such a specification is in error. Even in a perfect certainty framework, current period choices are a function of all current and future prices. Once that premise is granted the identification issues of the previous section become much more difficult. We now re-

<sup>88</sup> See Bronars and Grogger (1993).

<sup>89</sup> See Hotz et al. (1995).

<sup>90</sup> See Newman and McCulloch (1984).

<sup>91</sup> The birth certificate data only record births (so that it is a non-trivial problem to recover completed family size), the June CPS is usually asked only of women of childbearing (age 15–44), and by age 44 many children born to young mothers have often already left the household (so we cannot simply use the survey's own household rosters).

<sup>92</sup> See Heckman and MacCurdy (1980).

quire identifying information, not merely for the single current period price, but also information that separately identifies all possible past, current, and future prices. For standard instrumental variables approaches, what we argued above was a hard problem becomes nearly insurmountable. One role for a dynamic econometric approach is to use econometric theory to suggest more structure for the problem. Such a priori information would constrain the way in which the vector of prices enters current period decisions. Such cross-age restrictions lower the required amount of separate identifying information.<sup>93</sup>

The issues are particularly salient because one natural interpretation of age-specific regressions suggests a crucial role for past prices. It seems likely that some of the observed variation in age-specific fertility with respect to variation in prices is not variation in completed family size, but variation in the timing of fertility. In as much as this is correct, current period price effects should have the opposite sign from previous (and future) period price effects. A dynamic econometric model should help us to impose such structure.

For fixed-effect approaches, this critique raises a fundamental issue of interpretation. Fixed-effect approaches are usually applied across calendar years to an age-specific fertility rate. Such regressions should be interpreted as identifying the effect of a deviation from the mean level of the covariate over time. Thus, for example estimated income effects should be interpreted as the effect of transitory variations in income.<sup>94</sup> They do not identify the concept of interest in the static model – a lifetime shift in income. To identify the static income effects, we would need time-series of cross-sections on cohorts, i.e., lifetime fertility.<sup>95</sup>

### *5.3.2. Hazard models as a reduced-form approach to dynamic models*

The second consideration pushing analysis towards an explicitly dynamic econometric approach is our interest in the inherently dynamic characteristics of the fertility process. From both theoretical and policy perspectives, the age at first birth, the spacing between births, and the joint timing of fertility with other life-cycle choices are inherently interesting. These characteristics simply do not appear in the static formulation.

The standard empirical approach to modeling these dynamic characteristics of the birth process has been ad hoc. It applies standard single equation limited dependent variable approaches to the data.<sup>96</sup> Age at first birth is regressed on covariates; inter-birth timing is regressed on covariates. The summary measures presented in the second section of this paper are in that spirit. As we noted there, however, the fertility

<sup>93</sup> See Wolpin (1984) for more on this argument.

<sup>94</sup> See Silver (1965), Wilkinson (1973), Jackson and Klerman (1996), and Black et al. (1996) for examples of this line of research.

<sup>95</sup> See Schultz (1989) and Rosenzweig (1995).

<sup>96</sup> See Newman (1981) and Newman and McCulloch (1984) for references to the earlier literature.

decision is inherently discrete and there is considerable heterogeneity in completed family size. Thus, any single equation approach inherently runs into the problem of how to treat the women who never have the event. For example, how should we treat women who never have a birth in regressions on age at first birth? or women who have never had a birth up to the interview date? or women who never/up to the interview data had a subsequent birth in regressions on inter-birth timing? One approach to this problem is standard hazard modeling (Lancaster, 1990). In that approach, instead of directly modeling the timing of the event, we model the probability of the occurrence of the event in each period (Newman and McCulloch, 1984). Taking the probability of the event in period  $d$ , conditional on it not having occurred through period  $d - 1$  as  $h(d)$ , the probability of an event occurring in period  $d$  is simply

$$f(d) = h(d) \prod_{k=1}^{d-1} \{1 - h(k)\}$$

and the probability that the event does not occur through  $d$  periods is simply

$$f(d) = \prod_{k=1}^d \{1 - h(k)\},$$

where in both expressions, we can allow  $h(k)$  to depend on time-varying covariates.

