Birth Order Differences in Early Inputs and Outcomes*

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Abstract

We examine within-family differences in pre- and early postnatal investments as potential explanations for the "birth order effect" – significant differences in the educational and labor market outcomes across children of varying birth orders. Taking advantage of the rich information on *in utero* and early childhood conditions in the Children of the NLSY79, we find that, within the same household, siblings of higher birth order experience a lower reduction in cigarette usage during pregnancy, are breastfed less often, and experience less cognitive stimulation and emotional support at ages 0 to 1. Next, we test for the presence of birth order effects in early cognitive/non-cognitive test scores and educational attainment and examine whether these differences can be explained by variations in prenatal and early childhood inputs. While we do find a significant negative relationship between birth order and early test scores as well as educational attainment, these effects are robust to controlling for variations in early childhood factors.

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1 Introduction

A substantial body of recent research shows that pre- and early postnatal conditions are key determinants of adult outcomes (Cunha and Heckman 2007, Heckman, Stixrud and Urzua 2006). In particular, the fetal origins literature presents evidence that *in utero* nutrition, stress, and exposure to toxins have a lasting impact on adult health and labor market outcomes (Almond and Currie 2011, Heckman 2007). Moreover, both theoretical and empirical studies on the formation of skills over the life cycle demonstrates that early childhood inputs are critical for facilitating the productivity of later human capital investments (Cunha, Heckman, Lochner and Masterov 2006).

In this paper, we explore within-family differences in major prenatal and early childhood inputs as a potential explanation for the "birth order effect" – significant differences in adult outcomes by birth order across siblings or individuals from observably similar households. Although several studies have found a negative relationship between birth order and educational attainment and adult earnings (Kantarevic and Mechoulan 2006) and IQ (Black, Devereux and Salvanes 2007), research examining the possible causes of the birth order effect has been less successful. For example, Price (2008) and Monfardini and See (2011) investigate the role of parental time investment and find that although parents do spend less quality time with children of higher birth order at any given age, birth order differences in cognitive assessments are not explained by measures of maternal quality time. Similarly, the negative relationship between IQ and birth order found in Black et al. (2007) is robust to controlling for several birth endowments such as birthweight, gestational period, and head size.

We take advantage of the rich information on early childhood inputs and outcomes available in the National Longitudinal Survey of Youth 1979 (NLSY79) and the Children of the NLSY79 (CNLSY79) to test whether there are birth order differences in a wide range of prenatal and early postnatal inputs, including alcohol use and smoking during pregnancy, prenatal medical care, breastfeeding patterns, and the quality of the home environment. We then analyze whether birth order differences in the children's motor and social development (MSD) during their first three years depend on variations in these early inputs. Our results show that mothers are less likely to seek prompt prenatal care, to breastfeed, and to provide a high quality home environment for their later-born children. This negative relationship between the quality of early inputs and birth order is mirrored in the children's early MSD scores, with later-born children scoring up to 0.3 standard deviations lower than their older siblings. However, while early home environment is significantly associated with MSD scores at ages 0 to 1, both the statistical significance and the magnitude of the birth order differences in MSD remain robust to accounting for early inputs. Furthermore, we find that these birth order differences in early inputs and outcomes are most prominent in white families and among children of mothers with low Armed Forces Qualifying Test (AFQT) scores.

We find a strong negative relationship between increasing birth order and cognitive and non-cognitive test scores. Birth order effects are most significant in the children's reading scores and measures of self-worth at the beginning of their teen years. However, despite our finding that there are significant differences in prenatal and early childhood conditions across children of different birth order, we find that the size and the significance of the negative birth order effects on cognitive/non-cognitive tests, as well as in educational attainment, are robust to controlling for these early childhood factors. These results suggest several possible interpretations. One, birth order effects on educational outcomes are not determined by biological differences or variations in early childhood environments; two, its effects are latent until later in adulthood; or three, common measures of prenatal and early childhood conditions fail to adequately capture critical differences in early health and home conditions within a family.

Our paper makes a number of key contributions to the birth order literature. First, despite growing evidence of the importance of early childhood investments on later outcomes, no other study thus far has assessed whether early inputs other than parental time can help explain the lower achievement of later-born children. To our knowledge, this paper is also the first attempt to test whether there exists birth order effects across many types of early cognitive and non-cognitive test scores. Previous studies have largely focused on the relationship between birth order and adult educational attainment or earnings, yet we believe that assessing whether these differences in achievement are present even at early ages is important for unearthing the possible causes and dynamics of the birth order effect.[1] Second, despite growing evidence of the importance of prenatal and early childhood investments in health and education as well as early home environments on children's adolescent and adult outcomes, no study has assessed whether these early childhood conditions other than parental time can help explain the relationship between birth order and children's later achievement.[2] Finally, our findings shed light on an unexplored aspect of the birth order effect by assessing how the magnitudes and patterns of the birth order effect differ by the mother's cognitive

[1]Heiland (2009) is the only study of which that we are aware that examines the relationship between birth order and an early cognitive test. However, he focuses on only the Peabody Picture Vocabulary Test (PPVT) scores and does not include other cognitive tests. We do not know of any study that investigates the presence of birth order effects on early *non-cognitive* outcomes.

[2]Booth and Kee (2009) may be considered an exception. However, their conclusion that latter-born children have lower shares of educational resources is not directly identified, and they are unable to pinpoint what types of resources higher birth-order children lack. Moreover, due to data limitations, they are unable to estimate a family fixed effects model.

ability and race.

2 Related Literature

There are a number of theories outlining the potential channels through which birth order effects might occur. First, parents may face different time and financial constraints over their lifetime that may prevent them from equalizing their resources and investments across children. On one hand, if there are time and resources constraints, first-born and last-born children may benefit from their greater share of resources compared to middle-born children (Birdsall 1991). However, if parents' earnings tend to increase over their life cycle, later-born children may face more advantages than their earlier-born siblings (Parish and Willis 1993). Second, changing composition or parental characteristics may contribute to differing home environments across children of different birth order. For example, later-born children may be more intellectually stimulated by growing up with older children and better educated parents (Zajonc 1976). Yet, if the level of intellectual stimulation at home is closely tied to parental time constraints, later-born children may be disadvantaged by being part of a larger family. Third, biological or physiological differences may also induce varying outcomes. Later-born children have older mothers, and older mothers are more likely to give birth to children of lower weight[3] and experience greater number of complications during pregnancy and at birth. On the other hand, mothers may become better child caretakers as they gain experience with each child, and later-born children may benefit from better child rearing practices. Recently, more sophisticated optimal stopping models or endogenous fertility models have shown that less than expected draw in the quality of the latest child may either demotivate parents from having additional children or to continue having children until they reach an optimal stopping quality (Ejrnæs and Pörtner 2004). The former effect would imply that earlier-born children will tend to have better outcomes while the latter implies that later-born children would be advantaged.

Despite the theoretical ambiguity in the sign of the relation between birth order and children's educational and labor market outcomes, most of the latest empirical studies on birth order effects have found a strong, monotonically decreasing relationship. Improving upon earlier studies suffering from estimation limitations due to small sample sizes and/or inability to control for family fixed effects and/or cohort effects (Behrman and Taubman 1986, Kessler 1991, Hanushek 1992, Iacovou 2001), Black, Devereux and Salvanes (2005) use detailed national administrative data from Norway and find a strong, negative relationship between the birth order and the child's education attainment and adult earn-

[3] However, first-born children may also be more likely to have lower birth weight.

ings within a family, and these birth order effects appear to be of similar magnitude across families of varying sizes. The significance of birth effect on education and earnings has been corroborated using the U.S. Panel Study of Income Dynamics (PSID) in Kantarevic and Mechoulan (2006) who estimate a family fixed effects model and find that first borns have higher education achievement, high school completion rates, and earnings. Similarly, Conley and Glauber (2006) employ the sibling-sex composition instrument used in Angrist and Evans (1998) in analyzing educational data from the 1990 5%-sample of the Public Use Micro Sample (PUMS) and find that while the latter-born children in larger families are more likely to be held back in school, family size does not seem to affect the first-born. Heiland (2009) examines birth order effects on early verbal ability test scores using the Children of the NLSY79 and finds that compared to their middle-born siblings, first-born children have higher Peabody Picture Vocabulary Test (PPVT) scores. Ejrnæs and Pörtner (2004) remains an exception to these findings on the lower achievements and outcomes of later-born children. Using data from the Philippines, they find that birth order is associated with a *positive* impact on completed education and time spent on school activities, suggesting that resource allocation or cultural differences in child rearing and development between developing and developed countries may serve as potential explanations for the relationship between birth order and outcomes, not necessarily an inherent, genetic differences between the earlier and later-born children.

In view of these strong findings on birth order effects in educational attainment and earnings, much of the latest research on birth effects have focused on empirically exploring the possible causes of the relationship. Most of these studies have found that the birth order effect is robust to controlling for possible differences in birth endowments, parental time, and maternal quality time. Using the same Norway administrative dataset as in Black et al. (2005), Black et al. (2007) find a significant effect of birth order on IQ with the earlier born children having higher IQs by about one-fifth of a standard deviation or approximately three IQ points.[4] When controlling for birth endowments such as birthweight, gestational period, and head size, the estimated birth order effects remain significant, actually rising in their magnitudes.

Several studies have assessed the role of parental time variations across children of different birth order. Price (2008) uses data from the American Time Use Survey (ATUS) and finds that parents tend to spend equal time with each of their children at any given point in time, and the total parental time with children decreases with age, especially with the age of the oldest child. These patterns, in turn, translate into the first-born child receiving roughly 20 to 30 more minutes of quality time each day with a parent compared to a

[4]Black et al. (2007) note that this IQ gap is of similar magnitude as the black-white gap in the U.S.

second-born child. Despite his strong findings on parental time differences across siblings in his data, Price (2008) is unable to assess whether differences in parental time is significantly correlated with children's education outcomes and whether birth order effects are robust to controlling for parental quality time. Monfardini and See (2011) directly address these two remaining questions in their examination of maternal quality time and birth order in the Child Development Supplement (CDS) of the PSID. In a household fixed effects model, they find a significant negative relationship between maternal quality time and birth order, yet the birth order effects on education remain negative and significant even controlling for these differences in maternal quality time. Moreover, estimates show that differences in maternal quality time are insignificant correlates of variations in children's education outcomes.

