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# Measuring the Value of Children by Sex and Age Using a Dynamic Programming Model

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One of the important determinants of fertility is the value of children as perceived by parents. This paper estimates gender- and age-specific values of children using a dynamic programming model. The underlying hypothesis is that observed fertility outcome for any couple is the solution to their life-cycle optimization problem. Findings from the Korean data indicate that children impose net costs when young and net benefits when old. Both the early costs and the later benefits are larger for male children than female children, and for better-educated women than lower-educated women. Simulation studies which use estimated values of children suggest that a decrease in the costs of abortion and pre-natal gender-screening tests may raise the male-birth ratio through gender-selective abortions.

## I. INTRODUCTION

The value (costs and benefits) of children is one of the important determinants of parental fertility behaviour and other household decisions. One of the most convincing explanations of the decline in fertility rate over the world is the reduced value of children as perceived by parents along with the development of cheaper and more effective birth control methods. However, researchers face a number of questions during the investigation of this issue. What is the value of children to parents? How can it be measured? The value is likely to vary by child's age, sex, birth order, parental characteristics (such as ages of parents), household income, and other aspects of the socioeconomic environment. Furthermore, it may be non-economic as well as economic in nature. How can one evaluate non-economic costs and benefits relative to economic ones? The true value of children can only be obtained after a proper aggregation of these two different types of value.

A few previous studies on the value of children were from anthropological or demographic perspectives (see, for example, Caldwell (1982, 1983), and they were based on qualitative and attitudinal survey data (Arnold *et al.* (1975), Bulatao (1981), Fawcett (1983), Arnold and Kuo (1984) and Vlassoff (1990). There are also studies which attempt to measure the direct economic costs (including opportunity costs) and benefits of children.[1] However, there is little consensus on the net value of children even in terms of direct economic costs and benefits. The most agreed upon conclusion may be that children's most significant economic contributions might be old-age support and insurance against extreme adversity, especially in societies where other forms of insurance or alternative investment opportunities are not available.

1. See Mueller (1976), Cain (1977, 1981), Nag *et al.* (1978) and Lindert (1980) for developing countries and Lindert (1978), Espenshade (1984) and Robinson (1985) for U.S.

TABLE 1a

*Period fertility rate and average age*

| Period[a] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
|---|---|---|---|---|---|---|---|---|
| (i) Primary or lower | | | | | | | | |
| Fertility | 0·84 | 0·75 | 0·56 | 0·38 | 0·21 | 0·05 | 0·04 | 2·83 |
| Avg. Age[b] | 24·5 | 26·5 | 28·5 | 30·5 | 32·4 | 34·4 | 36·3 | |
| $N$[c] | 179 | 179 | 179 | 179 | 170 | 135 | 75 | |
| (ii) High school | | | | | | | | |
| Fertility | 0·78 | 0·81 | 0·54 | 0·36 | 0·12 | 0·08 | 0·05 | 2·74 |
| Avg. Age | 24·3 | 26·3 | 28·3 | 30·3 | 32·3 | 34·2 | 36·0 | |
| $N$ | 200 | 200 | 200 | 200 | 193 | 145 | 78 | |
| (iii) College | | | | | | | | |
| Fertility | 0·82 | 0·81 | 0·60 | 0·21 | 0·11 | 0·02 | 0·03 | 2·60 |
| Avg. Age | 24·7 | 26·7 | 28·7 | 30·7 | 32·7 | 34·7 | 36·6 | |
| $N$ | 196 | 196 | 196 | 196 | 187 | 132 | 58 | |

[a] Two-year period since marriage.
[b] Age at the start of the period.
[c] Number of women observed.

This paper does not measure the value of children qualitatively or by time-use data, nor through direct economic costs and benefits. Instead, it estimates gender- and age-specific values of children from observed fertility data using a dynamic programming model.

Fertility decision-making can be viewed in terms of stochastic dynamic control problems where outcomes take integer values (Heckman and Willis (1976), Wolpin (1984), Rosenzweig and Schultz (1985), Newman (1988), Montgomery (1988), Hotz and Miller (1988, 1993) and David and Mroz (1989). Uncertainties exist in many biological and socio-economic aspects, such as fecundity, mortality, gender prior to birth, and children's as well as own financial conditions in the future. Essentially, fertility decisions involve not only the number but also the timing and spacing of children. Suppose that parents' primary concern is to secure old-age support, which can be accomplished only by transfers from mature sons. Parents without a son are likely to put more efforts into having another child, all else being equal. Furthermore, parents would try to time their childbearing so that the period of transfers from children coincides with their own old age, the time of low income. The dynamic model employed in this paper properly integrates the overlapping life cycles between parents and children.

As a motivation for the application of a dynamic model, consider the observed fertility pattern among Korean women which is presented in Tables 1a and 1b. First, Table 1a reports the average period-specific fertility rates and the average age at each respective period for the sample used in this analysis drawn from 1980 Korean Census.

Fertility rate is highest in the first and the second period and then decreases rapidly, much more rapidly than in the case of no birth control. The rate of decline after the third period is greater among better educated women than less educated women; that is, highly educated women are likely to stop childbearing earlier than less educated women.

Another distinguishing feature of the observed fertility pattern among Korean women is differential parity progression rates by the sex of existing children as shown in Table 1b.

For example, a woman who has two girls is twice as likely to have another child than a woman who has two boys. A similar pattern is present among higher parities as well (see Ahn (1990) for a fuller discussion). To account for these differential fertility rates by woman's age and by sex and ages of children, a life-cycle optimization model is a natural

TABLE 1b

*Parity progression rate (%) by sex composition*

| Wife's completed education | Parity | All | 0 | 1 | 2 | 3 | Chi-square |
|---|---|---|---|---|---|---|---|
| | 1 to 2 | 95·3 (575) | 94·8 (328) | 96·0 (247) | | | 0·41 |
| All ($N=575$) | 2 to 3 | 59·5 (548) | 47·3 (148) | 55·6 (288) | 85·7 (112) | | 42·94 |
| | 3 to 4 | 24·5 (326) | 23·1 (26) | 7·1 (141) | 34·8 (112) | 53·2 (47) | 50·44 |
| | 1 to 2 | 92·2 (179) | 90·7 (107) | 94·4 (72) | | | 0·86 |
| Primary ($N=179$) | 2 to 3 | 69·7 (165) | 60·0 (50) | 66·7 (75) | 87·5 (40) | | 8·56 |
| | 3 to 4 | 29·6 (115) | 26·7 (15) | 10·6 (47) | 43·6 (39) | 57·1 (14) | 16·94 |
| | 1 to 2 | 96·5 (200) | 99·1 (114) | 93·0 (86) | | | 5·40 |
| High school ($N=200$) | 2 to 3 | 60·6 (193) | 48·9 (47) | 58·3 (115) | 87·1 (31) | | 12·06 |
| | 3 to 4 | 21·4 (117) | 0·0 (5) | 1·7 (59) | 34·2 (38) | 73·3 (15) | 42·79 |
| | 1 to 2 | 96·9 (196) | 94·4 (107) | 100·0 (89) | | | 5·15 |
| College ($N=196$) | 2 to 3 | 49·5 (190) | 33·3 (51) | 43·9 (98) | 82·9 (41) | | 24·90 |
| | 3 to 4 | 22·3 (94) | 33·3 (6) | 11·4 (35) | 25·7 (35) | 33·3 (18) | 4·303 |

basis for the analysis. The variations in individual childbearing behaviour will be the main source for the model identification in estimating the age- and sex-specific value of children.

