NBER WORKING PAPER SERIES

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Robert Kaestner
Luis F. Faundez

Working Paper 31199
http://www.nber.org/papers/w31199

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 2023

Nothing to disclose. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 31199
April 2023
JEL No. J13,J24

ABSTRACT

This article describes a conceptual and empirical approach for estimating a human capital production function of child development that incorporates mother- or child-fixed effects. The use of mother-or child-fixed effects is common in this applied economics literature, but its application is often inconsistent with human capital theory. We outline the problem and demonstrate its empirical importance with an analysis of the effect of Head Start and preschool on child and adult outcomes. The empirical specification we develop has broad implications for a variety of applied microeconomic analyses beyond our specific application Results of our analysis indicate that attending Head Start or preschool had no economically or statistically significant effect on child or adult outcomes.

Robert Kaestner
Harris School of Public Policy
University of Chicago
1307 East 60th Street (Room 3057)
Chicago, IL 60637
and NBER
kaestner.robert@gmail.com

Luis F. Faundez
2763-2719 Bancroft Way
R239 Law Building (North Addition)
Berkeley, CA 94720
luisfaundez.phd@gmail.com

An online appendix is available at: http://www.nber.org/data-appendix/w31199

Introduction

Investing in children is one of the most important activities of both families and society. Accordingly, identifying what are the most productive and cost-effective investments to promote child wellbeing is a critical research question that has concerned researchers from many disciplines including economics. In economics, research about investment in child development, or the accumulation of human capital, is guided by conceptual models of human capital production (Grossman 1972; Todd and Wolpin 2003). In the human capital model, the concept of a production function is central and the conceptual foundation for most empirical research. However, a substantial share of empirical analyses that purportedly rely on the human capital production function to study child development are inconsistent with the basic human capital model. Specifically, analyses that rely on mother- or child-fixed effects approaches often use mis-specified models, as do instrumental variables approaches that include mother- or child-fixed effects. The misspecification of the empirical model in these studies is likely to have serious consequences that bias estimates of the productivity of investments and the effect of public policies on child development.

The problem just described applies to many areas of research. The mother-fixed effects approach has been used to estimate the effect of Attention Deficit Hyperactivity Disorder on test scores and schooling attainment (Currie and Stabile, 2006), birthweight on adult outcomes (Black, Devereux and Salvanes 2007), children's participation in public- and voucher-assisted housing on earnings and adult incarceration (Andersson, et al. Forthcoming), neighborhood quality during childhood on adult outcomes such as earnings, college attendance, and fertility (Chetty and Hendren 2018), the Women, Infants, and Children (WIC) program on birth outcomes (Currie and Rajani, 2015), neonatal health on children's cognitive development (Figlio, et al. 2014), and breastfeeding on long-term child health and well-being (Colen and Ramey 2014), among other topics. A child-fixed effects approach has been used to estimate the effect of teacher quality on test scores (e.g., Clotfelter, Ladd and Vigdor 2007, Rockoff 2004, Harris and Sass 2011, Dee 2007, Eren and Henderson 2011), effects of income on child achievement (Dahl and Lochner 2012), and in health applications (e.g., French, et al. 2010, Austin, et al. 2019, Meraya, et al.

2018). In all these cases, the empirical model used is inconsistent with the basic human capital production function. Therefore, results from these studies should be viewed cautiously until found to be unaffected by using a more theoretically consistent approach.

In this article, we develop an empirical approach to estimating fixed effects models, both mother- and child-specific, that is more consistent with human capital theory (e.g., Grossman 1972; Todd and Wolpin 2003) and apply it to the evaluation of the effect of Head Start on child development. We show how past studies of Head Start deviated from the human capital conceptual model and test whether the restrictions often imposed by previous research are valid. Our contribution is novel, and it is fundamentally different and broader than the reassessments of the evidence on Head Start in Miller et al. (2019) and Pages et al. (2020). Miller et al. (2019) assessed the representativeness of a sample of siblings in comparison to a sample of all children and showed that a sample of siblings differs from a sample of all children, which bears on the external validity of estimates from sibling models. Pages et al. (2020) assessed whether the results of Deming (2009) extend to more recent birth cohorts. Neither of these papers do what we do, which is to provide a conceptual foundation and an empirical framework to estimate fixed effects models of child development. Our reassessment of the effects of Head Start is in service to this broader objective.

The development of a theoretically consistent, empirical framework using a child-fixed effects approach is also novel and highlights one of the most important inconsistencies of past research in studies of child investments that use a mother- or child-fixed effects approach. In the case of Head Start, but also for other variables measuring investment in children (e.g., WIC), or that proxy for investment (e.g., mother's education), the first thought of many researchers is that a child-fixed effects model cannot be estimated for the purpose at hand. Consider the case of Head Start. Because Head Start attendance is not age (time)-varying, the typical estimation of a child-fixed effects approach would drop the Head Start indicator and a child-fixed effects method would not be used. We show dropping the indicator of Head Start is not necessary and that dropping it is inconsistent with a more general version of the human capital production function that includes dynamic effects along the lines developed by Heckman and colleagues

(Cunha et al. 2006; Heckman 2007; Cunha and Heckman 2008; Cunha et al. 2010). We elaborate on this point below.

To illustrate the approach that is more theoretically appropriate, we provide new evidence on the effectiveness of Head Start (and preschool), which is one of the most important government programs investing in children of preschool age. The budget for Head Start is approximately $10 billion annually and Head Start serves over 1 million children. Head Start is intended to increase school readiness and promote social skills, emotional wellbeing, language and literacy skills, and mathematics, as well as improve a child's health and physical development.[1] Given its size and prominence, there has long been a debate over the efficacy of Head Start in meeting its objectives.[2] The evidence on the efficacy of Head Start is not uniform and that lack of consistency has fueled the debate over the value of the program.

Results of our analysis indicate that attending Head Start or preschool had no economically or statistically significant effect on child outcomes or adult outcomes. We also show that findings from past studies that report significant effects are likely due to a misspecification of the empirical model, specifically, using differences in outcomes of siblings of different ages and restricting effects of Head Start and preschool (and other covariates) to be the same across siblings. Estimates obtained for samples

[1] Office of Head Start, Administration for Children & Families, U.S. Department of Health and Huan Services, https://www.acf.hhs.gov/ohs/about/head-start

[2] The evidence on the effect of Head Start is extensive and generally finds positive effects. One of the most important studies of Head Start is the Head Start Impact Study (HSIS, U.S. Department of Health and Human Services 2010). Results, as reported in the Final Report (U.S. Department of Health and Human Services 2010), indicated that after one-year, those randomly given access to Head Start had better language and literacy skills than those not given access to Head Start. In a follow-up (U.S. Department of Health and Human Services 2012), researchers found that by kindergarten and third grade, the improvements in language skills observed after one year had dissipated and there were practically no differences in achievement. Other evidence on the near- and long-term effects of Head Start come from non-experimental research. A particularly important group of studies are those that used a mother fixed effects approach that compares outcomes of siblings that differ in their Head Start attendance (Currie and Thomas 1995; Garces et al. 2002; Deming 2009; Bauer and Schanzenbach 2016; Miller et al. 2019; Pages et al. 2020). It is exactly this approach that we discuss in this article. Except for Pages et al. (2020), all of these studies reported positive effects of Head Start including lasting effects of Head Start into adulthood (Garces et al. 2002; Deming 2009; Bauer and Schanzenbach 2016; Miller et al. 2019). Other studies that reported positive benefits of Head Start, particularly long-term benefits, often did so for children born in the 1960s and 1970s (Bailey et al. 2020; Johnson and Jackson 2019; Ludwig and Miller 2007; Thompson 2018), although Carneiro and Ginja (2014) used a relatively recent cohort of children.

stratified by race/ethnicity and mother's cognitive ability also suggest no meaningful effect of Head Start or preschool attendance for these groups.

Our article and findings have important implications for both applied empirical research and public policy. Applied research using sibling- or child-fixed effects approaches that are focused on human capital accumulation must recognize that additions to human capital come from investment. Investments in human capital occur even when there is no change in the determinants of those investments. For example, consider family income. Investments in children occur, and child human capital grows, even when there is no change in family income. Similarly, investments in health or other human capital occurs even when education or personal income does not change. The primary mistake of past studies is to exclude variables that affect investment when those variables do not differ over time (i.e., within child) or between siblings.

In terms of policy, conventional wisdom is that Head Start and preschool have positive and long-lasting effects on children. Much, although not all, of the support for this position, specifically with respect to Head Start and recent cohorts of children, is based on the data and methods we re-examined in this article. The failure of our analysis to find any evidence to support this position suggests that more evidence needed, particularly because the evidence of that research is inconsistent with the Head Start Impact Study (U.S. Department of Health and Human Services 201, 2012), which is a randomized control study.

Production of Cognitive Skills with Application to Head Start

To conceptually measure the effect of Head Start, or other investment, on cognitive skill formation, we focus on the production function that relates investment in a child's cognitive skill to the child's stock of skill, which empirically we will measure using achievement test scores. One description of the cognitive skill (*TEST*) production function is as follows:

$$\begin{aligned} TEST_t = {} & C_0(1-\delta_0)...(1-\delta_{t-1}) + \alpha I_0(1-\delta_1)...(1-\delta_{t-1}) + \alpha I_1(1-\delta_2)...(1-\delta_{t-1}) + \\ & ... + \alpha I_{t-2}(1-\delta_{t-1}) + \alpha I_{t-1} \end{aligned} \tag{1}$$

In equation (1), the test score of a child at age t is a function of the cognitive skill endowment (C_0), the quantity of all past investments in cognitive skills ($I_0, \ldots, I_{t-1}$), the effects (productivity) of those investments (α), and the depreciation rate in each period ($\delta_0, \ldots, \delta_{t-1}$). The form of equation (1) reflects the assumption that cognitive skill is determined by a cumulative process in which investments augment the stock of skill and depreciation erodes that stock. The production function of equation (1) is an essential element of human capital theory (e.g., Grossman 1972 and Todd and Wolpin 2003). For simplicity, we assume there is only one type of investment (I), but obviously there are many types of investments that affect child cognitive development including a child's own investments in self-learning (Del Boca et al. 2017; Fiorini and Keane 2014; Gureckis and Markant 2012).

Note that the increment to cognitive skill from an investment [e.g., ($\alpha(1-\delta_1)\ldots(1-\delta_{t-1})$)] will differ by age because of depreciation. The effect of an investment may also differ by age because the productivity of an investment—the same investment and the same amount of investment—may be age-specific. For instance, using maternal time as an example, the productivity of an hour of mother's time may differ by age. For example, at earlier ages when the child is beginning to learn math and how to read and doing so more at home than at school, mother's time may be more productive than at older ages when the child is advancing their skills and learning more at school (Del Bono et al. 2016; Dickson et al. 2016). This possibility is reflected in the following formulation of the production function:

$$(2)\quad TEST_t = C_0(1-\delta_0)\ldots(1-\delta_{t-1}) + \alpha_0 I_0(1-\delta_1)\ldots(1-\delta_{t-1}) + \ldots + \alpha_{(t-2)} I_{t-2}(1-\delta_{t-1}) + \alpha_{(t-1)} I_{t-1}$$

The point to note about equation (2) is that the effect of investments (α_t) now differs by age; the same quantity (e.g., one hour) of the same investment (e.g., mother's time) made at, for example, ages 5 and 12, will have a different effect on cognitive skill at each age. In short, the cognitive skill production function is age-dependent and empirical estimates of the parameters of the production function should be obtained using samples of children stratified by age. Indeed, this is a common mistake of prior empirical research in this area, which often uses samples of children spanning many ages (citation).

Attendance in Head Start may be thought of as one type of investment (*I*) and the (depreciated) effect of that investment will be present at all ages post attendance (if it is productive). For example, the cognitive production function of a child aged 8 who attended Head Start at age 4 is:

$$\begin{aligned}(3)\quad TEST_8 = {} & C_0(1-\delta_0)...(1-\delta_7)+\alpha_0 I_0(1-\delta_1)...(1-\delta_7)+...+b_4 HEADSTART_4(1-\delta_5)...(1-\delta_7) \\ & +a_4 I_4(1-\delta_5)...(1-\delta_7)+...+\alpha_7 I_7\end{aligned}$$

In equation (3), we make explicit the fact that there is more than one type of investment by including both the Head Start indicator at age 4 (*HEADSTART*) and the other investment (*I*) at age 4. At each age, there would be several types of investment, but to keep the notation simple we have not shown the presence of these investments in equation (3). The effect of Head Start at age 8 is: $b_4(1-\delta_5)...(1-\delta_7)$.

A notable finding of the HSIS was that initial improvement among the Head Start treatment group in socioemotional development and cognitive achievement observed at the end of Head Start participation faded by third grade at which time there were little difference between the treatment and control groups. Evidence from other early childhood programs shows similar fade out (Bailey et al. 2017; Barnett 2011). Fade out of initial effects may not be surprising because there is likely some depreciation of skills. Comparing the coefficient on Head Start from equation (3) at age 8 and age 4 makes the point:

(4) Age 4 Effect of Head Start = $b_4 > b_4(1-\delta_5)...(1-\delta_7)$ = Age 8 Effect of Head Start

Depreciation would naturally lead to fade out of the initial effect of Head Start at age 4 by age 8. The effect of Head Start measured at age 8 will be smaller than the effect of Head Start measured at age 4, if depreciation is non-zero.