Finally, Booth and Kee (2009) ask whether variations in family resources other than parental time across children can explain the birth order effect. Using the British Household Panel Survey, Booth and Kee show that the shares of the family educational resources are decreasing with birth order. Controlling for parental family income, parental age at birth and family level attributes, they find that children from larger families and with higher birth order have lower educational attainment. In contrast to Black et al. (2005), the family size effect does not disappear when controlling for birth order. Nevertheless, due to data limitations, they cannot estimate a family fixed effects model, and therefore cannot control for non-time varying unobservable family characteristics that are correlated with household resources or fertility decisions.

Motivated by the existing evidence on the significance of *in utero* and early childhood environments on children's later outcomes,[5] we explore prenatal and early childhood investments in health, education, and maternal emotion/verbal responsiveness during the child's first year as possible causes of birth order effects. We first investigate whether there are indeed significant differences in key prenatal and early childhood investments and home conditions across siblings of different birth order. Next, we examine birth order effects not merely in education attainment or adult earnings but in cognitive and non-cognitive test scores from early childhood and adolescence in an effort to disentangle the evolution of birth order effects from childhood to adulthood. Finally, we assess whether variations in prenatal and early childhood environments are able to explain differences in test scores and adult outcomes across children of different birth order.

The rest of the paper is organized as follows. Section 3 briefly describes the Children of the NLSY79 and summarizes our cognitive and non-cognitive assessments of interest.

[5] An extensive review of literature is outside the scope of this paper. See Gluckman and Hanson (2005), Heckman (2007), Almond and Currie (2010) for a detailed review of the fetal origins literature and Knudsen, Heckman, Cameron and Shonkoff (2006), Cunha and Heckman (2007), Heckman et al. (2006), and Heckman and Masterov (2007) for notable studies on the importance of the child's first few years of development.

We also include detailed description of our measures of prenatal and postnatal inputs and early home environment. Section 4 outlines our empirical strategy and presents the results. Finally, Section 5 concludes and suggests avenues for future research.

3 Data

The National Longitudinal Survey of Youth 1979 (NLSY79) is a nationally representative sample of 12,686 men and women between 14 and 21 years old who were first interviewed in 1979. Periodic surveys of these individuals have been conducted since then, collecting rich information on employment, income, welfare program participation, education, and other background variables.

Starting in 1986, 11,420 children of the 6,283 female NLSY79 respondents have been interviewed bi-annually forming the Children of the NLSY79 (CNLSY79) sample. The child survey includes information on prenatal investments, birth outcomes, early childhood parental investments and health, scores from cognitive and non-cognitive assessments, quality of the home environment, as well as additional demographic and development information collected from either the mother or the child. Some children born before or in 1972 never belonged to the CNLSY79, because once they turn fifteen years old, they leave the sample and start the NSLY79 Young Adults survey, which resembles the NLSY79 questionnaire. The CNLSY79 provides unique and detailed longitudinal information on a large nationally representative sample of mothers and their children. The availability of a thorough record of the mothers' employment records and their background characteristics along with extensive data on children's prenatal and early childhood health and cognitive/non-cognitive development indicators make the NLSY79 Children and Young Adults an ideal dataset to explore the relationship between birth order and child's cognitive and educational outcomes and its possible causes found in *in utero* and early childhood environments.

Pre/Postnatal Inputs and Birth Outcomes As potential explanations for the birth order effects on child cognitive/non-cognitive test scores and adult education/earnings outcomes, we examine various measures of prenatal and postnatal maternal behavior and investments as well as several key child outcomes at birth that have been shown to be important determinants of child/adult health and development in medical and health economics literature. Specifically, we investigate the role of (i) alcohol and smoking use and reduction during pregnancy, patterns of prenatal medical visits, (ii) gestational length, prematurity, birth weight/length, (iii) breastfeeding patterns in the child's first year, and (iv) home environment during the child's first year of life.To assess the quality of the children's home, we

Table 1: Summary statistics

Variable	Mean	Std. Dev.	N
Child characteristics			
Birth order	1.805	0.885	6200
White	0.785	0.411	6200
Black	0.147	0.354	6200
Hispanic	0.069	0.253	6200
Boy	0.520	0.500	6200
Mother's age at birth	25.259	4.748	6200
Prenatal Inputs:			
# of alcohol drinks per week (conditional on drinking at all)	2.357	5.376	2825
Reduction in alcohol use	0.885	0.319	2825
# of cigarettes per day	3.558	5.289	2113
Reduction in smoking	0.760	0.427	2113
Delayed prenatal care (first visit > 4 months)	0.167	0.372	6200
Month of first prenatal care (if not delayed)	1.907	0.711	5049
Birth Outcomes:			
Gestational length (weeks)	38.702	2.095	6200
Premature (weeks < 37)	0.205	0.403	6200
Birth weight (ounces)	119.038	21.123	6200
Low birth weight (bw < 88 oz)	0.067	0.250	6200
Overweight at birth (bw > 142 oz)	0.123	0.328	6200
Length at birth (inches)	20.149	1.611	6200
Postnatal Investments:			
Ever breastfed	0.533	0.499	6200
Weeks breastfed if at all	21.671	21.785	2848
HOME Score at Age 0 to 1 (Total)	142.039	22.959	3273
HOME Score at Age 0 to 1 (Cognitive)	67.651	15.517	3273
HOME Score at Age 0 to 1 (Emotional)	74.833	12.934	3273

Notes: Means are weighted using sampling weights. All alcohol and cigarette consumption variables are conditional on the mother having had smoked or consumed alcohol 12 months before giving birth. The sample is restricted to mothers/children with non-missing prenatal input, birth outcomes, breastfeeding.

rely on the Home Observation Measurement of the Environment (HOME) measure in the CNLSY79 that has been used by researchers to understand the quality of the child's home environment and maternal traits and behavior.

The top panel of Table 1 presents the summary statistics of children included in our sample. Most children in our sample are first-borns, 45.1%, while 35.1% are second children. Less than 20% of the children are born to mothers who already have two kids. Multiple births accounted for less than 2% of the sample and they are therefore dropped. Because our sample is comprised of births that occurred from 1979 to 1998, mothers were on average 25 years old when they gave birth. In our regressions, we include year of birth dummies to account for any cohort effects and any policy changes or new medical recommendations that could confound our estimates. [6]

Despite the evidence that alcohol and cigarette consumption during pregnancy are linked to increased rates of birth complications, defects, and development problems (CDC 2001, CDC 2004, Almond and Currie 2010), conditional on having had used alcohol or cigarettes before pregnancy,[7] the mothers in the CNLSY79 still consume on average 2.3 drinks per week and 3.6 cigarettes per day while pregnant. However, the vast majority of the women do report that they did reduce alcohol and cigarette use during pregnancy. Only about 17% of the women significantly delayed receiving prenatal care, having her first doctor's visit on the 4th month of pregnancy or later. For those who did not delay receiving prenatal care, the first visit typically occurs during the second month of pregnancy.

The third panel of Table 1 presents the means of birth outcomes. A typical child in our sample is born around the 38th week of gestation, weighs approximately 120 ounces (or 7.5 pounds), and measures 20 inches at birth. Although the proportion of children born with a low birth weight is only around 7%, it is notable that the proportion of those born overweight is almost twice as large. About 20% of the children in our sample are born prematurely, being born before the 37th week of gestation.

Despite American Academy of Pediatrics' (AAP) recommendation that infants should be exclusively breastfed during his/her first six months in light of the potential health benefits associated with breastfeeding (Belfield and Kelly 2010), the bottom panel of Table 1 shows that only half of the children in our sample are ever breastfed. For those children the mothers choose to breastfeed, the average duration is around 20 weeks, about one month less than the AAP's recommendation.

Finally, taking advantage of information on the children's home environment in the CNLSY79, we explore the role of early home environment and parental interaction as a potential explanation for birth order effects using the Home Observation Measurement of the Environment (HOME) measure.[8] We focus on the total HOME score as well as on the

[6] Although we rely on the family fixed effects model in all of our empirical specifications, there may be other time-varying family characteristics around the time of the child's birth that may impact our outcomes of interest, such as income or welfare eligibility. These variables are likely to be correlated, directly or indirectly through the mother's age at pregnancy, with birth order. Including them as controls or excluding observations that miss this information do not affect our results.

[7] More specifically, this condition refers to women who smoked or drank alcohol around 12 months before giving birth. However, the share of women who report not having had consumed alcohol or cigarettes in the NLSY97 is similar to the share in the entire U.S. population of non-pregnant women (CDC 2004).

[8] Starting in survey year 2006, only children 4 years and older were given the interviewer-administered assessments. Therefore, interview observations for children under the age of 4 are not available for many of

two sub-scores focusing on cognitive stimulation and emotional support. The HOME questionnaire for children aged 0 to 1 includes questions that ask about the number of books the child has at home, whether the mother reads to the child, availability of toys, interaction with parents, parental attentiveness, discipline patterns, and frequency of outings. These responses to these questions are either answered by the mother or recorded from observations of an official home visitor, and the composite HOME scores are reported as simple summations of the scores from individual items in the questionnaire, with higher scores signifying a better home environment. We choose to focus on HOME scores at ages 0 to 1[9] to minimize the concern that parents may systematically adjust their interactions with and investments in the child based on their assessment of the child's abilities as revealed through test scores or personal interactions.

Cognitive and Non-Cognitive Assessments The Children of the NLSY79 were tested from a very early age, which allows us to examine the appearance and the evolution of the birth order effect by age. In our aim to better understand the sources and the nature of birth order effects, we expand the set of outcome variables beyond adult education attainment and earnings that have typically been the focus of existing literature and examine a wide range of early cognitive and non-cognitive test scores. Table 2 presents their descriptive statistics.

– **Motor and Social Development (MSD)** Developed by the National Center for Health Statistics to measure motor, social, and cognitive development of young children from birth to three years, the MSD is based on the mother's answer to fifteen or sixteen age-appropriate questions about their child's social, motor and cognitive development and has been shown to be strongly associated with later cognitive test scores (Mott, Baker, Ball, Keck and Lenhart 1998). We examine the MSD scores at ages 0 and 1 and at ages 2 and 3.