Recently, there has been a growing literature on dynamic models of fertility and their estimation. Heckman and Willis (1976) developed a pioneering stochastic dynamic model of fertility in which parents choose a monthly conception probability in a discrete-time framework. A study by Wolpin (1984) has established important work on an estimable stochastic dynamic model. In particular, he addresses the dynamic implications of uncertain child mortality on fertility. Hotz and Miller (1988) examine fertility and female labour supply over the life cycle in a simultaneous decision framework. They use an index model which approximates the dynamic decision rule. They show, using U.S. data, that the material costs of children do not vary much with age while the time costs decrease with children's ages. In their recent paper, Hotz and Miller (1993) estimate a dynamic model of parental contraceptive choice and fertility using a new method which reduces substantially the computational cost. Their approach consists of a new representation of the valuation function in terms of choice probability and probability transitions of choices, which are estimated non-parametrically within the sample, thus avoiding the expensive computational costs of the backwards recursive method. Their empirical results again confirm the importance of existing numbers of offspring and the spacing of previous births in parental contraceptive choice.

Rust (1987) sets up a structural estimation framework to analyse a dynamic problem of optimal bus engine replacement. Applying a similar algorithm, Montgomery (1988) estimated a structural dynamic model of contraceptive use. Montgomery focused on imperfect fertility control, and a revealed-preference estimation of desired family sizes. Structural models of dynamic discrete choice have also been applied to other areas of economics (see Eckstein and Wolpin (1989) for a survey).

This paper builds on Wolpin (1984) and Hotz and Miller (1988, 1993), and adopts Rust's (1987) framework for estimation. While previous studies have used dynamic models to explain the number of children, desired probability of a birth, or the effect of mortality on fertility, this research focuses on estimating the costs and benefits of children. By estimating the relative costs (and benefits) of boys to girls by age, it attempts to infer the causes, types, and the extent of parental gender preferences of children and their effects on fertility. Furthermore, using the estimated parameters, the paper simulates the impact of the medical determination of foetal gender on fertility and sex ratios.

The subsequent exercise uses a set of Korean data to estimate values of children as perceived by parents. The results indicate that children impose net costs when young and net benefits when old. Both the early costs and the later benefits are larger for male children than female children, and for better-educated women than less-educated women. Furthermore simulation results suggest that, given the estimated age-sex specific values of children, reductions in the costs of gender-screening tests and abortions could drastically increase the male birth ratio through selective abortions. This concern is supported by recent evidence from Korean Vital Statistics (National Statistical Bureau (1991)), which shows that the registered male–female birth ratio rose to 1·17 in 1990 in Korea.

The rest of the paper is organized as follows. Section II describes a dynamic model of household fertility choice and the estimation strategy. The data are discussed in Section III. The estimation results and the sensitivity test of the model are in Section IV. Also in Section IV, effects of the screening test of foetal gender on fertility and sex ratios are simulated using the estimated value of children. The final section summarizes the findings and discusses possible extensions.

## II. A DYNAMIC MODEL OF FERTILITY

A couple's lifetime after marriage is divided into a series of periods. Denote $t=1$ as the first fertile period, $\tau$ the last fertile period, and $T$ the last living period. The couple's problem is to choose a contraceptive method (or a combination of multiple methods) and the extent of its use at each fertile period to maximize lifetime utility (utility is accrued only while one is alive) under a life-cycle budget constraint.

The model contains several assumptions mostly for analytical simplicity, empirical tractibility and due to the lack of data.

1. It is assumed that there are no savings or dis-savings. Although this assumption is critical and difficult to accept except for a subsistence level of economy, it is maintained due to both analytical simplicity and lack of data. However, in an empirical context the problem due to this assumption might not be so severe. Korean society during the 1960's and 1970's, the time when the women in my working sample had children, was still an underdeveloped and mostly agricultural society. The financial market was yet to develop and the social security system did not exist. Under these circumstances, children were an important source of old-age security, financially as well as psychologically.
2. It is assumed that the non-economic costs and benefits of children can be evaluated as money equivalents. Using this assumption, we set up a model to estimate the net value of children which includes both economic and non-economic costs and benefits. This is one of the main differences from most of the previous studies of

fertility, where the service flow from children and own consumption (income minus child costs) are taken to be different goods (see Hotz and Miller (1993), for example). One advantage of our structure is that our estimates are likely to be less susceptible to an identification problem when the model cannot identify the optimal fertility decision from multiple combinations of child costs and service flow.

3. It is assumed that there are no uncertainties in the age at death, onset of sterility, income schedule over life cycle, and perceived child value schedule. These assumptions are made to keep the model empirically tractable. Furthermore, it is assumed that children always survive their parents, which simplifies the model by eliminating uncertainties due to child mortality.[2]
4. Parents can control their childbearing perfectly without incurring any costs during their fertile time periods. The extension to the imperfect control regime is theoretically straightforward, but it involves major complications empirically.[3] In the Korean context this may not be as problematic as it looks, since the rate of contraceptive use (especially surgical sterilization) was high and its costs were kept low and often subsidized by government anti-natal policies. Even abortions of unwanted pregnancies are often subsidized and accepted favourably in Korean society.
5. The decision on the timing of marriage and marital dissolution as a consideration of fertility choice is not included in the model.[4] Similarly, the simultaneous feature of other household decisions made along with fertility, such as labour force participation and expenditure on children, is not considered in this paper.[5]

Given the restrictive structure of the model and the additional assumptions discussed later in the section on empirical specification, the empirical results should be seen as suggestive and treated with caution. Studies which use a less restrictive structure (such as Hotz and Miller (1993)) are highly desirable and assigned as future research agenda.