If we assume that Head Start attendance raises the effect (productivity) of future investments in cognitive development along the lines suggested by Heckman and colleagues (Cunha et al. 2006; Heckman 2007; Cunha and Heckman 2008; Cunha et al. 2010), then fadeout may be a less likely outcome. For example, as reported in the HSIS (U.S. Department of Health and Human Services, 2010), Head Start attendance improved socioemotional outcomes and children with more developed socioemotional behavior may learn more and get more out of any investment in cognitive development. To reflect this possibility, the following production function would be applicable:

$$(5)\quad \begin{aligned} TEST_8 &= C_0(1-\delta_0)...(1-\delta_7)+\alpha_0 I_0(1-\delta_1)...(1-\delta_7)+...+b_4 HEADSTART_4(1-\delta_5)...(1-\delta_7) \\ &\quad + a_4 I_4(1-\delta_5)...(1-\delta_7)+...+\alpha_7(HEADSTART_4)I_7 \end{aligned}$$

In this case, the effect of investment at age 7 (and ages 5 and 6 that are not shown) depends on Head Start attendance at age 4. Note that because this is a production function that includes the quantity of investment, we do not make the quantity of investment depend on Head Start, although a behavioral model would suggest that if Head Start raises the productivity of an investment, then the quantity of investment would likely be higher. The total effect of Head Start on achievement at age 8 is:

$$(6)\quad \begin{aligned} \frac{\partial TEST_8}{\partial HEADSTART_4} &= b_4(1-\delta_5)...(1-\delta_7)+\frac{\partial a_5}{\partial HEADSTART_4}I_5(1-\delta_6)(1-\delta_7)+\frac{\partial a_6}{\partial HEADSTART_4}I_6(1-\delta_7) \\ &\quad +\frac{\partial a_7}{\partial HEADSTART_4}I_7 \end{aligned}$$

As shown in equation (6), the total effect of Head Start is the depreciated effect from age 4 and the depreciated effects of subsequent investments that are more productive because of attending Head Start. The fact that the effect of Head Start faded out in the HSIS suggests that Head Start attendance does not increase the productivity of future investments, although Deming (2009) and Garces et al. (2002) find an effect of Head Start attendance on early adult outcomes and others have found effects of other early childhood programs on adults despite evidence of fadeout during the childhood years (Barnett 2011; Campbell et al. 2012; Heckman et al. 2013; Reynolds et al. 2011).

Sibling Differences

Now consider the cognitive production function of a sibling of the focal child (sibling 1), which we refer to as sibling 2 for clarity, when sibling 2 was also age 8 (in a different year).

$$(7)\quad \begin{aligned} TEST\_SIB_8 &= H_0(1-\lambda_0)...(1-\lambda_7)+\gamma_0 D_0(1-\lambda_1)...(1-\lambda_7)+...+\tilde{b}_4 HEADSTART\_SIB_4(1-\lambda_5)...(1-\lambda_7) \\ &\quad +\gamma_4 D_4(1-\lambda_5)...(1-\lambda_7)+...+\gamma_7 D_7 \end{aligned}$$

We can compare this to the cognitive production function of sibling 1:

$$\text{(8)} \quad \begin{aligned} TEST_8 &= C_0(1-\delta_0)...(1-\delta_7) + \alpha_0 I_0(1-\delta_1)...(1-\delta_7) + ... + b_4 HEADSTART_4(1-\delta_5)...(1-\delta_7) \\ &+ a_4 I_4(1-\delta_5)...(1-\delta_7) + ... + \alpha_7 I_7 \end{aligned}$$

As shown by equations (7) and (8), siblings 1 and 2 may have different cognitive endowments (*C* and *H*); different rates of depreciation (δ_t and λ_t); different effects of investments (a_t and γ_t , b_4 and $\tilde{b}_4$); and different quantities of investments (*I* and *D*). We believe that it is reasonable to expect such differences because of biological differences between siblings that may affect the endowment and depreciation of cognitive skills, as well as the effect of investments on cognitive development, and because of differences in siblings' family environments throughout childhood (up to age 8) that may affect the quantity and types of investments received by each sibling (Rosenzweig 1986; Datar et al. 2010; Jensen and McHale 2015; Pruckner et al. 2021). Whether the sibling attended Head Start may also differ. Note too, that if the effects of investment differ by sibling, then a sibling difference model includes all investments even if they are the same across siblings. Thus, even if both siblings attended Head Start, test scores may differ because of the difference in the effect of Head Start.

The important result of the above is that if we take the difference of equations (7) and (8), all the variables in each equation enter the model—there is no parsimony unless the quantity of investments are equal and the effects of those investments are equal. We believe this to be an unlikely case. However, this is the assumption underlying most previous research that use a mother-fixed effects model—a second theoretically inconsistent feature of most prior empirical applications.

A slightly different sibling approach is to take differences of sibling test scores that are observed in the same year, but at different ages. Here, we use age 6, and the cognitive production function of sibling 2 at this age is:

$$\text{(9)} \quad \begin{aligned} TEST\_SIB_6 &= H_0(1-\lambda_0)...(1-\lambda_5) + \gamma_0 D_0(1-\lambda_1)...(1-\lambda_5) + ... + \tilde{b}_4 HEADSTART\_SIB_4(1-\lambda_5) \\ &+ \gamma_4 D_4(1-\lambda_5) + \gamma_5 D_5 \end{aligned}$$

For comparison, we show the cognitive production function of sibling 1 at age 6:

$$\text{(10)} \quad TEST_6 = C_0(1-\delta_0)...(1-\delta_5) + \alpha_0 I_0(1-\delta_1)...(1-\delta_5) + ... + b_4 HEADSTART_4(1-\delta_5) + a_4 I_4(1-\delta_5) + ... + \alpha_5 I_5$$

The same issues described above apply to this model too—there are sibling differences in endowments, effects of investments and family environments. Taking the difference of equations (9) and (10) offers no parsimony. The only potential advantage of using differences in siblings in the same year, as opposed to siblings the same age in different years, is that the contemporaneous family environment is similar (possibly the same) for siblings in the same year.

More importantly, the coefficients on Head Start differ between the two siblings purely because of depreciation, but also possibly because of different underlying productivities. Thus, even if we assume the effect of Head Start was the same for each sibling, it is still incorrect to constrain the effect of Head Start to be the same when comparison siblings of different ages.

Within-child Differences

An alternative approach to estimating the effect of Head Start on academic achievement is to use within-child differences (i.e., child-fixed effects). This approach has not been used in prior research on Head Start, or any other study that is interested in an age-invariant factor. Consider the cognitive production function of the same child, but at ages 6 and 8. Equation (3) applies for the child at age 8, and at age 6, the production function is shown in equation (9), which we repeat for clarity:

$$\begin{aligned} TEST_6 &= C_0(1-\delta_0)...(1-\delta_5)+\alpha_0 I_0(1-\delta_1)...(1-\delta_5)+...+b_4 HEADSTART_4(1-\delta_5) \\ &\quad + a_4 I_4(1-\delta_5)+\alpha_5 I_5 \end{aligned} \tag{11}$$

The difference in test scores of the same child between ages 6 and 8 is:

$$\begin{aligned} & TEST_8 - TEST_6 = \alpha_6 I_6(1-\delta_7)+\alpha_7 I_7 -(\delta_6+\delta_7-\delta_6\delta_7)TEST_6 \\ & \text{or} \\ & TEST_8 = \alpha_6 I_6(1-\delta_7)+\alpha_7 I_7 +[1-(\delta_6+\delta_7-\delta_6\delta_7)]TEST_6 \end{aligned} \tag{12}$$

Equation (11) does not include Head Start explicitly, although Head Start attendance will influence the test score at age 6. If there is no depreciation, then the difference in test scores will depend only on the investments that occur between ages 6 and 8 and not Head Start. If there is depreciation, then the difference in test scores will depend on the lagged test score and implicitly all determinants of that score including Head Start and previous investments. An assessment of the importance of depreciation can be conducted by obtaining an estimate of the coefficient on the age 6 test score $[1-(\delta_6+\delta_7-\delta_6\delta_7)]$. If that coefficient is equal to one (in a statistical sense), then it is evidence that depreciation is small or even zero.

However, if we allow Head Start to affect the productivity of future investments, as in equation (5), then the difference in test scores of the same child between ages 6 and 8 is:

$$\begin{aligned}(13)\qquad & TEST_8 - TEST_6 = \alpha_6(HEADSTART)I_6(1-\delta_7) + \alpha_7(HEADSTART)I_7 - (\delta_6+\delta_7-\delta_6\delta_7)TEST_6 \\ & TEST_8 = \alpha_6(HEADSTART)I_6(1-\delta_7) + \alpha_7(HEADSTART)I_7 + [1-(\delta_6+\delta_7-\delta_6\delta_7)]TEST_6\end{aligned}$$

In this case, the difference in test scores of a child depends on Head Start explicitly and not just through Head Start's influence on lagged test score. Assuming no depreciation, the effect of Head Start on the difference in test scores is:

$$(14)\qquad \frac{\partial(TEST_8 - TEST_6)}{\partial HEADSTART_4} = \frac{\partial a_6}{\partial HEADSTART_4} I_6 + \frac{\partial a_7}{\partial HEADSTART_4} I_7$$

An estimate of equation (14)—the effect of Head Start on the productivity of subsequent investments—can be obtained by a regression of the change in test scores of a child on an indicator of Head Start attendance. If there is depreciation, then there would be an additional term that measured the (discounted) effect of Head Start on the age 6 test score.

Child Behavioral Outcomes

We, as did earlier studies, also study the effect of Head Start and preschool on childhood behavioral problems. We assume that childhood behaviors are determined by a similar process as just described for cognitive skills. Children have an endowment related to behavior and changes in behaviors are a result of investment, for example, attending Head Start, and depreciation.

Adult Outcomes

Conceptually, Head Start and preschool attendance may affect adult outcomes because these programs affect cognitive (and other) skills, in ways described above, and this variation in such skills affects adult outcomes that depend on those skills, for example, earnings.

Empirical Implementation

Sibling Models

Given all the potential differences between siblings that would influence their respective test scores and the absence of data to measure most investments, it is unlikely that analyses that examine differences in sibling test scores, for example, a mother-fixed effects regression model, would yield unbiased estimates of the effect of Head Start. However, even if we ignore this well-known problem (Griliches 1979; Elango et al. 2016; Petersen and Lange 2020), the mother-fixed effects approach has not been implemented in a theoretically consistent manner.

To obtain estimates of the effect of Head Start and preschool on child cognitive outcomes using a sibling difference approach, a regression model of differences in test scores of two siblings, for example, when both siblings were age 8 can be used. Such a model would be specified as the difference between equations (7) and (8). Theoretically, the right-hand side variables in this model would include the endowment and investments throughout both sibling's lives. These data are almost always unavailable, at least for some set of them, and proxy variables are typically used. For example, maternal characteristics are included because they are correlated with the quantity and quality of investments (e.g., maternal time input). Family income is also included for a similar reason. We acknowledge that these proxy variables (correlates of investments) are quite removed from the ideal, but this is the standard practice in the applied literature. This issue also underscores the value of the Head Start Impact Study. The experimental nature of the study implies that Head Start participation is uncorrelated with the missing endowment and missing investments.

As already noted, theoretically, the use of sibling differences is not any more parsimonious than estimating equations (7) and (8) separately unless the quantity of investments and the effects of those investments are equal across siblings. The assumption of the sibling differences approach is that all unobserved variables (endowment and investments) are equal for both siblings and that they have the same effect on both siblings. Just writing that statement makes us skeptical of the value of this approach, yet, as typically practiced, the problem is exacerbated because variables that are equal across siblings, for example, race in most cases, are dropped from the model and the effects of variables that differ, for example, mother's marital status in some case, are restricted to have the same effect across siblings.

In contrast to common practice, a mother fixed-effects empirical model that is consistent with the human capital model is the following.

$$
\begin{aligned}
(15)\qquad TEST_{8j} - TEST_{8k} &= a_0 + b_j HEADSTART_j - b_k HEADSTART_k + a_{1j} agemo_j - a_{1k} agemo_k \\
&\quad + \sum_m^M (\gamma_{jm} - \gamma_{km}) X_m + \sum_s^S (\delta_{js} Z_{js} - \delta_{ks} Z_{ks}) + e
\end{aligned}
$$

In equation (15), the difference in test scores of siblings of the same age (e.g., 8) depends on: an indicator of Head Start attendance (*HEADSTART*) for each sibling (j and k); each sibling's age in months at the time of test (*agemo*); characteristics of the siblings that have the same value for each sibling (*X*), for example, race/ethnicity[3] and several maternal characteristics that do not vary across siblings (e.g., AFQT, Rotter scale of locus of control, Rosenberg scale of self-esteem, mother's family structure at age 14); and characteristics of siblings that have different values for each sibling (*Z*), such as child's sex and birthweight, and several maternal characteristics (age at birth, education, marital status, family income). This specification is consistent with the conceptual model described earlier. It is age-specific, and it allows effects of determinants of academic achievement to differ by sibling.

Unlike the model just described, the typical approach used in the literature to estimate what we will refer to as sibling models is to estimate a regression with mother-fixed effects, and not the first-difference form in equation 14 (e.g., Currie and Thomas 1995, Deming 2009, Bauer and Schanzenbach 2016, Miller et al. 2019, and Pages et al. 2020). In these models, variables that have the same value across siblings (e.g., race) are omitted presumably under the assumption that the effect of these variables is the same for each sibling. Similarly, variables that have different values across siblings (e.g., Head Start) are included, but the effect of these variables is constrained to be the same across siblings. Both restrictions

[3] In all sibling pairs, race/ethnicity is reported to be the same. We use the race/ethnicity of what we refer to as sibling 1—the first born of siblings.

are not indicated by the conceptual model and are testable. While not exactly comparable, the analogous mother's fixed effects regression model in first-difference form that is typically estimated is:

$$\begin{aligned}(16)\qquad TEST_j - TEST_k &= a_0 + b(HEADSTART_j - HEADSTART_k) + a_1(agemo_j - agemo_k) \\ &+ \sum_s^S \delta_s (Z_{js} - Z_{ks}) + e\end{aligned}$$

A comparison of equations (15) and (16) reveal the restrictions imposed by the typical mother's fixed effect approach. Effects of variables that have different values for siblings are constrained to be the same across siblings and several variables that do not vary by siblings are omitted. We estimate both models and report the results below.