– **Cognitive Assessments** Children's cognitive outcomes are proxied by scores on the Peabody Individual Achievement Test - Mathematics (PIAT-M) and - Reading (PIAT-R) tests and the Peabody Picture Vocabulary Test (PPVT). All three assessments have been used extensively in a myriad of studies assessing the cognitive development of young children.[10]

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the youngest children in the CNLSY79 sample. This is the main reason for the decrease in our sample size in our regression analysis.

[9] The CNLSY79 is administered every two years. Therefore, we calculate HOME scores as equal to the scores at age 0. If scores are missing at age 0, we use scores at age 1. In our estimation sample, only 51 observations have scores from both ages 0 and 1. Treating scores from age 1 as the primary measure does not alter our conclusions.

[10] Descriptions of the cognitive and non-cognitive assessments, prenatal and postnatal inputs, and early home environment are drawn from the NLSY79 online guides to Child and Young Adult Data available at:

The PPVT is a vocabulary test administered to children between the ages of 3 through 18 and is widely recognized to be a good measure of cognitive ability, especially of verbal intelligence. It has been found to be highly correlated with scores on other intelligence tests and is viewed to be an important indicator of early and middle school outcomes (Baker, Keck, Mott and Quinlan 1993). We focus on PPVT scores from ages 4 and 5 and from ages 10 and 11 in an effort to examine how the scores change from the earliest ages for which we have test score information to the beginning of adolescence.

The PIAT-R is a test designed to assess word recognition and pronunciation ability and is divided into two parts. The PIAT-R: Reading Recognition assesses skills such as matching letters, naming names, and reading single words aloud. The second part, PIAT-R: Reading Comprehension measures the child's ability to derive meaning from sentences that are read silently. PIAT-M assesses knowledge and application of mathematical concepts and facts. Both the PIAT-R and the PIAT-M tests are administered to children between 5 to 18 years old. In our analysis, we examine test scores at ages 5 and 6 and at ages 12 and 13, the earliest and the latest ages for which we have score information for the majority of our children in our sample.

The second panel of Table 2 presents the descriptive statistics for these cognitive tests, where we restrict the sample to those children for whom we have information about their prenatal investments and birth outcomes. Since the test scores are age-standardized, differences in the means should not reflect the effect of age at test-taking. Nevertheless, except in the case of reading comprehension, children tend to perform slightly better in their second assessment.

– **Non-Cognitive Assessments** While cognitive assessments are important measures of children's early achievement, they, by themselves, may fail to capture critical differences in the children's mental and social development (Heckman et al. 2006). To investigate whether birth order differences are found in non-cognitive outcomes, we focus on the Self-Perception Profile for Children (SPPC). Its descriptive statistics are presented in the bottom panel of Table 2.

The SPPC is a measure of a child's sense of general self-worth and self-competence in their academic skills based on the child's self-reported answers to the interviewer's verbal questions. The score is divided into two sub-scores: a scholastic competence score and a global self-worth score. In the SPPC survey, each child is given a choice to select the former or the latter part of a two-part statement that describes him or her the best and indicate the

`http://www.nlsinfo.org/childya/nlsdocs/guide/topicalTOC.html`. Accessed on April 28, 2012.

Table 2: Summary of Cognitive and Non-Cognitive Tests

Variable	Mean	Std. Dev.	N
Motor and Social Development:			
1st assessment (age 0 to 1)	51.982	27.612	2330
2nd assessment (age 2 to 3)	53.884	27.810	2330
Cognitive tests:			
Peabody Picture Vocabulary Test			
1st assessment (age 4 to 5)	33.232	29.409	2234
2nd assessment (age 10 to 11)	42.930	30.170	2234
Peabody Individual Achievement Test - Mathematics			
1st assessment (age 5 to 6)	49.129	27.363	3220
2nd assessment (age 12 to 13)	51.735	27.138	3220
Peabody Individual Achievement Test - Reading Recognition			
1st assessment (age 5 to 6)	59.354	25.223	3172
2nd assessment (age 12 to 13)	56.175	29.597	3172
Peabody Individual Achievement Test - Reading Comprehension			
1st assessment (age 5 to 6)	70.460	18.846	1318
2nd assessment (age 12 to 13)	50.835	26.193	1318
Non-Cognitive tests:			
Self-Perception Profile for Children (Scholastic)			
1st assessment (age 8 to 9)	169.711	41.337	1431
2nd assessment (age 13 to 14)	176.516	42.855	1431
Self-Perception Profile for Children (Global)			
1st assessment (age 8 to 9)	201.660	34.462	1429
2nd assessment (age 13 to 14)	207.610	34.463	1429

Notes: Weighted means. Standard deviations in parentheses and number of observations in brackets. Motor and Social Development (MSD), Peabody Picture Vocabulary Test (PPVT), Peabody Individual Achievement Tests (PIAT) are in age-standardized percentiles, while Self-Perception Profile for Children (SPPC) scores range from 0 to 250.

extent to which the description is true for them.[11] The SPPC is completed by children eight years and older in the survey years 1986 to 1994, and beginning in 1996, the assessment was limited to children who were 12 years and older. We examine the SPPC scores at ages 8 and 9 and at ages 13 and 14.

[11]For example, a statement on the SPPC part of the survey declares, "Some kids feel like they are just as smart as other kids their ages, *but* other kids aren't so sure and wonder if they are as smart."

4 Results

We exploit the linked mother-child data structure of the CNLSY79 to measure the effect of birth order on early inputs and outcomes as follows:

$$Y_{if} = \alpha + \beta \mathrm{D}(\text{birth order})_{if} + \gamma X_i + \upsilon_f + \varepsilon_{if}$$

where i denotes child, f family, and Y_{if} the variable of interest. We additionally control for child-specific characteristics X_i that can affect mother's choices and children's outcomes: gender, age of the mother at birth, and birth cohort and region indicators.[12] υ_f are family (mother) fixed effects. To allow for a more flexible specification, we estimate a model with dummies for second born, third born and fourth or higher born. Therefore, β can be interpret as the average difference in the variable of interest of a child with his/her oldest sibling. Because siblings observations are likely to be correlated, standard errors are clustered at the family level.

4.1 Differences in Early Investments and Birth Outcomes by Birth Order

In this section, we examine whether there exist significant variations in pre- and postnatal investments, key birth outcomes, and child's early home environment across children of different birth order. Table 3 presents the results for prenatal and birth outcomes, and Table 4 presents the results for postnatal investments.

The top panel of Table 3 shows that, within the same family, there are significant differences in some measures of prenatal investments across siblings of different birth order. However, these patterns are not robust across all investment measures. First, we fail to find statistically significant differences in the probability of alcohol reduction during pregnancy across birth order, although the point estimates are sizable. However, while still not statistically significant, the average number of drinks per week tend to decrease with birth order as well. This pattern may be driven by women reducing their overall alcohol consumption as they age and family size increases.[13]

In contrast to alcohol consumption patterns, we find that the probability of reducing

[12] Because time-varying family level-variables are at risk of being outcome variables, our preferred specification does not include them as controls. Nevertheless, our results are robust to controlling for income, welfare recipiency, and mother's labor force participation, both contemporaneous and lagged, or to including father's presence at birth, age differences between siblings, or the gender of the first-born child in the family.

[13] Note that births occurred between 1980 and 1994, when the negative effects of smoking or drinking during pregnancy were already well established.

Table 3: Prenatal Investments and birth outcomes

Prenatal Investments:	# of drinks per week	Reduced alcohol	# cigarettes per day	Reduced smoking	Delayed prenatal care	Month of 1st prenatal visit
	(1)	(2)	(3)	(4)	(5)	(6)
2nd born	-0.409	-0.071**	0.222	-0.125***	0.001	0.126**
	(0.559)	(0.036)	(0.602)	(0.045)	(0.024)	(0.050)
3rd born	-0.677	-0.038	-0.507	-0.213***	0.006	0.308***
	(0.970)	(0.064)	(0.867)	(0.074)	(0.042)	(0.084)
4th or higher born	-1.054	-0.126	0.203	-0.357***	0.048	0.406***
	(1.732)	(0.097)	(1.291)	(0.114)	(0.060)	(0.131)
N	2825	2825	2113	2113	6200	5049
F-stat	1.486	2.408	2.232	3.199	1.461	2.343
R^2	0.066	0.079	0.037	0.123	0.020	0.043
Birth Outcomes:	Gestational length	Premature (weeks<37)	Birth weight	Low birth weight	Overweight at birth	Baby length
	(1)	(2)	(3)	(4)	(5)	(6)
2nd born	-0.062	-0.009	2.869***	-0.008	0.032	0.051
	(0.122)	(0.023)	(0.928)	(0.012)	(0.020)	(0.077)
3rd born	0.126	-0.032	5.052***	-0.032	0.069**	0.068
	(0.201)	(0.040)	(1.660)	(0.020)	(0.035)	(0.141)
4th or higher born	0.131	-0.018	5.333**	-0.047	0.138***	-0.044
	(0.300)	(0.057)	(2.461)	(0.031)	(0.053)	(0.224)
F-stat	1.596	0.658	3.665	0.879	2.444	1.497
R^2	0.018	0.007	0.052	0.009	0.041	0.022
N	6200	6200	6200	6200	6200	6200

Notes: All regressions are weighted and include family fixed effects. Standard errors clustered at the family level in parentheses. *= different from zero at the 10% level. **= different from zero at the 5% level. ***= different from zero at the 1% level. All specifications control for regional dummies, maternal age, gender of the child. A series of dummies on year of birth are also included. Alcohol consumption and smoking are defined for woman who reported drinking or smoking prior to the pregnancy. Prenatal care is classified as delayed if the first visit occurred at the 4th gestational month of pregnancy or later. Month of 1st prenatal visit is defined only for women who seek prenatal care early in their pregnancies (up to the 3rd gestational month).

cigarette smoking is significantly lower for higher order children. Compared to her first child, a woman who was a prior smoker is 12 percentage points less likely to reduce cigarette consumption during the pregnancy of her second child, 21 percentage points less likely while carrying her third child, and 36 percentage points less likely for her 4th or higher ordered children.[14] The results on the number of cigarettes smoked per day do not follow a consistent pattern.[15]

Finally, while we find no evidence that women are more likely to delay their first prenatal

[14] Unfortunately, we do not have information on the timing of the reduction in smoking. Stopping tobacco consumption early in the pregnancy has been reported to be correlated with better birth outcomes than stopping at a later point (MacArthur and Knox 1988).

