BIRTH ORDER AND THE INTRAHOUSEHOLD ALLOCATION OF TIME AND EDUCATION

Mette Ejrnæs and Claus C. Pörtner*

Abstract—This paper develops a model of intrahousehold allocation with endogenous fertility, which captures the relationship between birth order and investment in children. It shows that a birth order effect in intrahousehold allocation can arise even without assumptions about parental preferences for specific birth orders of children or genetic endowments varying by birth order. The important contribution is that fertility is treated as endogenous, a possibility that other models of intrahousehold allocation have ignored. The implications of the model are that children with higher birth orders (that is, who are born later) have an advantage over siblings with lower birth orders, and that parents who are inequality-averse will not have more than one child. The model furthermore shows that not taking account of the endogeneity of fertility when analyzing intrahousehold allocation may seriously bias the results. The effects of a child's birth order on its human capital accumulation are analyzed using a longitudinal data set from the Philippines that covers a very long period. We examine the effects of birth order on both number of hours in school during education and completed education. The results for both are consistent with the predictions of the model.

I. Introduction

PARENTS' decisions about their children's education affect not only the children's current well-being but also their future prospects. Uncovering how these decisions are made and what factors influence them has been an active research area in economics for many years. The focus has so far been on using differences between families to explain variations in the educational attainment of children. Though this approach can explain a significant portion of human resource investments, it ignores the role that intrahousehold allocation plays. A simple variance analysis of educational attainment of children from the Laguna Province in the Philippines[1] shows that the differences between families account for 49% of the total variation in completed education. Hence, although the interhousehold variation is clearly important, there is considerable variation within families.

Hence, one cannot satisfactorily examine human resource investments without analyzing how resources are allocated within the family. Increasing emphasis is therefore being placed on how parents distribute their resources among children.[2] One factor that has received relatively little attention is the effect of birth order on the allocation of resources. Only four published papers focus explicitly on the effects of birth order in developing countries. Birdsall

(1979, 1991) analyses the effect of birth order on educational attainment of children in urban Columbia. Behrman (1988b) studies the effects on child health and nutritional intake, with special attention to the effects of seasonality, using the Indian ICRISAT data. Horton (1988) also looks at children's nutritional status but uses data from the Bicol region of the Philippines.[3] We analyze the relationship between intrahousehold allocation and birth order by using a model of intrahousehold allocation with endogenous fertility, and present evidence on the effects of birth order on intrahousehold allocation in a developing country.

The plan of the paper is as follows. In section II different explanations for a birth order effect are discussed. Section III presents a model of intrahousehold distribution with endogenous fertility. Section IV provides a brief description of the data set and the area in which it was collected, and discusses the explanatory variables. In section V the effects of birth order on completed education are estimated; in section VI its effects on time allocation are analyzed. Finally, section VII draws conclusions from the findings and suggests areas for future research.

II. Review of the Literature

Researchers have suggested a number of potential reasons for the existence of birth order effects. The explanations can be divided into four categories: constraints, household environment, biological effects, and cultural effects. We provide a brief overview of these in this section.

The idea behind the constraint explanation is that parents are faced with time or financial constraints over the life cycle, making it impossible to equalize resources over children. In Birdsall (1991) the basic idea is that a mother's time cannot be transferred across periods, which can lead to birth order effects if the amount of time a child spends with its mother is a significant determinant of its human capital. Birdsall's results indicate that there are, indeed, no significant birth order effects for working mothers, who supposedly are not time-constrained because they have time enough to work; but there are effects for mothers not in the labor force. Generally, if there is a constraint, first-born and last-born children will benefit because they spend more time in smaller families than the middle-borns. Parish and Willis (1993) note, however, that if parents' earnings increase over their life cycle, this may favor later-borns over earlier-borns. It is also possible that a resource constraint could lead to

[1] The data are described in more detail in section IV.
[2] Behrman (1997) reviews the literature.

[3] Examples of studies using developed-country data are Behrman and Taubman (1986) and Kessler (1991).

older children entering the labor market earlier, thereby increasing the available resources for the younger children.[4]

In the household environment explanation, the number and age of children directly affect outcomes. It has, for example, been hypothesized that the intellectual environment is an important determinant of children's education (Zajonc, 1976). If that is the case, children of lower birth orders will have an advantage in that they reside in households with higher average education or IQ.[5] Though this effect is likely to be most important for the oldest children, it will also tend to place the youngest children in a better position than the middle-borns.

Biology may also create a birth order effect. One possible example is maternal depletion. Children of higher birth order naturally have older mothers, and older mothers tend to have children of lower birth weight. This would again tend to give the oldest children an advantage (Behrman, 1988b). Countering this biological disadvantage of the later-borns is the fact that the mother gains experience in child care with each child. There is, however, also a tendency for the first-born to be of lower birth weight.

Finally, birth order effects may also arise from cultural factors or preferences of the parents. An example, mentioned in Horton (1988), is the possibility that the oldest son is important in funeral rites. Another potential reason is the need for security in old age. Because the oldest children become economically independent first, they may be favored.

In our model the way that parents choose the number of children leads to a birth order effect, even in the absence of any of the explanations above. If all parents were forced to have the same number of children, the model predicts that the educational attainment of these children would be the same, on average, and hence there would be no birth order effect.

III. A Model of Intrahousehold Allocation

Despite the attention that intrahousehold allocation has received in the literature, there has been little attempt at integrating models of fertility with models of intrahousehold allocation (Behrman, 1997, p. 128, footnote 7). This is especially problematic when analyzing the relationship between intrahousehold allocation and birth order, for birth order is the realization of the parents' fertility decisions. Hence, this section presents a model of intrahousehold allocation of resources with endogenous fertility. Contrary to previous models of intrahousehold allocation, such as Behrman (1988b) and Birdsall (1991), the number of children is endogenously determined by parents, who take into account their budget constraint, the genetic endowments of

existing children, and their expectations about the genetic endowments of possible future children. We also assume that the endowments of children and parental preferences are unrelated to birth order. Still, it is possible to draw strong implications about the relation between the number of children, their birth order, and intrahousehold allocation.

