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The Early Bird gets the Worm? Birth Order Effects in a Dynamic Model of the Family

Elisabeth Gugl & Linda Welling

Department of Economics, University of Victoria

Victoria, B.C., Canada V8W 2Y2

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Abstract

Birth order effects are found in empirical work, but lack solid theoretical foundations in economics. Our new modeling approach to children provides this. Each child's needs change as it grows, and births are sequential. Each child has the same genetic make-up and parents do not favor one child over the other. Parental child care time lowers the caregiver's current and future wages; this opportunity cost varies across time. Benefits also vary, and when parental child care is a public input co-resident children allow economies of scope in child care. Birth order effects emerge from the changing benefits and costs.

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Authors' Contacts: Dept. of Economics, University of Victoria, P.O. Box 1700, STN CSC, Victoria, B.C., Canada, V8W 2Y2; FAX: (250) 721-6214. Gugl: e-mail: egugl@uvic.ca; Phone: (250) 721-8538. Welling: e-mail: lwelling@uvic.ca; Phone: (250) 721-8546.

"The great advantage of living in a large family is that early lesson of life's essential unfairness." ~Nancy Mitford (http://www.quotegarden.com/family.html)

I. INTRODUCTION

Birth order effects, well established in both the academic and popular psychology literature, have received considerable attention in recent empirical economics studies. For example, Ejrnæs and Pörtner (2004), Black, Devereux and Salvanes (2005), Conley and Glauber (2006), and Kantarevic and Mechoulan (2006) find significant differences between first-born and later-born children in outcomes -- such as educational attainment and/or earnings; Price (2008) finds differences in inputs, even after controlling for family size. In general, the first-born in the family is advantaged. Hanushek (1992) suggests that these differences arise because children of different birth order within the same family are born into different intellectual environments, with later-borns entering less stimulating environments. Price (2008) looks at quality time that parents spend with each child in multiple-child families, and finds that children of higher birth order receive less quality time with parents, at any given age, than do children of lower birth order at the same age. Zajonc (1976) suggests that older siblings partly replace parents in providing some of this quality time; this benefits the first-borns, because they have the opportunity to be teachers from an early age**.** Theoretical economic models of the family are typically atemporal when it comes to the decision of how much of the family's resources to devote to children, and hence birth order effects do not emerge endogenously.

Our paper fills an important gap in the theoretical literature on families with children by explicit consideration of the temporal production of both the child's well-being and its human capital, and the influence of birth order on the production conditions for children who are close in age.

We show cases in which the first-born receives more resources overall than the second, so the second-born never has higher utility than the first-born, at any stage (Proposition 1). In this case we can make clear predictions about outcomes as well as inputs, and we would expect tests to reveal higher scores of the first-born regardless of the age at which they are administered. In other cases the mix of resources devoted to older children differs with birth order, with ambiguous predictions for outcomes at some ages (Proposition 2a) or all ages (see e.g. Propositions 2b, 3).

We investigate the trade-off parents make between spending time with children and working for income to purchase consumption goods for family members. We consider a three-stage model of parental decision-making. A family has two children, who are born sequentially. Older children have different needs than younger ones, so the sequential nature of child rearing matters. Each child spends two periods with their parents: the first-born is a single child in its first period of life, and an older sibling in its second; the second-born is a younger sibling in its first period, and the sole child in the household in its second. Thus each child spends one period with parents and a sibling, and one period alone with its parents; the children differ with respect to the sequencing of these two phases.

In the second period the presence of two children, of different ages and with different needs, but both requiring some supervision time, raises the issue of economies of scope in child care.[1] Is a given amount of parental child care as productive if shared by two children, rather than devoted to one? There is little direct evidence on the nature of the home production function for child quality, but Mocan (1997) found evidence suggesting the existence of both scale and scope economies in the production functions for day care centers. In the main body of the paper we assume economies of scope for parents.[2]

Parents care about both the contemporaneous "utility" of each child, and their well-being as adults; we assume no societal or personal biases in favor of either child. We refer to child outcomes as "utility", although this can equally well be interpreted as other measures which are functions of parental inputs: for example, adult human capital or earnings, or standardized test scores. The utility of each child, in both stages of childhood and as an adult, depends on the time spent with parents and the goods purchased for them. Hence resources directed to children from the full family budget have both a consumption and an investment component for both the parents and the children. This distinction between current and adult well-being allows us to compare children at different stages. It is also important when we allow for family size effects. Under these assumptions, both the financial and time resources parents devote to their children differ with birth order: it is not optimal for parents to treat the first and second-born the same. Birth order differences in inputs arise because both the benefits and the opportunity costs of parental child care vary over time, depending on the current wage rate, the anticipated growth in wages over time, and the particular inputs required by children at each stage.

In the following section we discuss our assumptions on the process of child-rearing. We then present our three-period model, and formalize our assumptions on child utility for younger, older, and adult children, respectively. We then set out our assumptions on parents. Finally, we develop the contemporaneous budget constraints. Section III presents the results derived from solving the parents' three-period decision problem; in this section we also explain how the key assumptions drive our results and discuss empirical implications. Conclusions and extensions are in section IV.

Child-Rearing as Sequential Production

The sequential nature of child rearing is crucial to the development of our results. Our model is based on three fundamental assumptions:

(1) Children develop in stages, and their needs change as they grow. We simplify this process by distinguishing two periods in a dependent child's life. In the first period a child's dominant need is time spent with them; in the second period, parental time remains an essential input, but the child also needs consumption goods. The assumed declining importance of the time input is consistent with Waldfogel (2006), who summarizes evidence that suggests that interaction with the mother (primarily) is of primary importance in the first three years, whereas for the second half of the pre-school years good nutritional habits and socialization with peers becomes important as well. Recent data on Australian time use reported in Craig and Bittman (2008), showing that the age of the youngest child was more important than the number of children in the determination of parental time allocated to child care, is consistent with parents acting as if this is true.[3]

(2) Child care can be provided by parents, or purchased, but parental time is more valuable in producing child outcomes than is the same amount of time provided by others. There is a large empirical literature emphasizing the importance of parental (or more often maternal) time spent with the very young child.[4] However, theoretical models have not yet captured this distinction. We introduce this feature by making parental care for a younger child more productive than non-parental care.

(3) Children require immediate and continuous attention. In most models parents choose the quality and quantity of children simultaneously. Sequential childbearing and different needs of children of different ages suggest that multiple children should be viewed as joint products in household production, with the production mix varying over time. Our model makes explicit the sequential nature of decisions. Thus the first-born receives parental investments before the

second child arrives, and investment in the last-born continues after the first-born is fully grown and self-sufficient.[5]

A fourth key component of our model is that parental child care has an opportunity cost of foregone current and future earnings. The time each parent spends caring for a child affects not only current household income but also this parent's future wage rates and, therefore, the potential household earnings in each subsequent period. While this "family wage gap' is well-documented empirically,[6] most of the theoretical literature has assumed a fixed labor supply and so cannot capture this effect; Willis (1973) is an early exception. We explicitly incorporate both current and future implications of this time investment in a dynamic framework.

In a recent series of papers Cunha and Heckman (2007), along with various co-authors, have drawn on the psychological literature which stresses that human capital is multi-dimensional (at least cognitive and non-cognitive), and investment at particular stages/ages of childhood can be critical for adult ability in different dimensions. Their simplest theoretical model has two stages of childhood. In contrast to our model, they consider only financial investments in a single child. Multiple stages of development are important in their model because the production technology in the second stage can depend on inputs in the first stage; final adult utility depends on this cumulative investment. In section IV we present a first step to bridging the gap between our birth order model and their work.