[15] Fingerhut, Kleinman and Kendrick (1990) report a relapse ratio of 70 percent within a year of birth in the mid 1980s.

care visit for her latter children, column 6 of Table 3 shows that among those women who sought timely prenatal care, mothers are significantly more likely to postpone their first visit for higher order children.[16] The effect of early prenatal care on children in literature is still not well established. While some studies only find a weak impact of prenatal care on birth outcomes (Currie and Grogger 2002), others, such as Smith-Conway and Deb (2005), report that for normal pregnancies, a delay of one week in first prenatal visit is associated with a decrease of 1 to 1.2 ounces in birth weight.[17]

Despite our finding that mothers are less likely to reduce cigarette consumption and to seek timely prenatal care with her latter pregnancies, the birth outcomes of higher-order children do not seem to be adversely affected. The bottom panel of Table 3 presents the regression results for birth outcomes. Siblings born later are slightly less likely to be premature, and consequently, are more likely to be heavier (but not taller) than their older siblings. The effect of birth order on weight is ambiguous. Columns 3 and 4 show that while higher order children are less likely to suffer from low birth weight, they are also significantly more likely to be born overweight. Being overweight at birth has been shown to be associated with higher BMI later in life[18] and increased risk for obesity and diseases such as cancer, asthma, and atopy in adults.[19] Therefore, this positive relationship between birth order and increased probability of being overweight at birth may serve as a potential explanation for worse adult outcomes through its impact on health.

Although we do not find much evidence of subtantially adverse birth outcomes for children of higher birth order, Table 4 reveals a clear pattern of maternal underinvestment after birth in later-born children. Compared to firstborns, mothers are 9 to 16 percentage points less likely to breastfeed their younger children. However, conditional on being breastfed,

[16]The absence of statistically significant differences in our dataset may be due to the relatively small size of our sample. Using a larger sample of birth certificates, Lewis, Mathews and Heuser (1996) report a positive correlation between delayed prenatal care and pregnancies after the second live birth.

[17]Drinking alcohol, smoking, delayed access to prenatal care are also associated with a higher incidence of miscarriage and activities such as drug consumption that can cause fetal losses (e.g. Dominguez-Rojas, de Juanes-Pardo, Astasio-Arbiza, Ortega-Molina and Gordillo-Florencio 1994). Unfortunately, the CNLSY79 does not include information on pregnancies that ended in spontaneous or induced abortion. Risky activities would be higher for pregnancies that end in fetal loss and the children would have performed significantly worse, would they not have miscarried. If the incidence of these "non-random" fetal losses varies by previous birth histories of the women, its omission from the sample might affect our estimation. However, the proportion of heavy drinkers or heavy smoker in our sample is limited and does not appear to vary by birth order.

[18]For example, see Gillman, Rifas-Shiman, Berkey, Field and Colditz (2003), Leong, Mignone, Newcomb, Titus-Ernstoff, Baron, Trentham-Dietz, Stampfer, Willett and Egan (2003), Parsons, Power, Logan, Summerbell et al. (1999), Pietiläinen, Kaprio, Räsänen, Winter, Rissanen and Rose (2001), and Wei, Li, Sung, Lin, Chiang, Li and Chuang (2007).

[19]See Eriksson, Wedel, Wallander, Krakau, Hugosson, Carlsson and Svärdsudd (2007), Harder, Plagemann and Harder (2008), Hjalgrim, Westergaard, Rostgaard, Schmiegelow, Melbye, Hjalgrim and Engels (2003), and Remes, Patel, Hartikainen, Jarvelin and Pekkanen (2008).

Table 4: Postnatal Investment

	Breastfeed	Weeks Breastfed	HOME (Total)	HOME (Cognitive)	HOME (Emotion)
	(1)	(2)	(3)	(4)	(5)
2nd born	-0.086***	-0.653	-6.067***	-3.353***	-1.975**
	(0.019)	(1.323)	(1.856)	(1.222)	(1.002)
3rd born	-0.107***	1.742	-9.225***	-7.331***	-1.161
	(0.034)	(2.376)	(3.338)	(2.060)	(1.918)
4th or higher born	-0.158***	4.765	-7.959	-8.316**	0.549
	(0.052)	(4.361)	(5.014)	(3.371)	(2.874)
F-stat	2.409	2.395	3.235	6.243	2.431
R^2	0.036	0.083	0.084	0.134	0.068
N	6200	2848	3326	3326	3326

Notes: All regressions are weighted and include family fixed effects. Standard errors clustered at the family level in parentheses. *= different from zero at the 10% level. **= different from zero at the 5% level. ***= different from zero at the 1% level. All specifications control for regional dummies, maternal age, and gender of the child. A series of dummies on year of birth are also included.

there are no clear patterns in the relationship between the duration of breastfeeding and birth order. While the signs and magnitudes of the length of breastfeeding indicate a positive relationship between breastfeeding duration and birth order, the standard errors are too large to establish statistical significance. In light of the growing evidence that breastfeeding at birth, when compared with formula-feeding, is associated with better early health and cognitive outcomes,[20] the significant negative relationship between the probability of breastfeeding and birth order may potentially be a part of the explanation for worse adult outcomes in latter-born children.

Finally, the level of home investment as proxied by the HOME scores has been shown to be significant correlates of later cognitive achievement and health (Todd and Wolpin 2007, Strauss and Knight 1999, Carlson and Corcoran 2001)[21], and we find large and significant birth order differences in the HOME scores across all dimensions as reported in the last three columns of Table 4. Compared to the first child, latter-born children are associated with worse home environments – both in cognitive stimulation and emotional support – by nearly 3 to 9 points or approximately 0.2 to 0.35 standard deviations on the HOME score scale.

[20]For example, see Belfield and Kelly (2010), Oddy, Kendall, Blair, De Klerk, Stanley, Landau, Silburn and Zubrick (2003), Chung, Raman, Chew, Magula, Trikalinos and Lau (2007), Horwood and Fergusson (1998). Note, however, that none of these studies assess results from a randomized controlled study or utilize a natural experiment in the choice to breastfeed or not. All of the studies attempt to mitigate the problem of endogeneity in the choice to breastfeed by simply including a large set of controls on family or child characteristics or performing propensity score matching using these sets of controls.

[21]Todd and Wolpin (2007) find that equalizing home inputs at the average levels of white children would close the black-white and the Hispanic-white test score gaps in math and reading about 10 to 20%.

This negative relationship is especially pronounced for the cognitive home environment score, where there exists a monotonically decreasing relationship between the quality of the home environment and birth order.

4.2 Birth Order and Test Scores

Having established that there are significant differences in cigarette usage, prenatal care, breastfeeding, and early home environment across siblings of different birth order, we now turn to the main research questions that we seek to address in this paper. First, are there birth order effects in early cognitive and non-cognitive outcomes that mirror the patterns found in adult outcomes? Second, if yes, can variations in pre and postnatal investments, birth outcomes, and early home environments within a family explain these birth order effects in cognitive and non-cognitive assessments?

Tables 5, 6, and 7 present our results for a wide range of cognitive and non-cognitive test scores, respectively. For both types of assessments, all of the analyses below use age-standardized percentile scores that are transformations of the raw scores that were originally designed to have a normal distribution with a mean of 100 and a standard deviation of 15. For ease of interpretation, all scores have been normalized to have a standard deviation of 1 throughout the paper. Therefore, the regression coefficients show the change in standard deviations of the test score by a one unit increase in the explanatory variable.

Motor and Social Development Scores First, we turn to measures of child development in the time frame of these inputs to assess whether birth order differences are also evident in the earliest measures of cognitive and non-cognitive outcomes and whether prenatal and early postnatal inputs explain any differences in development by birth order. Table 5 presents results for the Motor and Social Development scores at each of the two periods during which the children were assessed.[22] We find a strong birth order effect even at the very start of the child's life. At ages between 0 and 3, children of higher birth order score 0.2 to 0.3 standard deviations lower in their MSD assessment than their older siblings. Furthermore, the size of the birth order effect on MSD does not appear to grow over the first years of life, suggesting that very early investments are key to determining the birth order effect in later outcomes.

To assess whether these differences in MSD scores can be attributed to lower early investments, columns (2) and (4) control for prenatal investments, birth outcomes, breastfeeding patterns, and HOME scores. Controlling for these early childhood investments does not change the significance or the general magnitude of the birth order coefficients.[23]

[22] We restrict the sample to those children for whom we have scores at both assessments.

[23] Nevertheless, HOME scores are significantly correlated with MSD scores at least at ages 0 to 1.

Table 5: Early outcomes: Motor and Social Development

	Ages 0 and 1		Ages 2 and 3	
	(1)	(2)	(3)	(4)
2nd born	-0.251**	-0.232*	-0.161	-0.203*
	(0.128)	(0.127)	(0.114)	(0.112)
3rd born	-0.319	-0.291	-0.374*	-0.399**
	(0.226)	(0.222)	(0.207)	(0.203)
4th or higher born	-0.771**	-0.720**	-0.364	-0.281
	(0.329)	(0.320)	(0.309)	(0.304)
F-stat	2.522	2.544	3.553	2.587
R^2	0.120	0.157	0.120	0.157
N	2330	2330	2330	2330
Controls (F-test of joint significance)				
prenatal investments	n/a	1.53	n/a	1.03
birth outcomes	n/a	1.69	n/a	1.45
postnatal investments	n/a	1.62	n/a	0.83
All controls	n/a	1.71**	n/a	1.21

Notes: All regressions are weighted and include family fixed effects. Standard errors clustered at the family level in parentheses. *= different from zero at the 10% level. **= different from zero at the 5% level. ***= different from zero at the 1% level. All assessments have a mean of 0 and a standard deviation of 1. All specifications control for regional dummies, maternal age, gender of the child, age in months at the time of the test and a series of dummies for year of birth.

