Do Preschool Investments Fadeout or Result in Dynamic Complementarities?

An Assessment Using the Head Start Impact Study

Robert Kaestner, Ph.D.; Cuiping Schiman, Ph.D.

August 05, 2022

Robert Kaestner, Ph.D.
The Harris School of Public Policy
University of Chicago
1307 E. 60th Street
Chicago, IL 60637
kaestner@uchicago.edu

Cuiping Schiman, Ph.D.
Department of Economics
Georgia Southern University
11935 Abercorn Street
Savannah, GA 31419
cschiman@georgiasouthern.edu

Acknowledgement: we thank the Inter-university Consortium for Political and Social Research (ICPSR) for providing access to the data.

Do Preschool Investments Fadeout or Result in Dynamic Complementarities?

An Assessment Using the Head Start Impact Study

Abstract: In this article, we take advantage of the experimental design of the Head Start Impact Study to assess the degree of depreciation of cognitive and behavioral skills and whether there are dynamic complementarities associated with preschool attendance. Evidence from our analyses suggests that investments in preschool depreciated significantly and that there were limited meaningful net social dynamic complementarities associated with preschool attendance one year after such investment. Furthermore, our findings suggest that only a small fraction of the accumulation of cognitive and behavioral skills from ages three to four and four to five can be explained by preschool attendance.

1. Introduction

Development of children's cognitive and behavioral skills—their human capital—is one of the most important processes that determine the future wellbeing of children and society. Investments in children that raise human capital have relatively high rates of return because the period of return on such investments is long (Becker 1964; Grossman 1972). However, human capital skills depreciate and high rates of depreciation may erode the benefits of investments in children (Todd and Wolpin 2007). Alternatively, investments in children's human capital may increase the productivity of later investments, which has been referred to as dynamic complementarity (Currie and Almond 2011; Almond, Currie, and Duque 2018; Doyle et al. 2009; Cunha and Heckman 2007; Johnson and Jackson 2019). If so, then investments in children's human capital may be particularly effective and have a high rate of return.

One of the most common, and arguably one of the most important, investments in children's human capital is childcare whether provided by parents or by childcare organizations. Indeed, most childcare today is non-parental. In 2019, 59% of children aged five or less and not in kindergarten are in some form of non-parental childcare and approximately 44% of all four-years old children were in publicly supported preschool programs (Friedman-Krauss et al. 2019). The relatively large share of children in center care is consistent with public support for non-parental childcare, which has been growing in recent years (Friedman-Krauss et al. 2019) and thought to be important to address socioeconomic disparities in child development (J. J. Heckman et al. 2010; Sawhill 1999; Cascio and Schanzenbach 2014; Duncan and Magnuson 2013; Magnuson and Duncan 2016; Taryn Morrissey 2020).

As noted, the benefits of non-parental childcare depend on whether these investments in children's cognitive and behavioral skills depreciate and/or affect the productivity of future investments. Studies of early child development interventions including Perry Preschool, Carolina Abecedarian Project, Head Start, and Tennessee STAR generally find that achievement gains from these interventions faded out shortly after the participants left the programs (J. Heckman, Pinto, and Savelyev 2013; Chetty et al. 2011; Deming 2009; Fitzpatrick 2008; U.S. Department of Health and Human Services, 2010a; J. Heckman, Pinto, and Savelyev 2013). These results suggest that depreciation is substantial. Other studies of early child education find little to no effect on cognitive achievement and negative effects on non-cognitive development (Baker, Gruber, and Milligan 2019; 2008; Kottelenberg and Lehrer 2013). Given the mixed evidence on the effect of early education on child development, questions remain as to how much and through what mechanisms early childhood interventions such as preschool attendance contribute to the production of cognitive and non-cognitive skills (Kottelenberg and Lehrer 2013; Baker, Gruber, and Milligan 2008; 2019; Lubotsky and Kaestner 2016; J. Heckman, Pinto, and Savelyev 2013; Fitzpatrick 2008; U.S. Department of Health and Human Services, 2010a; Duncan and Magnuson 2013).

In this article, we take advantage of the experimental design of the Head Start Impact Study to assess the degree of depreciation of cognitive and behavioral skills and whether there are dynamic complementarities associated with preschool attendance. The Head Start Impact Study randomized access to Head Start for one year in Fall 2002 among 4,442 newly entering eligible three-year-old children (three-year-old cohort) and four-year-old children (four-year-old cohort) and followed their progress into grade school (United States Department of Health and Human Services et al. 2018). Using the exogenous variation in preschool attendance caused by randomization, we assess the degree of depreciation of cognitive and non-cognitive skills as the children age from three to four years old and from four to five years old, and any gains in skills due to having attended preschool at an earlier age (i.e., dynamic complementarity).