II. THE MODEL

The family consists of two adults and two children. Parents make decisions over three periods. Births are deterministic and sequential: the first child is born in the first period, and the second in the second period. A child spends two periods with his or her parents, and then becomes a self-sufficient adult. The time path of family composition, then, is

Period 1 (k = 1): wife ($i = w$), husband ($i = h$), young first-born

Period 2 (k = 2): wife, husband, older first-born, young second-born

Period 3 (k = 3): wife, husband, older second-born; independent adult first-born.

Parents maximize their joint intertemporal utility. In each period they allocate their time between work and caring for their child(ren); we denote the time parent *i* spends with child *j* in period *k* by $t_{ik}^{j}, k = 1,2,3.$ Parents also choose consumption goods for themselves (x_k^p), and their children (x_k^j) . They care about the well-being of their independent adult children as well as of their children living at home. In this section we first describe the utility function of a child, then that of the parents. We then specify the household budget constraints. In the next section we analyze the parents' decisions**.**

Child's Utility

We differentiate the first and second-born children by superscripts: *a* denotes the child born in the first period and *b* the child born in the second period. Let $u_k^j, \quad j = a,b$ denote the utility of child *j* in period *k*. We assume $u_1^b = 0 = u_3^a$: in period k = 1 the unborn second child has utility of zero, and in period k = 3 the first-born is an adult rather than a child, with a distinct utility function specified below. Child utility is produced differently at different ages. While a dependent child requires both time with adults (t_k^j) and consumption goods (x_k^j), the relative importance of these two broad categories changes as the child grows.

Younger Child. To focus attention on the different production technologies, we assume that in the first stage of life a child needs only supervision equivalent to the time available to one adult; we normalize this time to one. Parents can provide child care themselves, or they can outsource this task by hiring a nanny or enrolling the child in paid care. Let t_{nk}^j be the time a younger child spends in non-parental care in period k = 1, 2.[7] Then the household's *kth*-period child care time constraint for a younger child *j* is

(1) $$t_{wk}^{j} + t_{hk}^{j} + t_{nk}^{j} = 1, \quad k = 1, 2.$$

Utility depends on the time the parents spend with the child. We assume that parental child care produces higher child utility than the same amount of time in non-parental care. Parents are perfect substitutes in child care; we focus on the sum $t_{pk}^{j} = t_{wk}^{j} + t_{hk}^{j}$. Using (1), assuming that parental time is more productive by a factor of *p*, the utility in period *k* of a younger child *j* is

(2) $$u_{k}^{j} = Y(t_{Yk}^{j}), \quad t_{Yk}^{j} = (p-1)t_{pk}^{j} + 1, \quad p > 1, \quad t_{pk}^{j} \in [0,1]$$

where $Y(\cdot)$ is a strictly concave, at least twice differentiable and increasing function. The variable $t_{Yk}^{j} \in [1, p]$ represents the "quality units" of supervision time for the younger child.[8]

Older Child. In the second period of life, a child no longer requires constant supervision; utility depends on both the child's consumption of private goods and interaction with parents.[9] As before, parents are perfect substitutes in child care. The utility in period *k* of an older child *j* is

(3) $$u_{k}^{j} = O\left(t_{pk}^{j}, x_{k}^{j}\right),$$

where $O(\cdot,\cdot)$ is strictly concave, twice differentiable and increasing in both variables, and its cross partials are non-negative.

Adult Child. After two periods as a dependant, the child is a self-sufficient adult who requires no further input from the parents.[10] Utility is a function of the child's earning potential, which is a function of the human capital of the child. Human capital depends on the parental time spent with the child in each prior stage, as well as the amount of private goods consumed by the older child. An adult child's utility is

(4) $$u_{A}^{a} = A\left(t_{p1}^{a}, t_{p2}^{a}, x_{2}^{a}\right), \qquad u_{A}^{b} = A\left(t_{p2}^{b}, t_{p3}^{b}, x_{3}^{b}\right)$$

where $A(\cdot,\cdot,\cdot)$ is a strictly concave, increasing and at least twice differentiable function, with non-negative cross partials. The latter assumption is particularly appealing when it comes to the impact of parental child care in the first stage on the productivity of second-stage resources.

Parents' Utility

We assume a joint utility function for the parents in each period denoted by u_k. Utility depends on both parents' private consumption in period k (denoted by x_k^p) and the contemporaneous utility of any dependent children. Moreover, we assume utility in period k =1, 2, 3 is given by

(5) $$u_k = u(u_k^a, u_k^b, x_k^p) = g(u_k^a + u_k^b) + f(x_k^p)$$

where $g(\cdot)$ and $f(\cdot)$ are both concave, increasing, and at least twice differentiable functions. In their planning, parents also consider the well-being of their adult children, so their joint intertemporal utility is given by

(6) $$U = u_1 + u_2 + u_3 + u_A^a + u_A^b.$$

Parents have an intertemporal discount factor of one, so their utility in future periods weighs as heavily as the current period in their decisions. This implies that they care about child utility tomorrow as much as they care about child utility today. When $g(u_k^a + u_k^b) = u_k^a + u_k^b,$ parents, in their preferences, value each child over its entire life span equally. These assumptions would be natural in the case of twin births, and are also appealing when births are sequential.[11] With $g(\cdot)$ strictly concave, parents' marginal utility of a child in period k depends on whether or not a sibling is co-resident. We interpret this effect as a family size effect, while an income effect on resources devoted to children is introduced when $f(\cdot)$ is strictly concave.

Full Budget Constraints

There are two uses for parent *i's* time in any period: child care (t_{ik}), and labor force participation

(l_{ik}). Time available to each parent in any period is normalized to one, so

(7) $$t_{ik} + l_{ik} = 1.$$

In the first period, parent *i* is employed at wage rate w_{i1}. The husband has an initial absolute advantage in earnings: $w_{w1} < w_{h1}$. The wage rate in each subsequent period is weakly increasing in the time spent in the labor force in the previous period:

(8) $$w_{ik} = w_{ik-1}(1+\pi l_{ik-1}), \quad \pi \geq 0; \quad k = 2,3.$$

For $\pi > 0,$ earnings in *k* = 2, 3 depend on past as well as current choices. While the parents' wage rates grow, we assume non-parental child care can be purchased for $n_k = n$ dollars per unit of time, and a unit of the private consumption good for both parents and children has a price of one in each period. With no borrowing or saving, the household faces three budget constraints, one for each period:[12]

(9) $$x_1^p + nt_n^a = w_{w1}l_{w1} + w_{h1}l_{h1} = \sum_{i=w,h} w_{i1}l_{i1}$$

(10) $$x_2^p + x_2^a + nt_n^b = \sum_{i=w,h} w_{i1}\left(1+\pi l_{i1}\right)l_{i2}$$

(11) $$x_3^p + x_3^b = \sum_{i=w,h} w_{i1}\left(1+\pi l_{i1}\right)\left(1+\pi l_{i2}\right)l_{i3}$$

III. PARENTAL CHOICES

As parents are perfect substitutes in the production of child utility, efficiency dictates that the spouse with the lower wage rate in period *k* is that period's primary caregiver, while the other parent is the primary wage earner. We assume parameters such that the optimal time allocation has the latter working full time, and the former part-time, for pay; by construction, the wife always provides parental child care. Thus we have $l_{hk} = 1$ and $t_{pk} = t_{wk} \in (0,1), k = 1,2,3;$ this also implies that $t_{Yk} = (p-1)t_{wk} + 1$.