To make the model tractable we assume that investment in children can only take place through human capital accumulation. The analysis of intrahousehold allocation is often cast in terms of two special cases, the wealth model suggested by Becker and Tomes (1976) and the separable earnings transfers (SET) model proposed by Behrman, Pollak, and Taubman (1982). Both of the models include two forms of intergenerational transfers (human capital investments and direct transfers), but in the wealth model parents care only about the total wealth (income plus transfers) of their children, whereas the SET model assumes that income and transfers are separable in the parents' utility function. The main difference between the outcomes is that the wealth model predicts that parents will always reinforce the genetic endowments of their children, whereas in the SET model parents may either reinforce, compensate, or be neutral.[6] In spirit our model is closest to the SET model, in that parents have only one way of transferring resources to their children and hence can be thought of as having separable preferences between human capital and transfers, and may either compensate, reinforce, or be neutral with respect to their children's endowments.[7] Indeed, the model is based on and uses the same functional form as Behrman (1988b), who also assumes only one mechanism of transfers. Finally, the model assumes that there is no feedback, of the kind suggested by Zajonc (1976), between children through learning or changes in the budget constraint.

Each child is born with a genetic endowment G_i (discussed below), which, together with the schooling input S_i, determines the human capital outcome of the child. The human capital production function is quasi-Cobb-Douglas,

$$H_i = G_i S_i^\alpha, \qquad i = 1, \ldots, n, \tag{1}$$

with diminishing marginal returns to schooling ($\alpha < 1$).

Parents derive utility from their n children's human capital H_i, $i = 1, \ldots, n$, and from other outcomes, such as parental consumption. The parents' utility function is separable between these two outcomes, and the subutility function for the children's human capital is CES,

$$U = \begin{cases} (\sum_{i=1}^{n} a_i H_i^c)^{1/c}, & c \le 1, \quad c \ne 0, \\ \prod_{i=1}^{n} H_i^{a_i}, & c = 0. \end{cases} \tag{2}$$

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[4] For an example see Emerson and Souza (2002). A similar effect can be also found if older children have a comparative advantage over younger children in taking care of other children, as suggested by Edmonds (2002).

[5] Zajonc (1976) also discusses the effects of older children learning from teaching younger siblings and the role of spacing between siblings.

[6] See, however, the discussions of the models in Becker (1991), Behrman, Pollak, and Taubman (1995), and Behrman (1997).

[7] An alternative is to assume that parents care about their children's consumption but are unable to transfer resources later in life through, for example, bequests. This is the approach used by Horowitz and Wang (2004), who present a model of schooling and child labor with heterogeneous children, although it does not allow for endogenous fertility.

The parents' inequality aversion is given by c, with a higher c indicating that parents are less averse to inequality. The parameters $a_1, \ldots, a_n$ reflect the weights parents place on each child's human capital. To simplify the discussion we assume that parents place equal weight on all children.[8] Hence, a birth order effect cannot arise from different weights being given to children of different birth orders.

The amount of income allocated to children, R, is constant. There is a fixed cost, k, of having a child, and p_s is the price of the schooling input. Hence, the budget constraint is given by

$$\sum_{i=1}^{n} (p_S S_i + k) \leq R. \tag{3}$$

A. Genetic Endowments

An important aspect of the model is the genetic endowments of children. This subsection discusses how they are observed and how parents form expectations about future children's endowments. The next subsection then looks at how parents decide on fertility.

Genetic endowments encompass a wide variety of different characteristics, some easily observed, others not. The most easily observed, both by parents and researchers, is the child's sex or other physical characteristics, such as stature. More difficult to observe is a child's resistance to illness, its ability to convert calorie intake into body mass,[9] or its innate abilities or talents.

The genetic endowments discussed above will all affect the return to investing in a child. If human capital is determined by physical strength, as would be the case in a rural underdeveloped economy, a child that grows more for a given input than other children will have a higher return. Hence, even though we have cast the discussion here in terms of human capital and schooling input, the model can be applied to any indicator that parents care about and for which the genetic endowments of the child matter.

The discussion of what genetic endowments are leads us to how parents observe them, or rather how soon they are observed. We assume that parents form an opinion about the genetic endowments of a child early in its life. Parents are able to observe the genetic endowments of their present children, but not their future children. We assume that the parents in family f know the distribution of the genetic endowments of their unborn children of birth order i and that it is given by

$$G_i \sim G^f(m_i, \sigma_i^2), \tag{4}$$

where m_i is the mean and σ_i^2 is the variance. Furthermore, the density function for G^f is g^f. This distribution can vary from family to family and by birth order, but for simplicity we will assume that it does not.[10] The sex of a child is a good example. Before birth the sex is not known, and parents without prior information will expect a slightly higher probability of having a boy than a girl.[11] After birth, however, the sex is easily observed. It is possible that parents update their expectations with each child, but we will not explore that possibility here.

B. Parents' Decision on Fertility

Parents decide on fertility sequentially; that is, they decide whether to have a child, observe the genetic endowments of the child, and then decide whether to have an additional child, and so on. Because we are mainly interested in the relation between fertility and intrahousehold allocation of resources, we focus on the final outcome and assume that the distribution of human capital inputs takes place after the fertility decisions are completed. This is not a serious problem if the majority of the differential investments in children are made after the fertility spell is completed.

As shown in the Appendix, one can derive an optimal stopping rule, which is that parents with n children will not have additional children if

$$(R - nk)^\alpha \left(\sum_{i=1}^{n} G_i^{\frac{c}{1-\alpha c}} \right)^{\frac{1-\alpha c}{c}}$$

$$> [R - (n+1)k]^\alpha \int \left(\sum_{i=1}^{n+1} G_i^{\frac{c}{1-\alpha c}} \right)^{\frac{1-\alpha c}{c}} g(G_{n+1}) \, dG_{n+1}. \tag{5}$$

The implications of this stopping rule depend on the value of c. We consider three special cases.

If $c > 0$, parents who have children with higher than expected genetic endowments will stop having children earlier than parents who have children with lower than expected genetic endowments. Say a family has two children with average genetic endowments. If they decide to have a third child and that child has a high genetic endowment, then they are more likely to stop than a similar family that had a third child with low or average endowment. What follows is a birth order effect where the last child tends to do best because parents chose their fertility taking into account the genetic endowment of their children and having a high-ability child makes it more likely that they will have no more children. Notice that this result in no way depends on

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[8] Hence, $a_i = a$, $i = 1, \ldots, N$, where N is the maximum number of children a family can have. Behrman (1988b) refers to this as equal concern.

[9] It is, however, possible to determine weight at birth, which may be a good predictor of the child's future health status.

[10] This does not change the results as long as each family knows the distribution.