The experimental design is important and allows us to obtain estimates of depreciation and the presence of dynamic complementarities that are plausibly interpreted as causal. While several previous

studies also relied on an experimental framework, they have not been able to separately identify depreciation and the presence of dynamic complementarities. For example, the HSIS obtained intention-to-treat (ITT) effects of randomization on cognitive and behavioral skills in several years after the intervention. Such estimates reflect the combined effect of depreciation and the presence of dynamic complementarities. A similar limitation characterizes other experimental studies (e.g., Perry Preschool).

Our findings indicate that preschool investments improved contemporaneous literacy and math skills for both cohorts of children and reduced behavioral problems for the three-year-old cohort during attendance, but that these improvements depreciated markedly within a year. For literacy, the depreciation rate centered around 50% for the three-year-old cohort and between 35% and 60% for the four-year-old cohort. For math, the depreciation rate is approximately 63% for the three- and four-year-old cohorts. For social and emotional development, depreciation is between 50% to 75% for both cohorts. For the three-year-old cohort, preschool attendance at age three generated no dynamic complementarity at age four for literacy skills, but a small dynamic complementarity in math skills (a gain of 0.13 standard deviation) and total problem behaviors (a reduction of 0.16 standard deviation). For the four-year-old cohort, we find evidence of significant negative dynamic complementarities.

These findings suggest that a small fraction of the accumulation of cognitive and behavioral skills from ages three to four and four to five can be explained by preschool. For example, the gain in PPVT score caused by preschool attendance at age three accounted for approximately 7.1% of the total gain in that score from age three to age four. For math, preschool attendance at age three contributed approximately 3.9% of the gain in that score from ages three to four. These findings suggest preschool attendance may have a limited role in addressing early childhood disadvantage. The development of human capital appears to be mainly a result of other investments than preschool and likely reflects self-learning and investments of parental time and resources.

2. Theory

2.a. Production of Child Cognitive Capital

The human capital production function can be used to explain variation in child cognitive ability. At a given age, a child's cognitive ability (i.e., stock of ability) reflects accumulated increases in ability that came from investments that enhance child cognitive ability (e.g. maternal time spent teaching a child) minus depreciation of the stock of ability that occurs over time. One description of the child cognitive ability production function at age t (measured at the end of the period) is as follows:

(1) $COG_ABILITY_t = COG_ABILITY_{t-1}(1-\delta_t) + \alpha I_t$

Equation (1) indicates that a child's cognitive ability at age t is equal to the depreciated level of ability from the previous age plus the increase in ability due to investment in the period. The quantity of investment is denoted by (I); the productivity of investment is indicated by (α); and depreciation is represented by (δ_t). Successively substituting for prior period ability leads to a production function of child cognitive ability at age t that depends on all prior investments, the initial level (endowment) of cognitive ability (C_0), and the rates of depreciation over time:

(2) $COG_ABILITY_t = C_0(1-\delta_0)\dots(1-\delta_t) + \alpha I_0(1-\delta_1)\dots(1-\delta_t) + \dots + \alpha I_{t-1}(1-\delta_t) + \alpha I_t$

In equations (1) and (2), we have shown only one type of investment denoted by (I) to keep the notation compact, but there are many activities and products that can enhance child cognitive ability and the productivity of each type of investment may differ. It is also possible that the productivity of an investment may be age specific, but we have not shown this possibility in equation (2). Shortly, we will allow the productivity of an investment to be age-specific by making the productivity depend on previous investments.

2.b. Preschool and Head Start are Investments in Child Cognitive Ability

Attending preschool is an investment (I) in child cognitive ability, although there are other benefits of attending preschool, such as developing socioemotional skills. If it is productive, the effect of attending any preschool (Head Start and other types) will be present at all ages post attendance. For example, the cognitive ability production functions of children ages three and four are:

$$(3)\quad COG_ABILITY_3 = C_0(1-\delta_0)\dots(1-\delta_3) + \alpha I_0(1-\delta_1)\dots(1-\delta_3) + \alpha I_1(1-\delta_2)(1-\delta_3) + aI_2(1-\delta_3) + \alpha I_3 + bANYPRE_3$$

$$COG_ABILITY_4 = C_0(1-\delta_0)\dots(1-\delta_4) + \alpha I_0(1-\delta_1)\dots(1-\delta_4) + \alpha I_1(1-\delta_2)\dots(1-\delta_4) + aI_2(1-\delta_3)(1-\delta_4) + \alpha I_3(1-\delta_4) + bANYPRE_3(1-\delta_4) + \alpha(ANYPRE_3)I_4 + b(ANYPRE_3)ANYPRE_4$$

Alternatively, cognitive ability at age four can be rewritten as:

$$COG_ABILITY_4 = COG_ABILITY_3(1-\delta_4) + \alpha(ANYPRE_3)I_4 + b(ANYPRE_3)ANYPRE_4$$

In (3), we make explicit that there is more than one type of investment by including both attendance at any preschool (*ANYPRE*), which in this example occurs at ages three and four, and other investment (*I*). We also allow the productivity of investments at age four to depend on prior investments, specifically, whether the child attended preschool from age three. More generally, the productivity of investment at age t can be made a function of the level of cognitive and other abilities at age t-1, which is consistent with Heckman and colleagues characterization that skills beget skills (Cunha and Heckman 2007).