With maternal child care a public input, the efficient outcome is determined by choices of time $\{t_{w1}^{a}, t_{w2}, t_{w3}^{b}\}$ and private goods $\{x_1^p, x_2^p, x_3^p, x_2^a, x_3^b\}$ which maximize $\sum_{k=1}^{3} u_k + u_A^a + u_A^b$ subject to the time and budget constraints above. We first consider the case where both $g(\cdot)$ and $f(\cdot)$ are linear, i.e. $u(u_k^a, u_k^b, x_k^p) = u_k^a + u_k^b + x_k^p$, so there are neither income effects on resources devoted to children nor any family size effect. We then generate income effects by assuming $f(\cdot)$ is strictly concave. Finally, we consider a family size effect together with income effects by assuming both $g(\cdot)$ and $f(\cdot)$ are strictly concave. All proofs are in Appendix A.

<u>Income Effects Absent</u>

Let $u_k = x_k^p + u_k^a + u_k^b$.[13] Then the household chooses private consumption goods and the time allocation in each period to maximize:

$$\begin{aligned}
&\sum_{k=1}^{3}(x_k^p + u_k^a + u_k^b) + (u_A^a + u_A^b) \\
&= [x_1^p + Y(t_{Y1}^a)] \\
&\quad + [x_2^p + \left(O(t_{w2}, x_2^a) + Y\left(t_{Y2}^b\right)\right)] \\
&\quad + [x_3^p + O(t_{w3}^b, x_3^b)] \; + (A(t_{w1}^a, t_{w2}, x_2^a) + A(t_{w2}, t_{w3}^b, x_3^b))
\end{aligned}$$

subject to constraints (7) and (9)-(11).

We first derive birth order effects in resource allocation and outcomes with very restrictive assumptions.

Proposition 1. *Suppose non-parental child care is prohibitively costly, so* $t_n = 0$ *in all periods, and thus* $t_{w1}^a = t_{w2}^b = 1$. *Then*

i) it follows immediately that $u_1^a = u_2^b$ *: the first and second-born are equally well off when* *younger;*

ii) $u_2^a + u_A^a > u_3^b + u_A^b$ *: the sum of older child and adult utility is higher for the first-born than the second; and*

iii) further, $x_2^a \geq x_3^b$ *: parents never purchase fewer consumption goods for the older first-born than for the older second-born. Therefore,* $u_2^a > u_3^b$ *and* $u_A^a > u_A^b$ *: the first-born is better off than the second-born both as an older child and as an adult.*

Proof: see appendix.

While *(ii)* holds even if the cross partials of $O(\cdot,\cdot) + A(\cdot,\cdot,\cdot)$ are negative, *(iii)* depends on our assumption of non-negative cross partials. Proposition 1 follows from the combination of the lack of choice over child care arrangements for a younger child and the public nature of maternal child care. Since the mother provides full time care for the younger child in the second period, the older child receives full time care as well. In the third period, on the other hand, only an older child is present in the household and the mother chooses to work part time. As the opportunity cost of maternal time for the older child in period two is zero, while it is strictly positive in period three, the cost of producing utility for an older child is higher in the third period than in the second. With no income effects on either maternal care or child consumption goods, the second-born has both a lower utility when older and a lower earning ability than the first-born.

In the next proposition we allow non-parental child care and wage growth.

Proposition 2. *Suppose* $\pi \geq 0$*, so future wage rates weakly depend on current labor force participation. a) If the intertemporal cross partials in the utility function of adult children are zero, then*

i) $t_{w1}^a < t_{w2}$ *: parents devote more time to the younger second-born than the younger first-born;*

ii) $t_{w3}^b < t_{w2}$ *: parents devote more time to the older first-born than the older second-born;*

iii) $x_2^a \geq x_3^b$ *: parents purchase more consumption goods for the older first-born than the older second-born; and*

iv) $u_2^a > u_3^b$ *: the older first-born has higher utility than the older second-born.*

(b) If the intertemporal cross partials in the utility function of adult children are strictly positive, then the first-born and the second-born receive unequal treatment with respect to resources.

Proof: see appendix.

The presence of two children in the second period, but only one in the first, increases the benefit of second-period time spent at home. With no future labor market costs to parental child care $(\pi = 0)$, the effect on the intertemporal budget constraint of time spent on child care in any period is indistinguishable from that of money spent on goods for the child(ren) with price equal to w_{w1}. In this case, only current costs and benefits matter. Any differences in parents' choice of time in the first two periods will be determined by the benefits accruing from child care time and the contemporaneous opportunity cost.

With $\pi > 0,$ time spent in child care in the first period, out of the paid labor force, lowers the wage rate in the subsequent period, and hence lowers the opportunity cost of parental time in that period. On the other hand, forward-looking parents recognize that the more time they spent at home in the second period, the less will be the income loss from lower second-period wages, and so the lower will be the opportunity cost of first-period child care time.

Proposition 2 implies that allowing this intertemporal feedback effect makes only a quantitative, not a qualitative one, difference, compared to the resource allocation without wage growth. As we show in Appendix B, this is not true if maternal child care is a rival input: in that case there are no birth order effects without intertemporal wage growth. This is because the absence of the public input means that the opportunity cost of producing utility for a child in a given stage of development does not vary over time. Wage growth leads to birth order effects, with the first-born better off as a younger child but worse off as an older child**.**

If the adult child utility function is not additively separable in its arguments, then the complementarity between inputs in this function introduces ambiguity. While the same pattern of maternal time use may be chosen as in Proposition 2a, how this translates into older child consumption depends on the sizes of the partials of $\partial u_A^j / \partial x_k^j$ with respect to maternal child care in periods *k* and *k* - 1. With respect to outcomes, we would expect the second-born to have a higher utility when younger than the first-born. If the first-born has an advantage over the second-born this must stem from resources received when older. Adult utility depends on resources received at each stage, and so which sibling has a higher earning ability will depend on the relative importance of first-stage versus second-stage resources received.

Income Effects Present

We consider two different specifications giving rise to income effects:

i) $u_k = \left(u_k^a + u_k^b\right) + f\left(x_k^p\right)$, where $f'(0) = \infty,\ f'(\cdot) > 0,\ f''(\cdot) < 0.$ Here income effects arise from the diminishing marginal utility of parental consumption; and

ii) $u_k = g\left(u_k^a + u_k^b\right) + f\left(x_k^p\right),$ where $f'(0) = \infty;\ f'(\cdot), g'(\cdot) > 0;\ f''(\cdot), g''(\cdot) < 0.$ Here we also have family size effects because the marginal utility of a child depends on the presence of siblings, although only when they are co-resident.

We proceed by presenting propositions analogous to those in the previous section, highlighting the added complications arising from the additional assumptions.

Proposition 3. *Suppose non-parental child care is prohibitively costly, so* $t_n = 0$ *in all periods, and hence* $t_{w1}^a = t_{w2}^b = 1$. *Then* *i) it follows immediately that* $u_1^a = u_2^b$ *: the first and second-born are equally well off when younger;*

ii) $t_{w2}^a > t_{w3}^b$ *: the first-born receives more maternal time when older than does the second-born; and*

iii) If $\partial^2 O(t_k^j, x_k^j) / \partial x_k^j \partial t_k^j + \partial^2 A(t_{k-1}^j, t_k^j, x_k^j) / \partial x_k^j \partial t_k^j = 0$ *, so the marginal utility of consumption goods over the child's lifetime is independent of time spent with the older child, then* $x_2^a < x_3^b$ *: parents purchase more consumption goods for the older second-born than for the older first-born.*

Proof: see appendix.