[11] The prevalent sex ratio at birth is approximately 105 boys per 100 girls. Ultrasound or other methods can, of course, determine the sex of a fetus before birth, but it cannot be changed. We will ignore the use of abortion to influence the endowments of children.

TABLE 1.—SIMULATION—SCHOOLING INPUT PER CHILD

Birth Order	Family Size						Average Input	Number of Children
	2	3	4	5	6	7		
1	40.25	18.91	12.58	6.95	4.46	2.30	20.52	2000
2	39.75	19.94	11.26	6.31	4.85	7.43	20.41	2000
3		31.14	11.35	7.12	4.31	2.69	19.44	1510
4			24.75	8.12	3.73	1.43	17.38	808
5				21.49	4.89	4.18	17.00	334
6					17.79	2.37	16.06	90
7						9.60	9.60	10
Average	40.00	23.33	15.00	10.00	6.67	4.29	19.62	3.38
No. HH	490	702	474	244	80	10	2000	2000

Note. 2,000 households with $R = 100$, $k = 10$, $\alpha = 0.9$, and $c = 0.75$.

having different characteristics for children of different birth orders.[12]

The second case is where parents' preferences are quasi-Cobb-Douglas, which will arise when $c \rightarrow 0$. Section 1 of the Appendix shows that parents will then distribute their resources equally among their children and that the genetic endowment of existing children does not matter when deciding on whether to have an additional child. Hence, the model is then equal to a simplified version of the standard household model of fertility where all children are assumed to be given the same amount of resources. Human capital outcomes will, of course, vary within the household because the children have different endowments, but because the amount of resources given to each child is the same and genetic endowments are independent of birth order, we will not see any birth order effects.

The third case is when $c < 0$, which we will call the inequality-averse case. If parents have more than one child, they will distribute more resources toward children with low endowments to compensate them.[13] As shown in Section 2 of the Appendix, however, it will never be optimal to have more than one child. Hence, parents who are inequality-averse will only have one child.[14]

C. Simulation Study

We examine the influence of inequality aversion, cost of children, and resources using simulation studies. All simulations are based on 2,000 households, and the genetic endowments of the children follow a uniform discrete distribution between 1 and 99. For Tables 1 and 2 each

TABLE 2.—SIMULATION—EFFECT OF INEQUALITY AVERSION

Inequality aversion c	0.25	0.50	0.75	1.00
Fertility	7.96	5.53	3.38	2.35
Schooling Input				
Average per child	2.56	8.07	19.62	32.63
Last born − first born	0.04	0.92	9.41	55.96
Human Capital				
Average per child	130	412	1,028	1,663
Last born − first born	6	74	592	2,963

Note. 2,000 households with $R = 100$, $k = 10$, and $\alpha = 0.9$.

household has 100 units of resources ($R = 100$), the fixed cost of a child is 10 units ($k = 10$), and $\alpha = 0.9$. Table 1 shows how average schooling depends on family size and birth order for a fixed inequality aversion ($c = 0.75$). The results illustrate three important features of the model. First, inputs of schooling per child decrease with increasing family size. Second, the last born receives, in general, the most schooling inputs, although in two-child families there is almost no difference between the two children. Third, the average schooling input decreases with (absolute) birth order, because the effect of increasing family size dominates the effect of being last born.[15] This suggests that not taking account of fertility would lead one to find a significant negative birth order effect, which is the opposite result to the correct one.

In Table 2 we report fertility, average schooling inputs, and human capital per child. We also report the difference between the first and the last child's schooling inputs and human capital for families with at least two children. The difference between last and first born is used as a measure of birth order effects. The simulations are done for $c = 0.25$, 0.5, 0.75, and 1. These values are chosen because they lie in the range of the estimates reported in Behrman (1988b).

Table 2 shows that increasing c leads to a decline in fertility and increases in schooling inputs and human capital per child. Furthermore, the results also indicate that birth order effects become more pronounced with increasing c. Although there is almost no birth order effect when $c =$

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[12] It is even possible to show that a birth order of the kind described here can arise if the mean endowment decreases with increasing birth order.

[13] A special case of this is Rawlsian preferences, when $c = -\infty$ and the parents' utility function becomes a Leontief function. In that case parents care only about the child with the least human capital.

[14] This result has an interesting implication for empirical analyses that aim to estimate parental inequality aversion, such Behrman, Pollak, and Taubman (1982, 1986), Behrman and Taubman (1986), and Behrman (1988a,b). It is standard in these studies to leave out one-child families when estimating inequality aversion, but if parents' fertility decisions are based on their inequality aversion, this will tend to bias the results toward the pure-investment case (where $c = 1$). Hence, the claim in Behrman (1997) that there will no selectivity bias from restricting a sample to families with at least two children does not necessarily hold.

[15] See the "Average Input" column in table 1.

TABLE 3.—SIMULATION—EFFECTS OF RESOURCES AND COSTS OF CHILDREN

	$R = 80$		$R = 100$		$R = 120$	
	$k = 10$	$k = 20$	$k = 10$	$k = 20$	$k = 10$	$k = 20$
Fertility	2.70	1.58	3.38	1.82	4.03	2.10
Schooling Input						
Average per child	19.65	30.66	19.62	34.84	19.80	37.11
Last born − First born	12.43	18.09	9.41	23.05	10.93	26.35
Human Capital						
Average per Child	1,026	1,416	1,028	1,643	1,040	1,782
Last born − First born	792	992	592	1,305	683	1,514

Note. 2,000 households with $c = 0.75$ and $\alpha = 0.9$.

0.25, the pure investment case leads to a difference between the last and first born of approximately 1.7 times the average schooling input. Finally, comparing schooling inputs and human capital shows that the birth order effect appears more pronounced in human capital than in schooling inputs.

Finally, table 3 presents summary statistics for different resource and cost combinations. The simulations are again based on 2,000 households with $\alpha = 0.9$, and the inequality aversion is fixed at $c = 0.75$. The cost of children is either $k = 10$ or $k = 20$, and the amounts of resources are $R = 80$, $R = 100$, and $R = 120$. All combinations of cost and resources are shown.

Increasing R leads to higher fertility; its effects on mean human capital and the measures of differences are ambiguous. The effects of increasing k are a reduction in fertility and an increase in average education. Provided that the fixed cost of children increases faster than the total amount of resources devoted to children, these results are consistent with the observed development in fertility. This would be the case if the main cost of having a child were the time the mother spends not working. The effect of cost of children or resources on the size of the birth order effect is ambiguous.