2.c. Depreciation and Dynamic Complementarities

Fadeout is the term used to describe empirical finding that the effect of investments in children at a given age decline over time. For example, a notable finding of the HSIS was that initial improvement among the Head Start treatment group in socioemotional development, literacy, and math skills observed at the end of the first year of Head Start participation faded by first grade with little difference observed between the treatment and control groups at that age (U.S. Department of Health and Human Services, 2010b). Evidence from other early childhood programs shows similar fadeout (Bailey et al. 2017; Barnett 2011). Theoretically, fadeout can be explained by depreciation, as shown in equation (3). The effect of attending preschool at age three on cognitive ability at age three is equal to *b*. By age four, however, the effect of attending preschool at age three is equal to $b(1-\delta_4)$. If depreciation of cognitive ability is not zero, then the effect of attending any preschool at age three will be smaller at age four than at age three (i.e., fadeout).

Equation (3) also reflects the possibility of dynamic complementarities because it indicates that any preschool attendance at age three affects, presumably raises, the productivity of investments in cognitive development at age four. For example, as reported in the HSIS, Head Start attendance reduced behavioral problems and it is possible that children with more developed socioemotional behavior may learn more and get more out of any investment in cognitive development. The total effect of preschool attendance at age three on cognitive ability at age four is:

$$(4) \quad \frac{\partial COG_ABILITY_4}{\partial ANYPRE_3} = b(1-\delta_4) + \frac{\partial a}{\partial ANYPRE_3} I_4 + \frac{\partial b}{\partial ANYPRE_3} ANYPRE_4$$

As shown in equation (4), the total effect of any preschool attendance at age three on test scores at age 4 is the depreciated effect of preschool attendance at age three plus the effects of attending preschool at age three at older ages that works through raising the productivity of subsequent investments.

Fadeout can be defined by whether the return on preschool at age 3 (b) is greater or less than $b(1-\delta_4) + \frac{\partial a}{\partial ANYPRE_3} I_4 + \frac{\partial b}{\partial ANYPRE_3} ANYPRE_4$.

3. Using the HSIS to Assess Depreciation and Dynamic Complementarities

The HSIS was a RCT that randomized access to Head Start among eligible three- and four-year-old first-time applicants. The experiment occurred from Fall 2002 to Spring 2003 for both cohorts. In the second year, all of the three-year-old cohort (who were then four-years old) were free to choose any child care arrangement including Head Start, while all of the four-year-old cohort (then five years old) attended kindergarten (U.S. Department of Health and Human Services, 2010b). HSIS collected information on cognitive achievement and socioemotional indicators and followed the children until third grade.

Results from the HSIS suggested that the effects of Head Start were modest. After one-year, among the three-year-old cohort, those randomly given access to Head Start had better literacy and math skills and fewer problem behaviors than those not given access. Among the four-year-old cohort, the Head Start group had better literacy skills than the control group children. Beyond one-year, there were few meaningful differences between the treatment and control groups. The effect sizes after one-year

were on the order of 0.1 to 0.3 standard deviations (U.S. Department of Health and Human Services, 2010a). In related analyses, Kline and Walters (2016) and Feller et al. (2016) compared Head Start to home care instead of either center care (non-Head Start) or home care. Results from these analyses indicated that Head Start attendance increased test scores relative to home care by approximately 0.3 to 0.5 standard deviations.

The basic regression models estimated in the HSIS were of the following form:

(5) $TEST_t = \pi_{0t} + \pi_t TREAT_3 + u_t$

t=3, 4 and 5

In equation (5), *TREAT* is the randomization indicator at age three (for the three-year-old cohort) and $TEST_t$ is cognitive ability at age t. In a human capital production function, it is unclear what these regressions measure. At age three, the regression may provide an estimate of the intention-to-treat (ITT) effect for Head Start or center care v. home care—randomization unambiguously decreased home care (Schiman 2022). Beyond age three, the regressions provide estimates of the ITT effect of the policy—making a child eligible for Head Start at age three (or age four).

How do estimates from these regressions relate to the empirical finding of fadeout? On net, the randomization caused an increase in non-home care, which we refer to as any preschool. Depreciation is likely to be positive so we would expect fadeout of the effects of this increase in any preschool attendance. If any preschool attendance enhances cognitive ability (or other skills), then there may be dynamic complementarities that would offset depreciation. The fact that fadeout was observed suggests that dynamic complementarities, if present, were not sufficient to offset depreciation. However, none of these mechanisms were identified in the HSIS or related studies (e.g., Kline and Walters 2016; Feller et al. 2016).