Corollary. *Under the conditions of Proposition 3, if* $\partial^2 O(t_k^j, x_k^j) / \partial x_k^j \partial t_k^j + \partial^2 A(t_{k-1}^j, t_k^j, x_k^j) / \partial x_k^j \partial t_k^j > 0$ *, so the marginal utility of consumption goods over the child's lifetime is increasing in the time spent with the older child, it is possible that* $x_2^a \geq x_3^b$ *: parents purchase more consumption goods for the older first-born than for the older second-born.*

With $\pi > 0,$ even with the mother devoting all her time to child care, the husband's labor force participation means that the maximum amount parents can consume is higher in the third period than in the second. Under the conditions of Proposition 1, this difference has no impact on resource allocation towards children, and so birth order effects are unambiguous. The introduction of an income effect changes this. Comparison of Propositions 1 and 3 shows that the income effect introduces ambiguity in outcomes. With respect to resources, which child receives more consumption goods when older is ambiguous. This raises the possibility that the second child may be better off, both as an older child and as an adult. (The family size effect further decreases the parents' incentives to devote consumption goods to the older first-born; see appendix.)

In the previous section, introducing wage growth for the husband only would not alter the resource allocation towards children, because this was independent of income. Here a pure income change affects the equilibrium.

Proposition 4. *Consider an equilibrium allocation with* $\pi = 0$. *Now suppose that wage growth depends on full-time labor force participation, so that the husband but not the wife faces* $\pi > 0$. *As family full income increases only in later periods, and the intertemporal financial implications of maternal child care are unchanged, this benefits the second-born.*

Proof: see appendix.

Now we consider the consequences of adding wage growth for the wife.

Proposition 5. *Suppose i)* $\pi \geq 0$, *so future wage rates weakly depend on current labor force participation and ii) the cross partials in the utility function of adult children are not equal to zero. Then the first-born and the second-born receive unequal treatment with respect to resources.*

Proof: see appendix.

The allocation pattern derived under Proposition 2(a) may still emerge, but both the income effect and intertemporal complementarity introduce more ambiguity.

Discussion of Results

Consider the constellation of conditions which must hold if the two children are treated identically. In our model, this means that each child receives the same amount of parental care as their sibling did in the same developmental stage, and the same amount of the private consumption good as their sibling in the second stage: that is, $(t_{w1}^{a}, t_{w2}, x_{2}^{a}) = (t_{w2}, t_{w3}^{b}, x_{3}^{b})$. As maternal care is a pure public input, identical treatment implies $t^a_{w1} = t_{w2} = t^b_{w3}$: the mother spends the same amount of time in the labor force in each of the three periods. Given positive returns to human capital acquisition in the labor market ($\pi > 0$) and constant prices for outsourced child care and private consumption goods, this implies that full family income increases each period. Identical treatment of the two children further implies that, since spending on the older child's private consumption is the same in the second and third periods, the parents consume more private goods in the third period than in the second. They would do this if the costs of raising children were constant and there were no income effect on resources devoted to children. But the cost of raising children changes each period due the changing production technology and opportunity cost of time.

Why is identical treatment unlikely? In our setup, with maternal child care a public input**,** the contemporaneous benefit of spending additional time at home in the second period, caring for two children, is higher than the corresponding benefit in either the first or third period, when there is only one child needing care. This suggests that more time would be devoted to parental care in the second period. However, given the positive impact of current labor force participation on future market wages, there is also an intertemporal link between the periods, as the opportunity cost of second period maternal care is decreasing in first period maternal care. As shown in Propositions 1 and 2, removing this intertemporal link only strengthens our results by making equal treatment in outcomes less likely.

Empirical Relevance

Proposition 1 derives birth order effects when non-parental child care is not available. One implication of this is that over time, as alternative child care has become more available, we might expect to see birth order effects diminishing: later cohorts are born to parents who make more use of third party child care, reducing the "free riding" by the first-born on the mother's care for the younger sibling.

A similar result follows if *p* is large, so that parental time is much more effective than other child care in producing utility for a younger child. If families differ with respect to *p*, then the presence of birth order effects in cross-sectional data should be correlated with higher values of *p*.

Proposition 2 shows the importance of the role of economies of scope in maternal child care in determining resource allocation. Using data from the American Time Use survey and restricting the age range of children from 4 to 13, Price (2008) finds that many parents spend equal time with each of their children at any given point in time, and time spent with children typically decreases from one period to the other (as the children grow). Our result that maternal care is higher in the second period than in the first is not at odds with Price's findings as he does not consider families with a single young child. Price's finding is consistent with an extension of our model in which what is now the "second period" is split into more periods in which both children reside with their parents, andt children's needs for parental time diminish as they grow. One could also test our assumption of economies of scope by checking how often parents spend time with one child while the other sibling is present.

IV. CONCLUSIONS AND EXTENSIONS

This paper examines birth order effects. Parents do not favor one child over the other in their preferences, but may in their choices. We do not require that parents devote the same resources to each child in each developmental stage. Central to our findings of birth order effects is the assumption that spending on children must begin at birth. Moreover children's needs change as they grow, so that parents deal with different production functions for child quality as a child grows. In any period where children of different ages are present, the technology to produce the sum of child quality also changes compared to the technology with only one child present who is of the same age as one of the children in the two-siblings household. This effect would not be present if the siblings were twins, which is effectively assumed in much of the previous literature.

The central message of this paper is that unless parents restrict themselves to equal treatment, there will always be unequal treatment in inputs. We also show that when we take the sequential nature of births seriously, modeling unbiased parental preferences rules out many specifications of parental utilities.

<u>Adapting the CH Technology of Skill Formation</u>

CH (2007) present a two-period model of skill formation in which the cumulative effect of parental investments on adult human capital stocks is represented by a CES function. They focus on a single child, and investments in the two periods are purely financial; we add a second child, and consider time as well as money expenditures on children. In this section we modify a simple version of the CH model to consider the sequential production model above, and show that birth order effects emerge here as well.

To keep the analysis simple, suppose that parents allocate resources to household consumption goods and the production of adult human capital of their children. Human capital is a function of time spent with the children in each period, and the consumption goods of the older child:

(12) $$h^a = [\gamma(t_{w1}^a)^\varphi + (1-\gamma)(t_{w2}^{\alpha} x_2^{a^\beta})^\varphi]^{\frac{1}{\varphi}}$$

(13) $$h^b = [\gamma(t_{w2})^\varphi + (1-\gamma)(t_{w3}^{b^\alpha} x_3^{b^\beta})^\varphi]^{\frac{1}{\varphi}}$$

where $\varphi, \alpha + \beta < 1$. This function differs from that in CH because it retains our assumed resource needs in the two periods. As in CH, when ϕ is small, low investment in a child in the first period is not easily compensated for by higher second period investment, and high investment in the first period should be continued in the second.

The intertemporal decision problem becomes one of choosing the time and consumption goods allocations to maximize $\sum_{k=1}^{3} f(x_k^p) + (h^a + h^b)$, subject to the same budget constraints as before. This is clearly a special case of the problem discussed in section III, so the two children will be treated differently.