### II.1. *Parental optimization problem*

The couple's utility function is assumed to be intertemporally additive, of identical form at all periods, and characterized by a constant discount rate. The control variable $d_t$ takes the value of either 0 (not to have a child) or 1 (to have a child) at each $t$ for $t=1,\ldots,\tau$. The couple's utility depends only on own consumption of a composite good $x$. The amount of consumption at period $t$ is the income at $t$ plus the money-equivalent value of children[6] during the period. The value of children depends on their

2. The model would be substantially more complicated to estimate if the onset of sterility, or own or child mortality were treated as a random variable.

3. This is particularly true if data are not available on contraceptive use. Even when the choices of contraceptive method (for the entire previous fertile periods) are observed, it still is difficult to apply to estimation, because the choice set includes all the available contraceptive methods and the implied size of the state space exceeds easily the practical limit. See Montgomery (1988) and Hotz and Miller (1988, 1993) for a study which considers imperfect fertility control.

4. I believe that this assumption is not very problematic, since, in Korean society, most women marry and do so at similar ages (especially within each education group) and the divorce rate is extremely low.

5. Moffitt (1984), Rosenzweig and Schultz (1985) and Hotz and Miller (1988) discuss models which feature simultaneous decision-making regarding fertility and labour force participation. See Becker and Lewis (1973) and Willis (1973) for a discussion of the interaction between quality and quantity of children, and Behrman, Pollak and Taubman (1982, 1986) for a model of differential expenditure on children according to gender.

6. It should be viewed as including non-economic values (or dis-values) converted to monetary terms as well as economic ones. However, the issue of aggregating different types of values is beyond the scope of this paper.

age and gender.[7] The value of a $k$-period-old boy (girl) at time $t$ is denoted as $m_k^t\,(f_k^t)$. It is assumed that the couple may have at most one child per period.

At time $t$, the couple's problem is to maximize

$$E_t \textstyle\sum_{k=t}^{T} \delta^{k-t} U(x_k) \tag{1}$$

where $E_t$ is an expectation operator at time $t$, $\delta$ a discount factor, $U$ a utility function, and the consumption amount of a composite good $x$ is

$$x_t = Y_t + \textstyle\sum_{k=0}^{t-1} (b_{k+1} m_{t-k-1}^t + g_{k+1} f_{t-k-1}^t) \tag{2}$$

where $Y_t$ denotes the couple's income at $t$, and $b_t\,(g_t)$ takes a value of one if the couple has a male (female) birth at $t$ and zero otherwise.

The couple's utility is determined by the age–sex composition of existing children and income. At any period the age–sex composition of children is determined by the choices made during the previous periods and their outcomes. Let $\pi$ denote the probability of any birth to be a male child. If a couple choose to have a child at the time $t$, the state facing the couple is a new-born boy with a probability of $\pi$ or a new-born girl with a probability of $(1-\pi)$, in addition to the existing children at the beginning of the period.

The optimal choices for the entire fertile life cycle can be determined by the method of backwards recursion. Let $b(t)$ represent $\{b_k\}_{k=1}^{t-1}$, the sequence of male birth event up to $t-1$, and $g(t)$ for female birth event. Thus, $b(t)$ and $g(t)$ represent the state faced by a couple at the start of period $t$.

$$s(t) = \{s_1, s_2, \ldots, s_{t-1}\} \qquad \text{for } s = (b, g). \tag{3}$$

Similarly, let $m(t)$ and $f(t)$ represent vectors of age-specific values of boys and girls as perceived by parents at $t$.

$$c(t) = \{c_{t-1}^t, c_{t-2}^t, \ldots, c_1^t\} \qquad \text{for } c = m, f. \tag{4}$$

Therefore, the vector multiplication, $b(t)m(t)$, denotes the net value of existing boys at time $t$, and $g(t)f(t)$ for girls.

The post-childbearing value function is defined as discounted expected utility during the sterile periods $(\tau+1, \ldots, T)$, and is written as

$$V_{\tau+1}(b(\tau+1), g(\tau+1)) = \textstyle\sum_{k=\tau+1}^{T} \delta^{k-\tau-1}(Y_k + b(\tau+1)m(k) + g(\tau+1)f(k)). \tag{5}$$

At the last fertile period $(\tau)$, given the income and value of children for the current and future periods, $\{Y_t, m(t), f(t)\}_{t=\tau}^{t=T}$, the discounted expected utility for a couple who choose $d_\tau$, given $b(\tau)$ and $g(\tau)$, is

$$\begin{aligned} EU_t = {} & d_\tau[\pi U(Y_\tau + b(\tau)m(\tau) + g(\tau)f(\tau) + m_0^\tau) \\ & + (1-\pi)U(y_\tau + b(\tau)m(\tau) + g(\tau)f(\tau) + f_0^\tau) \\ & + \pi V_{\tau+1}(b(\tau), g(\tau), b_\tau = 1) + (1-\pi)V_{\tau+1}(b(\tau), g(\tau), g_\tau = 1)] \\ & + (1-d_\tau)[U(Y_\tau + b(\tau)m(\tau) + g(\tau)f(t)) \\ & + V_{\tau+1}(b(\tau), g(\tau))]. \end{aligned} \tag{6}$$

7. I estimate the model separately according to the parent's socio-economic status, and therefore allow the net value of children to vary according to parental socio-economic status. However, I do not allow variation by the age of parents, birth order of children, or calendar time. Espenshade (1984) shows that there is a large variation in expenditure on children depending on the parents' socio-economic status, and Hotz and Miller (1993) find that the husband's education and age have smaller effects than the wife's on the contraceptive method chosen.

If the couple choose to have a child ($d_\tau = 1$), their expected current period utility (first two lines in (6)) is the probability of the child being male ($\pi$) or female ($1-\pi$) multiplied by the corresponding utility for the current period. The discounted expected utility during the sterile periods (third line) is also obtained by multiplying the chance of each sex by the corresponding post-childbearing value function. If the couple choose not to have child ($d_\tau = 0$), their utility is as in the fourth line for the current period and the fifth line for the future. The value function at the period $\tau$, as shown in (7), is defined as the maximum expected discounted utility one can obtain at $\tau$.

$$V_\tau(b(\tau), g(\tau)) = \max_{d_\tau = \{0,1\}} \mathrm{EU}_\tau(\mathrm{d}_\tau | \mathrm{b}(\tau), \mathrm{g}(\tau)). \tag{7}$$

It can be shown that a single solution to the above equation exists, and the optimal choice is determined for each possible state at $\tau$. Now, going one period backwards, we solve the problem for the second-to-last fertile period. Likewise, by a successive recursion, we can solve for the couple's state contingent optimal fertility decision over their entire fertile periods.