This hazard approach provides a natural way to model incomplete histories, non-occurrence of the event (a subsequent birth) and a natural set of covariates (current period values). It, however, does not solve several other problems. First, it provides little insight into how to summarize the information in past and future covariates. Second, it does not solve the dynamic selection problem. To be in the sample of individuals on which we estimate the time between the first and second birth, one must have had a first birth. This is a selected sample. This simple hazard model provides no insight into the effects of that selection. Finally, this model has the unfortunate characteristic of mixing the parameters for the speed with which the event occurs with the parameters for whether or not the event occurs. No such restriction follows from economic theory. It is not hard to imagine some values of covariates inducing those women who will desire a subsequent birth to do it more quickly, but inducing fewer women to desire the subsequent birth. This simple hazard model fails to allow for this possibility.

One such dynamic econometric strategy is to apply systems of hazard models. As is implied by the name, life-cycle fertility is naturally analyzed using the standard birth process of the stochastic processes literature.<sup>97</sup> In that approach, completed fertility is viewed as the result of separate processes governing the transition to each parity. In its

<sup>97</sup> See Karlin and Taylor (1975) and Sheps and Menken (1973).

most general form, the model simply posits that current period fertility is a function of age, time since last birth, the woman's time-invariant characteristics and all the time-path of all time-varying covariates. Thus, we have a system of hazard models (one for each parity), linked by woman-specific common covariates, some of which are observed by the econometrician and some of which are not.

Newman and McCulloch (1984), Heckman and Singer (1984), Heckman and Walker (1987, 1991) develop a refinement of this systems of hazards approach, the model suggests some natural simplifications of this general (and inestimable) specification. In these papers, the feasible formulation, the current period hazard is modeled as a linear index function, i.e.,

$$I_{ijt} = \alpha_j(a) + \delta_j(d) + X\beta_j + \rho_j\mu_i, \quad (27)$$

where the function includes, respectively, a general function of the age of the woman, a general function of the duration since the last birth, a linear vector of covariates, and a random effect,  $\mu_i$ . Each of the parameters – including the factor loading on the random effect,  $\rho_j$  – can be allowed to vary with parity. Newman and McCulloch (1984) take the random effect to be person-specific and time-invariant. In that case, given an assumed functional form for its distribution it can be integrated out as a random effect.<sup>98</sup>

This system of hazards formulation suggests natural restrictions on how the covariates enter the model. As in the static models, such models are usually implemented including only current period covariates in the current period hazard. The model summarizes the values of past covariates through its dependence on parity, time since last birth, and the dynamic selection of the time-invariant random effect. It thus easily imposes some of the ideas of the previous sections. Strongly peaked preferences for a given number of children (as in our first dynamic theoretical models) will be fit through non-defective hazards for parities below the desired fertility size and essentially zero hazards thereafter. See, for example, Heckman and Walker (1991) who use this characteristic of the model to focus on the decision to have a third child in Sweden. Similarly, the parity specific hazards provide a natural way to allow time-varying covariates to affect the timing of the transition to each parity separately from how they affect completed family size.

Heckman and Walker (1991) show that, under most conditions, if there is persistent heterogeneity across parities, estimates of the parameters of the hazards obtained by estimating the model separately will be biased. They note that "the study of unobservable in multi-state duration models is still in its infancy." Whether their permanent-transitory structure is the appropriate one is an open question. If we begin the process

<sup>98</sup> Heckman and Singer (1984) use non-parametric maximum likelihood estimator in the presence of such a mixing distribution.