Cognitive Test Scores Tables 6 examine birth order effects for early and later cognitive assessments for PPVT, PIAT-M, and PIAT-R tests. The odd columns of Tables 6 report regression results without early childhood controls while the even columns report results controlling for prenatal investment, birth outcomes, and postnatal investments, including HOME scores.[24]

We first focus on discussing the results in odd columns of Tables 6 without early childhood controls. Consistent with the existing literature on adult education and earnings, children of higher birth order tend to score significantly lower across several cognitive assessments. However, this negative relationship between test scores and birth order is not statistically robust across all assessments. For the PPVT, the birth order effect is only evident and significant in the second assessment (column 3). Compared to first-borns, second-born children score about 0.2 standard deviations lower at age 10 to 11 while the third and the higher ordered children score about 0.3 standard deviations lower. This increase in magnitude and

[24] To minimize the dramatic sample reduction due to missing HOME scores, we replace missing HOME scores with zero and include an indicator for missing.

Table 6: Cognitive Test Scores: PPVT and PIAT

	Peabody Picture Vocabulary Test				*PIAT-Math*			
	1st assessment (Ages 4 to 5)		2nd assessment (Ages 10 to 11)		1st assessment (Ages 5 to 6)		2nd assessment (Ages 12 to 13)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2nd born	0.062	0.050	-0.230**	-0.266***	-0.153*	-0.141*	-0.077	-0.102
	(0.100)	(0.091)	(0.100)	(0.098)	(0.079)	(0.082)	(0.064)	(0.063)
3rd born	-0.087	-0.087	-0.584***	-0.606***	-0.128	-0.099	-0.010	-0.051
	(0.165)	(0.149)	(0.167)	(0.171)	(0.127)	(0.129)	(0.114)	(0.115)
4th or higher born	0.056	0.020	-0.493*	-0.540**	-0.038	0.005	0.051	-0.028
	(0.286)	(0.260)	(0.266)	(0.260)	(0.191)	(0.196)	(0.178)	(0.179)
F-stat	1.769	1.554	1.460	1.874	2.198	1.723	2.221	1.767
R^2	0.086	0.121	0.069	0.117	0.058	0.067	0.058	0.076
N	2198	2198	2198	2198	3161	3161	3161	3161
Controls (F-stat test of joint significance)								
prenatal investments	n/a	1.93*	n/a	1.29	n/a	0.89	n/a	0.29
birth outcomes	n/a	0.37	n/a	1.38	n/a	0.57	n/a	1.06
postnatal investments	n/a	1.43	n/a	0.62	n/a	0.57	n/a	1.78*
All controls	n/a	1.29	n/a	1.59*	n/a	0.68	n/a	1.13
	PIAT-R (Recognition)				*PIAT-R (Comprehension)*			
	1st assessment (Ages 5 to 6)		2nd assessment (Ages 12 to 13)		1st assessment (Ages 5 to 6)		2nd assessment (Ages 12 to 13)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2ndBorn	-0.202***	-0.254***	-0.126*	-0.149**	-0.031	-0.047	-0.370**	-0.383**
	(0.075)	(0.076)	(0.069)	(0.070)	(0.141)	(0.147)	(0.154)	(0.166)
3rdBorn	-0.133	-0.192	-0.150	-0.160	-0.059	-0.083	-0.867***	-0.829***
	(0.126)	(0.131)	(0.133)	(0.135)	(0.244)	(0.251)	(0.286)	(0.314)
4th-or-higherBorn	-0.212	-0.299	-0.205	-0.237	-0.021	0.040	-1.573***	-1.558***
	(0.192)	(0.195)	(0.178)	(0.183)	(0.362)	(0.385)	(0.329)	(0.370)
F-stat	3.640	3.012	1.236	1.237	7.795	7.180	3.090	2.763
R^2	0.088	0.110	0.021	0.038	0.391	0.449	0.164	0.224
N	3116	3116	3116	3116	1298	1298	1298	1298
Controls (F-stat test of joint significance)								
prenatal investments	n/a	0.48	n/a	0.56	n/a	1.45	n/a	1.18
birth outcomes	n/a	3.53***	n/a	1.77	n/a	1.58	n/a	0.88
postnatal investments	n/a	0.63	n/a	0.72	n/a	0.66	n/a	1.75
All controls	n/a	1.39	n/a	0.99	n/a	1.67**	n/a	1.31

Notes: All regressions are weighted and include family fixed effects. Standard errors clustered at the family level in parentheses. *= different from zero at the 10% level. **= different from zero at the 5% level. ***= different from zero at the 1% level. All assessments are standardized to have a mean of 0 and a standard deviation of 1. All specifications control for regional dummies, maternal age and weight at birth and before pregnancy, gender of the child, age of the child in months at the time of the test and a series of dummies for year of birth.

significance of the birth order effect by time of second assessment may be due to differences in unobserved parental investments between the ages of 4-5 and 10-11 by birth order or the effect being latent until age 10-11. To place the magnitudes of these birth order effects in perspective, note that Lang and Sepulveda (2007) find a black-white gap in the PPVT at ages 3 to 4 of about 0.5 standard deviations after controlling for a myriad of mother and family controls, including mother's AFQT, parental interactions and the HOME score, pregnancy and early life history, and family structure. Thus, a gap of 0.2 to 0.3 standard deviations among siblings in the same family is quite substantial. While the coefficients on higher birth order dummies remain predominantly negative for the mathematics portion of the PIAT, we do not find statistically significant differences across siblings of different birth order.

Turning to the PIAT-Reading tests in the bottom panel of Table 6, we find evidence that children of higher birth order perform significantly worse on the PIAT-R Recognition test at both early and later assessments. At ages 5 to 6, a second-born and a third-born will score 0.2 standard deviations lower on the PIAT-R Recognition test, while fourth and higher birth order children will score 0.37 standard deviations lower (column 1). These negative birth order effects are sustained in both their magnitude and statistical significance at the beginning of their adolescence (column 3). While there is no evidence of birth order effects in the comprehension portion of PIAT-R at ages 5 to 6, we find large and statistically significant differences in the second assessment, with younger children scoring 0.25 to 0.4 standard deviations lower compared to the first-born in the same family. These results are robust to changing the age of 2nd assessment, and to restricting the sample to children who took both tests. The sizes of these birth order effects are notable considering that they are similar to the black-white gap in the PIAT-R scores of 0.3 to 0.4 standard deviations found in Fryer and Levitt (2004) at grade 5 and significantly larger than the black-white gap of 0.17 standard deviations reported in Lang and Sepulveda (2007) for the same age group after controlling for the mother's AFQT.

In summary, with the exception of PIAT-Mathematics for which we do not find evidence of birth order effects at either the first or the second assessment, we find strong evidence of a large negative relationship between birth order and test scores, especially at ages 10 to 13. The magnitudes of these birth effects are fairly consistent across all tests, with the second-born scoring about 0.2 standard deviations lower than the first-born and the higher-order children scoring lower by 0.3 to 0.4 standard deviations.

To investigate whether these birth order effects found in PPVT and PIAT-R Recognition tests are robust to accounting for differences in pre/postnatal investments, birth outcomes, and home environments, we add these controls in the even columns. Despite our finding that there some significant differences in early childhood conditions across children of different birth order, the observed differences in cognitive scores by birth order are robust to controlling for these factors. Neither the magnitude nor the statistical significance of the birth order effects is changed by the addition of these controls. Nonetheless, as we can see at the bottom of table 6, birth outcomes are jointly significantly correlated with test scores.[25]

Table 7: Non-cognitive Test Scores: SPPC Scholastic and SPPC Global

	SPPC Scholastic				*SPPC Global*			
	1st assessment (Ages 8 to 9)		2nd assessment (Ages 13 to 14)		1st assessment (Ages 8 to 9)		2nd assessment (Ages 13 to 14)	
2nd born	-0.216	-0.355	-0.434**	-0.623***	-0.623***	-0.712***	-0.181	-0.330
	(0.227)	(0.216)	(0.220)	(0.211)	(0.191)	(0.194)	(0.210)	(0.210)
3rd born	-0.408	-0.667*	-0.717	-1.072**	-0.765**	-0.880**	-0.347	-0.601
	(0.401)	(0.396)	(0.445)	(0.419)	(0.373)	(0.395)	(0.441)	(0.444)
4th or higher born	0.162	-0.152	-0.336	-0.658	-0.811	-1.059*	-0.479	-0.859
	(0.638)	(0.625)	(0.695)	(0.646)	(0.509)	(0.595)	(0.731)	(0.657)
F-stat	1.731	1.733	1.024	1.910	2.548	2.207	1.079	1.209
R^2	0.096	0.132	0.052	0.182	0.117	0.195	0.042	0.113
N	1431	1431	1431	1431	1429	1429	1429	1429
Controls (F-stat test of joint significance)								
prenatal investments	n/a	0.45	n/a	1.20	n/a	0.39	n/a	1.05
birth outcomes	n/a	0.31	n/a	4.91***	n/a	0.25	n/a	4.42***
postnatal investments	n/a	1.59	n/a	0.56	n/a	1.74	n/a	0.72
All controls	n/a	1.02	n/a	2.50***	n/a	1.02	n/a	2.10***

Notes: All regressions are weighted and include family fixed effects. Standard errors clustered at the family level in parentheses. *= different from zero at the 10% level. **= different from zero at the 5% level. ***= different from zero at the 1% level. All assessments have a mean of 0 and a standard deviation of 1. All specifications control for regional dummies, maternal age, gender of the child, age in months at the time of the test and a series of dummies for year of birth.

Non-Cognitive Tests We now test for the presence of birth order effects in non-cognitive assessments and investigate whether early childhood conditions can explain any differences in these alternative measures of children's mental and social development across children of different birth order in the same family. Table 7 reports these results.