It is worth clarifying the concept of dynamic complementarities. In a narrow sense, dynamic complementarities refer to a biological/physical process related to the productivity of investments. Specifically, the productivity of investments in cognitive skills depends on the initial level of cognitive and other skills—higher levels of skill increase productivity of current investments (Cunha and Heckman

2007). If attendance at preschool affects cognitive and other skills, then it may affect future productivity of investments in cognitive ability. However, there may be behavioral responses to the HSIS intervention by the family or others that affect the quantity or productivity of other investments that may have countervailing effects (Gonzalez 2020; Gelber and Isen 2013). For example, preschool teachers may respond to children with greater cognitive ability due to prior preschool attendance either by enhancing or diminishing their advantage. Similarly, families may alter investments (e.g., maternal labor supply) in response to the effect of past preschool attendance on cognitive ability.

In the remainder of the article, the use of the term dynamic complementarities refers to the net of these influences. We are unable to identify the narrow and conceptually precise type of dynamic complementarities that relate to the effect of the stock of skills on the productivity of investments. Still, from a social perspective, the net influence we describe is relevant for policy. Actions by families or others in response to the intervention will determine what may be referred to as the net social dynamic complementarity. It is this net influence that ultimately determines changes in cognitive ability from the investment.

3.a. Obtaining Estimates of Depreciation and Dynamic Complementarities in HSIS

Estimates of depreciation and the presence of dynamic complementarities can be obtained using the study design of the HSIS. For both cohorts, the intervention substantially increased preschool attendance and decreased home care for the treatment groups compared to the control groups in the experiment year. In the second year, the control group of the three-year-old cohort were also allowed to attend Head Start and, as a result, the control group children were almost equally likely as the treatment group children to attend any preschool in the second year (Kline and Walters 2016). The four-year-old cohort had similar experience except in the second year all children attended Kindergarten (U.S. Department of Health and Human Services, 2010a). The uptake and catch up in non-home care of the control group in the second year of the HSIS is what we refer to as “reverse” experiments. It is possible to exploit these “reverse” experiments to obtain estimates of depreciation and the presence of dynamic complementarities. Take the three-year-old cohort as an example. According to Equation (3), test scores

at age four are equal to the depreciated level of test scores at age three plus the effect of investments at age four:

(6) $$TEST_4 = TEST_3(1-\delta_4) + a(ANYPRE_3)I_4 + b(ANYPRE_3)ANYPRE_4 + v$$

In equation (6), the productivity of age four investments (*I* and *ANYPRE*) depends on whether a child attended any preschool at age three. This specification reflects the possibility of dynamic complementarities associated with prior preschool attendance. The coefficient on age three test score is an estimate of one minus depreciation. The difference in test scores at age four for those in the treated (T=1) and control (T=0) groups is:

(7) $$TEST_4(T=1) - TEST_4(T=0) =$$
$$(1-\delta_4)[TEST_3(T=1) - TEST_3(T=0)] + [a(ANYPRE_3)I_4(T=1) - aI_4(T=0)]$$
$$+[b(ANYPRE_3)ANYPRE_4(T=1) - bANYPRE_4(T=0)] + v$$

Equation (7) indicates that the difference in test scores at age four conditional on test scores at age three between treated and control groups is equal to the difference in productivity of age four investments between treated and control groups due to the treated group's greater preschool attendance at age three. There may also be a greater quantity of investment among the treated group than the control group if the productivity of investment is greater for the treated than control group. The higher productivity is likely to bring forth greater investment. This is just another mechanism stemming from the higher productivity, which is the essential feature of dynamic complementarities. Importantly, the difference in test scores conditional on prior test scores between the treated and control groups is plausibly only from the effects of the intervention because of the valid randomization. Other than the greater take-up of any preschool at age three, the treatment and control groups are similar.

If there are no dynamic complementarities of the type we have hypothesized, then the difference in age four test scores between the treated and control groups is:

(8) $$TEST_4(T=1) - TEST_4(T=0) =$$

$$(1-\delta_4)[TEST_3(T=1)-TEST_3(T=0)]+v$$

As shown in equation (8), absent dynamic complementarities and given that the treated and control groups were randomly selected, the difference in test scores at age four conditional on test scores at age three between the treated and control groups is zero.[1]

The upshot of this discussion is it is possible to obtain estimates of depreciation and the presence of dynamic complementarities by estimating a regression model of age four test scores on age three test scores and the randomization indicator:

(9) $$TEST_4 = TEST_3(1-\delta_4)+\gamma RANDOMIZATION_3+v$$

The coefficient on age three test scores provides an estimate of the amount of depreciation and the coefficient on the randomization indicator provides an estimate of the presence of net social dynamic complementarities. A similar approach can be used for the four-year-old cohort.