with exposure to regular non-contracepting sexual relations, this is a natural characterization of the demographic concept of fecundity. In their work on the Hutterites, a non-contracepting (natural fertility) population (Heckman and Walker, 1987), they find that such woman-specific time-invariant effects are quite important in explaining the joint timing of births. In their work on Sweden, Heckman and Walker (1991) find no evidence of such individual specific heterogeneity. The motivation used by Newman and McCulloch (1984) in their study of birth intervals may suggest part of the reason. Dynamic theories of fertility suggest that woman-specific (approximately) time-invariant population heterogeneity in the unobserved component of preferences and prices will not always have similar effects on inter-birth timing as it has on first birth timing; such differences in effects would arise if the timing of the first birth was determined by different factors than was the spacing of subsequent births. If this were the case, then future analysts may wish to generalize the specification of the heterogeneity to detach the interval until the first birth from subsequent inter-birth intervals in a manner consistent with the general formulation in Heckman and Singer (1985). Such an approach, however, is unlikely to be promising in many developed countries because for the modal family size of two, there is only one inter-birth interval, making estimation of the correlation in unobservable between inter-birth intervals impossible. This is especially true in Sweden – the source of the data in Heckman and Walker (1991) – where third births are not common and fourth births are rare.

Heckman and Walker (1987) generalize this model to include previous durations as covariates and to allow for specific stopping behavior. In particular, they model the probability of no birth within  $d$  periods of the  $j$ th birth (the survivor function) as

$$S_j(d) = P^{j-1} + (1 - P^{j-1}) \prod_{k=1}^d \{1 - h(k)\},$$

i.e., the probability of parity-specific stopping behavior after the  $(j - 1)$ th birth,  $P$ , plus the probability that that there is not parity-specific stopping behavior, but that the birth has not occurred yet. Since the fertility process only runs for finite time – it is conventionally truncated at age 45 – some of the  $1 - P$  women who do not exhibit parity-specific stopping behavior will nevertheless never have the  $j$ th birth. According to the specification of the model, they might have done so under some time-path of the covariates.

### 5.3.3. Estimating structural models of life-cycle fertility using dynamic stochastic discrete choice models

Estimable stochastic dynamic programs are an alternative explicitly dynamic ap-

proach.<sup>99</sup> This approach attempts to impose more directly the insights of economic theory both to summarize the effect of non-contemporaneous prices and to estimate deeper structural parameters. Wolpin's (1984) approach builds directly from an explicit optimization problem, where he deliberately adopts a sufficiently simple formulation to allow numerical computation of the exact optimal life-cycle profiles.

He begins with an additively separable life-cycle utility function. In each period,  $t$ , the woman's/household's problem is

$$\max E_t \sum_{k=0}^{\tau-t} \delta^k U_{t+k}(M_{t+k}, X_{t+k}), \quad (28)$$

where  $M$  is the stock of children and  $X$  is other consumption, subject to a period-by-period budget constraint (i.e., no borrowing or saving),

$$Y_t = X_t + cn_t, \quad (29)$$

where  $Y$  is income,  $X$  is consumption (with a price normalized to unity) and  $c$  is the price of a child in its first year of life (denoted by the dummy variable  $n$ ; after the first period children are assumed to be free).<sup>100</sup> For given values of the parameters, this model can be solved numerically by the principle of optimality.<sup>101</sup> In particular, the model has only a single control variable ( $n$ , whether or not to have a child in this period) and a single state variable ( $M$ , the stock of children at the beginning of the period). The optimal policy is computed by backwards recursion, comparing the utility of each choice.

To simplify the computation of the optimal policy, Wolpin assumes that the utility function is quadratic in the stock of children and other consumption:

$$U_t(M_t, X_t) = (\alpha_1 + \xi_t)M_t - \alpha_2 M_t^2 + \beta_1 X_t - \beta_2 X_t^2 + \gamma M_t X_t. \quad (30)$$

The second term,  $\xi$ , induces the stochastic element into the model. This component is assumed to be an i.i.d. preference shock that is observed by the decision-maker, but not by the econometrician. Assuming that  $\xi$  is normally distributed induces a probit

<sup>99</sup> For a general overview of the literature on estimable dynamic programs, see Eckstein and Wolpin (1989). Papers applying a dynamic programming approach to the theory of fertility include Heckman and Willis (1976), Wolpin (1984), Rosenzweig and Schultz (1985), Newman (1988), Montgomery (1988), Hotz and Miller (1988a,b, 1993), David and Mroz (1989), and Ahn (1995).