There is a strong negative birth order effect on both scholastic and global measures of self-worth (SPPC), yet slightly different trends for the two measures. The negative effects of higher birth order appear to be reinforced with age for the scholastic SPPC, although the estimates in the first assessment lack precision, ranging from a difference of 0.21 to 0.44

[25]The significant effect of birth outcomes on cognitive test scores is mainly driven by the positive impact of birth weight on test scores. For PIAT-R Comprehension, we find a significantly negative effect of being born prematurely. We do not find evidence of the importance of HOME scores ages 0 to 1. Detailed regression results for all tables are available upon request.

standard deviations between the second- and the first-born. However, the global measures of self-worth reveal, if anything, evidence of an opposite trend: a first-born scores 0.62 standard deviations better than the second-born at ages 8 to 9 but only 0.18 standard deviations better at ages 13 to 14. The trends are similar for higher-birth order children. However, for both scales of SPPC, there exists a significant and large negative relationship between birth order and the children's self-reported sense of self-worth. Psychological literature has found that there is a statistically significant correlation between measures of self-worth as a teenager and educational attainment (Bachman and O'Malley 1977). Thus, differences in the children's view of self and confidence may be a channel through which early childhood environment can contribute to birth order differences in adult outcomes.

To investigate whether these significant birth order effects found are robust to accounting for differences in early childhood conditions, we add these controls in the even columns of Tables 7 and report the F-statistics for the test of joint significance of each subset of added controls. Again, as in the case of cognitive tests, differences in early investments and conditions, including HOME scores, fail to account for the large observed birth order effect on non-cognitive tests. In fact, the inclusion of early childhood conditions appear to increase the size of birth order effects on SPPC scores.[26]

In summary, although we find significant differences in pre/postnatal investments, birth outcomes, and home environment across children of different birth order, these early childhood conditions fail to explain the negative relationship between birth order and measures of cognitive and non-cognitive outcomes in our data. These results are robust to including controls for family income and welfare payments and mother's employment status as well as the presence of the birth father in the household at the time of the assessment. Further, restricting the sample to children with scores from both the first and the second assessments do not alter our main results.[27]

4.3 Heterogeneous Birth Order Effects

We take advantage of the detailed demographic data available in the NLSY79 to explore whether birth order differences vary by household characteristics such as mother's ability and race.[28]

[26]Again, detailed regression results from Tables 7 are available upon request. The significant effect of birth outcomes on cognitive test scores is again mainly driven by negative impact of being overweight or underweight at birth on test scores. We find some evidence of a positive impact of cognitive and emotional home environment on MSD scores at 2nd assessment.

[27]The sample restriction yields similar point estimates, however, due to the decreased sample size, the estimates are not as precise and we lose some statistical significance.

[28]We find no consistent differences in the birth order effect by race, AFQT or maternal income in 1979 in prenatal investments or birth outcomes (results available upon request). Increases in birth weight by birth

Our conservative estimation strategy requires one additional restriction in order to be able to precisely estimate heterogeneous effects. We assume that the birth order effect is linear, which implies that the outcome gap between a first born and a second born is the same as between a second born and third born, and so on. We allow this difference to vary by characteristics, namely race and mother's AFQT. In this case, the parameter reported can be interpreted as the average difference in investment or score between a child and his/her immediately older sibling.

Table 8: Postnatal Investment: Heterogeneous effects

	Breastfeed	Weeks Breastfed	HOME (Total)	HOME (Cognitive)	HOME (Emotion)
	(1)	(2)	(3)	(4)	(5)
Birth order*White	-0.052***	0.616	-3.614**	-3.062***	-0.152
	(0.018)	(1.447)	(1.658)	(1.150)	(0.983)
Birth order*Black	-0.051**	1.058	-1.329	-1.786	0.238
	(0.023)	(2.468)	(2.159)	(1.493)	(1.427)
Birth order*Hispanic	-0.045*	1.576	-3.336	-1.837	-1.336
	(0.027)	(1.933)	(2.366)	(1.294)	(1.639)
Birth order*AFQT	-0.012	0.073	-0.873	-0.541	-0.419
	(0.010)	(0.795)	(1.006)	(0.669)	(0.622)
F-stat	2.121	2.322	3.195	5.823	2.097
R^2	0.033	0.075	0.079	0.135	0.060
N	6200	2848	3326	3326	3326

Notes: All regressions are weighted and include family fixed effects. Standard errors clustered at the family level in parentheses. *= different from zero at the 10% level. **= different from zero at the 5% level. ***= different from zero at the 1% level. All specifications control for regional dummies, maternal age, and gender of the child. A series of dummies on year of birth are also included.

Postnatal investments present a particular pattern by the mother's characteristics. Table 8 shows the results for postnatal investments by birth order interacted with race and AFQT[29]. While the reduction in the probability of being breastfed is similar for all races, the reduction in the quality of the home environment by order of birth is mostly driven by white children. Children with a white mother experience a 0.15 to 0.2 standard deviations reduction in the quality of their home environment compared to their older sibling born just before him/her, while younger children in African-American families do not appear to experience a lower quality home environment than their older siblings. This difference is robust to differences in income in 1978, AFQT or grandmother's education.

Table 9 presents the estimates of the birth order effect in Motor and Social Development

order does not occur for blacks, but no significant differences appear in outcomes.

[29]AFQT is measured in 1979, the first year of the survey, and is standardized with mean 0 and standard deviation 1

Table 9: Early outcomes: Motor and Social Development heterogeneous effects

	Ages 0 and 1		Ages 2 and 3	
	(1)	(2)	(3)	(4)
Birth order*White	-0.344***	-0.355***	-0.206*	-0.208*
	(0.112)	(0.111)	(0.114)	(0.119)
Birth order*Black	-0.132	-0.120	0.069	0.071
	(0.158)	(0.155)	(0.114)	(0.114)
Birth order*Hispanic	-0.324**	-0.335***	-0.230*	-0.201
	(0.137)	(0.128)	(0.134)	(0.142)
Birth order*AFQT	0.119**	0.143**	0.029	0.036
	(0.059)	(0.060)	(0.055)	(0.057)
F-stat	2.767	2.995	3.405	2.513
R^2	0.122	0.163	0.125	0.156
N	2330	2330	2330	2330
Controls (F-test of joint significance)				
prenatal investments	n/a	1.53	n/a	1.03
birth outcomes	n/a	1.69	n/a	1.45
postnatal investments	n/a	1.62	n/a	0.83
All controls	n/a	1.71**	n/a	1.21

Notes: All regressions are weighted and include family fixed effects. Standard errors clustered at the family level in parentheses. *= different from zero at the 10% level. **= different from zero at the 5% level. ***= different from zero at the 1% level. All assessments have a mean of 0 and a standard deviation of 1. All specifications control for regional dummies, maternal age, gender of the child, age in months at the time of the test and a series of dummies for year of birth.

by race and mother's ability. We find a strong birth order effect even at the very start of the child's life, but again, only in white families. At ages between 0 and 3, white children of higher birth order score 0.2 to 0.3 standard deviations lower in their MSD assessment than their older siblings, while birth order differences are not present among black children. The magnitude of the negative relationship between MSD score and birth order is somewhat mitigated among children of high ability (AFQT) mothers. Furthermore, the size of the birth order effect on MSD does not appear to grow over the first years of life, suggesting that very early investments are key to determining the birth order effect in later outcomes.

To assess whether these differences in MSD scores can be attributed to lower early investments, columns (2) and (4) control for prenatal investments, birth outcomes, breastfeeding patterns, and HOME scores. Although the patterns of birth order differences in early inputs across race and AFQT are mirrored in MSD scores, controlling for these early childhood investments does not change the significance or the general magnitude of the birth order coefficients.

4.4 Differences in Educational Attainment by Birth Order: The Role of Early Investments and Early Test Scores

To place our results in the context of existing literature, we now turn to investigating the presence of and the potential sources of birth order effects in educational attainment, an outcome that has been the focus of most previous studies on birth order. Table 10 presents the results for years of education completed and high school graduation. College attendance provides similar results as high school graduation, but the estimates are too imprecise to warrant further investigation. We measure educational attainment in the latest survey year 2010 to include as many observations as possible of individuals with completed education. All specifications include cohort controls to account for the obvious impact of age on years of completed education.

First, we find evidence of birth order effects in educational attainment, similar to the findings in the previous literature. Second-born children, on average, have about 0.5 less years of education than first-borns, and this difference increases to 0.8 years for third children and to more than a year for fourth and higher-ordered children (Table 10, column 1).[30] The size of these birth effects on educational attainment is comparable to the finding in Kantarevic and Mechoulan (2006) in which the first-born tend to receive 0.4 to 0.9 years of more education compared to higher-ordered children.

The bottom panel of Table 10 presents the results for high school completion for children who were at least 20 years old by 2010. We find that higher order children are between 3 and 6 percentage points less likely to graduate from high school than the first-born.

The Role of Early Investments Column 2 of Table 10 shows the robustness of the birth order effect in educational attainment when controlling for pre/postnatal investment and birth outcomes. Similar to cognitive and non-cognitive tests, differences in early investments do not appear to drive the birth order effect in educational attainment. Although better early investments (particularly in the case of postnatal investments, such as breastfeeding or HOME scores) are associated with higher educational attainment even within the same family, our results show that these disparities are not the main driving forces behind the observed birth order effect on educational attainment.

[30]The results below are robust to a more restrictive specification in which we restrict the sample to those who are at least 20 years old.