In summary, the model shows that a birth order effect in intrahousehold allocation can arise even without assumptions about parental preferences for specific-birth-order children or genetic endowments varying by birth order. The important contribution is that fertility is treated as endogenous, something that other models of intrahousehold allocation have failed to do despite the large literature on determinants of fertility (see, for example, Schultz, 1997). In the model there are no inherent preferences for first- or earlier-born, but the prediction is that children with higher birth orders have an advantage over siblings of lower birth orders. The model furthermore shows that not taking account of fertility when analyzing intrahousehold allocation may seriously bias the results.

IV. Data

The data used here are from the Laguna Multipurpose Household Surveys.[16] The first survey took place in 1975,

and since then resurveys have taken place in 1977, 1982, 1985, 1990, 1992, and 1998 on a progressively smaller number of households using almost the same questionnaire. Unfortunately, the 1975 survey round is unavailable, and time allocation data were not collected for the 1998 resurvey. The 1998 survey does, however, allow us to study the completed education of the children of the household followed throughout the first five waves. The background for the original survey is described in Evenson (1978a, Appendix) and Evenson, Popkin, and Quizon (1980).[17]

The Laguna Province, located south of Manila, covers an area of 1,759 km², and had a population of 803,750 in 1975 with a growth rate of 2.8% (see Ho, 1979). It is bounded on the north by the province of Rizal, on the east by Quezon, on the west by Cavite, and on the south by Batangas. Although Laguna is an inland province, it does have a big fresh-water lake (Laguna de Bay) that constitutes most of the province's northern border. Approximately 80% of the total area of the province—which mainly consists of plains, with some elevated area in the northeast—is used for agriculture, and water supplies are reliable and abundant in most parts.

In 1975 the shortest distance between the province and Manila was approximately 30 km. During the survey period Manila has expanded so that some areas in the northern part of the province are now within Manila's urban zone. This proximity to Manila, together with the fact that it is home to the country's largest agricultural college and the International Rice Research Institute (IRRI), as well as having fertile land, explains why Laguna is one of the more developed provinces in the Philippines. The surveyed households are located in 20 different communities, also known as barangays.

The educational system in the Philippines consists of elementary schools with six grades,[18] high schools with four grades, colleges with either four or five years of education, and finally postgraduate study. There is mandatory schooling from the first academic year after a child reaches age seven and until completion of elementary education, that is, until the child is approximately thirteen years old. Most of the elementary schools are public and tuition-free, but secondary schools and colleges are mostly private.

A. Variables

We analyze two aspects of human capital investment: completed education and time spent on school activities.[19]

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[16] The survey is also called several other things, such as the Laguna Household Studies Project or the Laguna Household Economics Survey.

[17] Evenson (1978a) contains a collection of 13 papers using data from the Laguna Province. Other works using data from the Laguna Province include King and Evenson (1983), Evenson (1978b, 1994, 1996), and Rosenzweig and Wolpin (1986).

[18] Some private schools do have a seventh-grade elementary class, but if a respondent has more than elementary school education, it is not indicated whether he received 6 or 7 years of elementary schooling.

[19] As mentioned above, there may also be other types of transfers between parents and children, such as direct transfers or bequests. We unfortunately do not have data on these other transfers and therefore focus

TABLE 4.—SUMMARY STATISTICS

	1998		1982–1992	
	Mean	Std. Dev.	Mean	Std. Dev.
Years of education	8.89	3.43		
Hours of school (per week)			31.41	19.72
Year of birth	1970	8.85	1973	4.63
Age	28.18	8.35	13.02	3.26
Girls	0.47	0.50	0.47	0.50
Birth order	4.41	2.80	5.04	2.87
Mother's education (years)	4.96	2.41	5.03	2.35
Father's education (years)	4.79	2.72	4.83	2.68
Landowners	0.23	0.42	0.10	0.30
Value of land owned*	0.88	0.83	1.10	1.55
Observations	817		1470	

* Units: 10 million pesos.

TABLE 5.—MEAN EDUCATION BY BIRTH ORDER

Birth Order	All		Boys		Girls	
	Mean	Obs.	Mean	Obs.	Mean	Obs.
1	9.23	125	8.57	58	9.80	67
2	9.23	124	8.40	60	10.01	64
3	9.13	115	8.42	61	9.92	54
4	8.78	104	8.20	62	9.71	41
5	9.47	87	8.81	48	10.28	39
6	9.13	69	8.96	31	9.26	38
7	9.07	53	8.89	28	9.28	25
8	8.67	40	8.50	24	8.94	16
9	9.00	27	9.29	17	8.50	12
10	8.66	22	8.00	10	9.58	12
11	7.64	14	6.00	6	8.80	8
12	7.8	5	6.33	3	10.00	2
13	11.00	3	11.00	1	1.00	2
14	12.00	1	12.00	1		0

Educational attainment is measured in years. An additional year is added if a college degree is completed; that is, four years of college education with a degree is equivalent to five years of college education without a degree.[20] Postgraduate study and postgraduate study with a degree are equivalent to seventeen and eighteen years of education, respectively.

The key explanatory variable in this study is the birth order. Because economic theory provides little guidance on suitable measures, the choice is somewhat ad hoc.[21] The absolute birth order is the most natural candidate and is the first measure we use. The main problem with using the absolute birth order is that most of the variation will be due to larger families. We therefore also employ a measure of relative birth order. This is constructed so that the first-born's relative birth order equals 0 and the last-born's equals 1, and it is defined as $\frac{p-1}{n-1}$, where p is the birth order and n the number of children in the family. Other approaches have also been considered, and we will return to this issue in the following two sections.

The choice of the remaining explanatory variables is dictated partly by the model and partly by the availability of information in the surveys. In addition to birth order, individual-specific information about the sex and age of the children is included.[22] The household-specific information covers the education of the mother and the father and the value of the household's landholdings (in units of 10 million pesos). The education of the mother serves as a proxy for the cost of children, because it is mainly the mother's time that is used giving birth to and rearing the children and increasing education leads to a higher opportunity cost of time. Because the father's time is generally not involved to any great extent in the rearing of children, his education can be viewed as having a pure income effect on the demand for children and human capital. Some parents have received vocational training, which is assumed to be equivalent to 10 years of education. The value of the household's landholding is expected to both increase the income of the household and reduce the cost of children (because they can work on the land).[23] Summary statistics are provided in table 4, and the average education by birth order is shown in table 5.