One point to highlight about equation (16) is its implication for analyses that use siblings of different ages. For example, consider siblings aged 8 and 4. As shown in equation (4) above, the effect of Head Start for these two siblings differs because of depreciation even if all else was equal. Restricting the effect to be the same as in equation (15) is incorrect without an assessment of the restriction. In fact, if the difference is between an older (younger) sibling and a younger (older) sibling, then the estimate of the coefficient on Head Start in equation (15) would be less (greater) than the true effect even if the effect was the same for both siblings. Indeed, this misspecification may explain the common finding of fadeout because, in samples that combine siblings of different ages, older children are being compared to their younger siblings, which biases the true effect of investment downward, and younger siblings are being compared to older siblings, which biases the true effect of investment upward.

The problem just described is even more pronounced if Head Start affects the productivity of future investments. In this case, and assuming that all else is equal between siblings, the difference in the effect of Head Start between siblings ages 8 and 6 is:

$$\begin{aligned}\frac{\partial TEST_8}{\partial HEADSTART_4} - \frac{\partial TEST_6}{\partial HEADSTART_4} &= b_4(1-\delta_5)[(1-\delta_6)(1-\delta_7)-1] + \frac{\partial a_5}{\partial HEADSTART_4} I_5[(1-\delta_6)(1-\delta_7)-1] \\ &+ \frac{\partial a_6}{\partial HEADSTART_4} I_6(1-\delta_7) + \frac{\partial a_7}{\partial HEADSTART_4} I_7\end{aligned}$$

In the expression above, the first two terms are negative because the effect of Head Start depreciates more for the child age 8 than the child age 6, and the next two terms are positive because Head Start may raise the productivity of investments at ages 6 and 7. And if we reverse the difference:

$$\frac{\partial TEST_6}{\partial HEADSTART_4} - \frac{\partial TEST_8}{\partial HEADSTART_4} = b_4(1-\delta_5)[1-(1-\delta_6)(1-\delta_7)] + \frac{\partial a_5}{\partial HEADSTART_4} I_5[1-(1-\delta_6)(1-\delta_7)]$$
$$-\frac{\partial a_6}{\partial HEADSTART_4} I_6(1-\delta_7) - \frac{\partial a_7}{\partial HEADSTART_4} I_7$$

In this case, the first two terms are positive and the last two terms are negative. In sum, it is unclear what parameter is being estimated when differences are between siblings of difference ages. All prior studies that used the family fixed effects approach included siblings of different ages and the differences between them.

Within-Child Models

We also estimate the within-child model motivated by equations (11) and (12). In this model, we take differences in child test scores at two ages and stratify the sample by baseline ages (e.g., 5, 6, …,10). The within-child regression model for the sample of children aged 6 at baseline is:

$$TEST_8 - TEST_6 = a_0 + bHEADSTART + a_1(agemo_8 + agemo_6)$$
$$+ \sum_m^M (\gamma_{8m} - \gamma_{6m}) X_m + \sum_s^S (\delta_{8s} Z_{8s} + \delta_{6s} Z_{6s}) + e \qquad (17)$$

The coefficient on the indicator for Head Start participation in equation (17) theoretically measures the effect of Head Start on the productivity of investments during the period from ages 6 to 8, as shown in equation (14), which we repeat here for clarity:[4]

$$\frac{\partial (TEST_8 - TEST_6)}{\partial HEADSTART_4} = \frac{\partial a_6}{\partial HEADSTART_4} I_6 + \frac{\partial a_7}{\partial HEADSTART_4} I_7$$

Equation (17) assumes that there is no depreciation of skills between ages 6 and 8. An alternative is to allow (or test) for depreciation and estimate the "value-added" model given by:

[4] We use a two-year window to illustrate this approach because the data we use—the Children of the National Longitudinal Survey of Youth (CNLSY)—conducts interviews roughly every two years and we observe children approximately two years apart.

$$TEST_8 = \rho TEST_6 + a_0 + bHEADSTART + a_1(agemo_8 + agemo_6) + \sum_m^M (\gamma_{8m} - \gamma_{6m}) X_m + \sum_s^S (\delta_{8s} Z_{8s} + \delta_{6s} Z_{6s}) + e \tag{18}$$

As noted earlier, if the coefficient on the lagged test score (ρ) is equal to one (in a statistical sense) then this is evidence that there is no or little depreciation.

This within-child model tests whether Head Start raised the productivity of later investments in child development, which is a slightly different hypothesis than the family fixed effects approach that tests whether Head Start had a contemporaneous effect, for example, at age 4, and whether Head Start raised the productivity of later investments. The within-child approach only tests the latter component. However, it is a novel approach to assess whether prior investments affect the productivity of future investments ((Cunha et al. 2006; Heckman 2007; Cunha and Heckman 2008; Cunha et al. 2010).

Adult Outcomes

Estimates of the effect of Head Start and preschool on adult outcomes follow along similar lines as those just described. For sibling models, versions of equation (14), which is the less restrictive approach, and equation (15), which is the more restricted approach, can be estimated. The primary difference between the child and adult analyses is that maternal characteristics at the time of the survey (e.g., marital status) are not particularly relevant and are omitted. Fixed maternal characteristics, such as AFQT score and education, are still included in the model. Similarly, within-child estimates can be obtained using a modified version of equation (16).

Data

We use data from the National Longitudinal Survey of Youth (NLSY) and the Children of the National Longitudinal Survey of Youth (CNLSY). The NLSY began in 1979 and included 12,686 youths born between 1957 and 1964. In 1986, a separate survey (CNLSY) began to collect data about the biological children of the original female participants. As of 2018, 11,545 children have been interviewed in at least one survey wave. The CNLSY has interviewed every child born to a female NLSY respondent, which allows to compare siblings within the same family. Beginning in 1988, mothers have been asked whether their children had ever been enrolled in Head Start and in any other preschool program. We combine data on children and their mothers from the CNLSY with mothers' data drawn from the NLSY.

Child Sample

In 1988, which is the first time Head Start and preschool enrollment data were collected, enrollment questions included all children 3 and older. In later years, these questions were asked only for children ages 3 to 7 or 3 to 8 depending on the year[5]. For most children, enrollment data are available for two survey waves, and in some cases, even three waves. This multi-year enrollment questions generate some inconsistency over time. While for most children enrollment answers follow a consistent pattern, either they always answer yes or no to ever been enrolled in a particular program, for approximately 15% of children with non-missing enrollment data, an inconsistent pattern over time is reported (no-yes, yes-no, no-yes-no, yes-no-yes). Most children with the pattern of no-yes fall within the normal age range for enrollment in preschool: had not been enrolled at early ages (3-4); and reported enrollment at later ages (5-6). We consider that these children effectively attended a preschool program. The rest of children with this pattern of answers reported no enrollment within normal ages[6] (3-7) and reported enrollment at later ages. Since enrollment in a preschool program after age 7 is extremely unlikely, we excluded these children from the sample. We also excluded children whose parents reported enrollment in a preschool program before age 5, but at age 5 answered that their children had never been enrolled in a preschool program. For all other cases where children were reported as ever been enrolled in a preschool program within normal age (3-7) and at later ages their parents reported the opposite, we consider that they attended a preschool program. In some cases, parents reported that their children attended both Head Start and preschool. In such cases, we consider those children as Head Start participants only, which is how previous analyses that used the NLSY addressed the issue (e.g., Deming 2009).

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[5] In 1990 and 1996-2014, the group eligible to answer preschool enrollment questions included children ages 3 to 7, and in 1992 and 1994, those questions were asked about children ages 3 to 8.

[6] Given that children can be enrolled in Head Start between ages 3 to 5 and the biannual nature of the CNLSY, we consider that the normal age range for enrollment to be reported in the survey is between ages 3 to 7.

After excluding children with inconsistent enrollment patterns and children with missing enrollment data (13.8% of all children)[7], we selected children ages 4 to 12 with at least one sibling observed between ages 4 to 12. They constitute our sample for the child outcomes analyses using the typical mother fixed effects models. To implement the empirical approach that is theoretically consistent, we selected children ages 4 to 12 with at least one sibling observed at the same age. For each child, we create sibling pairs using every sibling observed at the same age. For example, in a family with three children that we observed all three children at age 6, we have three pairs of siblings at age 6: siblings 1 and 2, siblings 1 and 3, and siblings 2 and 3. We assign each sibling a unique number so pairs are unique. For the within-child analyses (child fixed effects), the unit of analysis is pair of consecutive survey waves. For each child we create pairs of consecutive survey waves that contain all relevant data (outcomes and covariates) for each year in the pair. For example, if a child is observed in 1994, 1996, 1998 and 2000 (between ages 6 and 12), we will have three pairs of consecutive survey waves for that child: 1994-1996, 1996-1998, and 1998-2000.

Child outcomes

We assess the effects of Head Start and preschool on two types of child outcomes: achievement test scores and behavior problems. Achievement test scores are measured using the Peabody Picture Vocabulary Test (PPVT) and the Peabody Individual Achievement Test (PIAT) for mathematics and reading (recognition and comprehension).[8] For all achievement tests, we use the total raw score. For the PPVT analysis, the sample is restricted to children ages 4 and 5, and for all PIAT analyses, the sample includes children ages 5 to 12. Behavior problems are measured using the Behavior Problems Index (BPI).[9] We use the total raw score, and the sample includes children ages 5 to 12.

Child outcomes

[7] The majority of those with missing enrollment data is either because they had no child interview during the period those questions were asked or because they were not asked due to age eligibility criteria.
[8] All these tests are widely used and have been validated as tests of cognitive function and/or academic achievement of children (Deming 2009).
[9] BPI used in the CNLSY includes 28 questions administered to mothers. Mothers are asked about specific behaviors that their children ages 4 to 14 (13 in 2016) might have displayed in the previous three months.

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Covariates

We use an extensive set of covariates that includes children's characteristics and their mother's characteristics. Children's characteristics include basic demographics such as sex, race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Hispanic), age in months, and age in months squared. We also include dummies for child's birthweight (less than 90 oz, 90 to 104 oz, 105 to 129 oz, 130 oz or more), and dummy variables for average real family income at the time of the test ($0-$10,000, $10,001-$25,000, $25,001-$50,000, over $50,000).[12]

Mother's characteristics include both variables that vary across siblings (and/or over time) and variables that are the same for each sibling. The first group includes dummy variables for mother's age at child's birth (18 or less, 19-23, 24-30, 31-35, more than 35), dummy variables for mother's marital status at the time of test assessment (never married, married, separated/divorced/widow), mother's employment status at the time of the test, and dummy variables for mother's education at the time of test (high school

[10] All these tests are widely used and have been validated as tests of cognitive function and/or academic achievement of children (Deming 2009).
[11] BPI used in the CNLSY includes 28 questions administered to mothers. Mothers are asked about specific behaviors that their children ages 4 to 14 (13 in 2016) might have displayed in the previous three months.
[12] We create average real family income at the time of the test for each child by averaging real family income (converted into real dollars using the CPI-U) from the first survey the child is observed (for most children this corresponds to the first survey immediately after their birth) up to the current survey. If family income is missing in any year used to calculate average family income, we only use observed income to calculate the average; hence, average family income is only missing if a child has no family income information from birth until the time of test.

dropout, high school diploma, some college, bachelor's degree).[13] The second group includes indicators for each quartile of mother's AFQT score, Rosenberg self-esteem, and Rotter locus of control. Other variables include an indicator for whether there were magazines, newspapers, and /or library card in mother's household at age 14, dummy variables for mother's marriage at time of first birth (not married before first child's birth, married before first birth, married within a year after first birth), and dummy variables for mother's highest grade ever achieved[14] (high school dropout, high school diploma, some college, bachelor's degree).

We address missing covariate values in two ways. In the case of continuous variables, we replace the missing value with the sample mean for that variable and include a missing indicator in the regressions. In the case of categorical variables, we include a missing category for each variable in the regressions. Missing values for most covariates are less than 3% of observations. The covariate with the largest proportion of missing values is birthweight (~10%), which also varies across siblings (birthweight is more likely to be missing for younger siblings).

Adult Sample

Our adult sample consists of the same children that are part of the child samples, but observed at ages 24 and older. For the typical mother fixed effects models, we restrict the sample to respondents with at least one sibling observed at age 24 or older. For our theoretically consistent approach, we restrict the sample to respondents with at least one sibling observed at the same age. For our adult outcomes analyses that use sibling models and within-person models, we create sibling pairs of the same age and pairs of consecutive survey waves in the same way as we did for the child analyses.

Adult Outcomes

[13] Since the variation in maternal education across siblings (and over time) is minimal, in the regressions we only include dummies for one sibling (sibling 1) or only for one year (baseline year), in the case of the within-child analysis.

[14] In adult outcomes analyses we use mother's highest grade ever achieved instead of education at the time of interview due to the high proportion of missing maternal education in young adult interviews. Also, when children are 24 and older, most mothers are over 40 years old, therefore changes in maternal education at those ages are extremely unlikely.

We focus on three types of adult outcomes: labor market outcomes, marital status, and educational attainment. Labor market outcomes include employment (working at the time of interview), total hours usually worked per week, and total income from wages and salary in the previous year. We transform income into real dollars using the Consumer Price Index (CPI-U), which base period is 1982-1984. For marital status outcomes, we created two indicator variables based on the marital status at each interview: married and separated, divorced, or widow. In the case of educational attainment, we use the highest grade completed at each interview to create three indicator variables: high school graduation (12 or more years of completed schooling), at least one year of college (13 or more years of completed schooling), and bachelor's degree (16 or more years of completed schooling).