Before presenting a statistical model it is useful to discuss intuitive implications of the model for the optimal fertility choice with alternative income profiles. If income is flat, then in order to have any children, they must have a positive net benefit. But if children had positive value at every age while the parents are alive, then a couple will bear children in all fecund periods. Since most Korean women tend to have children earlier rather than later and then stop, it is likely that children are costly when young and have positive value when old.[8] If income profiles are upward sloping; having children makes sense only if they bring benefits while young and costs while old. The steeper the profile the more likely it is that this effect will dominate. Finally, consider the case of an upward sloping profile up to a certain age and then a diminished income until the end of life. Now, having children early will be particularly beneficial if they have positive value just when income is very low. However, if young children impose too high a cost, couples might be better-off delaying childbearing until their income is sufficiently high. The net result depends on these three effects, and keeping this in mind will help to understand our estimation results.

### II.2 *Statistical model*

A couple decides on childbearing sequentially at each fertile period under the uncertainties only in the sex of unborn children. For researchers, an additional stochastic element exists in the unobserved error terms of the utility function, $e_t$. Thus the single-period utility associated with decision $d_t$ at period $t$ given $(b(t), g(t), e_t)$ is

$$U(d_t | b(t), g(t)) + e_t(d_t). \tag{8}$$

The unobserved term $e_t$ is assumed to be choice-specific and additive to the systematic part of utility. The value of $e_t(d_t)$ can be interpreted as an unobserved transitory utility cost of choosing $d_t$. Given the stochastic evolution of the state embodied by the transition probability and the choices made, the couple choose a sequence of decision rules $\{d_t\}$ to maximize the discounted expected utility over their lifetime. The decision rule is determined from Bellman's equation as in

$$V_t(b(t), g(t)) = \max\,\{U(b(t), g(t), d_t) + \delta E V_{t+1}(b(t), g(t), e_t, d_t)\}. \tag{9}$$

8. If it were the other way around, then parents could avoid the cost of older children by delaying births.

Note that the expectation in the last term is with respect to both the randomness in the sex of the child ($\pi$) and the distribution of $e_t$.

If $e_t$ consists of identically and independently distributed bivariate extreme value errors, the probability of choice $d_t$ reduces to binary logit formula as in

$$\Pr(d_t|b(t), g(t)) = \frac{\exp[U(d_t|b(t), g(t)) + \delta EV_{t+1}(d_t|b(t), g(t))]}{\sum_{d_t=\{0,1\}} \exp[U(d_t|(b(t), g(t))) + \delta EV_{t+1}(d_t|b(t), g(t))]}. \tag{10}$$

The sample likelihood is then

$$\sum_{i=1}^{I} \sum_{t=1}^{\tau_i} \Pr(d_t^i|b^i(t), g^i(t)) \tag{11}$$

where $I$ is the number of women in the sample, $t=1$ is the age at marriage, and $\tau_i$ is the age at the survey of woman $i$. Using an iterative method we can obtain consistent estimates of parameters which maximize the sample likelihood.

### II.3. *Empirical specifications*

For the purpose of empirical tractability, several assumptions are imposed on the objective function and in forming the parameters.

1. The net monthly value of children is assumed to be constant within each of four age groups for each sex: age 0 to 10, 11 to 20, 21 to 30, and 31 to 50. It is reasonable to suspect that the value of children differs by age within each age interval, and also that the marginal value of children varies by the number and the composition of existing children. Specifications which take these into account would be necessary to obtain more accurate estimates. In this study, a simpler specification is used to reduce the computational burden. Therefore, the estimates should be interpreted as money equivalents of the average monthly net value of a child within each age interval.
2. The utility function is assumed to take a logarithmic form, and the discount factor per period is assumed to be 0·95.[9] A logarithmic form of utility function emphasizes the risk-averse preference of parents, that is, the gains from a balanced consumption intertemporally. The objective function is then written as
$$E_t \sum_{k=t}^{T} 0{\cdot}95^{k-t} \operatorname{Log}(x_k) \tag{12}$$
where $x$ is as defined previously in (2).
3. For computational tractability, a seven decision-period model is used here. Since the dynamic programming model proposed in this paper (as in most other discrete-choice dynamic models) can only be solved numerically by the backwards induction method, estimation involves a burdensome computation. Seven periods with two years of duration per period give 14 fertile years after marriage. Even this simple framework of the seven decision periods with three possible states (male birth, female birth or no birth) for each period involves a substantial computational burden. For example, to carry out the estimation, a value function has to be

9. The attempt to estimate the discount rate failed. The model is estimated with various values of discount rate, 0·90, 0·95, and 1·00. The value of log-likelihood at convergence was highest with 0·95. Other values of discount rates gave similar estimation results. The discount factor estimated in Hotz and Miller (1993) is 0·646. This low discount factor might be reflecting the no-savings assumption since the financial market in the U.S. is relatively well developed. However, the estimated standard error of 0·678 indicates an insignificant estimate of the discount factor.

computed for each individual for each of the 2187 ($=3^7$) possible states that one can face at the end of the seventh period, a value function for each of the 729 ($=3^6$) possible states for the sixth period, and so on.

The set-up of two years for each decision period has some advantages as well as disadvantages. For example, in a framework with a one-year decision period, it is likely that, regardless of their choices, very few couples would be observed having births in two consecutive years due to the existence of infertile periods following each birth. Therefore, without the control of this post-partum infertility, estimates are likely to be biased since infertile periods would be treated as the periods that the couples chose not to have children. Under the framework of perfect birth control as used in this paper this bias is likely to be reduced with a two-year decision period.[10]

The model is identified by the variations in income profile, sex and age composition of children at each period, and the non-linearity embedded in the utility function and the multi-period structure of the model.

## III. DATA

The data are drawn from a two-percent sub-sample of the 1980 Korean Population and Housing Census which was conducted by the National Bureau of Statistics of Korea. The Census is organized as a household survey. The observation for each household member is given in the order of head of household, spouse, children and others. The working sample for this study includes once and currently married woman. We observe the couple's age, age at marriage, education level, place of residence, work status, occupation, and children's age and sex.

Unfortunately, the Census did not gather information on wages or income. The husband's income profile is constructed using the Korean Occupation Wage Survey (1982), conducted by the Ministry of Labour in Korea. This survey includes workers from a stratified random sample of firms with 10 or more employees. The average monthly income is estimated by OLS using age, age-squared, schooling and two-digit industry dummies as regressors.[11] Husbands are assumed to retire at age 65, and income after retirement is assumed to be one-fifth of income during the last working year. These assumptions are maintained due to the lack of dependable data. Since the sample used here includes only non-working women,[12] the household income schedules differ between households only due to the differences in the husband's characteristics which affect income. The income profiles are presented in Table 2. Since the income profile is the main identifying variable of the model, inexactly predicted income profiles may yield incorrect estimates. A test is performed to assess the sensitivity of estimates by estimating the model with different income profiles, specifically, with different assumptions on old-age income.