Probabilistic Second Birth and Spacing of Children

We assumed above that fertility was deterministic. Suppose instead that the birth of the second child is probabilistic rather than certain. The household's intertemporal objective function is now the expected utility of the parents. That is, parents maximize intertemporal utility knowing that they have one child in the first period, but are uncertain whether they will have a second child or not. Thus parents who, in the second period, have one child, and those with two children, will have made identical investments in the first period. In the second period, the uncertainty is resolved, and second-period maternal care for the first-born will depend on the existence of the second child: the first child will enjoy more maternal care if the second child is present and maternal care is a public input. This is consistent with Zajonc (1976), who notes that only children tend to perform less well than first-borns. Exploring this extension, and the implications of different spacing of children, is the subject of future research.

Is Maternal Time a Public Input?

A key factor in our analysis is the nature of the production function for child quality. Our focus here is on production within the household, and we simplified our analysis by explicitly assuming economies of scope in maternal child care, while assuming that any such benefits in third-party child care would not be passed on to parents. Our assumption that time is a public input may change if the spacing between the births of the two children is greater. The greater the spacing between children, the less likely it is that demands will overlap and the more likely that time becomes a rival input: Mocan (1997) reports evidence of economies of scope in day care centers between preschoolers and school-age children, and between infant-toddlers and preschoolers, but not between infant-toddlers and school-age children.

V. APPENDIX A: PROOFS

Throughout this section it is assumed that the husband spends all his time in employment in each period, that is $t_{hk} = 0, \quad k = 1,2,3.$

Income Effects Absent

Without income effects on child care and child consumption the objective function of parents is

$$\begin{aligned}
&\sum_{k=1}^{3}(x_k^p + u_k^a + u_k^b) + (u_A^a + u_A^b) \\
&= [x_1^p + Y(t_{Y1}^a)] \\
&\quad + [x_2^p + \left(O(t_{w2}, x_2^a) + Y\left(t_{Y2}^b\right)\right)] \\
&\quad + [x_3^p + O(t_{w3}^b, x_3^b)] \; + (A(t_{w1}^a, t_{w2}, x_2^a) + A(t_{w2}, t_{w3}^b, x_3^b))
\end{aligned}$$

where

$$\begin{aligned}
x_1^p &= (w_{w1} - n)(1 - t_{w1}^a) + w_{h1} \\
x_2^p + x_2^a &= (w_{w1}(1 + \pi(1 - t_{w1}^a)) - n)(1 - t_{w2}) + w_{h1}(1 + \pi) \\
x_3^p + x_3^b &= w_{w1}(1 + \pi(1 - t_{w1}^a))(1 + \pi(1 - t_{w2}))\left(1 - t_{w3}^b\right) + w_{h1}(1 + \pi)^2
\end{aligned}$$

Since maternal care is a public input, $t_{w2}^a = t_{w2}^b = t_{w2}$. The household's problem reduces to one of choosing the sequences of maternal care and private goods for each child: $\{t_{w1}^a, t_{w2}, t_{w3}^b, x_2^a, x_3^b\}$. The FOC's are:

$$\text{wrt } t^a_{w1}, \quad \left\{ \begin{array}{c} (\partial u^a_1/\partial t^a_{Y1})(p-1) + \partial u^a_A/\partial t^a_{w1} \\ -\left[\begin{array}{c} (w_{w1}-n) + \pi w_{w1}(1-t_{w2}) \\ +\pi w_{w1}(1+\pi(1-t_{w2}))(1-t^b_{w3}) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } t_{w2}, \quad \left\{ \begin{array}{c} \partial u^a_2/\partial t_{w2} + \partial u^a_A/\partial t_{w2} + \left(\partial u^b_2/\partial t^b_{Y2}\right)(p-1) + \partial u^b_A/\partial t_{w2} \\ -\left[\begin{array}{c} (w_{w1}-n) + \pi w_{w1}(1-t^a_{w1}) + \\ \pi w_{w1}(1+\pi(1-t^a_{w1}))(1-t^b_{w3}) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } t^b_{w3}, \quad \left\{ \begin{array}{c} \partial u^b_3/\partial t^b_{w3} + \partial u^b_A/\partial t^b_{w3} \\ -\left[\begin{array}{c} w_{w1} + \pi w_{w1}(1-t^a_{w1}) + \\ \pi w_{w1}(1+\pi(1-t^a_{w1}))(1-t_{w2}) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } x^a_2, \quad \partial u^a_2/\partial x^a_2 + \partial u^a_A/\partial x^a_2 - 1 = 0$$

$$\text{wrt } x^b_3, \quad \partial u^b_3/\partial x^b_3 + \partial u^b_A/\partial x^b_3 - 1 = 0$$

<u>Proof of Proposition 1.</u> When non-parental child care is not available, then $t^a_{w1} = t_{w2} = 1$ and the wife's wage rate is constant across time. Since maternal child care is a public input, $t^a_{w2} = 1$ and the sum of the first-born's utility when older and when an adult is equal to $O(1, x^a_2) + A(1,1, x^a_2)$. Utility maximization implies cost minimization and so we can first determine the cost of producing utility for a child in a given period. The cost to produce a certain level of $O(1, x^a_2) + A(1,1, x^a_2)$ depends on the price of child consumption in the second period only. In the third period, the cost to produce the same amount of $O(1, x^b_3) + A(1, t^b_{w3}, x^b_3)$ (the sum of the second-born's utility when older and when an adult) is always higher as both inputs, time and the consumption good, have a positive price, and the price of the consumption good is the same in both periods. Since the marginal rate of substitution between this sum for the first-born (second-born) and the parental consumption in the second period (third period) is constant and equal to

one, the marginal cost of producing these sums must be the same for both children. Since it is cheaper to produce a given level for the first-born and marginal cost is increasing, equal marginal cost implies a higher sum of older child and adult utility for the first-born than the second-born. Next we check whether we can compare older child utility and earning ability separately. Inspection of the FOC's wrt x_2^a and x_3^b, with $t_{w1}^a = t_{w2} = 1$ and $t_{w3}^b < t_{w2}$, shows that the first-born receives higher second-stage consumption if the cross partials between maternal care and child consumption are non-negative. Then the second-born has a lower utility when older and a lower adult earning ability than the first-born.

<u>Proof of Proposition 2.</u> (a) Suppose the adult child's utility function is additively separable in first and second-stage resource allocations, so intertemporal cross partials are zero, that is

$$\partial A / \partial t_{wk-1}^j \partial t_{wk}^j = 0 = \partial A / \partial t_{wk-1}^j \partial x_k^j .$$

(i) Note that for $\pi \geq 0$, the opportunity cost of maternal time is equal for $k = 1,2$ if $t_{w1}^a = t_{w2}$. When k = 2 the older child also benefits from maternal care, and hence the marginal benefit of maternal child care is higher in the second period than in the first. Concavity of functions Y and A then implies $t_{w1}^a < t_{w2}$.