Results for Children

Descriptive Statistics

Table 1 presents means of achievement test scores, demographic variables and select maternal characteristics for the sample of siblings by age. Ages are grouped into two-year categories. The first point to note about the figures in Table 1 is that, at every age, children who attended Head Start have the lowest achievement test scores and children who attended preschool have the highest achievement test scores. The differences in achievement are between 2 to 4 points at ages 5 to 6 and between 7 to 8 points at ages 11 to 12, and the differences are statistically significant. Another marked difference is that children who attended Head Start are much more likely to be Black, Non-Hispanic than children who attended preschool or attended neither. Finally, the mothers of children who attended preschool have the most education and highest AFQT test scores. Overall, the descriptive information in Table 1 reveals substantial differences in test scores and family background between children with different preschool experiences. Children who attended Head Start (preschool or neither) are not a random sample and that other factors that influence test scores, for example, mother's education, differ across children.

Estimates from Typical Mother Fixed Effects Approach

We start the analysis with estimates obtained from the type of mother-fixed effects approach that was typically estimated in prior studies (e.g., Currie and Thomas 1995; Deming 2009). The analysis uses a combined sample of children ages 5 to 12 with at least one sibling. We focus on PIAT tests because the PPVT was given mostly to young children (age 4), although we examine this outcome in later analyses. Three regression models are estimated using the combined sample of children ages 5 to 12. The first model is typical of prior studies and includes a mother fixed effect—a dummy variable for each mother—and variables that generally take on different values between siblings, for example, mother's marital status. Variables that are constant within mother are excluded (absorbed by the mother fixed effects). In addition, effects of variables that vary across siblings, including Head Start and preschool, are constrained to be the same for siblings. A second model adds variables that have the same value between siblings (within a mother), which are typically excluded, and the effect of these variables is allowed to differ by sibling (by age), as suggested by the conceptual model. The third model includes the same variables in the second model, but it allows the effect of all covariates, including those that take on different values between siblings, to differ by sibling age. All three model specifications allow the effects of Head Start and preschool attendance to differ by child age.

Table 2 presents these estimates. The notes below the table describe the regression model specification. Estimates in Table 2 from the "typical" mother fixed effects approach indicate that Head Start attendance significantly increased both math and reading achievement test scores at ages 5 to 6, and effect sizes are quite large. At ages 5 to 6, the standard deviation of PIAT tests is approximately 7, so an effect size of 1.17, which is the estimate for the math test, indicates that Head Start raised math test scores by almost 0.2 standard deviations, which is similar to other estimates (e.g., Deming 2009). Estimates of the effect of Head Start from the same "typical" model at older ages are relatively small and not statistically significant, which is consistent with prior evidence of fade out. In fact, by ages 11 to 12, estimates of Head Start are negative and significant for the two reading assessments.

A similar, but opposite pattern is found for preschool; estimates indicate that preschool attendance lowered test scores significantly of children ages 5 to 6. Effect sizes are approximately 0.1 to

0.2 standard deviations. At older ages, preschool attendance has relatively small and statistically insignificant effects.

Next, we discuss estimates from models that add covariates that have the same value for siblings, such as maternal education, AFQT and Rotter index of locus of control. The model allows the effect of these variables to differ by sibling. As shown results related to the effect of Head Start change substantially (see Appendix Table A1 for full set of estimates). In these models, Head Start and preschool have no statistically significant relationship with achievement test scores at any age. These results highlight how past studies may have obtained misleading estimates because of empirical restrictions that are rejected here and that are inconsistent with theory.

The last set of estimates in Table 2 are from the "typical" mother fixed effects specification, but are obtained using a specification that allows the effect of all covariates to differ by child age. Estimates from these models are all statistically insignificant and small (<10% of a standard deviation). Overall, estimates in Table 2 highlight the potential problems with the typical implementation of the mother fixed effects model and how that implementation may lead to misleading results—for example, that Head Start had positive effects at younger ages that fade out and even reverse at older ages. When a more theoretically consistent model is estimate, neither Head Start or preschool have any meaningful effect on achievement tests.

Same-age Sibling Test Score Estimates

An important point to note about the models that produced estimates in Table 2 is that comparisons are largely made between siblings of different ages, for example one sibling is 12 and another is 8. The conceptual model described above shows that effects of variables are likely to differ by age and that it is difficult to interpret estimates from such models even if the effect if allowed to differ by age because at each age, there are differences between siblings that are younger and older.

In this section we provide estimates of the effect of Head Start that are more consistent with the theoretical model of child human capital development. The sample for analyses in this section is sibling pairs of the same age between the ages of 4 and 12. Using siblings of the same age avoids the problems associated with interpreting estimates when differences are for siblings of different ages. We estimate separate regressions for each of the achievement results: PPVT and the PIAT tests for reading (recognition and comprehension) and math.

Table 3 shows estimates for the PPVT and the sample is restricted to those ages 4 to 5 because those are the ages when the PPVT was assessed.[15] The table is structured to highlight the different model specifications. Our preferred specification (equation 14) is that with the least restrictions in terms of being consistent with the conceptual model. For that model, variables indicating Head Start and preschool attendance, as well as all other variables, of each sibling enter the model separately and are allowed to have a different effect. We also estimated a slightly modified version of this model that restricted the coefficients on Head Start and preschool to be the same for each sibling, but allowed other covariates to have sibling-specific effects. We denote this as the "Restricted Model." To compare our preferred model to those used in most prior studies, we estimated a mother's fixed effects model (equation 15) analogous to models estimated in previous studies. We denote this as "Mother's Fixed Effects." In these models, variables that are constant within mother are omitted and effects of other variables are constrained to be the same across siblings. Finally, we obtained estimates for samples stratified by race/ethnicity and mother's AFQT, but we delay our discussion of these estimates until later in the article.

All estimates in column 1 (Full Sample) of Table 3 are not statistically significant and most are small in magnitude, for example, around one point (or less), or 5% of a standard deviation. Generally, estimates are precise enough to rule out (statistically) effect sizes of 3 points or 15% of a standard deviation or larger. The tests for whether coefficients on Head Start and preschool are equal and opposite signed, as implied by the standard mother's fixed effects specifications, do not reject the null hypothesis, which is not surprising because all estimates are small. However, it is worth noting that the indicated effects of Head Start and preschool are both negative (coefficients on Sibling 1 variables). Estimates from the "Restricted Model" reflect this negative association, but estimates are still not significant. Finally,

[15] The PPVT was also given to those ages 10 and 11 starting in 1988 and only in a couple of survey waves; all children 3 and older were eligible to take the PPVT.

estimates of the effects of attending Head Start or preschool from the "Mother's Fixed Effects" are negative and insignificant, and close to estimates from the "Restricted Model".

The last result merits further comment. The "Mother's Fixed Effects" model embeds many restrictions that are not imposed in our preferred model or in the "Restricted Model". These restrictions do not seem to matter much, which is notable. This result implies that the significant effects of Head Start and preschool in Table 2 are primarily because of using differences in sibling test scores at different ages and the problems of interpretation that this creates. Overall, we find little evidence that attending Head Start or preschool significantly affected PPVT scores at ages 4 to 5. The full set of estimates for the unrestricted first difference model and the mother's fixed effects model are presented in Appendix Tables A2 and A3.

Table 4 presents estimates of the effect of attending Head Start and preschool on PIAT math scores (see Appendix Tables A4 and A5 for full set of estimates). The table has a similar structure as Table 3, but in this case, we show estimates for four age groups: 5-6, 7-8, 9-10 and 11-12. We estimate the same models (preferred, "Restricted Model", and "Mother's Fixed Effects") for each age group.

The most notable fact about estimates in Table 4 is that not one is statistically significant, and all are relatively small—less than 10% of a standard deviation. Estimates are generally precise enough to rule out (statistically) effect sizes of 15% of a standard deviation or larger. The second fact about estimates in Table 4 is that the model specification does not seem to matter. Estimates from our preferred model indicate small (no) effects of Head Start and preschool on math test scores, and more restrictive and less conceptually valid models indicate the same.

The next set of tables present results for the PIAT reading tests: Table 5 shows estimates for the PIAT Reading Recognition test and Table 6 contains estimates for the PIAT Reading Comprehension test (see Appendix Tables A6 through A9 for full set of estimates). Both tables have the same format, which is identical to that of Table 4. The remarkable finding revealed in Tables 5 and 6 is that in all instances, save a handful, estimates of the effect of Head Start or preschool on PIAT reading test scores are statistically insignificant and small (less than 10% of a standard deviation). Again, there is little evidence that Head Start or preschool affected academic achievement at ages 5 to 12.

However, there is substantial evidence that the restrictions imposed in “Mother’s Fixed Effects” models matter. In 7 out of 8 cases, the typical restriction of the “Mother’s Fixed Effects” model that the effect of Head Start is the same across siblings is rejected. In analyses where the restriction of equal effects of Head Start across siblings is rejected, estimates indicate that Head Start had a relatively large positive effect on Sibling 2’s reading scores. Thus, when the restriction is imposed, the estimate suggests that Head Start had a negative effect on reading scores. These results highlight the potential problems with the “Mother’s Fixed Effects” approach.

Same-age Sibling Test Score Estimates—Stratified by Race/Ethnicity

Prior studies have highlighted differences in the effects of Head Start and preschool by race/ethnicity. Given this prior interest, we conducted analyses stratified by race/ethnicity. Results of these analyses are reported in Tables 3 (PPVT) and Tables 7 through 9 for the three PIAT tests. A limitation of the analyses conducted on stratified samples is a lack of statistical power. For example, for the PPVT outcome and the sample of white children, which is the largest group, standard errors are such that an effect size for Head Start of less than 35% of a standard deviation cannot be detected with common standards of statistical reliability. For the PIAT tests and the sample of white children, effect sizes less than 20% of a standard deviation cannot be reliably detected. The statistical power associated with Black, Non-Hispanic and Hispanic samples of children is often less.

Starting with Table 3 and PPVT scores, all estimates pertaining to samples of Black, Non-Hispanic and Hispanic children are not statistically significant, although, as noted, the lack of statistical power suggests some caution with respect to this conclusion. For white children, estimates suggest that Head Start and preschool attendance reduced PPVT scores and effects are quite large—20% to 33% of a standard deviation. These estimates are the opposite sign of what Currie and Thomas (1995) reported. Estimates related to preschool were statistically significant for the white children. While differences between white and Non-Hispanic, Black children are large and negative, given the lack of statistical power, we are cautious about putting too much credence in these effects. As for whether the model specifications matter, the lack of statistically significant estimates and large standard errors makes the test of the model restrictions relatively weak.

Tables 7 through 9 show estimates of the effect of Head Start and preschool on PIAT test scores. With the caveat about statistical power in mind, we note that almost every estimate of the effect of Head Start and preschool on PIAT test scores in Tables 7 through 9 are not statistically significant. Moreover, a large majority of estimates are small—less than 10% of a standard deviation—and, not surprisingly, estimates larger than 10% of a standard deviation almost always pertain to the Hispanic sample, which is the smallest and which has the most imprecise estimates. Putting aside the precision and statistical significance of estimates, there are few noticeable patterns. Among white children, preschool is consistently associated with lower test scores, but other than that, there is little evidence indicative of a possible effect of either Head Start or preschool.

Overall, estimates in Tables 7 to 9 are consistent with those from the full sample and provide no evidence of a significant relationship between Head Start or preschool attendance and test scores for samples stratified by race/ethnicity. And like the results for the full sample, there is evidence from the analyses of reading test scores that the typical mother's fixed effects approach is invalid. Test of whether the coefficients on Head Start are equal and opposite signed for siblings is rejected in several instances.

Same-age Sibling Test Score Estimates—Stratified by Mother's AFQT

There are plausible reasons why effects of Head Start or preschool attendance may differ by mother's AFQT—a measure of cognitive ability. One possibility is that the productivity of maternal time invested in children may be higher for mothers with higher AFTQ scores, or mothers with higher AFQT scores may select higher quality preschools or Head Start programs. Conceptually, it is not necessarily clear how mother's AFQT will moderate effects of Head Start and preschool on test scores. Thus, like some previous studies, we obtained estimates of the effect of Head Start and preschool on test scores for samples of children stratified by mother's AFQT. We divide children into two groups using the median AFQT score.

Estimates from analyses of the effect of Head Start and preschool on test scores for samples stratified by AFQT are presented in Tables 10 to 12. Our reading of these results is that there are few noticeable differences in the effects of Head Start and preschool by mother's AFQT score. Almost all estimates are not statistically significant and are small in magnitude using 10% of a standard deviation threshold to define small. And as in earlier analyses, there is some evidence rejecting the typical mother's fixed effects specification when reading test scores are the outcome. These results add to the substantial prior evidence suggesting that Head Start and preschool attendance had no meaningful effect on children's test scores between ages 5 to 12.

Within-child Test Score Estimates

An alternative way to estimate the effect of Head Start and preschool on children's test scores is the within-child, or child fixed effects, approach. This novel approach has some advantages over the sibling approach because it eliminates all time-invariant, child-specific influences of test scores (e.g., cognitive endowment) that may confound the relationship between Head Start and preschool attendance and achievement test scores. In short, the within-child approach provides some parsimony and addresses unobservable variables in an arguably more effective way than the mother fixed effects approach. Additionally, if there is little depreciation of cognitive skills, the within-child approach requires information only on recent investments and not the entire history of investments from birth onward. The within-child approach obtains estimates of the effect of Head Start and preschool that works through changes in the productivity of investments post attendance, as described above.

Table 13 shows estimates from the within-child regression models for ages 5 to 12 (see Appendix Tables A10 through A12 for full set of estimates). We use two-year differences in age due to the survey timing. We report estimates from first-difference (equation 16) and value-added (equation 17) specifications. Estimates for all three PIAT tests are shown in Table 13.