If there is no depreciation, then equation (9) is a standard difference-in-differences regression. The difference-in-differences approach can be shown graphically, as in Appendix Figure 1, and is useful to elucidate the nature of the "reverse" experiment. As shown in Appendix Figure 1, at the end of the first year of participation (age three), the test score of the treated group increases due to any preschool attendance, which is consistent with the empirical evidence from the HSIS. At the end of the second year, the test scores of both the treated and control groups increase due to any preschool attendance during the second period. It is important to recognize that the treated group's test score at age four reflects preschool attendance at both ages three and four —they receive two years of this type of investment. As drawn in Appendix Figure 1, the difference-in-differences is approximately zero, which assumes that the effect of preschool attendance at age three is approximately the same as it is at age four, and that there is zero depreciation and no dynamic complementarities. If there were dynamic complementarities, then the

[1] If there is persistence in preschool attendance, then equation (8) would be non-zero because the treated group would have greater preschool attendance at age four. Empirically, rates of any preschool attendance at age four are similar for the treated (92%) and control (87%) groups (see Table 3 of Kline and Walters 2016). For the four-year-old cohort, all children attend Kindergarten at age five, so there are no differences in attendance.

increase in test scores at age four would be larger for the treated than control group. If there was depreciation, which is assumed to be zero in Appendix Figure 1, then the test scores of both the treated and control groups would decline from age three to age four.

Because not everyone in the treated group attended preschool at age three (or age four for the four-year-old cohort), an instrumental variables approach can be used to obtain an estimate of the presence of dynamic complementarities for those who did attend preschool. Specifically, we can estimate the following:

$$(10)\quad TEST_4 = TEST_3(1-\delta_4) + \rho ANYPRE_3 + v$$

$$ANYPRE_3 = TEST_3(1-\delta_4) + \pi RANDOMIZATION_3 + u$$

Equation (10) provides the instrumental variables estimate of the presence of dynamic complementarities for those who attended preschool at age three. The randomization indicator is used to predict any preschool attendance at age three. The same approach applies to the four-year-old cohort.

3.b. Data

Data for all analyses come from the HSIS. Measures of cognitive abilities came from child assessments that were conducted at baseline (Fall 2002) and at the end of each school year (Spring 2003 and 2004). Following the HSIS analyses and using measures that were available through preschool and first grade, measures of cognitive abilities include the Peabody Picture Vocabulary Test, Woodcock-Johnson III Spelling, Woodcock-Johnson III Applied Problems, Woodcock-Johnson III Oral Comprehension, and Woodcock-Johnson III Letter-Word Identification. We use the W score for all Woodcock-Johnson tests because they are more suitable for measuring the progression of skills over time than the standard or percentile scores (Jaffe 2009). Following Kline and Walters (2016), we also create a summary measure for cognitive abilities using PPVT and Woodcock-Johnson III pre-academic W score.

Additionally, we explore the nature of any depreciation and dynamic complementarity in non-cognitive development. We examine several measures of social and emotional development including total problem behaviors, social competencies and social skills, and positive approaches to learning. All

three outcomes are measured as a score. Total problem behaviors is a composite score of aggressive behavior, hyperactive behavior, and withdrawn behavior. These data were drawn from the parental interviews (Fall 2002, Spring 2003 and 2004).

Information on the focal childcare settings came from parental interviews. Baseline covariates include indicator variables for child's sex, race, whether child lived with both biological parents, had limited English proficiency, had special needs, whether child's baseline preacademic skills was in the lowest quartile, whether child's mom is a recent immigrant, teen mom, mom's marital status and education, mom's race, household risk indicators, whether the child lives in urban areas, and primary care giver's age. Additional covariates include child's age (in weeks) at child assessment and weeks at assessment since September 01, 2002. The analysis sample is limited to observations with non-missing dependent variable and covariates. All analyses are done separately by birth cohort since the randomization occurred separately for each birth cohort.

4. **Results**

Appendix Table 1 provides descriptive statistics of the three-year-old and four-year-old cohorts by treatment status. As shown elsewhere (U.S. Department of Health and Human Services, 2010a; Schiman 2022; Kline and Walters 2016), estimates in Appendix Table 1 indicate the treatment and control group are balanced on covariates for each birth cohort. Several differences exist between the two birth cohorts including a 10 percentage points higher probability that the four-year-old cohort (30%) are more likely to be Hispanic and their mothers also had lower education attainment.

4.a. ITT and IV Estimates of Effect of Any Preschool on Child Assessments

We begin the presentation of results by discussing ITT estimates of the effect of randomization into being eligible for Head Start at age three (or age four) and IV estimates of the effect of attending any preschool at age three (or age four).[2] The regressions providing the ITT estimates are like those in the

[2] Note that IV estimates we present differ from Kline and Walters (2016) who estimated the effect of "ever" attending Head Start. It is unclear what this specification reflects because it constrains the effect of attending Head

HSIS. In order, we present the estimates for PPVT, WJIII Spelling, WJIII applied, WJIII oral comprehension, WJIII word, and the Kline-Walter summary Index. For each outcome, we report the ITT and IV estimates using data from the experiment year then from the following year. All regressions include center fixed effects because the randomization occurred within Head Start centers and the standard errors are clustered by center. All regressions also control for the baseline covariates shown in Appendix Table 1.