Table 10: Birth order and Educational Attainment

	Years of Education				
	(1)	(2)	(3)	(4)	(5)
2nd born	-0.460***	-0.411***	-0.267*	-0.264	-0.231
	(0.120)	(0.116)	(0.137)	(0.229)	(0.224)
3rd born	-0.789***	-0.728***	-0.502**	-0.140	-0.509
	(0.222)	(0.217)	(0.252)	(0.431)	(0.409)
4th or higher born	-1.057***	-1.003***	-0.637*	-0.758	-1.230**
	(0.388)	(0.372)	(0.345)	(0.622)	(0.589)
F-stat	28.872	17.415	21.116	14.368	12.388
R^2	0.327	0.339	0.362	0.536	0.621
N	4496	4496	3075	1612	1458
Controls (F-test for joint significance)					
Early investments	n/a	1.71**	n/a	n/a	3.43***
Cognitive scores	n/a	n/a	11.11***	n/a	2.01*
Non-cognitive scores	n/a	n/a	n/a	5.95***	4.88***

	High school graduate				
	(1)	(2)	(3)	(4)	(5)
2nd born	-0.030**	-0.028*	-0.025*	-0.005	0.006
	(0.015)	(0.016)	(0.015)	(0.015)	(0.017)
3rd born	-0.064**	-0.059**	-0.053*	0.013	0.039
	(0.030)	(0.030)	(0.031)	(0.025)	(0.039)
4th or higher born	-0.062	-0.057	-0.066	0.014	0.055
	(0.045)	(0.047)	(0.044)	(0.034)	(0.047)
R^2	0.020	0.023	0.029	0.050	0.261
N	4218	4218	2841	1391	1252
Controls (F-test for joint significance)					
Early investments	n/a	0.58	n/a	n/a	0.60
Cognitive scores	n/a	n/a	2.97**	n/a	0.71
Non-cognitive scores	n/a	n/a	n/a	0.58	0.34

Notes: All regressions are weighted and include family fixed effects. Standard errors clustered at the family level in parentheses. *= different from zero at the 10% level. **= different from zero at the 5% level. ***= different from zero at the 1% level. All specifications control for regional dummies, maternal age, gender, and a series of dummies for year of birth. Education attainment is measured in 2010, and high school graduation is defined for children over 20. Cognitive and non-cognitive scores correspond to the second assessment.

Early Test Scores and Years of Education Completed In Tables 5 to 7, we observed strong birth order effects in both cognitive and non-cognitive outcomes in the children's early years. Columns 3 and 4 of Table 10 test whether these observed differences in cognitive and non-cognitive outcomes early in life can explain differences in educational attainment in adulthood.[31] We choose to focus on test scores from the second assessment, because differences in scores by birth order appear most strongly in early adolescence in our data. Furthermore, controlling for the first assessments decreases our sample size by a significantly larger number than with the second assessments, and we are able to retain a much larger statistical power by focusing on the second.[32]

As shown in column (3), cognitive test scores have, as expected, some predictive power in explaining differences in years of education completed, especially PIAT-M and PIAT-R Recognition scores. Additionally, cognitive scores at adolescence appear to partially explain the birth order effect, reducing the magnitude by about 35 percent.[33] We obtain similar results when we control for non-cognitive test scores (column 4), mainly driven by measures of self-worth and behavior problems. Test for the joint significance of the non-cognitive scores reveal that early non-cognitive outcomes are significant predictors of years of education completed. Non-cognitive scores are also able to partially explain the birth order effects in educational attainment, reducing the size of the birth order effects by similar magnitudes as the addition of cognitive test controls, at least for the second-born. However, the addition of all non-cognitive as controls substantially reduces our sample size, and the birth order effects lose their statistical significance.

In order to shed a greater light on the underlying channels behind the birth order effects in educational attainment, we run a "horse race" in column (5) between the three potential explanations explored in Table 10. While the estimates lose their significance due to the large drop in sample size, the point estimates remain very similar to columns (3) and (4), with the birth order effects being reduced by at least 0.2 years of education for the second- and third-born children, while higher-ordered children still showing significantly lower educational attainment when compared to the first-born.

The reduction of the birth order effects in educational attainment when controlling for cognitive test scores is not reflected in the share of children that completed high school (bottom panel of Table 10, columns 3 to 5). While cognitive test scores, in particular PIAT-R Recognition scores, are able to predict variations in high school graduation, the trend by birth order is robust to their inclusion. Controlling for non-cognitive scores reduces the point

[31] The results are robust to restricting the sample to children reporting early investment and both cognitive and non-cognitive scores at age of second assessment.

[32] Using the cognitive scores from the first assessments reduces our sample size from 4496 in column (2) to 912 in column (3), 489 in column (4), and a mere 112 in column (5). Controlling for test scores from the first assessments despite this dramatic reduction in sample size reveals that the size of the birth order effects on years of education completed is robust to the addition of these controls. Early cognitive assessments do not have much explanatory power for years of education while non-cognitive scores, especially SPPC, have some predictive power.

[33] However, we cannot reject the null that the size of the birth order effects are equal between columns (2) and (3) or between columns (2) and (4).

estimates, but the lack of precision in the estimates prevents any further interpretation of the results.[34]

5 Conclusion

Our paper makes a number of key contributions to the birth order literature. First, motivated by the rich literature on the significance of *in utero* and early childhood environment and later outcomes, we consider differences in parental investment from the moment of conception to the earliest years of the child's life as potential explanations of birth order effects in education outcomes. We examine a wide range of prenatal and postnatal investments, as well as birth outcomes, in an attempt to pinpoint the earliest start of birth order differences in achievement. We find that some measures of maternal investments before and after birth are negatively correlated with increasing birth order. For example, women are less likely to reduce their smoking during pregnancy and are less likely to breastfeed children of higher order. We also find strong and significant differences in the home environment for children ages 0 to 1 across birth order. Compared to the first-born, children of higher birth order face lower cognitive stimulation/resources and emotional support from their parents. While we do not observe significant differences in birth outcomes, the children motor and social development at ages 0 to 3 is negatively correlated with birth order. Moreover, the pattern by mother's race and ability in postnatal investments are mirrored in early outcomes.

Second, to our knowledge, this is the first attempt to test whether there exist birth order effects across many types of early cognitive and non-cognitive test scores. We observe significant differences by the order of birth in several cognitive and non-cognitive tests. Higher order children perform worse on PIAT-Reading and PPVT tests and exhibit significantly lower measures of self-worth, both scholastically and globally.

Despite our finding that there exist some significant differences in pre/postnatal investments across children of different birth order, including the home environment, we find that the observed differences in cognitive and non-cognitive scores by birth order are robust in both their magnitude and significance to accounting for these systematic variations in early childhood conditions. We find a strong negative relationship between birth order and educational attainment for the first time in the CNLSY79 cohorts. Even in this very young cohort, we find birth order effects that are of similar magnitudes found in previous studies, suggesting that these effects have not diminished over time. As in the case of cognitive and non-cognitive outcomes, while breastfeeding patterns and early home environment have some

[34] While the sample size is reduced by requiring children to have reached age 20 in 2010 to be included in this sample, variation in high school completion within family is also lower.

predictive power for years of education completed, we find that variations in early childhood conditions do not diminish the size of the birth order effects in educational attainment.

Additionally, we find that early cognitive and non-cognitive test scores are able to explain a significant portion of the birth order effects. The inclusion of these test scores from adolescence reduces the size of the birth order effects by about 35 percent. Test scores, however, are of course endogenous to the child's mental, physical, and social development, and we are unable to draw much causal inferences from these associations. This difficulty is especially complicated by our finding that our measures of pre/postnatal investments and early home environment are unable to explain the birth order effects in cognitive and non-cognitive test scores both in the child's early ages and adolescence.

We believe that the results from this paper suggest several possible interpretations that can guide future research. One, birth order effects on educational outcomes are indeed not determined by biological differences or variations in early childhood environments; two, its effects are latent until later in adulthood possibly through the late onset of health effects; or three, common measures of prenatal and early childhood conditions fail to adequately capture critical differences in early health and home environment conditions within a family. Greater future inquiries into these various interpretations is required to assess the relative strengths of these hypotheses.

Finally, in light of the strong relationship between measures of self-worth at adolescence and educational attainment as well as the significant relationship between early home environment and the SPPC scores, we surmise that a magnification of difference in children's early family investments and environments through the early years on the children's view of self-worth, motivation, and parent-imposed expectations may be a potential channel through birth order effects in adult outcomes may arise. In that vein, a recent study examining the relationship between adolescent depression and labor market outcomes using a school-based, longitudinal study on health-related behaviors in the U.S. find that individuals with depressive symptoms as an adolescent experienced 5 percentage point reductions in labor force attachment and approximately 20% reduction in adult earnings (Fletcher 2012). Further exploring the origins of birth order differences in the children's view of self and parental expectations using rigorous statistical techniques may shed some light on the unexplained relationship between higher birth order and lower achievement in adolescence and adulthood.

References

Almond, Douglas and Janet Currie (2010) "Human Capital Development before Age Five," NBER Working Papers 15827, National Bureau of Economic Research, Inc.

——— (2011) "Killing me Softly: The Fetal Origins Hypothesis," *The Journal of Economic Perspectives*, Vol. 25, No. 3, pp. 153–172.

Angrist, Joshua D. and William N. Evans (1998) "Children and Their Parents' Labor Supply: Evidence from Exogenous Variation in Family Size," *The American Economic Review*, Vol. 88, No. 3, pp. 450–477.

Bachman, Jerald G. and Patrick M. O'Malley (1977) "Self-esteem in Young Men: A Longitudinal Analysis of the Impact of Educational and Occupational Attainment," *Journal of Personality and Social Psychology*, Vol. 35, No. 6, pp. 365–380.

Baker, Paula C., Canada K. Keck, Frank L. Mott, and Stephen V. Quinlan (1993) *The NLSY Child handbook 1993: A Guide and Resource Document for the NLS of Youth - Child Data*: Columbus, OH: Center for Human Resource Research, The Ohio State University.

Behrman, Jere R. and Paul Taubman (1986) "Birth Order, Schooling, and Earnings," *Journal of Labor Economics*, Vol. 4, No. 3, pp. 121–145.

Belfield, C.R. and I.R. Kelly (2010) "The Benefits of Breastfeeding Across the Early Years of Childhood," NBER Working Papers 16496, National Bureau of Economic Research.

Birdsall, N. (1991) "Birth Order Effects and Time Allocation.," *Research in population economics*, Vol. 7, p. 191.

Black, Sandra E., Paul J. Devereux, and Kjell G. Salvanes (2005) "The More the Merrier? The Effect of Family Size and Birth Order on Children's Education," *Quarterly Journal of Economics*, Vol. 120, No. 2, pp. 669–700.

——— (2007) "Older and Wiser? Birth Order and IQ of Young Men," *NBER Working Paper #13237*.

Booth, Alison L. and Hiau Joo Kee (2009) "Birth Order Matters: The Effect of Family Size and Birth Order on Educational Attainment," *Journal of Population Economics*, Vol. 22, No. 2, pp. 367–397.