10. The works of Hotz and Miller (1988, 1993) adopt the framework of one-year decision period under imperfect birth control. Their estimated probability of conception is 0·022 (0·05) for contraceptive users and 0·304 (0·38) for non-users in their 1988 (1993) study. According to their estimates, the conception probability during an interval of two years for a woman less than 35 years old (the model and the sample used in our data) is not much higher than zero for non-users and not much lower than one for non-users. In these studies conception probability does not consider post-partum infertility directly, but indirectly through the effects of the ages of existing children on contraceptive choice.

11. The OLS estimation result is; Log monthly income $=4{\cdot}429+0{\cdot}106*$ Middle school completed $+\ 0{\cdot}387*$ High school completed $+0{\cdot}646*$ Jr. college completed $+0{\cdot}999*$ College completed $+0{\cdot}077*$ Age $-\ 0{\cdot}00132*$ Age-Squared + Industry dummies.

12. This is imposed due to the problem of computing the wages for the whole life cycle for women, since many women have many career interruptions due to various reasons. It is less problematic for men since they are more likely to work without interruption until they retire.

TABLE 2

*Household income profile*
*(monthly income in* 1000 *Korean currency)*

| | Wife's completed education | | |
|---|---|---|---|
| Period | Primary | High school | College |
| 1 | 219·74 | 287·16 | 365·11 |
| 2 | 237·78 | 316·89 | 406·79 |
| 3 | 254·73 | 346·20 | 448·57 |
| 4 | 270·16 | 374·42 | 489·56 |
| 5 | 283·66 | 400·86 | 528·79 |
| 6 | 294·86 | 424·86 | 565·29 |
| 7 | 303·44 | 444·93 | 598·10 |
| 8 | 309·14 | 462·21 | 626·29 |
| 9 | 311·79 | 475·30 | 649·06 |
| 10 | 311·32 | 483·82 | 665·73 |
| 11 | 307·74 | 487·49 | 675·79 |
| 12 | 300·61 | 485·96 | 678·94 |
| 13 | 291·29 | 479·42 | 675·08 |
| 14 | 279·42 | 467·19 | 664·33 |
| 15 | 264·85 | 450·03 | 644·92 |
| 16 | 248·51 | 424·58 | 606·82 |
| 17 | 222·75 | 388·69 | 552·07 |
| 18 | 189·17 | 330·22 | 448·44 |
| 19 | 143·49 | 233·93 | 311·77 |
| 20 | 83·39 | 130·10 | 164·49 |
| 21 | 48·12 | 83·11 | 115·41 |
| 22 | 41·16 | 76·28 | 112·05 |
| 23 | 40·55 | 75·86 | 112·05 |
| 24 | 40·55 | 75·86 | 112·05 |
| 25 | 40·55 | 75·86 | 112·05 |

The final sample is selected according to individual's demographic and socio-economic conditions. The idea is to make the sample more homogeneous, therefore maintaining the number of parameters within computational feasibility. To begin, I select women who are residing in the capital city of Korea, Seoul. Wife's age at marriage is between 23 and 26, and current age between 35 and 40.[13] Due to the lack of information about deceased children, I selected only women whose number of children ever born equals the number of existing children. I further select only women with at least one child. This is imposed to exclude those couples who are innately sterile. Although this will also exclude those who have no children by choice, it is believed that few couples in Korea desire no child.[14] One should note, however, that even within each sub-sample, it is likely that there exists unobserved heterogeneity in fecundity and preference, in which case the estimates of the parameters would be inconsistent.

## IV. ESTIMATION RESULTS

For the purpose of estimation, a woman's life after marriage is divided into two-year periods of which the first seven (14 years) are assumed to be fertile. There were a few cases where a woman had two children in one period. In those cases the first of the two

13. For the sample under study the mean age at marriage is 25 suggesting that childbearing is completed at age 39, which is true for more than 95% of women in Korea; 4·4%, 2·7%, and 2·6% of total births are from women older than 39 in 1970, 1975, and 1980, respectively (Korean Population and Housing Census).

14. For example, the proportion of childless couple at wife's age between 35 and 40 was about 5%, which is about the probability of innate sterility.

TABLE 3

(*Estimated monthly net value of boys and girls* (*in* 1000 *Korean currency*)

| | Woman's completed education level | | |
|---|---|---|---|
| Parameter | Primary | High school | College |
| Boy's net value by age | | | |
| Age 0–10 | −4·55 (1.48) | 0·10 (0·59) | 49·33 (21·15) |
| Age 11–20 | −40·62 (43·86) | −42·76 (32·30) | −45·61 (38·85) |
| Age 21–30 | −41·65 (15·23) | −80·89 (40·59) | −196·5 (68·32) |
| Age 31–50 | 32·64 (14·74) | 52·13 (27·49) | 131·7 (44·57) |
| Girl's net value by age | | | |
| Age 0–10 | −3·09 (0·67) | 2·08 (1·26) | 50·35 (21·15) |
| Age 11–20 | −29·56 (9·81) | −38·66 (19·07) | −33·96 (26·63) |
| Age 21–30 | −36·12 (21·30) | −41·92 (12·02) | −56·37 (56·37) |
| Age 31–50 | 22·21 (13·79) | 19·61 (10·73) | 4·77 (53·75) |
| Log-likelihood | −667·24 | −726·07 | −667·60 |

*Note.* Unsigned asymptotic *t*-statistics are in parentheses.

births is moved to the previous period. If there is no previous period without a birth, then the second birth is moved to the next period. Also, only a few cases were detected in which a woman had a birth later than the final decision period under the seven-period framework. In those cases a birth is moved to the last fertile period in which there is no birth. The couple is assumed to live 50 years (25 periods) after the marriage.

Three sub-samples are formed according to each woman's education level: primary or lower, high school, and college or higher. Total periods (women) observed are 1096 (179), 1198 (200), and 1161 (196) for primary, high-school, and college education groups respectively. The estimation results are presented in Table 3, which shows that the value of children varies substantially according to their gender and age, and the education level of women. The estimates should be interpreted as money equivalent monthly net value, non-pecuniary as well as pecuniary, of a child during each respective age interval.