(ii) For $t_{w3}^b < t_{w2}$: Suppose the opposite, so $t_{w3}^b > t_{w2}$. Then we can reallocate the resources devoted to the first-born older child and the second-born older child in the following way. Switch $\left(t_{w3}^b, x_3^b\right)$ and $\left(t_{w2}, x_2^a\right)$.[14] This changes neither the utility of the younger first-born (u_1^a) , nor the *sum* of the utilities of the older first and second-born, $u_2^a + u_3^b$. However, because t_{w2} increases, this switch increases the utility of the young second-born and the sum of adult utilities, $u_2^b + u_A^a + u_A^b$. Next we evaluate the change in parental consumption. There is no change in first-period parental consumption, x_1^p, nor in the total expenditure on child consumption goods,

$x_2^a + x_3^b$. The husband's earnings in the second and third period do not change either, so any change in the sum of second and third-period parental consumption depends on the change in the wife's earnings and in non-parental child care costs only. These amounts under the two scenarios are

$$w_{w2}(1 - t_{w2}) - n(1 - t_{w2}) + w_{w2}(1 + \pi(1 - t_{w2}))\left(1 - t_{w3}^b\right)$$

versus

$$w_{w2}\left(1 - t_{w3}^b\right) - n(1 - t_{w3}^b) + w_{w2}\left(1 + \pi\left(1 - t_{w3}^b\right)\right)(1 - t_{w2})$$

If $t_{w3}^b > t_{w2}$, then the second value is larger. Therefore the parents' objective function cannot be maximized at this assumed allocation. Thus, by contradiction, $t_{w2} \geq t_{w3}^b$. However, equal treatment in time when older would require equal treatment in child consumption goods and by inspection of the FOC's wrt x_2^a and x_3^b this can be ruled out. Thus $t_{w2} > t_{w3}^b$.

iii) Given $\partial O / \partial t_{wk}^j \partial x_k^j + \partial A / \partial t_{wk}^j \partial x_k^j \geq 0$ and $t_{w2} > t_{w3}^b$, from inspection of the FOC's wrt x_2^a and x_3^b we have $x_2^a \geq x_3^b$. Therefore $u_2^a > u_3^b$.

(b) Suppose the adult utility function is not additively separable in first and second-stage resource allocations, so intertemporal cross partials are not zero, that is

$$\partial A / \partial t_{wk-1}^j \partial t_{wk}^j \neq 0, \quad \partial A / \partial t_{wk-1}^j \partial x_k^j \neq 0.$$

Suppose $\{ t_{w1}^{a^*}, t_{w2}^{a^*}, x_2^{a^*} \} = \{ t_{w2}^{b^*}, t_{w3}^{b^*}, x_3^{b^*} \}$. Full economies of scope for maternal care and equal treatment together imply $t_{w1}^{a^*} = t_{w2}^* = t_{w3}^{b^*}$: the time the mother spends at home is the same regardless of family composition. However, comparing the FOC's wrt to maternal child care time in periods one and two shows that while the opportunity cost of maternal time is the same, there are greater marginal benefits of maternal time in period two. Hence we have a contradiction.

<u>Income Effects Present</u>

We consider two specifications for u_k:

$$\begin{aligned} (i) \quad u_k &= u_k^a + u_k^b + f(x_k^p) \\ (ii) \quad u_k &= g\left(u_k^a + u_k^b\right) + f(x_k^p) \end{aligned}$$

where

$$\begin{aligned} x_1^p &= (w_{w1} - n)(1 - t_{w1}^a) + w_{h1} \\ x_2^p + x_2^a &= (w_{w1}(1 + \pi(1 - t_{w1}^a)) - n)(1 - t_{w2}) + w_{h1}(1 + \pi) \\ x_3^p + x_3^b &= w_{w1}(1 + \pi(1 - t_{w1}^a))(1 + \pi(1 - t_{w2}))\left(1 - t_{w3}^b\right) + w_{h1}(1 + \pi)^2 \end{aligned}$$

Since *(ii)* reduces to *(i)* when $g'(\cdot) = 1$, we present only the FOC's of the parents' decision problem for the more general function:

$$\text{wrt } t^a_{w1}, \quad \left\{ \begin{array}{c} g'(u^a_1)(\partial u^a_1/\partial t^a_{Y1})(p-1) + \partial u^a_A/\partial t^a_{w1} \\ -\left[\begin{array}{c} f'(x^p_1)(w_{w1}-n) + f'(x^p_2)\pi w_{w1}(1-t_{w2}) \\ +f'(x^p_3)\pi w_{w1}(1+\pi(1-t_{w2}))(1-t^b_{w3}) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } t_{w2}, \quad \left\{ \begin{array}{c} g'\left(u^a_2+u^b_2\right)\left((\partial u^a_2/\partial t_{w2}) + (\partial u^b_2/\partial t^b_{Y2})(p-1)\right) + \partial u^b_A/\partial t_{w2} + \partial u^a_A/\partial t_{w2} \\ -\left[\begin{array}{c} f'(x^p_2)(w_{w1}(1+\pi(1-t^a_{w1}))-n) + \\ f'(x^p_3)\pi w_{w1}(1+\pi(1-t^a_{w1}))(1-t^b_{w3}) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } t^b_{w3}, \quad \left\{ \begin{array}{c} g'\left(u^b_3\right)(\partial u^b_3/\partial t^b_{w3}) + \partial u^b_A/\partial t^b_{w3} \\ -f'(x^p_3)\left[\begin{array}{c} w_{w1} + \pi w_{w1}(1-t^a_{w1}) + \\ \pi w_{w1}(1+\pi(1-t^a_{w1}))(1-t_{w2}) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } x^a_2, \quad g'\left(u^a_2+u^b_2\right)(\partial u^a_2/\partial x^a_2) + \partial u^a_A/\partial x^a_2 - f'(x^p_2) = 0$$

$$\text{wrt } x^b_3, \quad g'\left(u^b_3\right)(\partial u^b_3/\partial x^b_3) + \partial u^b_A/\partial x^b_3 - f'(x^p_3) = 0$$

<u>Proof of Proposition 3.</u> When non-parental child care is not available, then $t^a_{w1} = t_{w2} = 1$ and the wife's wage rate is constant across time. Relevant FOC's are

$$\begin{array}{ll} \text{wrt } t^b_{w3}, & g'\left(O(t^b_{w3},x^b_3)\right)(\partial O(t^b_{w3},x^b_3)/\partial t_{w3}) + \partial A(1,t^b_{w3},x^b_3)/\partial t^b_{w3} - f'\left(x^p_3\right)w_{w1} = 0 \\ \text{wrt } x^a_2, & g'\left(O(1,x^a_2)+Y(t^b_{Y2})\right)(\partial O(1,x^a_2)/\partial x^a_2) + \partial A(1,1,x^a_2)/\partial x^a_2 - f'\left(x^p_2\right) = 0 \\ \text{wrt } x^b_3, & g'\left(O(t^b_{w3},x^b_3)\right)(\partial O(t^b_{w3},x^b_3)/\partial x^b_3) + \partial A(1,t^b_{w3},x^b_3)/\partial x^b_3 - f'\left(x^p_3\right) = 0 \end{array}$$

If $\partial^2 O(t^j_k,x^j_k)/\partial x^j_k \partial t^j_k + \partial^2 A(t^j_{k-1},t^j_k,x^j_k)/\partial x^j_k \partial t^j_k = 0$, then $x^b_3 > x^a_2$. Suppose not, so in equilibrium $x^b_3 \le x^a_2$. This implies $O(1,x^a_2)+Y(t^b_{Y2}) > O(t^b_{w3},x^b_3)$. By concavity of functions *O* and *A*, the assumption on the cross partials, and concavity of *g*, the first two terms of the FOC wrt x^a_2 are smaller than the first two terms of the FOC wrt x^b_3. Since $x^b_3 \le x^a_2$ implies $x^p_2 < x^p_3$, by concavity of f we have $f'\left(x^p_2\right) > f'\left(x^p_3\right)$. Thus, comparing the FOC's wrt x^a_2 and x^b_3, we have a contradiction since these two first order conditions cannot hold simultaneously. Only with positive cross partials could x_2^a be larger than x_3^b.