With only limited information about the household, we are not able to control for all household characteristics. This is a problem, because birth order, which is a measure of fertility, is likely to be correlated with unobservable characteristics of the household, leading to biased results. We solve this problem by using household fixed effects. The main drawback of this approach is that it is not possible to directly include variables that do not vary between children of the same household. It is, however, possible to control for interactions between birth order and these variables, which we do. Hence, we are able to determine whether or not the birth order effect becomes more or less important with parental education and landholdings.

V. Completed Education

This section examines the effect of birth order on completed education. First, various issues concerning the data are discussed. Second, the estimation strategy is examined. Finally, the results are presented.

The data used in this section are from the last wave of the survey. The data were collected in 1998, when most of the children were adults and had completed their education. We

on human capital investments. Because most of the households are not wealthy and do not have much land (only 23% have any land, and average landholdings for those are less than 1 acre), we expect that the most substantial transfer of resources from parents to children takes place through human capital investment. Quisumbing (1994) examines human capital investments and other intergenerational transfers in another area of the Philippines.

[20] The results are virtually identical for other measures of completed education, among them actual number of years in school and whether a child has passed certain levels, such as secondary.

[21] The four papers mentioned in the Introduction all use different measures of birth order. Horton (1988) uses the absolute birth order of each child, with the first-born child given a birth order of 0. Behrman (1988b) does not have information about the absolute birth order of the children in his sample and therefore uses the relative birth order between pairs of children. Finally, Birdsall (1991) employs dummies for first- and last-born children.

[22] We return to the reason for including age and the interpretation of its effect in the next section.

[23] An alternative interpretation is discussed below.

exclude four households because there is no information about one or both of the parents' education, and one household with only one child. The final sample size is 817 children between 8 and 53 years of age from 125 households. Of these children, 427 are boys (52%), and they have an average education of 8.3 years. The average length of schooling of the 390 girls is 9.5 years. This is significantly higher than that of the boys. In the 1998 sample 98 (or 12%) of the children were still in school. Finally, the average number of children per household is 6.6.[24]

A. A Censored Ordered Conditional Logit Model

Because educational attainment is inherently a discrete variable, an ordered logit or an ordered probit model is often used (see, for example, King & Lillard, 1987). A potential problem is, however, that some children are still in school. This can lead to biased estimates if one does not take into account that these children will most likely have a higher education than the one currently attributed to them. We therefore extend the standard ordered logit model to allow for unobserved household specific effects and censoring.

Let k be a given level of education, and K its maximum level. To estimate an ordered logit with fixed effects, we transform the model into K different logit models using the continuation regression model (see Andersen, 1997, pp. 188–190). The estimation is performed in two steps. First, we estimate the parameters $\boldsymbol{\beta}^{(k)}$ using the conditional logit approach. Second, we use minimum distance to obtain a combined estimate of $\boldsymbol{\beta}$.

Let y_{ij} be the final educational attainment of child i in household j, where $y_{ij} \in \{0, \ldots, K\}$. Final education is generated by a latent variable y_{ij}^*:

$$y_{ij} = \begin{cases} 0 & \text{if } y_{ij}^* \leq \theta_1, \\ 1 & \text{if } \theta_1 < y_{ij}^* \leq \theta_2, \\ \vdots & \\ K & \text{if } \theta_K < y_{ij}^*. \end{cases}$$

The latent variable is determined by $y_{ij}^* = x_{it}\boldsymbol{\beta}^{(k)} + \mu_j + \varepsilon_{ij}$, where the vector x_{ij} includes the explanatory variables, μ_j is a household-specific effect, and ε_{ij} is the error term. The cumulative distribution function of ε_{ij} conditioned on x_{ij} and μ_j, is given by $F(z) = \dfrac{\exp(z)}{1 + \exp(z)}$.

Let s_{ij}^k be a binary variable, equal to 1 if $y_{ij} \leq k$ and 0 otherwise. These K variables $s_{ij}^0, \ldots, s_{ij}^{K-1}$ follow logit models where

$$Pr(s_{ij}^k = 1) = Pr(y_{ij} \leq k) = F(\theta_{k+1} - x_{ij}\boldsymbol{\beta}^{(k)} - \mu_j),$$
$$k = 0, \ldots, K - 1.$$

The advantage of using the s-variables is that it is possible to obtain a consistent estimate of $\boldsymbol{\beta}^{(k)}$ in a logit model by using conditional maximum likelihood estimation (see Chamberlain, 1980, or Andersen, 1973).

In the second step we use minimum-distance estimation to obtain one estimate of $\boldsymbol{\beta}$. Let δ be a vector of the K different estimates of $\boldsymbol{\beta}$ such that $\delta = (\hat{\boldsymbol{\beta}}^{(0)\prime}, \ldots, \hat{\boldsymbol{\beta}}^{(K-1)\prime})'$. A new estimate of $\boldsymbol{\beta}$ is found by minimizing

$$(\delta - \iota_n \otimes \boldsymbol{\beta})'W(\delta - \iota_n \otimes \boldsymbol{\beta}),$$

where ι_K is a K-vector consisting of 1's, and W is a positive definite matrix. The covariance matrix of $\boldsymbol{\beta}$ is given by

$$V(\boldsymbol{\beta}) = [(\iota_n \otimes I)'W(\iota_n \otimes I)]^{-1}(\iota_n \otimes I)'WV(\delta)$$
$$\times W(\iota_n \otimes I)[(\iota_n \otimes I)'W(\iota_n \otimes I)]^{-1}.$$

Ejrnæs and Pörtner (2002) show how to derive the covariance matrix for δ.

The problem with censoring is that it may introduce bias, in that the children who are censored are also those who are likely to receive the most education. Fortunately, because we know if a child is still enrolled in school, we have a clear indication of which observations are censored. We deal with censoring by limiting the sample for each logit model so that only observations that cannot be censored are used in the estimation. The underlying idea is that children older than 23 cannot be censored, because the maximum education (16 years) will have been obtained at that age, because schooling begins at age 7 ($23 = 7 + 16$). Similarly, if we consider the probability of receiving 15 years of education, no children aged 22 years or more be censored. This implies that we can estimate $\boldsymbol{\beta}^{(k)}$ using only the subsample containing children aged more than $7 + k$. Because we base the selection of the sample on an exogenous variable, age, this method will not lead to sample selection bias and solves the censoring problem.