The main thing to note about estimates in Table 13 is that almost all are small and statistically insignificant. The only exception pertains to estimates of the effect of preschool on reading test scores for those age six at baseline. Overall, the within-child estimates provide additional evidence that Head Start and preschool attendance have no statistically significant effect, or an effect that is larger than 0.1 standard deviations.

Behavioral Problems Index Estimates

Besides achievement test scores, we also examined whether Head Start and preschool affect childhood behavioral problems, as measured by the Behavioral Problems Index (BPI). Estimates of the effect of Head Start and preschool on the BPI are shown in Table 14. Almost all estimates in Table 14 are not statistically significant and small in magnitude (<10% of a standard deviation). In sum, there is little evidence that attending Head Start or preschool affected childhood behavioral problems. Estimates of the effect of Head Start and preschool on BPI for samples stratified by race/ethnicity and mother's AFQT are in Appendix Tables A13 and A14. These estimates also indicate that Head Start and preschool attendance had no meaningful effect on BPI for these samples.

Results for Adults

Descriptive Statistics

Table 15 presents means for the adult outcomes and for a select number of covariates included in the regression model. The average age of the adult sample is 27. Outcomes examined include employment, hours of work conditional on being employed, wage and salary earnings, marital status and educational attainment. Consistent with differences observed for the sample while they were children, those who attended Head Start have the lowest levels of employment, earnings and educational attainment, and those who attended preschool have the highest levels of employment, earnings and educational attainment. All differences in these outcomes are statistically significant. And as previously noted, those who attended Head Start have mothers who are less educated and who have lower AFQT scores than those in the other groups.

Regression Estimates

Estimates of the effect of Head Start and preschool on adult outcomes are shown in Tables 16 through 18. Table 16 displays the estimates from the typical mother fixed effects models, Table 17 shows estimates from sibling-difference models, which are the analog of mother fixed effects models when sibling pairs are used, and Table 18 present estimates from within-person models. We examined several outcomes: employment, earnings, marital status, and educational attainment. There is no need to spend too much time describing results in these tables because all but three of the many estimates in the tables are not statistically significant and small in magnitude. The first significant estimate is from the typical mother fixed effects models (Table 16). The estimate shows that preschool attendance decreased earnings by over $1,100 a year. The other two significant estimates are from the within-person analysis (Table 18). In this case, estimates indicate that Head Start attendance increased employment by 2.2 percentage points and reduced the probability of having a Bachelor's degree by approximately 1 percentage point. These two estimates are not intuitive as greater educational attainment is usually associated with greater employment. Otherwise, there is virtually no significant evidence that Head Start or preschool attendance affected adult outcomes

Conclusion

The main contribution of our research is the derivation of a theoretically consistent, empirical framework for implementing mother- and child-fixed effects approaches used in analyses based on the human capital production function. Surprisingly, much research across many areas in economics has used mis-specified models that exclude variables that are constant within mother or child, restrict effects of variables to be the same across siblings, or over time, and use differences in outcomes of children of different ages (in mother-fixed effects approach).

A secondary contribution is the re-assessment of evidence related to the efficacy of Head Start from models that use a mother's fixed effect approach (i.e., sibling differences). We apply our approach to the question of the effectiveness of Head Start and preschool. Notably, we present evidence that the deviation from theory matters. Moreover, estimates from the various models, including analyses stratified by race/ethnicity and maternal AFQT, all point to the same conclusion—Head Start and preschool attendance had virtually no statistically or economically significant effect on child academic and behavioral outcomes, or on adult outcomes. While there is a relatively large amount of evidence on the effectiveness of Head Start and preschool, a substantial portion of that evidence is derived from empirical approaches that we show are problematic.

To sum up, we have shown how the empirical approach used across many areas of economics focused on determinants of human capital is inconsistent with theory. For one application, the effects of Head Start and preschool, we show that incorrectly specified models produce different results than a more theoretically consistent approach. Typical applications of mother- or child(person)-fixed effects models often use empirical specifications that are highly restrictive in terms of the underlying conceptual model of human capital. The typical specification assumes that investments in human capital have the same effect (productivity) on siblings, or at different ages of the same child, and that variables that are constant across siblings or over time for a child do not enter the model. There are plausible reasons for these restrictions to be invalid and the bias caused by them potentially large. Accordingly, findings from these studies need to be interpreted with caution and reassessments are justified to investigate the extent of the biases.

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Table 1. Descriptive Statistics for Child Sample
Sample Restricted to Children with a Sibling of the Same Age

	Age 5-6			Age 7-8			Age 9-10			Age 11-12		
	Head Start	Pre-school	Neither	Head Start	Pre-school	Neither	Head Start	Pre-school	Neither	Head Start	Pre-school	Neither
PIAT Math	13.8*	17.2*	15.2	26.3*	32.9*	29.5	39.8*	46.7*	42.3	46.8*	54.3*	49.8
PIAT Reading Recog.	15.8*	18.6*	17.0	29.2*	35.6*	32.5	41.3*	48.8*	44.5	49.4*	58.1*	53.4
PIAT Reading Comp.	15.4*	17.8*	16.3	27.5*	33.0*	30.1	37.1*	44.1*	40.5	43.7*	51.3*	47.4
Female	0.464	0.489	0.489	0.466	0.490	0.505	0.498	0.496	0.501	0.474	0.495	0.502
Black, Non-Hispanic	0.562*	0.202*	0.266	0.561*	0.187*	0.276	0.588*	0.203*	0.303	0.575*	0.202*	0.303
White, Non-Hispanic	0.207*	0.636*	0.456	0.202*	0.639*	0.453	0.187*	0.629*	0.441	0.197*	0.632*	0.436
Hispanic	0.231*	0.162*	0.278	0.237	0.174*	0.271	0.225	0.168*	0.256	0.228	0.166*	0.261
Age in Months	71.6	71.4	71.9	95.3	95.1	95.6	119.4	118.9*	119.7	143.6	143.3	143.3
Mother's Education												
Less Than High School	0.234	0.077*	0.228	0.268	0.086*	0.243	0.276	0.081*	0.244	0.271	0.087*	0.238
High School	0.502	0.359*	0.475	0.498	0.378*	0.474	0.464	0.375*	0.498	0.465	0.380*	0.474
Some College	0.216	0.287*	0.199	0.195	0.264*	0.193	0.222*	0.283*	0.170	0.226*	0.281*	0.191
Bachelor's Degree	0.047*	0.276*	0.095	0.039*	0.271*	0.087	0.035*	0.258*	0.085	0.037*	0.250*	0.090
Mother's AFQT	23.6*	51.6*	35.6	22.2*	50.3*	35.5	21.8*	49.8*	33.4	21.5*	48.7*	33.5
Rosenberg	21.1*	22.3*	21.5	21.0*	22.2*	21.3	20.9	22.3*	21.2	21.0	22.3*	21.3
Rotter	9.3*	8.6*	8.9	9.4*	8.5*	9.0	9.4*	8.6*	9.1	9.3*	8.6*	9.0
Mother Married 1st Birth	0.401*	0.793*	0.637	0.393*	0.784*	0.604	0.378*	0.769*	0.594	0.361*	0.757*	0.593
Number of Obs.	765	1633	1183	827	1666	1326	908	1609	1367	890	1557	1332

* Indicates that the mean for children who attended Head Start or other Preschool is statistically different from mean for children who did not attend any preschool program at 0.05 level.

Table 2. Estimates of the Effect of Head Start and Preschool on Test Scores by Age
Estimates from Mother Fixed Effects Models

	PIAT Math			PIAT Reading Recognition			PIAT Reading Comprehension		
	Typical Mother FE	Mother FE w/ Constant Covariates	Mother FE w/ Age-Specific Covariates	Typical Mother FE	Mother FE w/ Constant Covariates	Mother FE w/ Age-Specific Covariates	Typical Mother FE	Mother FE w/ Constant Covariates	Mother FE w/ Age-Specific Covariates
Head Start by Age									
Ages 5-6	1.17**	0.30	0.23	1.77**	0.78*	0.53	1.59**	0.53	0.38
	(0.34)	(0.33)	(0.33)	(0.41)	(0.39)	(0.39)	(0.34)	(0.33)	(0.33)
Ages 7-8	-0.52	-0.33	-0.33	0.11	0.10	0.049	-0.077	-0.046	-0.11
	(0.39)	(0.39)	(0.39)	(0.41)	(0.42)	(0.42)	(0.36)	(0.36)	(0.36)
Ages 9-10	-0.36	-0.087	0.0041	-0.91	-0.59	-0.44	-0.85*	-0.50	-0.38
	(0.40)	(0.41)	(0.41)	(0.47)	(0.47)	(0.47)	(0.40)	(0.40)	(0.40)
Ages 11-12	-0.58	-0.21	-0.17	-1.62**	-0.94	-0.76	-1.54**	-0.85*	-0.78
	(0.42)	(0.43)	(0.43)	(0.51)	(0.51)	(0.52)	(0.42)	(0.42)	(0.43)
Preschool by Age									
Ages 5-6	-1.04**	-0.15	-0.046	-1.59**	-0.53	-0.40	-1.45**	-0.40	-0.32
	(0.28)	(0.27)	(0.27)	(0.34)	(0.33)	(0.33)	(0.28)	(0.27)	(0.27)
Ages 7-8	-0.17	-0.22	-0.19	-0.51	-0.25	-0.21	-0.37	-0.17	-0.19
	(0.31)	(0.31)	(0.31)	(0.36)	(0.36)	(0.36)	(0.31)	(0.32)	(0.32)
Ages 9-10	0.14	-0.22	-0.29	0.11	-0.39	-0.42	0.24	-0.18	-0.14
	(0.32)	(0.33)	(0.33)	(0.39)	(0.40)	(0.40)	(0.34)	(0.35)	(0.35)
Ages 11-12	0.50	0.045	-0.065	0.46	-0.37	-0.52	0.37	-0.43	-0.48
	(0.34)	(0.34)	(0.34)	(0.43)	(0.44)	(0.44)	(0.35)	(0.36)	(0.36)
Mean Dependent Variable	35.4	35.4	35.4	38.1	38.1	38.1	34.9	34.9	34.9
SD Dependent Variable	16.6	16.6	16.6	18.0	18.0	18.0	15.5	15.5	15.5
Observations	24464	24464	24464	24349	24349	24349	23796	23796	23796

Notes: Standard errors in parentheses clustered at the family level. All regressions include the following variables: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, more than 130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test, maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Mother FE w/ Constant Covariates regressions include the interaction between child's age (in years) and the following variables: mother's education at time of test (high school diploma, some college, bachelor's degree, missing), mother's Rosenberg, Rotter and AFQT quartiles, whether there were magazines, newspapers, or library card in mother's household at age 14, and whether mother got married before first birth. Mother FE w/ Age-Specific Covariates regressions include the interaction between child's age (in years) and all covariates (except for age in months and year dummies). * $p < 0.05$, ** $p < 0.01$

Table 3. Estimates of the Effect of Head Start and Preschool on PPVT Score by Race/Ethnicity for Children Ages 4 and 5
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Full Sample	Low AFQT	High AFQT	White	Black	Hispanic
Head Start (Sib. 1)	-0.47	-1.40	0.45	-1.33	3.60	-3.84
	(1.50)	(1.93)	(3.38)	(3.73)	(2.30)	(2.99)
Head Start (Sib. 2)	0.89	1.27	-1.31	4.67	-1.34	-1.20
	(1.53)	(1.82)	(3.40)	(3.82)	(2.63)	(2.44)
Head Start (Sib.1) = -Head Start (Sib. 2)	0.41	-0.13	-0.86	3.34	2.26	-5.04
	(1.73)	(2.13)	(4.11)	(4.32)	(2.70)	(3.04)
Δ Head Start (Restricted Model)	-0.79	-1.39	0.89	-3.26	2.48	-0.71
	(1.25)	(1.55)	(2.71)	(3.12)	(2.05)	(2.19)
Δ Head Start (Mother's Fixed Effects)	-0.89	-1.96	0.57	-2.68	2.59	-1.05
	(1.29)	(1.52)	(2.57)	(3.00)	(2.08)	(2.35)
Preschool (Sib. 1)	-1.99	-0.21	-3.74^{*}	-5.54^{**}	0.64	1.78
	(1.26)	(1.90)	(1.88)	(1.96)	(2.36)	(2.34)
Preschool (Sib. 2)	0.84	-1.02	3.02	4.89^{*}	0.16	-3.34
	(1.32)	(1.84)	(1.93)	(2.01)	(2.65)	(2.59)
Preschool (Sib.1) = -Preschool (Sib. 2)	-1.15	-1.23	-0.72	-0.65	0.80	-1.57
	(1.49)	(2.40)	(1.92)	(2.15)	(2.96)	(3.11)
Δ Preschool (Restricted Model)	-1.44	0.38	-3.39^{*}	-5.12^{**}	0.35	2.63
	(1.05)	(1.43)	(1.64)	(1.66)	(1.99)	(1.91)
Δ Preschool (Mother's Fixed Effects)	-1.16	0.25	-3.00	-4.86^{**}	0.86	2.53
	(1.01)	(1.41)	(1.54)	(1.52)	(1.90)	(2.01)
Mean Dependent Variable	109.5	101.2	118.9	118.2	100.9	104.8
SD Dependent Variable	19.8	17.7	17.7	17.2	17.3	21.1
Observations	1345	592	753	674	364	307