Family Size Effect. Comparing the FOC's of *(i)* with the FOC's of *(ii)*, we see in the latter case what we label a family size effect: the marginal utility parents derive from a child in period *k* now depends on the utility of a co-resident sibling. Evaluating the negative terms in each equation at the equilibrium resource allocation with *(i)* leads to the same negative values, and evaluating the marginal adult utility in each equation at the equilibrium resource allocation with *(i)* leads to the same positive values. What changes are the values of the first term in each equation and the ratio of the marginal utility of consumption of the older first-born to the marginal utility of consumption (maternal child care) of the older second-born. Suppose that under *(i)*, $O(1, x_2^a) = O(t_{w3}^b, x_3^b)$ and $g'\left(O(t_{w3}^b, x_3^b)\right) = 1.$ Then with *(ii)* the resource allocation to the second-born would not change, while due to $g'\left(O(t_{w3}^b, x_3^b) + Y(t_{Y2}^b)\right) < 1,$ the first-born would now receive less of the consumption good than before and thus be worse off.

Proof of Proposition 4. Let $\{t_{w1}^{a'}, t_{w2}^{'}, t_{w3}^{b'}, x_2^{a'}, x_3^{b'}\}$ be the equilibrium resource allocation to children when $\pi = 0$ for both the husband and the wife. Now assume $\pi > 0$ for the husband but not for the wife. At $\{t_{w1}^{a'}, t_{w2}^{'}, t_{w3}^{b'}, x_2^{a'}, x_3^{b'}\},$ when $\pi > 0$ both x_2^p and x_3^p are higher, with a larger absolute increase in the latter. Inspection of the FOC's at these values shows that such a change would decrease the negative terms in the second and third-period FOC's while leaving the positive terms unchanged. There would be no change in the first-period FOC. If the intertemporal cross partials of *A* are zero, first-period maternal child care would not change, but both maternal care and child consumption in the second and third periods would increase. If the intertemporal cross partials of *A* are greater than zero, first-period maternal care would increase as well because higher second-period resources for the first-born would then imply a higher marginal benefit of first-period maternal care in the first-born's adult utility. This is a secondary effect, while the second-born would benefit from first order effects, and so would benefit more from such a change in the family's income.

<u>Proof of Proposition 5</u>. Suppose $t^a_{w1} = t_{w2} = t^b_{w3}$ and $x^a_2 = x^b_3$ are equilibrium choices. Then $x^p_3 > x^p_2$, and therefore $f'(x^p_3) < f'(x^p_2)$. However, then the FOC's wrt x^a_2 and x^b_3 cannot hold simultaneously. So we have a contradiction.

VI. APPENDIX B: RIVAL INPUTS

We present in this section results based on assumptions that parallel those in Proposition 2 in the main body of the paper except that maternal time is rival**.** This section shows that without an intertemporal feedback through wage growth, birth order effects do not appear without income effects on resources devoted to children, because the opportunity cost of producing child utility in any given period is the same. The first order conditions are given by

$$\text{wrt } t_{w1}^a,\quad \left\{ \begin{array}{c} (\partial u_1^a/\partial t_{Y1}^a)(p-1) + \partial u_A^a/\partial t_{w1}^a \\ -\left[\begin{array}{c} (w_{w1}-n) + \pi w_{w1}(1-t_{w2}) \\ +\pi w_{w1}(1+\pi(1-t_{w2}^a - t_{w2}^b))(1-t_{w3}^b) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } t_{w2}^b,\quad \left\{ \begin{array}{c} \left(\partial u_2^b/\partial t_{Y2}^b\right)(p-1) + \partial u_A^b/\partial t_{w2}^b \\ -\left[\begin{array}{c} (w_{w1}(1+\pi(1-t_{w1}^a)) - n) + \\ \pi w_{w1}(1+\pi(1-t_{w1}^a))(1-t_{w3}^b) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } t_{w2}^a,\quad \left\{ \begin{array}{c} \partial u_2^a/\partial t_{w2}^a + \partial u_A^a/\partial t_{w2}^a \\ -\left[\begin{array}{c} w_{w1}(1+\pi(1-t_{w1}^a)) + \\ \pi w_{w1}(1+\pi(1-t_{w1}^a))(1-t_{w3}^b) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } t_{w3}^b,\quad \left\{ \begin{array}{c} \partial u_3^b/\partial t_{w3}^b + \partial u_A^b/\partial t_{w3}^b \\ -\left[\begin{array}{c} w_{w1} + \pi w_{w1}(1-t_{w1}^a) + \\ \pi w_{w1}(1+\pi(1-t_{w1}^a))(1-t_{w2}^a - t_{w2}^b) \end{array} \right] \end{array} \right\} = 0$$

$$\text{wrt } x_2^a,\quad \partial u_2^a/\partial x_2^a + \partial u_A^a/\partial x_2^a - 1 = 0$$

$$\text{wrt } x_3^b,\quad \partial u_3^b/\partial x_3^b + \partial u_A^b/\partial x_3^b - 1 = 0$$

Proposition 6. *Suppose* $\pi = 0$*, so future wage rates are independent of current labor force participation. Then we have equal treatment.*

Proof. *By inspection, we see that the FOC's wrt* t_{w1}^a *and* t_{w2}^b *are symmetric, as are those wrt* t_{w2}^a *and* t_{w3}^b*, and wrt* x_2^a *and* x_3^b*.*

If time is rival and $\pi = 0,$ then the opportunity cost of maternal time depends only on the developmental stage of the child, not the time period.

Proposition 7. *Suppose i)* $\pi > 0$*, so future wage rates increase with current labor force participation; and ii) the intertemporal cross partials in the utility function of an adult child are* *zero. Then the first-born receives more when younger and less when older than the second-born.*

Proof. *From the FOC's wrt* t_{w1}^{a} *and* t_{w2}^{b}*, observe that the opportunity cost of maternal child care for the younger child in the first period is*

$$c_1^y = (w_{w1} - n) + \pi w_{w1}(1-(t_{w2}^a + t_{w2}^b)) + \pi w_{w1}(1+\pi(1-(t_{w2}^a + t_{w2}^b))(1-t_{w3}^b)$$

and in the second period is

$$c_2^y = (w_{w1} - n) + \pi w_{w1}(1-t_{w1}^a) + \pi w_{w1}(1+\pi(1-t_{w1}^a))(1-t_{w3}^b).$$

By inspection, $c_1^y \geq c_2^y$ *iff* $(t_{w2}^a + t_{w2}^b) \leq t_{w1}^a$. *From the FOC's wrt* t_{w2}^a *and* t_{w3}^b*, the opportunity cost of maternal child care for the older child in the second period is*

$$c_2^O = w_{w1}(1+\pi(1-t_{w1}^a))(1+\pi(1-t_{w3}^b))$$

and in the third period is

$$c_3^O = w_{w1}\left(1+\pi(1-t_{w1}^a)\right)(1+\pi(1-(t_{w2}^a + t_{w2}^b))).$$

By inspection, $c_2^O \geq c_3^O$ *iff* $(t_{w2}^a + t_{w2}^b) > t_{w3}^b$.

i) For $u_2^b < u_1^a$ *: Suppose* $t_{w1}^a \leq t_{w2}^b$. *Then the marginal benefits of maternal time are greater or equal in the FOC wrt* t_{w1}^a *compared to that wrt* t_{w2}^b*, while* c_1^y*, the opportunity cost of maternal time, is lower for* t_{w1}^a *than it is for* t_{w2}^b. *Hence* $t_{w1}^a \leq t_{w2}^b$ *cannot be part of the solution and we must have* $t_{w2}^b < t_{w1}^a$ *and* $u_2^b < u_1^a$.