B. Birth Order Effects and Completed Education

We estimate the effect of birth order using the explanatory variables discussed in section IV and the method just described.[25] The results are presented in table 6.[26] Columns (1) and (2) use absolute birth order; columns (3) and (4) use relative birth order.

Columns (1) and (3) show a simple specification where we control for the sex, year of birth, and birth order of the child. Both the absolute and the relative birth order have positive and very significant effects on completed education. It appears to be an advantage to be born as one of the later children. Because this is the opposite of what most previous studies of birth order have found, we have also

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[24] Bias may arise from households with incomplete fertility spells. That, however, is unlikely to be a problem here, because the average age of mothers is 54.7 years and the youngest mother is 41 years old. This potential bias is more likely to be a problem when analyzing time in school and will therefore be discussed in more detail below.

[25] The estimation of the final $\boldsymbol{\beta}$ is based on $\boldsymbol{\beta}^{(4)}, \ldots, \boldsymbol{\beta}^{(15)}$. The remaining $\boldsymbol{\beta}^{(k)}$'s are excluded owing to too few observations.
[26] In Ejrnæs and Pörtner (2002) the results of standard fixed-effects estimations are presented for comparison.

TABLE 6.—COMPLETED EDUCATION

	Ordered Logit Estimation			
	(1)	(2)	(3)	(4)
Dummy for girl	0.932*** (0.067)	1.356*** (0.152)	0.975*** (0.068)	0.927*** (0.113)
Year of birth	−0.051*** (0.002)	−0.028*** (0.002)	0.004** (0.002)	−0.039*** (0.002)
Birth order	0.245*** (0.009)	0.410*** (0.023)		
Birth order × mother's education		−0.041*** (0.005)		
Birth order × father's education		−0.011*** (0.002)		
Birth order × value of land		0.401*** (0.001)		
Birth order × dummy for girl		−0.089*** (0.034)		
Relative birth order			0.860*** (0.137)	3.042*** (0.232)
Relative birth order × mother's education				−0.182*** (0.036)
Relative birth order × father's education				−0.193*** (0.016)
Relative birth order × value of land				2.962*** (0.461)
Relative birth order × dummy for girl				0.159 (0.227)
Observations	817	817	817	817
Number of households	125	125	125	125

Note. Standard errors in parentheses. * Significant at the 10% level.
** Significant at the 5% level. *** Significant at the 1% level.

tried other specifications. We tried a quadratic term for birth order, a dummy for being the first-born child together with the linear birth order term, dummies for being among the first third and the second third of the children, and various other specifications. None of these extra terms turned out to be significant.

To examine whether the birth order effect is related to other observable characteristics of the household, we interact birth order with the educational attainment of the mother and the father, a dummy for being a girl, and the value of landholdings. For both absolute and relative birth order there is a negative effect of parental education interacted with birth order. This effect eliminates the birth order effect for parents with high school education (10 years) and above.

The effect of landholdings of the household is opposite to that of parental education. There is a positive and significant effect of the value of a household's landholding, so that the birth order effect is more pronounced in families with more valuable landholdings. One explanation for this behavior may be that the parents are trying to compensate later-born children who are presumably less likely to inherit the land than their older siblings.[27] Another, related explanation is that parents follow an efficient investment strategy. That would be the case if the return to education for farmers were lower than that of other jobs after a certain level of education is achieved.

To investigate if birth order effects are more pronounced for girls than for boys, we interact birth order and a dummy for being a girl. The interaction term is positive but insignificant in the specification with relative birth order, but significant and negative, although small, for absolute birth order. This indicates that birth order effects are less important for girls than for boys.

In all columns there is a positive and significant effect of being a girl on completed schooling. Though this may

appear to be the opposite of what most people expect for developing countries, there are a substantial number of developing countries where this pattern can be found.[28] One potential reason for the difference is that the return to women's education is higher because it is mostly women who migrate abroad to work. Though it is beyond the scope of this study to examine this and other potential reasons, it is definitely an area worthy of further research.

One might imagine that what appears to be a birth order effect could simply be a cohort effect. This would be the case if the schooling system improved over time. The younger siblings would then find themselves with better schooling and easier access to education, which could lead to the results presented above. We have therefore included the year of birth of the child as a control. It is surprising that the effect is negative and significant, although it is quite small. In an extreme example with a family with two children, born 10 years apart, the total effect from year of birth would only be one-tenth of the birth order effect using the relative birth order estimates. This is confirmed by estimating the models without the year-of-birth variable, in which case the birth order effects are slightly smaller but still very significant.

There are two possible explanations for the negative effect of birth cohort. First, it might be that the access to and quality of schooling have decreased over the years, although that appears unlikely. Second, the year of birth captures not only the cohort effect, but also the effect of the mother's age when giving birth, because the fixed-effect estimation means that we only consider differences from the household means. One way of looking at this difference from the mean is that it represents the spacing between children: A child who is much further away from his siblings in age is likely

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[27] Quisumbing (1994) examines the relation between landholdings and transfers in the Philippines, although in a different area than the one used in this paper.

[28] As discussed in Behrman, Duryea, and Székely (1999, p. 10), in two-thirds of the analyzed countries in Latin America and the Caribbean the educational level is higher for girls than for boys for the cohort born in 1970. For South Africa the schooling is approximately equal for boys and girls (Anderson, Case, & Lam, 2001; Lam, 1999).

to be provided with more resources, and this may, to some extent, counter the birth order effect.

VI. Time in School

The completed education of an individual is the final outcome of a number of different factors such as time spent in school, the quality of the school, the support of the family, the abilities of the child, and so on. Because parents do not control all these factors, they can only influence the final education to a certain extent. Hence, we look at the effects of birth order on the time spent in school and on studying, because we suspect that parents are able to control more directly the time in school of their children. It is, however, not obvious that birth order effects should be stronger in time spent in school than in completed education, because time in school is only one of the inputs.

The data used in this part of the paper are based on surveys conducted in 1982, 1985, 1990, and 1992. The data contain information about how many hours each child spent in school and about other school activities in the particular week when the survey was conducted.[29] For the analyses of time spent in school we limit the sample to include only children aged 7 to 18. The sample contains 1,122 observations from 226 different households.