Table 1 presents the ITT and IV estimates for the three-year-old cohort. ITT estimates in Table 1 show with one exception (Oral Comprehension) that achievement scores at the end of one year (i.e., age three) of the treated group were higher than scores of the control group. Effect sizes are approximately 0.15 to 0.25 standard deviations. These estimates are like those reported in the HSIS. At age four, ITT estimates are about half the size of those at age three, which is consistent with claims of fadeout. IV estimates of the effect of any preschool attendance at age three in Table 1 are about twice as large (0.3 to 0.5 standard deviations) as the ITT estimates reflecting the fact that the treated group had any preschool attendance that was 50 percentage points greater than the control group.[3] At age three, the IV estimate reflects the productivity of any preschool attendance at age three and is consistent with a human capital production function approach. At age four, it is unclear what IV estimates measure (see equation 3). The estimates are some combination of the effect of attendance at age three and any correlated effects of that attendance, including the effect of attending any preschool at age four.

Table 2 presents ITT and IV estimates for the four-year-old cohort. At age four, ITT estimates suggest with one exception (Oral Comprehension) that achievement scores of the treated group are about 0.1 to 0.2 standard deviations higher than achievement scores of the control group. These ITT estimates of the intervention at age four are close in size to ITT estimates of the intervention at age three, which

Start at age three to be equal to the effect of attending Head Start at age four and to be equal to the effect of attending Head Start at both ages. It is clearly not consistent with a human capital production approach.

[3] The IV estimate of the effect of attending any preschool on the Kline-Walters index is 0.39, which is not too different from the average of the estimates of the effect of Head Start and the effect of other preschools reported in Kline and Walters (2016). As noted, the HSIS randomization unambiguously increased any preschool attendance and the IV estimate in Table 1 is the just identified estimate of the effect of attending any preschool.

suggests the productivity of any preschool attendance at age three and age four are similar, although estimates for the four-year-old cohort are somewhat smaller. At age five, ITT estimates are all negative and smaller in (absolute) magnitude than ITT estimates at age four. Here too, estimates are consistent with claims of fadeout of the effect of investments. IV estimates in Table 2 are about 2.2 times larger than ITT estimates, which is consistent with the fact that at age four, attendance at any preschool was 45 percentage points higher among the treated group than the control group. The IV estimate of any preschool attendance in the experiment year is an estimate of the productivity of any preschool attendance at that age in the human capital production function.

4.b. Estimates of Depreciation and the Presence of Dynamic Complementarities

The ITT estimates in Tables 1 and 2 are relevant for policy, but they do not provide direct evidence of depreciation or the presence of dynamic complementarities. Nor do they provide information about the productivity of attendance at any preschool in the human capital production function. IV estimates of the effect of any preschool attendance at age three for three-year cohort and at age four for the four-year cohort are estimates of the productivity of any preschool attendance and are relevant to the human capital production function.[4] However, neither the ITT or IV estimates provide evidence of depreciation or the presence of dynamic complementarities. Instead, we exploit the reverse experiments and estimate regressions given by equation (9) and (10). These analyses regress achievement at age t on lagged achievement and the randomization indicator for treatment status. The coefficient on lagged test scores provides an estimate of depreciation and the coefficient on the randomization indicator provides an estimate of the presence of dynamic complementarities.

Table 3 presents estimates of equations (9) and (10) for the three-year-old cohort (Panel A) and the four-year-old cohort (Panel B). For the three-year-old cohort (Panel A), depreciation is substantial. Estimates of the coefficient on lagged test scores suggest that depreciation is 40% to 60%--approximately

[4] Again, we note that this is a reduced form effect and not an uncontaminated estimate of the productivity of any preschool attendance because the intervention did not just alter preschool attendance. For example, Schiman (2022) shows that the intervention also increased maternal work effort.

half of the stock of cognitive ability is eroded within a year. These estimates of depreciation are similar to what others have found using non-experimental data (e.g., Todd and Wolpin 2007; Hanushek 2010). Such high rates of depreciation reduce the benefit of investments and reduce the incentive to make such investments. Given this amount of depreciation, fadeout of the effects of investment in cognitive ability is highly likely. To offset this depreciation, dynamic complementarities must be relatively large. However, estimates of the coefficient on the randomization indicator suggest that dynamic complementarities are not large, and in fact zero. Most of these estimates are small and not statistically significant. Only for the Woodcock-Johnson Applied Problems assessment is there evidence of positive and statistically significant dynamic complementarities. For this outcome, attendance at any preschool at age three is associated a roughly 0.13 standard deviation higher test score at age four holding constant the lagged test score. As noted, this is an estimate of the effect of dynamic complementarities broadly defined.