The results may be summarized by several notable aspects. First, young children incur net costs while mature children yield net benefits. However, it shows a significant net value on children of age 0 to 10 among the sample of college-educated women, whereas it is close to zero and insignificant among the less-educated women. It is difficult to interpret this positive net value as an economic one. It must then be the case that the non-economic value is dominating the economic costs. However, it is not clear why this should not be the case among the less-educated women.

Second, although children impose highest costs from age 11 to 30 and yield net benefits after age 30 in all education groups, they show substantial differences in costs and benefits according to their sex. Both the costs of young children and the benefits from mature children are larger for boys than girls. The largest difference between sex is observed in the value of adult children. There are substantial benefits from grown-up sons whereas grown-up daughters yield insignificant benefits to parents. This seems to reflect the Korean custom that daughters are considered to be outside the family once married. This also supports the differential parity progression rates by the sex of existing children observed in the data. Son preferences based on the old-age security seem to be one of the main determinants of fertility in Korea.

Third, the costs of children show considerable differences according to the mother's education level. While primary- and high-school-educated women consider costs of children of age 11 to 20 and 21 to 30 about the same, college-educated women consider children of age 21 to 30 most costly. This is suggestive of variations in the expenditure plan for children according to parental education level. In particular, the substantial difference in net costs between boys and girls of age 21–30 among college education group is suggestive of the costs of college education for boys.[15] This may also reflect, since the sample includes only non-working women, the differences in the opportunity cost of a child in terms of wife's foregone wages by education level.

Finally, better-educated women seem to expect greater benefits from grown-up sons (ages 31 or more) than less-educated women do. This difference may reflect the differential earning power of children due to the different investment received while they were young. The expected benefits from a mature son (age 31 to 50) are 23·6, 34·8, and 67·0 among primary, high school, and college-educated women, respectively.[16]

Overall, the findings suggest that the old-age security (whether it is pecuniary or non-pecuniary) from mature sons is an important factor that identifies the differential fertility behaviour according to sex–age composition of children. I tested whether the value of children is statistically different by gender or age. All three tests (three education groups) reject at 1% significance level the null hypothesis that the child costs are the same between gender.[17] Also, all tests reject at 1% significance level the null hypothesis that the child costs are the same over the four age intervals.[18]

### IV.1. *Sensitivity of the model to the assumption of old-age income*

Since old-age security appears to play a major role in parents' fertility decision-making, I test the sensitivity of the estimates by changing the assumption on the old-age income among the high-school educated women (tests on other education groups yield similar results). In comparison to the benchmark case in which old-age income is assumed as one-fifth of the income during the last working period, new estimates were obtained assuming the old-age income equal to one-half, and one-tenth of the income during the last working period. The results are reported in Table 4.

Since the estimation is based on the same fertility data, the estimated benefits from a grown-up child are expected to increase as old-age income increases. That is, to yield the same observed fertility pattern with higher old-age income, the benefit from a child during parent's old age should be larger, or/and the costs of young children should be smaller. The empirical results support this conjecture. The net positive value of very young (age 0 to 10) and mature children (age 30 or higher) increases, as old-age income increases. The test result supports the robustness of the model estimated in this paper[19].

15. In Korea, college enrollment rate among males is much larger than among females. For example, according to UNESCO (1988) the college enrollment rates were 23% and 39% among males in 1980 and 1984 respectively, while they were 8% and 19% among females. Also, Korean men usually have to serve for three years in the military during their late teens and early twenties. In those cases, the college education is taken mostly during one's 20's. In general in Korea, the cost of college education is high and is financed mostly by parents.

16. The value of mature sons is about the same as the own old-age income for primary or high school educated women, but a little higher for the college educated women.

17. Twice the differences of the estimated likelihood with and without restriction are 14·24, 13·70 and 26·20, respectively for primary, high school, and college education group, and the critical value of Chi-square statistics is 13·28 at 4 degrees of freedom for 1% significance level.

18. Twice the differences of the estimated likelihood with and without restriction are 19·82, 18·44 and 24·48, respectively for primary, high school, and college education group, and the critical value of Chi-square statistics is 16·82 at 6 degrees of freedom for 1% significance level.

19. However, one should note that, without any formal misspecification test (for computational reasons), our test is only indirectly supportive of the model. In fact, Hotz and Miller (1993) failed to recover a structural specification that was not rejected.

TABLE 4

*Sensitivity of the estimates to changes in the assumption on old-age income (High school educated women)*

| | Old-age income as a ratio to the last working period income | | |
|---|---|---|---|
| Parameter | One-half | One-fifth | One-tenth |
| Boy's net value by age | | | |
| Age 0–10 | 16·44 (2·81) | 0·10 (0·59) | 1·43 (1·11) |
| Age 11–20 | −52·47 (11·27) | −42·75 (32·30) | −24·09 (11·75) |
| Age 21–30 | −92·34 (17·80) | −80·89 (40·59) | −59·41 (20·12) |
| Age 31–50 | 90·52 (19·34) | 52·13 (27·49) | 67·84 (19·33) |
| Girl's net value by age | | | |
| Age 0–10 | 12·67 (3·11) | 2·08 (1·26) | 4·72 (1·92) |
| Age 11–20 | −36·15 (9·76) | −38·66 (19·07) | −26·99 (10·75) |
| Age 21–30 | −44·84 (18·22) | −41·92 (12·02) | −40·32 (15·36) |
| Age 31–50 | 42·55 (12·84) | 19·61 (10·72) | 10·58 (4·89) |
| Log-likelihood | −733·54 | −726·07 | −729·34 |

*Note.* Unsigned asymptotic *t*-statistics are in parentheses.

## IV.2. *Predicted fertility profile*

One way of testing the estimation results of a discrete-choice model is to compare predicted optimal fertility choices with those actually made as shown in Table 5a. The fertility rates in the first two periods are predicted to be higher than the actual. Given the slowly rising income schedule with reduced income in old age, the optimal strategy is to have births early (especially in the first two periods), and to have none in later periods. The prediction of higher fertility in early periods and lower fertility in later periods than the actual is due to a rather uniform income profile across individuals and the perfect fertility control, both true by assumption. However, the predicted pattern and the total rate of fertility match reasonably well with the actual ones. For example, the total fertility rate is predicted as 2·56 compared to the actual one of 2·60.

We also compare the predicted parity progression rates with those observed as shown in the second panel of Table 5a. In general, the predicted progression rates show a similar pattern as one observed. The variation of the predicted parity progression rate by the sex of existing children is somewhat larger than that observed. While the predicted progression rate is very similar to that observed for the couples who have only girls, the predicted rate is much smaller than that observed for those who have one or more boys. This is again due to the assumption of perfect fertility control.