A. A Sample Selection Model

A potential problem when analyzing time in school is sample selection, in that not all children attend school. A frequently used method for estimation in sample selection models is the Heckman (1979) two-step estimator. This estimation technique cannot, however, be applied directly when fixed effects are present. The problem is that the Heckman procedure requires a consistent estimate of the parameters associated with the binary variable, and estimating these parameters in a fixed-effects model may lead to inconsistent estimates if the number of time periods is small.[30] Kyriazidou (1997) proposes a method to estimate sample selection models for panel data with fixed effects. Although this method is developed for models with individual fixed effects rather than household-specific fixed effects, the methodology can easily be modified to cover the better framework (Ejrnæs & Pörtner, 2002).

A crucial assumption is that at least one of the variables determining the participation process does not enter the equation for hours. Because the mandatory schooling is from age 7 to completing elementary school, normally at age 12, we expect a dummy variable for children aged 7 to 12 to be a good predictor of participation.[31] Furthermore, we

assume that this variable does not affect the time spent on school activities. Using this variable as an exclusive restriction, we are able to estimate the model.

B. The Estimation Results

Except for the dummy variable of being older than mandatory school age, we use the same explanatory variables for both participation and time in school, and the same measures of birth order as in the previous analyses. A potential problem is households with incomplete fertility spells, for their presence can lead to biased estimates of the birth order effect. This is most likely when using the relative birth order, for in that case the child categorized as last born would not really be the last child. We tried both the number of children in the household for each year and the completed fertility measured in 1998 when computing the relative birth order. We do not, however, find any significant differences in the results, and because using the 1998 fertility data restricts the sample size, we use the current household size. In addition to the explanatory variable used for the analysis of completed education, we include age and age squared to control for the changes in the amount of schooling over age.[32] The estimation results are reported in tables 7 and 8.

Examining the results of the participation in school, we find very few variables are significant. The most significant variables are the age variables, indicating a strong age pattern in the participation. The effect of birth order is not significant in any of the analyses. Thus birth order seems less important for participation in school.

With regard to the results for the number of hours, the evidence is mixed. For the specifications using relative birth order, the birth order variable is not significant in the model with interactions, although two of the interaction variables are. We concentrate on the specifications using absolute birth order, which show strong and positive birth order effects. The only interaction term that has a significant effect is the interaction with the girl dummy. This negative effect is consistent with the results for completed education, implying that birth order effects are less important for girls. Year of birth has a positive and significant effect on the hours spent in school. This result is in contrast to the result found for completed education.

To sum up, the result for participation and hours of work are less clear than for completed education. We find weaker evidence for birth order effects in participation and in most of the specifications of hours of school than in completed education. However, the results seem to be consistent with the fact that last-borns spend more time in school.

VII. Conclusion

To our knowledge there has so far been no attempt to combine intrahousehold allocation and fertility decisions in

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[29] Information on time allocation is only available if the child is still living at home.
[30] The inconsistency in a logit model with fixed effects is discussed in Anderson (1973) and Chamberlain (1980).
[31] The fraction participating in school drops by approximately 15 percentage points between 12 and 13 years of age.

[32] Other functions of age have been tried, but the results for the remaining parameters are essentially unaffected.

TABLE 7.—PARTICIPATION IN SCHOOL†

	Conditional Logit Estimation			
	(1)	(2)	(3)	(4)
Dummy for girl	0.312 (0.202)	0.436 (0.424)	0.329 (0.203)	0.491 (0.436)
Age	0.771* (0.394)	0.756* (0.398)	0.796** (0.395)	0.771* (0.398)
Age squared	−0.039*** (0.013)	−0.039*** (0.013)	−0.040*** (0.014)	−0.040*** (0.013)
Dummy for age > 12	−1.638*** (0.522)	−1.621*** (0.524)	−1.635*** (0.523)	−1.597*** (0.525)
Year of birth	0.074 (0.083)	0.081 (0.085)	0.156*** (0.050)	0.157*** (0.051)
Birth order	0.155 (0.198)	0.121 (0.210)		
Birth order × mother's education		−0.003 (0.002)		
Birth order × father's education		0.012 (0.011)		
Birth order × value of land		−0.075 (0.051)		
Birth order × dummy for girl		−0.021 (0.072)		
Relative birth order			−0.365 (0.701)	−0.318 (0.810)
Relative birth order × mother's education				−0.024 (0.022)
Relative birth order × father's education				0.048 (0.038)
Relative birth order × value of land				−0.345 (0.365)
Relative birth order × dummy for girl				−0.276 (0.705)
Observations	1122	1122	1122	1122
Number of households	226	226	226	226

Standard errors in parentheses. * Significant at the 10% level.
** Significant at the 5% level. *** Significant at the 1% level.
† Children aged 7 to 18 who spend a positive amount of time in school.

TABLE 8.—TIME SPENT ON SCHOOL ACTIVITIES†

	Kyriazidou's Method			
	(1)	(2)	(3)	(4)
Dummy for girl	1.228* (0.719)	7.915*** (1.467)	1.376** (0.653)	3.909** (1.928)
Year of birth	0.947*** (0.346)	0.560 (0.369)	2.461*** (0.281)	2.002*** (0.280)
Age	4.805** (1.939)	5.054*** (1.872)	6.435*** (1.751)	4.437** (1.787)
Age squared	−0.092 (0.095)	−0.106 (0.091)	−0.198** (0.086)	−0.104 (0.087)
Birth order	2.096** (0.886)	3.543*** (0.970)		
Birth order × mother's education		0.019 (0.021)		
Birth order × father's education		0.018 (0.026)		
Birth order × value of land		0.204 (0.136)		
Birth order × dummy for girl		−1.116*** (0.176)		
Relative birth order			−8.712* (2.452)	−4.428 (3.532)
Relative birth order × mother's education				−0.172 (0.114)
Relative birth order × father's education				0.163** (0.065)
Relative birth order × value of land				0.135 (2.881)
Relative birth order × dummy for girl				−4.653* (2.473)
Observations	1470	1470	1470	1470
Number of households	201	201	201	201

Standard errors in parentheses. * Significant at the 10% level.
** Significant at the 5% level. *** Significant at the 1% level.
† Number of hours spent in school by children aged 7 to 18.

one model. This is especially problematic when analyzing the effects of birth order on intrahousehold allocation, for birth order is the realization of fertility. We show, using a model of intrahousehold allocation with endogenous fertility, that birth order effects can arise even without parents having stronger preferences for children with specific birth order or the endowments of the children being related to birth order. The model shows that parents tend to favor the last-born children and that it is of great importance to treat fertility correctly when estimating intrahousehold allocation. Furthermore the model provides a possible explanation for why compensatory behavior has not been observed, in that the model predicts that parents who are inequality-averse will only have one child.