Panel B (Table 3) shows estimates for the four-year-old cohort. Again, we see rates of depreciation of between 40% to 60%, implying fadeout of investment effects in cognitive ability at this age is likely. For this age group, remarkably there seems to be negative and substantial dynamic complementarities. Estimates suggest that achievement test scores at age five are 0.15 to 0.3 standard deviations lower for those who attended any preschool at age four. The exact cause of these negative dynamic complementarities is not revealed by our analysis, but the lack of similar findings for the three-year-old cohort suggests that the negative effects may have to do with attendance in formal school—Kindergarten. Intuitively, we do not expect the biological process underlying dynamic complementarities to be negative, or to differ between ages three and four. Therefore, it is likely that the behavioral responses at age five (Kindergarten) are the cause.

4.c. Behavioral Development

A growing literature studies the role of non-cognitive skills on economic, social, and health outcomes (Almlund et al. 2011). Understanding the production of non-cognitive skills has implications for the use of investment to address economic, social, and health disadvantages (Almlund et al. 2011; Cunha, Heckman, and Schennach 2010; Attanasio et al. 2020). In addition to cognitive development,

Head Start and preschool are also intended to improve social and emotional development. To explore the impact of preschool on social and emotional development, we repeat the same analyses as above for social and emotional outcomes.

Table 4 presents the ITT estimates of randomization and IV estimates of any preschool attendance for these outcomes for the three-year-old cohort (Panel A) and the four-year-old cohort (Panel B). For the three-year-old cohort, the IV estimates suggest that attending any preschool at age three decreased the total problem behaviors score by 0.34 standard deviations at age three, but it did not have any significant impact on social competencies and social skills and positive approach to learning. For the four-year-old cohort, attending any preschool at age four had no effect on any of the three outcomes and the estimates are small.

Table 5 shows the estimates of depreciation and presence of dynamic complementarity for the three-year-old cohort (Panel A) and the four-year-old cohort (Panel B). For the three-year-old cohort, there is substantial depreciation in social and emotional skills from age three to age four – the depreciation rates are approximately 57% for total problem behavior and 68% for social competencies and social skills and positive approach to learning. There is some dynamic complementarity for reducing problem behaviors from attending any preschool at age three. Specifically, the total problem behaviors score reduced by 0.16 standard deviation due to any preschool attendance at age three. However, there is no dynamic complementarity for social competencies and social skills and positive approach to learning.

Panel B (Table 5) presents the estimates of depreciation and presence of dynamic complementarity for the four-year-old cohort. Like the three-year-old cohort, there is substantial depreciation in social and emotional skills from age four to age five –depreciation rates are approximately 53% for total problem behavior, 63% for social competencies, and 75% for social skills and positive approach to learning. Unlike the three-year-old cohort, attending preschool at age four for the four-year-old cohort increased problem behaviors in kindergarten (i.e., negative dynamic complementarity). Additionally, attending preschool at age four exhibited no dynamic complementarity in kindergarten for social competencies and social skills and positive approach to learning.

5. Discussion

Overall, evidence from our analyses strongly suggests that investments in preschool depreciate significantly within a year and that net social dynamic complementarities are inadequate to offset this depreciation from age three to age four and, remarkably, are negative from age four to age five. Between ages three and four for the three-year-old cohort, and as shown in Appendix Table 2, the PPVT and Woodcock-Johnson spelling scores grow by approximately 40 and 30 units from initial levels of about 258 and 340, respectively. Estimated rates of depreciation imply that the PPVT and Woodcock-Johnson spelling score would decline by approximately 129 and 170 units between ages three and four, respectively. Therefore, net investments added 169 and 200 points to the PPVT and Woodcock-Johnson spelling scores, respectively, between ages three and four. IV estimates in Table 1 suggest that attendance at any preschool at these ages contributed very little to this net investment; IV estimates indicate that attendance at preschool raised these test scores by 12 and 6 units, respectively. And the absence of any dynamic complementarities leaves the contribution of any preschool largely unchanged or even diminished.

The results from this analysis suggest that it is self-learning and family investments in cognitive ability that matters most to child cognitive development, and that interventions focused on preschool attendance to ameliorate family differences in cognitive achievement at this age will have limited impact. Effects of these investments are small and depreciate substantially. Similar findings and conclusions apply to behavioral outcomes. The analysis also indicated that there were limited meaningful net social dynamic complementarities associated with preschool attendance one year after such investment. Admittedly, our estimate of dynamic complementarities pertains to a broader set of processes than the narrow biological process described by Heckman and colleagues, and it is the broader processes that matter for policy because public policy has little to no ability to control responses to preschool investment.

References

Almlund, Mathilde, Angela Lee Duckworth, James J. Heckman, and Tim D. Kautz. 2011. "Personality Psychology and Economics." Working Paper. Working Paper Series. National Bureau of Economic Research. https://doi.org/10.3386/w16822.

Almond, Douglas, Janet Currie, and Valentina Duque. 2018. "Childhood Circumstances and Adult Outcomes: Act II." Journal of Economic Literature 56 (4): 1360–1446. https://doi.org/10.1257/jel.20171164.