ii)For $u_2^a < u_2^b$*: First note that with contemporaneous non-negative cross partials of functions O and A, and* $t_{w2}^a < t_{w3}^b$ *it follows that* $x_{w2}^a \leq x_{w3}^b$ *and thus* $u_2^a < u_2^b$. *It remains to show that* $t_{w2}^a < t_{w3}^b$. *Suppose not, so* $t_{w3}^b < t_{w2}^a$. *Then we can reallocate resources devoted to the first-born* *older child and the second-born older child by switching* $\left(t_{w3}^b, x_3^b\right)$ *and* $\left(t_{w2}^a, x_2^a\right)$.[15] *This would not change the sum of the children's utilities over their lifespan. Also, there is no change in* x_1^p, *nor in the expenditure on child consumption goods,* $x_2^a + x_3^b$, *nor in non-parental child care. The husband's earnings in the second and third period do not change either, so any change in the sum of second and third-period parental consumption depends only on the change in the wife's earnings. These amounts under the two scenarios are:*

$$w_{w2}(1-(t_{w2}^a + t_{w2}^b)) + w_{w2}\left(1+\pi(1-(t_{w2}^a + t_{w2}^b))\right)\left(1-t_{w3}^b\right)$$

versus

$$w_{w2}\left(1-\left(t_{w3}^b + t_{w2}^b\right)\right) + w_{w2}\left(1+\pi\left(1-\left(t_{w3}^b + t_{w2}^b\right)\right)\right)(1-t_{w2}^a)$$

If $t_{w3}^b < t_{w2}^a$, *then the second value is larger. Therefore the parents' objective function cannot be maximized at the assumed allocation. Thus, by contradiction,* $t_{w2}^a \le t_{w3}^b$. *However, by inspection of FOC's wrt* x_2^a *and* x_3^b, *equal treatment in time when older would require equal treatment in child consumption goods. This, however, contradicts equal treatment in time when considering the FOC's wrt* t_{w2}^a *and* t_{w3}^b. *Thus* $t_{w2}^a < t_{w3}^b$.

If the intertemporal cross partials of *A* wrt time and consumption goods are strictly positive, the prediction could change to the benefit of the first-born.

REFERENCES

Black, S. E., P. J. Devereux, and K. G. Salvanes. "The More the Merrier? The Effect of Family Size and Birth Order on Children's Education." *Quarterly Journal of Economics*, 120(2), 2005, 669-700.

Conley, D., and R. Glauber. "Parental Educational Investment and Children's Academic Risk - Estimates of the Impact of Sibship Size and Birth Order from Exogenous Variation in Fertility." *Journal of Human Resources*, 41(4), 2006, 722-37.

Craig, L., and M. Bittman. "The incremental time costs of children: An analysis of children's impact on adult time use in Australia." *Feminist Economics*, 14(2), 2008, 59-88.

Cunha, F., and J. J. Heckman. "The Technology of Skill Formation." National Bureau of Economic Research working paper 12840, 2007.

Ejrnæs, M., and C. C. Pörtner. "Birth Order and the Intrahousehold Allocation of Time and Education." *Review of Economics and Statistics*, 86(4), 2004, 1008-19.

Guryan, J., E. Hurst, and M.S. Kearney. "Parental Education and Parental Time with Children." National Bureau of Economic Research Working Paper 13993, 2008.

Hanushek, E. A "The Trade-off between Child Quantity and Quality." *Journal of Political Economy*, 100(1),1992, 84-117.

Heckman, J. J. "The economics, technology and neuroscience of human capability formation." National Bureau of Economic Research working paper 13195, 2007.

Huang, F. "Child Development Production Function." working paper 24-2006, Singapore Management University, School of Economics, 2006.

Kantarevic, J., and S. Mechoulan. "Birth Order, Educational Attainment, and Earnings - An Investigation Using the PSID." *Journal of Human Resources*, 41(4), 2006, 755-77.

Price, J. “Parent-Child Quality Time: Does Birth Order Matter?” *Journal of Human Resources,* 43(1), 2008, 240-65.

Pollak, R. “Allocating Time: Individuals’ Technologies and Household Technology.” mimeo, Department of Economics and Olin School, Washington University in St. Louis, 2008.

Pollak, R., and M. L. Wachter. “The Relevance of the Household Production Function and Its Implications for the Allocation of Time.” *Journal of Political Economy*, 83(2), 1975, 255-78.

Ruhm, Ch. J. “The Economic Consequences of Parental Leave Mandates: Lessons from Europe.” *Quarterly Journal of Economics*, 112(1), 1998, 285-317.

Ruhm, Ch. J. “Parental Leave and Child Health,” *Journal of Health Economics*, 19(6), 2000, 931-60.

Todd, P. E., and K. I. Wolpin. “The Production of Cognitive Achievement in Children: Home, School, and Racial Gap Test Scores.” *Journal of Human Capital*, l(1), 2007, 91-136.

Waldfogel, J. *what children need,* Cambridge, MA: Harvard University Press, 2006.

Willis, R. J. “A New Approach to the Economic Theory of Fertility Behavior.” *Journal of Political Economy*, 81(2), part 2: New Economic Approaches to Fertility, 1973, S14-S64.

Zajonc, R. B. “Family Configuration and Intelligence.” *Science*, New Series, 192(4236), 1976, 227-236.

FOOT NOTES

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1. If the children were twins, the appropriate concept would be economies of scale.

2. Issues of economies of scope in household production in general are raised in Pollak and Wachter (1975) and Pollak (2008). Neither paper focusses on child care. In Appendix B we discuss the implications of removing this assumption.

3. See also Huang (2006) and Keane and Wolpin (2007) for related results.

4.See, e.g., Ruhm (1998; 2000). Using time use data, Guryan, Hurst and Kearney (2008) find that more educated parents spend more time in child care than their less educated counterparts.

5. Ejrnæs and Pörtner (2004) consider sequential fertility; parents decide on future children once they observe the nature of the current infant, but invest in all children simultaneously.

6. For example, Waldfogel (2006: 13) notes: "...women work shorter hours when they have children and are, if anything, paid less per hour than comparable women without children."

7. Recall there is no younger child in the household in the third period.

8. The data in Guryan *et al.* (2008) suggests that the value of p depends on education.

9. While time spent with the child by the parents in the first period contributes to the child's earning potential and therefore the adult utility of the child, we assume that the older child's utility is independent of this input. This is a strong assumption but we find it reasonable to

distinguish between a child's utility when it is still a child and has a high discount factor and that child's human capital that translates into utility most significantly in later periods.

10. Wishful thinking on our parts, no doubt. More seriously, we do not consider bequests.

11. There are two obvious ways in which parents may favor the first-born. Parents may value their current utility more highly than future utility, at any point in time, and so a discount factor would automatically put more weight on the utility of the first-born in each period. Alternatively, they might weigh more heavily the adult utility of the first-born if, for example, this child would provide support for the elderly parents. Introducing either, or both, of these factors would alter our results in predictable ways.

12. For a model with complete financial markets, but fixed labor supply, see CH (2007).

13. This utility specification has the advantage of being grounded in methodological individualism, with each parent's intertemporal utility function given by

$$U_i = \sum_{k=1}^{3}\left[x_k^i + 0.5\left(u_k^a + u_k^b\right)\right] + 0.5\left(u_A^a + u_A^b\right).$$

14. We assume that such a switch is feasible, i.e. that parental consumption is not negative in the second period after the switch.

15. Again we assume that such a switch is feasible.