Using a longitudinal data set from the Philippines, we find strong evidence for a birth order effect in both completed education and time spent on school activities. The results show that the last-born children receive more education than their earlier-born siblings. Furthermore, we find that the effect of birth order is less pronounced in families where the parents have more education, but it is stronger in families holding land. The findings are consistent with the predictions of the model, although they do not constitute a direct test of it.[33]

This paper gives rise to a number of interesting questions that deserve more attention. First, the reason for the large difference between the length of boys' and girls' education should be analyzed in more depth. Second, we have suggested possible reasons for the strong effect of landholdings, but without further analysis it is not possible to provide a

[33] One possible way to test the model directly would be to estimate whether birth order effects exist in aptitude test scores (in the hope that these measure innate ability).

completely satisfactory answer. One possible beneficial approach is to look at patterns of inheritance as suggested in this paper.

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APPENDIX

The Model

This appendix shows, in detail, the implications of the model outlined in section III. The maximization problem of the parents is

$$\max_{n,\{S_i\}_1^n} U = \left(\sum_{i=1}^n a_i H_i^c\right)^{1/c}, \qquad c \le 1, \quad c \ne 0,$$

subject to

$$H_i = G_i S_i^\alpha,$$

$$R \ge \sum_{i=1}^n S_i + nk,$$

$$G_i \sim G^f(m_i, \sigma_i^2).$$

To simplify notation assume $a_i = 1 \; \forall i$. For a given n the optimal distribution of schooling inputs are

$$S_i = (R - nk) \frac{G_i^{\frac{c}{1-\alpha c}}}{\Sigma_{j=1}^n G_j^{\frac{c}{1-\alpha c}}}. \tag{A-1}$$

The utility is then

$$U_n = (R - nk)^\alpha \left(\sum_{i=1}^n G_i^{\frac{c}{1-\alpha c}} \right)^{\frac{1-\alpha c}{c}}. \tag{A-2}$$

If parents have only one child, the realized utility is simply $U_1 = G_1 (R - k)^\alpha$, which is independent of the value of c.

Because the problem is sequential, we can solve it backward. Parents will go from having n children to having $n + 1$ until

$$(R - nk)^\alpha \left(\sum_{i=1}^n G_i^{\frac{c}{1-\alpha c}} \right)^{\frac{1-\alpha c}{c}}$$

$$> [R - (n + 1)k]^\alpha \int \left(\sum_{i=1}^{n+1} G_i^{\frac{c}{1-\alpha c}} \right)^{\frac{1-\alpha c}{c}} g(G_{n+1}) \, dG_{n+1}. \tag{A-3}$$

This stopping rule gets easier and easier to fulfill as the number of children increases. Hence, parents who have very high-endowment children will stop having children earlier than those who have low-endowment children (provided they have the same distribution function). There is no need to worry about the utility of having $n + 2$ or more children, because for the stopping rule the requirement derived from the expected utility of $n + 1$ children is stronger than of $n + 2$ or more.

1. The Cobb-Douglas Case

At $c = 0$ the utility function is a Cobb-Douglas function, $U = \prod_{i=1}^n H_i$. It is straightforward to show that, for a given number of children, the size of the schooling input is the same for all children. Hence, the realized utility for parents with n children will be

$$U_n = \prod_{i=1}^n G_i \left(\frac{R - nk}{n} \right)^{n\alpha}. \tag{A-4}$$

One implication of Cobb-Douglas preferences is that the genetic endowments of previous children do not matter in the fertility decision. Parents with n children will have $n + 1$ children if

$$\int \prod_{i=1}^{n+1} G_i \left(\frac{R - (n + 1)k}{n + 1} \right)^{(n+1)\alpha} g(G_{n+1}) \, dG_{n+1}$$

$$> \prod_{i=1}^n G_i \left(\frac{R - nk}{n} \right)^{n\alpha}. \tag{A-5}$$

Reducing this leads to the following condition on the expected genetic endowment of the $n + 1$'st child, which does not depend on G_n,

$$E(G_{n+1}) = \int G_{n+1} \, g(G_{n+1}) \, dG_{n+1}$$

$$> \left(\frac{R - nk}{n} \right)^{n\alpha} \left(\frac{R - (n + 1)k}{n + 1} \right)^{-(n+1)\alpha}. \tag{A-6}$$

2. The Inequality-Averse Case

If $c < 0$, parents with more than one child would compensate the children who have lower endowments.[34] We show, however, that if $c < 0$, it is never optimal to have more than one child. To simplify the notation denote $\frac{1 - \alpha c}{c}$ by β. If $c < 0$, it follows that $\beta < 0$. The proof is made by contradiction. Assume that it is optimal for a household to have two children. This implies by equation (5) that

$$(R - k)^\alpha G_1 < (R - 2k)^\alpha \int (G_1^{1/\beta} + G_2^{1/\beta})^\beta g(G_2) \, dG_2.$$

From this we must have that

$$G_1 < \left(\frac{R - k}{R - 2k} \right)^\alpha G_1 < \int (G_1^{1/\beta} + G_2^{1/\beta})^\beta g(G_2) \, dG_2, \tag{A-7}$$

because $\left(\frac{R - k}{R - 2k} \right)^\alpha > 1$, which follows from $\alpha > 0$.

To prove the contradiction we show that $(G_1^{1/\beta} + G_2^{1/\beta})^\beta < G_1$. First notice that the function $f(x) = (G_1^{1/\beta} + x)^\beta$ is a monotonic decreasing function for $x \geq 0$.[35] This implies that $(G_1^{1/\beta} + G_2^{1/\beta})^\beta < (G_1^{1/\beta})^\beta = G_1$ and hence that

$$\int (G_1^{1/\beta} + G_2^{1/\beta})^\beta g(G_2) \, dG_2 < \int G_1 g(G_2) \, dG_2 = G_1.$$

If we compare this with equation (12), we have a contradiction. It will therefore never be optimal to have more than one child.

[34] This includes the special case of Rawlsian preferences, where $c = -\infty$. In this case the parents' utility function becomes a Leontief function $U = \min(H_1, \ldots, H_n)$, and they care only about the child with the least amount of human capital.

[35] This can easily be seen from $\frac{\partial f}{\partial x} = \beta(G_1^{1/\beta} + x)^{\beta - 1} < 0$ for all $x \geq 0$.