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include siblings' race/ethnicity (White, Black, Hispanic), dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 4. Estimates of the Effect of Head Start and Preschool on PIAT Math Score by Age for Stratified Sample
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12
Head Start (Sib. 1)	0.13	0.87	1.20	-0.84
	(0.53)	(0.85)	(0.87)	(0.88)
Head Start (Sib. 2)	0.12	0.31	0.24	1.31
	(0.47)	(0.89)	(0.88)	(0.87)
Head Start (Sib.1) = -Head Start (Sib. 2)	0.25	1.17	1.44	0.47
	(0.47)	(0.86)	(0.89)	(0.80)
Δ Head Start (Restricted Model)	-0.027	0.26	0.46	-1.06
	(0.44)	(0.76)	(0.75)	(0.78)
Δ Head Start (Mother's FE)	0.0084	0.44	0.67	-0.84
	(0.43)	(0.75)	(0.74)	(0.78)
Preschool (Sib. 1)	-0.59	-0.47	-0.17	-0.45
	(0.39)	(0.66)	(0.76)	(0.73)
Preschool (Sib. 2)	-0.20	0.50	0.92	1.36
	(0.41)	(0.62)	(0.71)	(0.71)
Preschool (Sib.1) = -Preschool (Sib. 2)	-0.79	0.033	0.76	0.91
	(0.46)	(0.72)	(0.75)	(0.69)
Δ Preschool (Restricted Model)	-0.22	-0.47	-0.54	-0.90
	(0.33)	(0.53)	(0.63)	(0.63)
Δ Preschool (Mother's Fixed Effects)	-0.22	-0.39	-0.45	-0.98
	(0.32)	(0.52)	(0.62)	(0.63)
Mean Dependent Variable	15.7	30.0	43.2	50.6
SD Dependent Variable	6.7	10.8	10.9	11.0
Observations	2371	2576	2623	2563

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include siblings' race/ethnicity (White, Black, Hispanic), dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). $^{*}\ p < 0.05$, $^{**}\ p < 0.01$

Table 5. Estimates of the Effect of Head Start and Preschool on PIAT Reading Recognition Score by Age for Stratified Sample
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12
Head Start (Sib. 1)	0.90	1.56*	1.47	-0.33
	(0.55)	(0.79)	(0.92)	(1.05)
Head Start (Sib. 2)	0.57	0.61	1.52	1.09
	(0.48)	(0.78)	(0.92)	(1.06)
Head Start (Sib.1) = -Head Start (Sib. 2)	1.47**	2.18**	2.99**	0.76
	(0.53)	(0.75)	(0.97)	(1.08)
Δ Head Start (Restricted Model)	0.092	0.43	-0.092	-0.69
	(0.44)	(0.69)	(0.79)	(0.91)
Δ Head Start (Mother's FE)	0.11	0.34	-0.21	-0.70
	(0.44)	(0.68)	(0.77)	(0.90)
Preschool (Sib. 1)	0.28	0.095	-0.73	-0.24
	(0.46)	(0.70)	(0.90)	(0.94)
Preschool (Sib. 2)	-0.057	0.47	1.51	1.57
	(0.43)	(0.66)	(0.86)	(0.94)
Preschool (Sib.1) = -Preschool (Sib. 2)	0.22	0.56	0.78	1.33
	(0.49)	(0.73)	(0.92)	(0.97)
Δ Preschool (Restricted Model)	0.16	-0.17	-1.10	-0.90
	(0.38)	(0.58)	(0.75)	(0.81)
Δ Preschool (Mother's Fixed Effects)	0.075	-0.24	-1.32	-1.04
	(0.37)	(0.58)	(0.74)	(0.81)
Mean Dependent Variable	17.3	32.9	45.2	53.9
SD Dependent Variable	7.1	10.8	12.9	13.9
Observations	2286	2574	2615	2556

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include siblings' race/ethnicity (White, Black, Hispanic), dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 6. Estimates of the Effect of Head Start and Preschool on PIAT Reading Comprehension Score by Age for Stratified Sample
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12
Head Start (Sib. 1)	1.03	0.82	0.73	0.23
	(0.54)	(0.74)	(0.86)	(0.87)
Head Start (Sib. 2)	0.11	0.96	1.72*	2.09*
	(0.48)	(0.70)	(0.83)	(0.84)
Head Start (Sib.1) = -Head Start (Sib. 2)	1.14*	1.78*	2.45**	2.32**
	(0.51)	(0.79)	(0.85)	(0.80)
Δ Head Start (Restricted Model)	0.40	-0.12	-0.57	-0.95
	(0.44)	(0.60)	(0.73)	(0.73)
Δ Head Start (Mother's FE)	0.40	-0.10	-0.58	-0.78
	(0.43)	(0.59)	(0.72)	(0.73)
Preschool (Sib. 1)	0.12	-0.65	-0.74	0.12
	(0.44)	(0.67)	(0.85)	(0.76)
Preschool (Sib. 2)	-0.12	0.58	0.27	1.19
	(0.42)	(0.63)	(0.79)	(0.77)
Preschool (Sib.1) = -Preschool (Sib. 2)	-0.003	-0.068	-0.47	1.31
	(0.46)	(0.73)	(0.85)	(0.76)
Δ Preschool (Restricted Model)	0.12	-0.58	-0.48	-0.52
	(0.37)	(0.54)	(0.70)	(0.67)
Δ Preschool (Mother's Fixed Effects)	0.059	-0.52	-0.58	-0.45
	(0.36)	(0.54)	(0.69)	(0.66)
Mean Dependent Variable	16.7	30.5	40.7	47.6
SD Dependent Variable	6.4	10.0	11.1	11.7
Observations	2140	2404	2574	2523

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include siblings' race/ethnicity (White, Black, Hispanic), dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 7. Estimates of the Effect of Head Start and Preschool on PIAT Math Score by Age and Race/Ethnicity
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	White				Black				Hispanic			
	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12
Head Start (Sib. 1)	-0.83	2.07	1.74	-1.10	1.37	1.28	1.74	-0.69	-1.07	0.11	0.02	-0.94
	(0.99)	(1.76)	(1.98)	(2.17)	(0.93)	(1.30)	(1.22)	(1.19)	(0.99)	(1.73)	(1.81)	(1.76)
Head Start (Sib. 2)	1.42	0.08	2.04	-1.02	-0.61	-0.11	-0.95	0.20	0.33	1.66	1.23	4.51*
	(1.08)	(1.59)	(1.79)	(2.03)	(0.75)	(1.25)	(1.19)	(1.11)	(0.81)	(1.96)	(1.90)	(1.95)
Head Start (1) = -Head Start (Sib. 2)	0.59	2.15	3.78*	-2.12	0.76	1.17	0.80	-0.49	-0.74	1.77	1.25	3.57
	(0.89)	(1.56)	(1.65)	(1.82)	(0.79)	(1.28)	(1.30)	(1.17)	(0.98)	(2.06)	(2.00)	(1.91)
Δ Head Start (Restricted Model)	-1.22	0.88	-0.34	0.11	0.97	0.72	1.35	-0.45	-0.61	-0.88	-0.68	-2.93
	(0.93)	(1.49)	(1.67)	(1.88)	(0.74)	(1.11)	(1.01)	(0.99)	(0.74)	(1.57)	(1.57)	(1.64)
Δ Head Start (Mother's FE)	-1.30	1.06	-0.47	0.02	1.06	1.09	1.73	-0.48	-0.62	-0.59	-0.56	-1.95
	(0.92)	(1.53)	(1.60)	(1.72)	(0.71)	(1.08)	(1.00)	(1.02)	(0.68)	(1.64)	(1.52)	(1.64)
Preschool (Sib. 1)	-0.96	-1.01	-0.27	-0.25	0.38	1.44	0.78	-0.59	-0.41	-3.00	-1.98	-0.91
	(0.60)	(0.84)	(0.97)	(0.92)	(0.73)	(1.34)	(1.43)	(1.46)	(0.75)	(1.56)	(2.01)	(1.75)
Preschool (Sib. 2)	0.24	0.97	1.70	1.17	-1.15	1.00	0.19	-0.28	0.51	0.76	1.63	2.30
	(0.66)	(0.87)	(0.97)	(0.98)	(0.73)	(1.40)	(1.36)	(1.33)	(0.79)	(1.39)	(1.71)	(1.65)
Preschool (1) = -Preschool (Sib. 2)	-0.72	-0.04	1.43	0.92	-0.77	2.44	0.96	-0.87	0.10	-2.23	-0.35	1.38
	(0.63)	(0.85)	(0.95)	(0.91)	(0.92)	(1.48)	(1.77)	(1.45)	(0.87)	(1.65)	(1.84)	(1.77)
Δ Preschool (Restricted Model)	-0.62	-0.97	-0.97	-0.74	0.77	0.27	0.29	-0.17	-0.43	-1.68	-1.79	-1.54
	(0.55)	(0.74)	(0.85)	(0.84)	(0.58)	(1.16)	(1.08)	(1.19)	(0.64)	(1.20)	(1.61)	(1.47)
Δ Preschool (Mother's Fixed Effects)	-0.78	-0.79	-0.67	-1.11	0.86	0.79	0.39	-0.78	-0.46	-1.36	-1.82	-1.48
	(0.51)	(0.74)	(0.81)	(0.85)	(0.54)	(1.01)	(1.03)	(1.13)	(0.64)	(1.20)	(1.56)	(1.46)
Mean Dependent Variable	17.5	33.5	47.0	55.0	14.2	26.2	39.5	46.3	14.1	28.0	41.4	48.1
SD Dependent Variable	7.1	10.3	10.0	10.2	6.3	10.1	10.6	9.6	5.7	10.6	10.9	11.2
Observations	1106	1179	1160	1143	721	792	885	847	544	605	578	573

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 8. Estimates of the Effect of Head Start and Preschool on PIAT Reading Recognition Score by Age and Race/Ethnicity
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	White				Black				Hispanic			
	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12
Head Start (Sib. 1)	1.77	2.06	-0.45	1.11	1.84*	1.41	2.34	-1.97	-1.56	2.01	2.97	1.26
	(1.13)	(1.55)	(1.82)	(2.19)	(0.81)	(1.10)	(1.31)	(1.51)	(1.10)	(1.86)	(2.12)	(2.05)
Head Start (Sib. 2)	1.54	-0.59	1.37	-0.46	-0.07	1.11	0.06	0.66	1.13	0.45	4.10*	2.92
	(1.09)	(1.41)	(1.73)	(2.18)	(0.75)	(1.06)	(1.35)	(1.55)	(0.87)	(1.85)	(1.96)	(2.17)
Head Start (1) = -Head Start (Sib. 2)	3.31**	1.47	0.92	0.65	1.77*	2.52*	2.41	-1.31	-0.43	2.46	7.08**	4.18
	(1.15)	(1.63)	(1.95)	(2.22)	(0.84)	(1.18)	(1.39)	(1.56)	(1.11)	(1.72)	(2.11)	(2.28)
Δ Head Start (Restricted Model)	-0.17	1.24	-0.99	0.75	0.94	0.19	1.16	-1.31	-1.30	0.65	-1.05	-0.96
	(0.95)	(1.23)	(1.48)	(1.89)	(0.67)	(0.90)	(1.14)	(1.34)	(0.80)	(1.68)	(1.75)	(1.81)
Δ Head Start (Mother's FE)	-0.33	1.28	-1.97	0.19	0.96	0.02	1.57	-1.50	-0.81	0.58	-1.68	0.38
	(0.93)	(1.22)	(1.41)	(1.80)	(0.66)	(0.82)	(1.07)	(1.32)	(0.73)	(1.67)	(1.64)	(1.89)
Preschool (Sib. 1)	-0.21	-0.11	-1.90	-1.97	1.16	1.27	1.09	0.62	0.29	-1.87	0.03	3.55
	(0.76)	(0.93)	(1.24)	(1.25)	(0.78)	(1.34)	(1.40)	(1.82)	(0.83)	(1.71)	(2.38)	(2.21)
Preschool (Sib. 2)	0.31	0.31	1.78	1.86	0.48	1.95	1.64	3.03	-0.54	-0.37	1.57	-0.72
	(0.62)	(0.93)	(1.27)	(1.22)	(0.96)	(1.24)	(1.56)	(1.77)	(0.78)	(1.65)	(2.03)	(2.22)
Preschool (1) = -Preschool (Sib. 2)	0.09	0.21	-0.12	-0.11	1.64	3.22*	2.73	3.65	-0.25	-2.24	1.60	2.83
	(0.71)	(0.97)	(1.20)	(1.25)	(1.08)	(1.52)	(1.84)	(2.13)	(0.88)	(1.80)	(2.25)	(2.37)
Δ Preschool (Restricted Model)	-0.29	-0.20	-1.84	-1.90	0.43	-0.28	-0.27	-1.29	0.41	-0.52	-0.78	2.25
	(0.60)	(0.79)	(1.10)	(1.06)	(0.68)	(1.06)	(1.17)	(1.47)	(0.68)	(1.43)	(1.91)	(1.88)
Δ Preschool (Mother's Fixed Effects)	-0.29	-0.25	-1.85	-2.12*	0.35	-0.24	-0.48	-1.74	0.24	-0.73	-1.44	2.10
	(0.57)	(0.78)	(1.06)	(1.07)	(0.61)	(0.98)	(1.12)	(1.46)	(0.68)	(1.48)	(1.92)	(1.83)
Mean Dependent Variable	18.3	35.5	48.7	58.1	16.9	30.2	41.5	49.1	16.0	31.2	43.8	52.5
SD Dependent Variable	7.3	10.6	12.3	12.9	6.8	10.1	12.2	13.4	7.0	11.0	13.4	14.3
Observations	1066	1180	1149	1143	694	796	885	848	526	598	581	565