Now, given the estimates of the value of children in Table 3, the effect of the changes in old-age income on fertility can be predicted. Increases in old-age income from one-fifth to one-third and to one-half of the income of the last-working period are examined among the college-educated women (Table 5b, first panel).[20] The fertility rate in the first two periods does not change much when the old-age income increases. The effect appears most prominently in the decrease of fertility rate in later periods. As old-age income increases, parents are not so desperate to have children to provide security in their old age, even those who have only girls. The expected fertility rate decreases from 2·56 to 2·06 and to

20. Note that in this section we simulate the effects of the changes in old-age income on the optimal fertility pattern given the value of children as estimated in the Table 3, while in Section IV.1 the value of children is reestimated using different assumptions on the old-age income.

TABLE 5a

*Predicted optimal fertility choice (College educated women)*

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
|---|---|---|---|---|---|---|---|---|
| (i) Period fertility rate | | | | | | | | |
| Observed | 0·82 | 0·81 | 0·60 | 0·21 | 0·11 | 0·02 | 0·03 | 2·60 |
| Predicted | 1·00 | 0·86 | 0·42 | 0·17 | 0·09 | 0·02 | 0·00 | 2·56 |

| | | Number of girls among existing children | | | | |
|---|---|---|---|---|---|---|
| Parity | | All | 0 | 1 | 2 | 3 |
| (ii) Parity Progression Rate | | | | | | |
| 1 to 2 | Observed | 96·9 | 94·4 | 100·0 | | |
| | Predicted | 94·4 | 90·7 | 98·9 | | |
| 2 to 3 | Observed | 49·5 | 33·3 | 43·9 | 82·9 | |
| | Predicted | 39·0 | 9·8 | 35·7 | 82·9 | |
| 3 to 4 | Observed | 22·3 | 33·3 | 11·4 | 25·7 | 33·3 |
| | Predicted | 10·6 | 0·0 | 0·0 | 11·4 | 33·3 |

TABLE 5b

*Some predictions (College educated women)*

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
|---|---|---|---|---|---|---|---|---|
| Income effect | | | | | | | | |
| One-third[a] | 1·00 | 0·72 | 0·30 | 0·04 | 0·00 | 0·00 | 0·00 | 2·06 |
| One-half[b] | 0·98 | 0·47 | 0·01 | 0·00 | 0·00 | 0·00 | 0·00 | 1·46 |
| Effect of changes in value of children | | | | | | | | |
| Equal[c] | 1·00 | 0·03 | 0·41 | 0·13 | 0·05 | 0·04 | 0·00 | 2·56 |
| Average[d] | 1·00 | 0·95 | 0·53 | 0·15 | 0·05 | 0·01 | 0·00 | 2·64 |
| $N$ | 196 | 196 | 196 | 196 | 187 | 132 | 58 | — |

[a] Old-age income increases to one-third of the income in the last working period.
[b] Old-age income increases to one-half of the income in the last working period.
[c] Value of girls is set as the same as the estimated value of boys.
[d] Value of a child of either sex is set as the average of the estimated value of boys and girls.

1·46, as old-age income increases to one-third and to one-half of the last working period income respectively.

One of the main interests of the paper is to infer the type and the intensity of parental sex preferences and their effects on fertility. Therefore, it is interesting to predict the effect of the changes in value of children on fertility. Two hypothetical profiles of the value of children are used for the simulation (Table 5b, second panel).

First, if daughters have the same value estimated for sons from Table 3, the fertility rate might increase due to the rise in the average value of children. On the other hand, it may also decrease since any child will provide support when parents are old, so that even parents with only girls do not have to go on having children to provide themselves with security in old age. The overall effect on the fertility rate is ambiguous. The predicted fertility rate is higher early in the life cycle and lower later than in the benchmark case. However, the total fertility rate is about the same at 2·56. In the opposite case (that is, sons have the same value as estimated for daughters), the fertility rate would be zero due to the negative values for any child of any age.

Finally, if a child of either sex has the same value profile which is the average of the estimated value of boys and girls, the fertility rate increases slightly, from 2·56 to 2·64.

This is due to the smaller variations in costs and benefits of children; that is, risk-averse parents demand more of the less risky investment given the same expected returns.

The simulation results suggest that, given other things the same, increases in old-age income (or development of financial market) or decreases in the expected support from mature sons likely to decrease the fertility.

### IV.3. *Selective abortion, fertility and sex ratio*

Modern technology, which enables the determination of foetal gender, has added a new dimension to the problem of fertility choice (Bennett and Mason (1983), Bloom and Grenier (1983), Kobrin and Potter, Jr. (1983)). Parents who prefer to have children of one sex than the other may use this technology to terminate selectively unwanted pregnancies, which could affect the sex ratio among children in society.

One notable case is Korea. According to the report of 1991 Korean Vital Statistics (National Statistical Bureau (1991)), during the 1980's the male–female birth ratio in Korea increased dramatically, especially at high birth orders (Table 6). For example, in 1990, among children born of the third or higher birth orders, the male–female sex ratio exceeds two,[21] when it is normally less than 1·1 males to 1·0 female. Although the sex ratio is not so high in total due to the low proportion of higher-order births, the steady increase in the sex ratio at lower birth orders suggests a high likelihood that the sex ratio even in total might go up to a much higher level in the near future. It seems that more and more parents want only one or two children, but preferably male children.

It is likely from the estimates in Table 3 that unless the costs of screening test or abortion are high, this sample of Korean women would have only boys. However, as shown in Table 6, the selective abortions seem to occur mostly at high orders of birth. In general, parents seem to leave the sex of the first two children to chance. Only those who were "unlucky" in their first two births seem to be practicing selective abortion. This might be due to the high costs of the screening test and abortion relative to incomes or only a small gain from the selective abortion during the first two pregnancies. Given the value of children and the sex composition of existing children, whether or not a couple uses the gender screening test depends on the costs of the test relative to income. If the cost of the test is high relative to income during the early periods, people are better off delaying the test to later periods when the income is high.

Now, using the estimated values of children from Table 3, I simulate the effects of alternative test costs on conception, screening test, selective abortion, and the sex ratio of children in consequence. The estimated proportions of women who choose to conceive and, among them, who take the screening test at each fertile period are presented in Table 7. If the test cost is 50 (in 1000 won per month during the period, which is about one-tenth of the income),[22] no conception is tested for its gender during the first two periods. But at the third and fourth period, 44% and 88% of conceptions are tested. As the price of screening test decreases to 30, 3% of women take the test in the first period, while the percentage goes up to about 88% at the second period and 100% in the third or later periods. In later periods, however, only few women choose to conceive. If the test costs nothing, most women who choose to conceive take the test in all periods.