Carlson, M.J. and M.E. Corcoran (2001) "Family Structure and Children's Behavioral and Cognitive Outcomes," *Journal of Marriage and Family*, Vol. 63, No. 3, pp. 779–792.

CDC (2001) "Women and Smoking: A Report of the Surgeon General,"Technical report, US Department of Health and Human Services, Atlanta, GA.

——— (2004) "The Health Consequences of Smoking: A Report of the Surgeon General,"Technical report, US Department of Health and Human Services, Atlanta, GA.

Chung, M., G. Raman, P. Chew, N. Magula, T. Trikalinos, and J. Lau (2007) "Breastfeeding and Maternal and Infant Health Outcomes in Developed Countries," *Evid Technol Asses (Full Rep)*, Vol. 153, pp. 1–186.

Conley, Dalton and Rebecca Glauber (2006) "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*, Vol. 41, No. 4, pp. 722–737.

Cunha, Flavio, James J. Heckman, Lance J. Lochner, and Dimitriy V. Masterov (2006) "Interpreting the evidence on life cycle skill formation," in E. Hanushek and F. Welch eds. *Handbook of the Economics of Education*, Amsterdam: North Holland, Chap. 12, pp. 697–812.

Cunha, Glavio and James J. Heckman (2007) "The Economics of Human Development: The technology of Skill Formation," *The American economic review*, Vol. 97, No. 2, pp. 31–47.

Currie, Janet and Jeffrey Grogger (2002) "Medicaid Expansions and Welfare Contractions: Offsetting Effects on Prenatal Care and Infant Health?" *Journal of Health Economics*, Vol. 21, No. 2, pp. 313–335.

Dominguez-Rojas, V., J. R. de Juanes-Pardo, P. Astasio-Arbiza, P. Ortega-Molina, and E. Gordillo-Florencio (1994) "Spontaneous Abortion in a Hospital Population: Are Tobacco and Coffee Intake Risk Factors?" *European Journal of Epidemiology*, Vol. 10, pp. 665–668. 10.1007/BF01719278.

Ejrnæs, M. and C.C. Pörtner (2004) "Birth Order and the Intrahousehold Allocation of Time and Education," *Review of Economics and Statistics*, Vol. 86, No. 4, pp. 1008–1019.

Eriksson, M., H. Wedel, M.A. Wallander, I. Krakau, J. Hugosson, S. Carlsson, and K. Svärdsudd (2007) "The Impact of Birth Weight on Prostate Cancer Incidence and Mortality in a PopulationBased Study of Men Born in 1913 and Followed up from 50 to 85 Years of Age," *The Prostate*, Vol. 67, No. 11, pp. 1247–1254.

Fingerhut, L A, J C Kleinman, and J S Kendrick (1990) "Smoking Before, During, and After Pregnancy," *Am J Public Health*, Vol. 80, No. 5, pp. 541–544.

Fletcher, Jason M. (2012) "Adolescent Depression and Adult Labor Market Outcomes," Working Paper 18216, National Bureau of Economic Research.

Fryer, R.G. and S.D. Levitt (2004) "Understanding the BlackWhite Test Score Gap in the First Two Years of School," *Review of Economics and Statistics*, Vol. 86, No. 2, pp. 447–464.

Gillman, M.W., S. Rifas-Shiman, C.S. Berkey, A.E. Field, and G.A. Colditz (2003) "Maternal Gestational Diabetes, Birth Weight, and Adolescent Obesity," *Pediatrics*, Vol. 111, No. 3, pp. e221–e226.

Gluckman, Peter D. and Mark Hanson (2005) *The Fetal Matrix: Evolution, Development, and Disease*: Cambridge University Press.

Hanushek, Eric A. (1992) "The Tradeoff between Child Quantity and Quality," *Journal of Political Economy*, pp. 84–117.

Harder, T., A. Plagemann, and A. Harder (2008) "Birth Weight and Subsequent Risk of Childhood Primary Brain Tumors: A Meta-Analysis," *American Journal of Epidemiology*, Vol. 168, No. 4, pp. 366–373.

Heckman, J.J., J. Stixrud, and S. Urzua (2006) "The Effects of Cognitive and Noncognitive Abilities on Labor Market Outcomes and Social Behavior,"Technical report, National Bureau of Economic Research #12006.

Heckman, James J. (2007) "The Economics, Technology, and Neuroscience of Human Capability Formation," *Proceedings of the National Academy of Sciences*, Vol. 104, No. 33, p. 13250.

Heckman, James J. and Dimitriy V. Masterov (2007) "The Productivity Argument for Investing in Young Children," *Applied Economic Perspectives and Policy*, Vol. 29, No. 3, p. 446.

Heiland, Frank (2009) "Does the Birth Order Affect the Cognitive Development of a Child?" *Applied Economics*, Vol. 41, No. 14, pp. 1799–1818.

Hjalgrim, L.L., T. Westergaard, K. Rostgaard, K. Schmiegelow, M. Melbye, H. Hjalgrim, and E.A. Engels (2003) "Birth Weight as a Risk Factor for Childhood Leukemia: A Meta-Analysis of 18 Epidemiologic Studies," *American Journal of Epidemiology*, Vol. 158, No. 8, pp. 724–735.

Horwood, L.J. and D.M. Fergusson (1998) "Breastfeeding and Later Cognitive and Academic Outcomes," *Pediatrics*, Vol. 101, No. 1, pp. e9–e9.

Iacovou, Maria (2001) "Family Composition and Children's Educational Outcomes," *ISER Working Paper Series*.

Kantarevic, Jasmin and Stéphane Mechoulan (2006) "Birth Order, Educational Attainment, and Earnings," *Journal of Human Resources*, Vol. 41, No. 4, pp. 755–777.

Kessler, Daniel (1991) "Birth Order, Family Size, and Achievement: Family Structure and Wage Determination," *Journal of Labor Economics*, pp. 413–426.

Knudsen, Eric I., James J. Heckman, Judy L. Cameron, and Jack P. Shonkoff (2006) "Economic, Neurobiological, and Behavioral Perspectives on Building America's Future Workforce," *Proceedings of the National Academy of Sciences*, Vol. 103, No. 27, p. 10155.

Lang, Kevin and Carlos E. Sepulveda (2007) "The BlackWhite Test Score Differential," *Boston University Working Paper*.

Leong, N.M., L.I. Mignone, P.A. Newcomb, L. Titus-Ernstoff, J.A. Baron, A. Trentham-Dietz, M.J. Stampfer, W.C. Willett, and K.M. Egan (2003) "Early Life Risk Factors in Cancer: The Relation of Birth Weight to Adult Obesity," *International Journal of Cancer*, Vol. 103, No. 6, pp. 789–791.

Lewis, CT, TJ Mathews, and RL Heuser (1996) "Prenatal Care in the United States, 1980-94.," *Vital and health statistics. Series 21, Data on natality, marriage, and divorce*, No. 54, p. 1.

MacArthur, C and EG Knox (1988) "Smoking in Pregnancy: Effects of Stopping at Different Stages," *Br J Obstet Gynaecol*, Vol. 95, No. 6, pp. 551–555.

Monfardini, Chiara and Sarah Grace See (2011) "Birth Order and Child Outcomes: Does Maternal Quality Time Matter?" *Unpublished Manuscript*.

Mott, Frank, Paula C. Baker, David E. Ball, Canada K. Keck, and Steven M. Lenhart (1998) *The NLSY Children, 1992: Description and Evaluation*: Center for Human Resource Research, Ohio State University.

Oddy, W.H., G.E. Kendall, E. Blair, N.H. De Klerk, F.J. Stanley, L.I. Landau, S. Silburn, and S. Zubrick (2003) "Breastfeeding and Cognitive Development in Childhood: A Prospective Birth Cohort Study," *Paediatric and perinatal epidemiology*, Vol. 17, No. 1, pp. 81–90.

Parish, W.L. and R.J. Willis (1993) "Daughters, Education, and Family Budgets Taiwan Experiences," *Journal of Human Resources*, pp. 863–898.

Parsons, TJ, C. Power, S. Logan, CD Summerbell et al. (1999) "Childhood Predictors of Adult Obesity: A Systematic Review.," *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity*, Vol. 23, p. S1.

Pietiläinen, K.H., J. Kaprio, M. Räsänen, T. Winter, A. Rissanen, and R.J. Rose (2001) "Tracking of Body Size from Birth to Late Adolescence: Contributions of Birth Length, Birth Weight, Duration of Gestation, Parents' Body Size, and Twinship," *American Journal of Epidemiology*, Vol. 154, No. 1, pp. 21–29.

Price, Joseph (2008) "Parent-Child Quality Time," *Journal of Human Resources*, Vol. 43, No. 1, pp. 240–265.

Remes, ST, SP Patel, A.L. Hartikainen, M.R. Jarvelin, and J. Pekkanen (2008) "High Birth Weight, Asthma and Atopy at the Age of 16 yr," *Pediatric Allergy and Immunology*, Vol. 19, No. 6, pp. 541–543.

Smith-Conway, Karen and Partha Deb (2005) "Is Prenatal Care Really Ineffective? Or, Is the 'Devil' the Distribution?" *Journal of Health Economics*, Vol. 24, No. 3, pp. 489–513.

Strauss, R.S. and J. Knight (1999) "Influence of the Home Environment on the Development of Obesity in Children," *Pediatrics*, Vol. 103, No. 6, pp. e85–e85.

Todd, P.E. and K.I. Wolpin (2007) "The Production of Cognitive Achievement in Children: Home, School, and Racial Test Score Gaps," *Journal of Human capital*, Vol. 1, No. 1, pp. 91–136.

Wei, J.N., H.Y. Li, F.C. Sung, C.C. Lin, C.C. Chiang, C.Y. Li, and L.M. Chuang (2007) "Birth Weight Correlates Differently with Cardiovascular Risk Factors in Youth," *Obesity*, Vol. 15, No. 6, pp. 1609–1616.

Zajonc, R.B. (1976) "Family Configuration and Intelligence: Variations in Scholastic Aptitude Scores Parallel Trends in Family Size and the Spacing of Children," *Science*.