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 9. Estimates of the Effect of Head Start and Preschool on PIAT Reading Comprehension Score by Age and Race/Ethnicity
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	White				Black				Hispanic			
	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12
Head Start (Sib. 1)	1.80	2.00	-1.36	1.56	2.13*	-0.03	1.68	-0.29	-1.86*	0.35	2.59	1.04
	(1.01)	(1.44)	(1.76)	(1.84)	(0.91)	(1.12)	(1.25)	(1.28)	(0.81)	(1.59)	(1.86)	(1.76)
Head Start (Sib. 2)	0.83	0.11	2.45	1.20	-0.37	0.83	0.35	2.23	0.77	1.12	3.96*	2.11
	(0.91)	(1.32)	(1.50)	(1.86)	(0.77)	(1.04)	(1.24)	(1.29)	(0.83)	(1.60)	(1.83)	(1.66)
Head Start (1) = -Head Start (Sib. 2)	2.63*	2.10	1.10	2.76	1.76*	0.80	2.04	1.94	-1.08	1.47	6.55**	3.15
	(1.05)	(1.72)	(1.82)	(1.82)	(0.87)	(1.11)	(1.28)	(1.41)	(0.97)	(1.77)	(1.92)	(1.76)
Δ Head Start (Restricted Model)	0.23	0.86	-2.13	0.11	1.25	-0.44	0.67	-1.24	-1.19	-0.50	-1.07	-0.67
	(0.81)	(1.08)	(1.34)	(1.62)	(0.73)	(0.92)	(1.06)	(1.08)	(0.67)	(1.35)	(1.58)	(1.46)
Δ Head Start (Mother's FE)	0.19	1.07	-2.42	-0.12	1.30	-0.42	0.85	-1.15	-0.97	-0.44	-1.59	-0.11
	(0.79)	(1.08)	(1.32)	(1.56)	(0.69)	(0.84)	(1.05)	(1.04)	(0.63)	(1.37)	(1.45)	(1.53)
Preschool (Sib. 1)	-0.56	-1.17	-1.31	-1.32	0.75	-0.44	0.85	0.23	0.86	-1.52	-1.39	3.15*
	(0.69)	(0.91)	(1.25)	(1.08)	(0.81)	(1.30)	(1.21)	(1.51)	(0.87)	(1.53)	(2.17)	(1.53)
Preschool (Sib. 2)	0.26	1.39	-0.23	1.64	0.62	0.01	-0.003	2.49	-1.18	-0.22	2.94	-1.43
	(0.62)	(0.90)	(1.17)	(1.05)	(0.96)	(1.22)	(1.39)	(1.58)	(0.76)	(1.28)	(1.69)	(1.67)
Preschool (1) = -Preschool (Sib. 2)	-0.31	0.22	-1.54	0.32	1.37	-0.43	0.84	2.73	-0.32	-1.74	1.55	1.72
	(0.65)	(1.04)	(1.19)	(1.10)	(1.12)	(1.41)	(1.67)	(1.61)	(0.86)	(1.59)	(1.85)	(1.75)
Δ Preschool (Restricted Model)	-0.45	-1.27	-0.54	-1.46	0.17	-0.22	0.43	-1.06	1.03	-0.50	-2.14	2.35
	(0.58)	(0.74)	(1.06)	(0.91)	(0.68)	(1.05)	(1.00)	(1.33)	(0.71)	(1.16)	(1.70)	(1.34)
Δ Preschool (Mother's Fixed Effects)	-0.49	-1.31	-0.58	-1.65	0.11	0.03	0.42	-1.00	0.67	-0.73	-2.30	2.24
	(0.55)	(0.73)	(1.01)	(0.92)	(0.60)	(0.99)	(0.96)	(1.24)	(0.70)	(1.14)	(1.79)	(1.32)
Mean Dependent Variable	17.4	33.1	44.1	51.9	16.5	28.1	37.3	43.0	15.4	28.6	39.3	46.1
SD Dependent Variable	6.4	10.1	10.7	11.1	6.5	9.1	10.2	10.9	6.3	9.7	11.2	11.1
Observations	982	1114	1143	1131	651	743	863	836	507	547	568	556

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 10. Estimates of the Effect of Head Start and Preschool on PIAT Math Score by Age and Maternal AFQT for Stratified Samples
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Ages 5-6		Ages 7-8		Ages 9-10		Ages 11-12	
	Low AFQT	High AFQT	Low AFQT	High AFQT	Low AFQT	High AFQT	Low AFQT	High AFQT
Head Start (Sib. 1)	0.25	-0.42	0.81	0.65	1.47	1.35	-0.42	-1.72
	(0.69)	(0.89)	(1.05)	(1.57)	(1.07)	(1.63)	(1.05)	(1.88)
Head Start (Sib. 2)	0.075	0.025	0.12	0.65	0.20	0.069	1.11	2.24
	(0.53)	(1.02)	(1.13)	(1.47)	(1.08)	(1.56)	(1.07)	(1.59)
Head Start (Sib.1) = -Head Start (Sib. 2)	0.33	-0.39	0.93	1.30	1.67	1.42	0.69	0.52
	(0.60)	(1.00)	(1.08)	(1.52)	(1.13)	(1.56)	(0.97)	(1.69)
Δ Head Start (Restricted Model)	0.061	-0.23	0.32	-0.030	0.63	0.60	-0.74	-2.00
	(0.53)	(0.83)	(0.96)	(1.32)	(0.91)	(1.39)	(0.95)	(1.52)
Δ Head Start (Mother's FE)	0.13	-0.26	0.50	0.060	0.70	0.61	-0.56	-1.65
	(0.51)	(0.78)	(0.94)	(1.27)	(0.91)	(1.29)	(0.94)	(1.49)
Preschool (Sib. 1)	0.21	-1.15*	-0.57	-0.10	0.29	-0.42	0.26	-1.13
	(0.56)	(0.55)	(1.03)	(0.85)	(1.13)	(1.06)	(1.06)	(0.97)
Preschool (Sib. 2)	-0.73	0.14	0.31	0.50	0.64	1.42	1.36	1.44
	(0.54)	(0.58)	(0.96)	(0.86)	(1.07)	(0.98)	(1.04)	(0.98)
Preschool (Sib.1) = -Preschool (Sib. 2)	-0.52	-1.01	-0.26	0.40	0.92	1.00	1.61	0.31
	(0.63)	(0.61)	(1.20)	(0.87)	(1.24)	(0.92)	(1.08)	(0.91)
Δ Preschool (Restricted Model)	0.45	-0.64	-0.42	-0.28	-0.17	-0.90	-0.56	-1.28
	(0.45)	(0.48)	(0.79)	(0.73)	(0.91)	(0.91)	(0.91)	(0.86)
Δ Preschool (Mother's Fixed Effects)	0.33	-0.71	-0.61	-0.10	-0.022	-0.89	-0.73	-1.38
	(0.44)	(0.47)	(0.75)	(0.73)	(0.89)	(0.87)	(0.88)	(0.86)
Mean Dependent Variable	13.7	17.5	26.3	33.7	39.2	47.6	46.3	55.1
SD Dependent Variable	5.6	7.2	10.1	10.2	10.5	9.7	10.0	10.2
Observations	1124	1247	1288	1288	1361	1262	1322	1241

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include siblings' race/ethnicity (White, Black, Hispanic), dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 11. Estimates of the Effect of Head Start and Preschool on PIAT Reading Recognition Score by Age and Maternal AFQT for Stratified Samples
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Ages 5-6		Ages 7-8		Ages 9-10		Ages 11-12	
	Low AFQT	High AFQT	Low AFQT	High AFQT	Low AFQT	High AFQT	Low AFQT	High AFQT
Head Start (Sib. 1)	1.15	0.42	2.75^{**}	-1.19	2.31^{*}	-0.84	0.032	-0.94
	(0.70)	(0.93)	(0.97)	(1.29)	(1.16)	(1.64)	(1.31)	(1.84)
Head Start (Sib. 2)	-0.030	1.68	0.16	0.10	1.48	2.19	0.88	2.03
	(0.58)	(0.87)	(0.96)	(1.39)	(1.10)	(1.63)	(1.29)	(1.83)
Head Start (Sib.1) = -Head Start (Sib. 2)	1.12	2.10^{*}	2.90^{**}	-1.09	3.79^{**}	1.35	0.91	1.09
	(0.67)	(0.87)	(0.91)	(1.45)	(1.15)	(1.70)	(1.34)	(1.88)
Δ Head Start (Restricted Model)	0.53	-0.71	1.25	-0.62	0.39	-1.55	-0.34	-1.53
	(0.54)	(0.78)	(0.85)	(1.13)	(0.97)	(1.40)	(1.11)	(1.58)
Δ Head Start (Mother's FE)	0.61	-0.80	1.07	-0.94	0.28	-1.72	0.031	-1.56
	(0.54)	(0.72)	(0.85)	(1.08)	(0.95)	(1.27)	(1.08)	(1.62)
Preschool (Sib. 1)	0.73	-0.049	0.48	-0.49	0.19	-1.37	2.76	-2.67^{*}
	(0.57)	(0.68)	(1.16)	(0.87)	(1.30)	(1.23)	(1.44)	(1.17)
Preschool (Sib. 2)	-0.85	0.71	-0.085	1.07	1.23	2.11	1.39	2.76^{*}
	(0.68)	(0.57)	(1.00)	(0.89)	(1.19)	(1.24)	(1.39)	(1.25)
Preschool (Sib.1) = -Preschool (Sib. 2)	-0.12	0.66	0.39	0.59	1.42	0.74	4.14^{*}	0.10
	(0.68)	(0.70)	(1.20)	(0.96)	(1.45)	(1.22)	(1.61)	(1.16)
Δ Preschool (Restricted Model)	0.76	-0.37	0.31	-0.79	-0.50	-1.72	0.63	-2.72^{*}
	(0.52)	(0.52)	(0.90)	(0.73)	(1.02)	(1.07)	(1.17)	(1.06)
Δ Preschool (Mother's Fixed Effects)	0.66	-0.44	0.18	-0.92	-0.75	-1.80	0.67	-2.79^{**}
	(0.50)	(0.48)	(0.90)	(0.72)	(1.01)	(1.03)	(1.14)	(1.08)
Mean Dependent Variable	15.7	18.8	29.5	36.2	40.8	50.0	48.9	59.1
SD Dependent Variable	6.5	7.4	9.9	10.7	12.2	12.0	13.7	12.2
Observations	1082	1204	1281	1293	1355	1260	1315	1241

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include siblings' race/ethnicity (White, Black, Hispanic), dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 12. Estimates of the Effect of Head Start and Preschool on PIAT Reading Comprehension Score by Age and Maternal AFQT for Stratified Samples
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Ages 5-6		Ages 7-8		Ages 9-10		Ages 11-12	
	Low AFQT	High AFQT	Low AFQT	High AFQT	Low AFQT	High AFQT	Low AFQT	High AFQT
Head Start (Sib. 1)	1.31*	0.69	1.39	0.44	1.80	-1.73	1.48	-2.08
	(0.66)	(0.88)	(0.89)	(1.42)	(1.04)	(1.68)	(1.07)	(1.64)
Head Start (Sib. 2)	-0.12	0.055	0.72	0.40	2.14*	1.93	2.02	2.85
	(0.55)	(0.90)	(0.87)	(1.30)	(1.03)	(1.54)	(1.06)	(1.54)
Head Start (Sib.1) = -Head Start (Sib. 2)	1.19	0.75	2.11*	0.84	3.94**	0.21	3.50**	0.776
	(0.64)	(0.94)	(0.88)	(1.80)	(1.05)	(1.58)	(1.09)	(1.51)
Δ Head Start (Restricted Model)	0.66	0.28	0.30	0.00018	-0.18	-1.88	-0.25	-2.50
	(0.52)	(0.76)	(0.76)	(1.02)	(0.89)	(1.40)	(0.91)	(1.40)
Δ Head Start (Mother's FE)	0.72	0.0092	0.30	-0.27	-0.042	-2.01	-0.12	-2.26
	(0.52)	(0.73)	(0.73)	(1.00)	(0.87)	(1.31)	(0.88)	(1.41)
Preschool (Sib. 1)	0.89	-0.60	0.47	-1.36	-0.0075	-1.18	1.88	-1.47
	(0.62)	(0.64)	(1.09)	(0.85)	(1.10)	(1.25)	(1.14)	(1.00)
Preschool (Sib. 2)	-0.79	0.41	-0.081	1.56	1.32	-0.15	1.70	1.08
	(0.63)	(0.57)	(0.91)	(0.90)	(1.02)	(1.20)	(1.17)	(1.01)
Preschool (Sib.1) = -Preschool (Sib. 2)	0.10	-0.19	0.39	0.20	1.31	-1.33	3.59**	-0.39
	(0.68)	(0.65)	(1.14)	(0.98)	(1.30)	(1.10)	(1.26)	(0.98)
Δ Preschool (Restricted Model)	0.82	-0.50	0.29	-1.45*	-0.62	-0.52	0.13	-1.28
	(0.52)	(0.51)	(0.82)	(0.72)	(0.84)	(1.09)	(0.98)	(0.88)
Δ Preschool (Mother's Fixed Effects)	0.77	-0.57	0.23	-1.42*	-0.60	-0.67	0.19	-1.30
	(0.48)	(0.50)	(0.79)	(0.71)	(0.84)	(1.07)	(0.95)	(0.87)
Mean Dependent Variable	15.2	18.0	27.3	33.7	36.7	45.1	42.8	52.7
SD Dependent Variable	6.0	6.5	8.9	10.0	10.2	10.3	10.8	10.4
Observations	1027	1113	1176	1228	1329	1245	1297	1226

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test (never married, married, separated/divorced, missing), maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include siblings' race/ethnicity (White, Black, Hispanic), dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 13. Estimates of the Effect of Head Start and Preschool on PIAT Scores by Baseline Age
Estimates from Within-Child Difference Model