<sup>100</sup> Consistent with the developed country context of this review, we have suppressed the child mortality terms which are a substantive focus of Wolpin's paper. Note also that the model Wolpin estimates adds to this budget constraint dummy costs for births in the first two periods and an additional quadratic set of cost terms in the age of the woman.

<sup>101</sup> See Bellman (1957).

form for the choice probabilities. The non-stochastic part of the probit is given by the difference in the expected utility of choosing to have or not have a child in this period. Since for given values of the parameters, these two components can be computed (by backwards recursion), the structural parameters of the economic choice problem – those appearing in the utility function and in the budget constraint – can be estimated by maximizing the implied likelihood.

This formulation is attractive because the restrictions on how current, past, and future prices enter the model are explicitly stated in terms of the underlying economic theory. The major problem appears to be computational. Wolpin deliberately formulates his decision problem in nearly the simplest possible form. There is only one state variable, the number of children. The utility function is quadratic. In particular, this specification rules out human capital accumulation, both saving and borrowing, differential utility or cost of children by their age, and heterogeneity in preferences or in fecundity. These restrictions are not intrinsic to the method, but including any of them will require significantly greater computational effort. However, with computing power for a given price doubling every eighteen months (Moore's Law), these purely computational considerations are likely to recede in importance. As they recede, the direct relation between the economic choice problem facing the household and the econometric parameters should make this approach more widely used.<sup>102</sup>

Hotz and Miller (1993) propose and implement an alternative, much less computationally intensive, approach to the estimation of the structural parameters of the utility function in dynamic models. Wolpin's approach is computationally intensive because he requires backwards recursion to compute the probability of each choice. Hotz and Miller show that, under certain conditions (including no unobserved heterogeneity), the future choice probabilities can be replaced by non-parametric estimates of those probabilities, where the non-parametric estimates are based on observed individuals with the same (or similar) state variables. The resulting Conditional Choice Probability (CCP) estimator is no more difficult to estimate than a standard multinomial logit model.

Their empirical application exploits this computational simplicity to estimate a much richer model than in the earlier dynamic programming literature. Rather than Wolpin's assumption of perfect fertility control, they allow for imperfect contraception and also sterilization. They also allow the utility and cost of children to vary with the age of the children (in years) which induces a desire for spacing. They then estimate the model and explore its implications by simulation of the comparative dynamics. The implied contraceptive choice decision rules imply that, *ceteris paribus*, "the more children a couple has, especially past two, the more likely they are to use more effec-

<sup>102</sup> See Ahn (1995) which focuses its substantive interest on the relative value of children by sex, using Korean data. That model allows the utility of children to vary with their age and sex. Note also that Ahn adopts Rust's (1987) specification of the choice probabilities as extreme value. Because a closed form exists for the expected value of an extreme value choice, this considerably simplifies the computational problem.

tive contraceptive control and that parents do alter their contraceptive strategies to space births and to diminish the chances of pregnancy at later stages of their life cycles as their children grow older.”

## 6. Conclusion

Following Becker's insights that the standard tools of economic theory could be usefully applied to private household choices, a large theoretical and empirical literature has emerged. This chapter has reviewed that theory and the econometric issues in estimating models based on the theory. As is true in much of applied economics, the theory and econometric methods are much better developed than the empirical literature. The crucial challenge is to find plausibly exogenous variation in proxies for the price and income concepts appearing in the theories. Our discussion has provided a taxonomy of possible identifying information and gives us considerable hope that additional progress can be made in advancing our empirical understanding of fertility behavior.

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