21. Infanticide or discriminatory child care which leads to differential mortality rate between male and female children would also cause the biased sex ratio. In the context of Korea these cases are believed to be trivial compared to the case of selective abortion.

22. There is no way of knowing the overall costs (both pecuniary and non-pecuniary) of screening test and abortion. The costs proposed here is purely for the purpose of illustration.

TABLE 6

*Male–Female birth ratios by birth order in Korea*

| Year | Total | Birth order 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1990 | 1·17 (626861) | 1·09 (334442) | 1·17 (246606) | 1·96 (36934) | 2·34 (6471) | 2·15 (2408) |
| 1989 | 1·13 (613240) | 1·05 (328044) | 1·14 (241249) | 1·90 (34794) | 2·17 (6551) | 2·14 (2605) |
| 1988 | 1·14 (620316) | 1·08 (335449) | 1·14 (238279) | 1·70 (35880) | 1·99 (7402) | 1·87 (3306) |
| 1987 | 1·09 (613556) | 1·05 (333111) | 1·09 (230097) | 1·37 (37523) | 1·50 (8474) | 1·63 (4351) |
| 1986 | 1·13 (613703) | 1·08 (325517) | 1·12 (229794) | 1·43 (42294) | 1·61 (10406) | 1·61 (5685) |
| 1985 | 1·10 (636621) | 1·06 (328212) | 1·08 (241201) | 1·33 (47228) | 1·57 (12778) | 1·54 (7191) |
| 1984 | 1·09 (660234) | 1·07 (326720) | 1·08 (250939) | 1·19 (55585) | 1·32 (17188) | 1·34 (9793) |
| 1983 | 1·08 (757930) | 1·06 (339091) | 1·06 (291298) | 1·13 (84508) | 1·21 (27225) | 1·28 (15801) |
| 1982 | 1·07 (840279) | 1·06 (351335) | 1·06 (299408) | 1·10 (124383) | 1·13 (40708) | 1·18 (24442) |
| 1981 | 1·07 (864958) | 1·06 (354298) | 1·07 (290228) | 1·07 (142096) | 1·13 (47913) | 1·15 (30347) |
| 1980 | 1·04 (888355) | 1·06 (351213) | 1·04 (278814) | 1·03 (149015) | 1·02 (59370) | 0·96 (49859) |

*Note*: Number of births are in parentheses.
*Data*: Annual report on the Vital Statistics (1991), National Bureau of Statistics, Economic Planning Board of Korea.

TABLE 7

*Predicted proportion of conception (D) and screening test (H) with various costs of screening test (College educated women)*

| Cost of screening test | | Period 1 | 2 | 3 | 4 | 5[a] | Preg. | CEB | S.R. |
|---|---|---|---|---|---|---|---|---|---|
| $TC=0$ | $D$ | 1·00 | 0·94 | 0·72 | 0·44 | 0·30 | 3·56 | 1·83 | inf. |
| | $H$ | 1·00 | 1·00 | 1·00 | 1·00 | 1·00 | | | |
| $TC=30$ | $D$ | 1·00 | 0·89 | 0·53 | 0·25 | 0·16 | 2·92 | 2·02 | 2·91 |
| | $H$ | 0·03 | 0·88 | 1·00 | 1·00 | 1·00 | | | |
| $TC=40$ | $D$ | 1·00 | 0·86 | 0·45 | 0·21 | 0·13 | 2·74 | 2·27 | 1·64 |
| | $H$ | 0·00 | 0·16 | 0·90 | 1·00 | 1·00 | | | |
| $TC=50$ | $D$ | 1·00 | 0·86 | 0·42 | 0·18 | 0·12 | 2·65 | 2·39 | 1·33 |
| | $H$ | 0·00 | 0·00 | 0·44 | 0·88 | 1·00 | | | |

*TC*: Monthly cost (in 1000 won) during the period (24 months) when the screening test is taken.
Preg: Average number of pregnancy.
CEB: Children ever born.
S.R.: Male–Female child ratio among children born.
*D*: The proportion who choose to conceive.
*H*: The proportion, among those who choose to conceive, who choose to take the test.
[a] There are very few who choose to conceive in periods 6 and 7.

The number of conceptions, number of live births, and the sex ratio for alternative test costs are also computed in Table 7. It is assumed that the probability of any conception being a boy is 0·515, that the test is perfectly accurate; and that the female foetuses, if tested, are aborted. As the test cost becomes cheaper, the number of live births decreases, while the number of conceptions goes up. Consequently, the male–birth ratio increases. For example, the male-female birth ratio rises to 2·91 from 1·33 as the test cost decreases from 50 to 30.

## V. CONCLUSIONS

This paper estimates the value of children by gender and age using a dynamic programming model. The underlying hypothesis is that the observed fertility outcomes for any couple are the solutions to their life-cycle optimization problem. Estimated value of children is interpreted as a combined net value, both pecuniary and non-pecuniary. The model is estimated using data from the 1980 Korean Population Census.

The empirical findings in this research indicate that parental valuation of children varies according to a child's gender and age, and own education levels. Although at young ages boys impose relatively higher costs, they are preferred to girls because of greater expected support in old age. Furthermore, the analysis suggests that better-educated women not only expect higher costs of rearing young children but also anticipate higher benefits from them when grown than less-educated women. Overall, old-age support from mature sons appears to be the most important influencing factor in parental decisions on fertility among Korean women. Simulations show that as old-age income, the social security system, or the financial market improves, parents are less concerned about having additional children, even those who have only girls. The continuous decline of the fertility rate in Korea over the last three decades may be the result of this development.

As the estimation results suggest, the preference for sons in Korea is still strong. Therefore, selective abortions subsequent to a screening test of foetal gender, which has become widely available in recent years, bring a new aspect to the problem of fertility choice. Simulations suggest that the sex ratio will increase further in the future, if the costs of the screening test and abortion decrease while the differential value of children by sex is maintained. The dramatic increase of the male–birth ratio in Korea during the late 1980's provides evidence of this development.

How might the sex ratio change in future? Will the value of girls increase relative to that of boys as the number of females decreases relative to that of males? What will be the effects of changes in income, education, and other elements of the socioeconomic environment on the sex ratio? How effective will the legal or institutional regulations on the pre-screening test or gender-selective abortions be? These are promising questions for future research.

Finally, it should be noted that the econometric model in this paper has a very restrictive structure. This is mainly in order to make its estimation computationally feasible. More flexible parameter structures, such as a finer division of values of children by age, incorporation of imperfect birth control and unobserved heterogeneity, and consideration of uncertainties in income schedule, are desirable. Applications of the method developed in Hotz and Miller (1993) could make promising future work.

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