	Age 7-5		Age 8-6		Age 9-7		Age 10-8		Age 11-9		Age 12-10	
	First-Difference	Value-Added	First-Difference	Value-Added	First-Difference	Value-Added	First-Difference	Value-Added	First-Difference	Value-Added	First-Difference	Value-Added
Panel A: PIAT Math												
Head Start	-0.81	-0.78	0.16	-0.076	-0.061	-0.28	0.21	-0.027	0.35	0.059	-0.091	0.055
	(0.45)	(0.45)	(0.50)	(0.49)	(0.46)	(0.43)	(0.47)	(0.42)	(0.45)	(0.41)	(0.47)	(0.43)
Preschool	-0.26	-0.17	-0.082	0.079	-0.0036	0.21	-0.60	-0.29	-0.17	0.22	0.45	0.55
	(0.37)	(0.37)	(0.39)	(0.37)	(0.38)	(0.36)	(0.38)	(0.34)	(0.37)	(0.33)	(0.41)	(0.38)
Mean Dependent Variable	27.2	27.2	35.3	35.3	42.0	42.0	46.3	46.3	50.1	50.1	52.7	52.7
SD Dependent Variable	9.35	9.35	10.6	10.6	10.7	10.7	10.4	10.4	10.5	10.5	10.8	10.8
Observations	2652	2652	2722	2722	2784	2784	2744	2744	2794	2794	2449	2449
Panel B: PIAT Reading Recognition												
Head Start	-0.71	-0.71	-0.089	-0.20	-0.74	-0.75	-0.083	-0.18	-0.34	-0.45	0.30	0.23
	(0.43)	(0.43)	(0.49)	(0.49)	(0.42)	(0.41)	(0.42)	(0.42)	(0.42)	(0.42)	(0.47)	(0.46)
Preschool	-0.42	-0.35	0.76	0.77	-0.37	-0.25	-0.51	-0.46	-0.53	-0.31	0.10	0.24
	(0.37)	(0.37)	(0.41)	(0.40)	(0.37)	(0.37)	(0.35)	(0.35)	(0.37)	(0.36)	(0.41)	(0.40)
Mean Dependent Variable	30.1	30.1	38.0	38.0	43.8	43.8	49.0	49.0	53.2	53.2	57.2	57.2
SD Dependent Variable	9.56	9.56	11.0	11.0	12.1	12.1	13.0	13.0	13.2	13.2	13.9	13.9
Observations	2598	2598	2684	2684	2780	2780	2740	2740	2792	2792	2450	2450
Panel C: PIAT Reading Comprehension												
Head Start	-0.47	-0.48	0.12	0.020	-0.18	-0.33	-0.16	-0.35	-0.19	-0.38	0.23	0.11
	(0.40)	(0.40)	(0.50)	(0.50)	(0.49)	(0.48)	(0.49)	(0.46)	(0.48)	(0.45)	(0.54)	(0.48)
Preschool	-0.42	-0.26	0.82^{*}	0.82^{*}	0.031	0.34	-0.27	-0.026	-0.28	0.19	-0.44	-0.22
	(0.37)	(0.37)	(0.41)	(0.40)	(0.42)	(0.39)	(0.41)	(0.38)	(0.41)	(0.37)	(0.46)	(0.42)
Mean Dependent Variable	27.8	27.8	34.9	34.9	40.2	40.2	44.0	44.0	47.7	47.7	50.3	50.3
SD Dependent Variable	8.89	8.89	10.0	10.0	10.4	10.4	10.7	10.7	11.4	11.4	11.5	11.5
Observations	2450	2450	2484	2484	2626	2626	2648	2648	2741	2741	2408	2408

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each year: age in months, mother's marital status, maternal employment status, and dummies for average real family income until the time of the test (10,001-25,000, 25,001-50,000, >50,000, missing). Regressions also include child's sex, race/ethnicity, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), dummies for mother's education at baseline (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date), and a dummy for each year of baseline test. * $p < 0.05$, ** $p < 0.01$

Table 14. Estimates of the Effect of Head Start and Preschool on Total BPI Score by Age for Stratified Sample
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Ages 5-6	Ages 7-8	Ages 9-10	Ages 11-12
Head Start (Sib. 1)	1.11*	-0.18	0.34	0.40
	(0.56)	(0.58)	(0.53)	(0.53)
Head Start (Sib. 2)	0.38	-0.22	0.14	-0.30
	(0.53)	(0.56)	(0.52)	(0.53)
Head Start (Sib.1) = -Head Start (Sib. 2)	1.49**	-0.39	0.49	0.10
	(0.58)	(0.60)	(0.59)	(0.56)
Δ Head Start (Restricted Model)	0.30	0.028	0.10	0.33
	(0.46)	(0.48)	(0.44)	(0.45)
Δ Head Start (Mother's FE)	0.21	-0.037	0.032	0.35
	(0.45)	(0.47)	(0.43)	(0.46)
Head Start (Typical Family FE) (n=23473)	0.28	0.42	0.22	0.37
	(0.24)	(0.24)	(0.23)	(0.25)
Preschool (Sib. 1)	0.11	0.015	0.78	0.056
	(0.39)	(0.40)	(0.40)	(0.40)
Preschool (Sib. 2)	0.22	0.11	-0.25	-0.77*
	(0.38)	(0.42)	(0.38)	(0.38)
Preschool (Sib.1) = -Preschool (Sib. 2)	0.32	0.12	0.53	-0.71
	(0.43)	(0.47)	(0.44)	(0.44)
Δ Preschool (Restricted Model)	-0.060	-0.051	0.51	0.42
	(0.32)	(0.33)	(0.32)	(0.32)
Δ Preschool (Mother's Fixed Effects)	-0.041	-0.060	0.54	0.39
	(0.32)	(0.33)	(0.31)	(0.32)
Preschool (Typical Family FE) (n=23473)	0.39*	0.35	0.44*	0.34
	(0.18)	(0.19)	(0.18)	(0.19)
Mean Dependent Variable	8.4	9.1	8.7	8.3
SD Dependent Variable	6.0	6.5	6.4	6.4
Observations	2202	2329	2406	2364

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: age in months, age in months square, sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), mother's marital status at time of the test, maternal employment status, dummies for average real family income until the time of the test (0-10,000, 10,001-25,000, 25,001-50,000, >50,000, missing), and a dummy for each year of test. Regressions also include siblings' race/ethnicity, dummies for mother's education at time of sibling 1's test (high school dropout, high school diploma, some college, bachelor's degree, missing), dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 15. Descriptive Statistics Adult Sample
Sample Restricted to Children with a Sibling of the Same Age

	Head Start	Pre-school	Neither
Female	0.521	0.521	0.522
Black, Non-Hispanic	0.618*	0.259*	0.359
White, Non-Hispanic	0.148*	0.536*	0.369
Hispanic	0.235*	0.206*	0.272
Age	27.7	27.3*	27.8
Employed	0.651*	0.766*	0.704
Weekly Hours	39.8	40.7	40.4
Earnings	8,982*	12,823*	10,974
Never Married	0.683*	0.635	0.621
Married	0.201*	0.298	0.295
Separated/Divorced	0.117*	0.066*	0.084
High School Diploma	0.775*	0.881*	0.811
Some College	0.384*	0.666*	0.468
Bachelor's Degree	0.086*	0.328*	0.155
Mother's Education			
Less Than High School	0.235*	0.097*	0.174
High School	0.419*	0.368*	0.501
Some College	0.265*	0.306*	0.213
Bachelor's Degree	0.081*	0.229*	0.112
Mother's AFQT	20.9*	43.2*	28.9
Mother's Rosenberg	21.1	22.2*	21.0
Mother's Rotter	9.5*	8.6*	9.0
Mother Married 1st Birth	0.344*	0.699*	0.543
Number of Obs.	2033	2644	3050

* Indicates that the mean for adult who attended Head Start or other Preschool is statistically different from mean for adult who did not attend any preschool program at 0.05 level.

Table 16. Estimates of the Effect of Head Start and Preschool on Labor Market Outcomes, Marital Status, and Educational Attainment
Estimates from Mother Fixed Effects Models

	Employed	Weekly Hours	Earnings	Married	Separated/ Divorced	High School Graduation	At Least 1 Year of College	Bachelor's Degree
Head Start	-0.0037	-0.25	-439.7	-0.011	0.0085	0.034	0.0046	0.0072
	(0.021)	(0.68)	(513.7)	(0.020)	(0.015)	(0.020)	(0.024)	(0.016)
Preschool	-0.012	-0.86	-1114.6*	-0.031	0.00017	-0.0024	0.037	0.0035
	(0.017)	(0.53)	(483.9)	(0.019)	(0.012)	(0.016)	(0.021)	(0.016)
Mean Dependent Variable	0.73	41.0	12,247	0.30	0.098	0.85	0.56	0.21
SD Dependent Variable	0.44	12.6	11,766	0.46	0.30	0.36	0.50	0.41
Observations	18862	13739	17073	18873	18873	18447	18447	18447

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables: sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), age dummies, and a dummy for each year of outcome measurement.
* $p < 0.05$, ** $p < 0.01$

Table 17. Estimates of the Effect of Head Start and Preschool on Labor Market Outcomes, Marital Status, and Educational Attainment
Estimates from Unrestricted First Difference Model, Restricted First Difference Model and Mother's Fixed Effects Model

	Employed	Weekly Hours	Earnings	Married	Separated/ Divorced	High School Graduation	At Least 1 Year of College	Bachelor's Degree
Head Start (Sib. 1)	-0.016	0.48	316	0.055	-0.0062	0.029	-0.045	-0.025
	(0.041)	(1.18)	(820)	(0.031)	(0.023)	(0.040)	(0.037)	(0.024)
Head Start (Sib. 2)	-0.050	0.042	-1049	0.011	-0.037	-0.068	-0.0013	0.0041
	(0.040)	(1.16)	(809)	(0.030)	(0.022)	(0.036)	(0.037)	(0.023)
Head Start (1) = -Head Start (Sib. 2)	-0.066	0.53	-733	0.067*	-0.043	-0.039	-0.046	-0.021
	(0.034)	(1.17)	(822)	(0.033)	(0.024)	(0.035)	(0.037)	(0.027)
Δ Head Start (Restricted Model)	0.018	0.21	686	0.022	0.016	0.049	-0.021	-0.015
	(0.037)	(1.01)	(704)	(0.025)	(0.019)	(0.034)	(0.032)	(0.020)
Δ Head Start (Mother's FE)	0.015	-0.17	659	0.018	0.015	0.048	-0.018	-0.017
	(0.037)	(1.01)	(718)	(0.025)	(0.020)	(0.034)	(0.033)	(0.019)
Preschool (Sib. 1)	0.015	-1.77	-639	0.031	-0.0010	-0.0027	0.043	-0.012
	(0.033)	(1.04)	(743)	(0.031)	(0.019)	(0.028)	(0.035)	(0.026)
Preschool (Sib. 2)	-0.026	1.53	443	0.013	0.0055	0.025	0.0069	-0.018
	(0.032)	(0.95)	(791)	(0.029)	(0.018)	(0.029)	(0.034)	(0.024)
Preschool (.1) = -Preschool (Sib. 2)	-0.010	-0.24	-195	0.045	0.004	0.022	0.050	-0.030
	(0.031)	(1.09)	(854)	(0.033)	(0.022)	(0.029)	(0.035)	(0.029)
Δ Preschool (Restricted Model)	0.019	-1.62*	-556	0.0093	-0.0049	-0.016	0.014	0.0035
	(0.028)	(0.83)	(641)	(0.026)	(0.015)	(0.025)	(0.029)	(0.020)
Δ Preschool (Mother's FE)	0.014	-2.08*	-758	0.013	-0.0029	-0.017	0.013	0.0020
	(0.028)	(0.81)	(665)	(0.026)	(0.015)	(0.025)	(0.029)	(0.020)
Mean Dependent Variable	0.694	40.2	10,607	0.267	0.086	0.804	0.494	0.184
SD Dependent Variable	0.461	12.5	10,701	0.443	0.280	0.397	0.500	0.387
Observations	4980	2502	4024	4987	4987	4702	4702	4702

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), dummies for mother's education at time of interview (high school dropout, high school diploma, some college, bachelor's degree, missing), and a dummy for each year of outcome measurement. Regressions also include siblings' race/ethnicity, dummies for siblings' age in years, dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$

Table 18. Estimates of the Effect of Head Start and Preschool on Labor Market Outcomes, Marital Status, and Educational Attainment
Estimates from Within-Child First Difference Model

	Employed	Weekly Hours	Earnings	Married	Separated/ Divorced	High School Graduation	At Least 1 Year of College	Bachelor's Degree
Head Start	0.022*	0.19	-261	-0.0056	-0.0017	-0.0042	0.00069	-0.0096*
	(0.011)	(0.44)	(206)	(0.0084)	(0.0059)	(0.0047)	(0.0060)	(0.0038)
Preschool	-0.011	-0.088	67	0.016*	-0.0081	0.0046	0.0049	-0.0054
	(0.0095)	(0.37)	(218)	(0.0080)	(0.0054)	(0.0035)	(0.0056)	(0.0045)
Mean Dependent Variable	0.732	40.8	12,057	0.311	0.095	0.848	0.549	0.217
SD Dependent Variable	0.443	12.4	11,307	0.463	0.294	0.359	0.498	0.412
Observations	7951	4803	6684	7964	7964	7673	7673	7673

Notes: Standard errors in parentheses clustered at the mother level. All regressions include the following variables for each sibling: sex, dummies for birthweight (<90 oz, 90 to 104 oz, 105 to 129 oz, >=130 oz, missing), dummies for mother's age at child's birth (<=18, 19-23, 24-30, 31-35, >35), dummies for mother's education at time of interview (high school dropout, high school diploma, some college, bachelor's degree, missing), and a dummy for each year of outcome measurement. Regressions also include siblings' race/ethnicity, dummies for siblings' age in years, dummies for each Rosenberg self-esteem quartile, dummies for each AFQT quartile, dummies for each Rotter locus of control quartile, indicator for magazines, newspapers, library card in mother's house at age 14, and dummies mother's marriage date (not married, before first birth, within a year after first birth, missing date). * $p < 0.05$, ** $p < 0.01$