Attanasio, Orazio, Richard Blundell, Gabriella Conti, and Giacomo Mason. 2020. "Inequality in Socio-Emotional Skills: A Cross-Cohort Comparison." Journal of Public Economics 191 (November): 104171. https://doi.org/10.1016/j.jpubeco.2020.104171.

Bailey, Drew, Greg J. Duncan, Candice L. Odgers, and Winnie Yu. 2017. "Persistence and Fadeout in the Impacts of Child and Adolescent Interventions." Journal of Research on Educational Effectiveness 10 (1): 7–39. https://doi.org/10.1080/19345747.2016.1232459.

Baker, Michael, Jonathan Gruber, and Kevin Milligan. 2008. "Universal Child Care, Maternal Labor Supply, and Family Well-Being." Journal of Political Economy 116 (4): 709–45. https://doi.org/10.1086/591908.

———. 2019. "The Long-Run Impacts of a Universal Child Care Program." American Economic Journal: Economic Policy 11 (3): 1–26. https://doi.org/10.1257/pol.20170603.

Barnett, W.S. 2011. "Effectiveness of Early Educational Intervention." Science 333 (6405): 975–78. https://doi.org/10.1126/science.120453.

Becker, Gary S. 1964. "Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education, First Edition." NBER. https://www.nber.org/books-and-chapters/human-capital-theoretical-and-empirical-analysis-special-reference-education-first-edition.

Cascio, Elizabeth U., and Diane Whitmore Schanzenbach. 2014. "Expanding Preschool Access for Disadvantaged Children." https://www.brookings.edu/research/expanding-preschool-access-for-disadvantaged-children/.

Chetty, Raj, John N. Friedman, Nathaniel Hilger, Emmanuel Saez, Diane Whitmore Schanzenbach, and Danny Yagan. 2011. "How Does Your Kindergarten Classroom Affect Your Earnings? Evidence from Project Star *." The Quarterly Journal of Economics 126 (4): 1593–1660. https://doi.org/10.1093/qje/qjr041.

Cunha, Flavio, and James Heckman. 2007. "The Technology of Skill Formation." American Economic Review 97 (2): 31–47. https://doi.org/10.1257/aer.97.2.31.

Cunha, Flavio, James J. Heckman, and Susanne M. Schennach. 2010. "Estimating the Technology of Cognitive and Noncognitive Skill Formation." Econometrica 78 (3): 883–931. https://doi.org/10.3982/ECTA6551.

Currie, Janet, and Douglas Almond. 2011. "Chapter 15 - Human Capital Development before Age Five**We Thank Maya Rossin and David Munroe for Excellent Research Assistance, Participants in the Berkeley Handbook of Labor Economics Conference in November 2009 for Helpful Comments, and Christine Pal and Hongyan Zhao for Proofreading the Equations." In Handbook of Labor Economics, edited by David Card and Orley Ashenfelter, 4:1315–1486. Elsevier. https://doi.org/10.1016/S0169-7218(11)02413-0.

Deming, David. 2009. "Early Childhood Intervention and Life-Cycle Skill Development: Evidence from Head Start." American Economic Journal: Applied Economics 1 (3): 111–34. https://doi.org/10.1257/app.1.3.111.

Doyle, Orla, Colm P. Harmon, James J. Heckman, and Richard E. Tremblay. 2009. "Investing in Early Human Development: Timing and Economic Efficiency." Economics & Human Biology 7 (1): 1–6. https://doi.org/10.1016/j.ehb.2009.01.002.

Duncan, Greg J., and Katherine Magnuson. 2013. "Investing in Preschool Programs." Journal of Economic Perspectives 27 (2): 109–32. https://doi.org/10.1257/jep.27.2.109.

Feller, Avi, Todd Grindal, Luke Miratrix, and Lindsay C. Page. 2016. “Compared to What? Variation in the Impacts of Early Childhood Education by Alternative Care Type.” The Annals of Applied Statistics 10 (3): 1245–85. https://doi.org/10.1214/16-AOAS910.

Fitzpatrick, Maria. 2008. “Starting School at Four: The Effect of Universal Pre-Kindergarten on Children’s Academic Achievement.” The B.E. Journal of Economic Analysis & Policy 8 (1): 1–40.

Friedman-Krauss, Allison H, W Steven Barnett, Karin A Garver, Katherine S Hodges, G G Weisenfeld, and Nicole DiCrecchio. 2019. “The State of Preschool 2018.” The National Institute for Early Education Research.

Gelber, Alexander, and Adam Isen. 2013. “Children’s Schooling and Parents’ Behavior: Evidence from the Head Start Impact Study.” Journal of Public Economics 101 (May): 25–38. https://doi.org/10.1016/j.jpubeco.2013.02.005.

Gonzalez, Kathryn E. 2020. “Within-Family Differences in Head Start Participation and Parent Investment.” Economics of Education Review 74 (February): 101950. https://doi.org/10.1016/j.econedurev.2019.101950.

Grossman, Michael. 1972. “On the Concept of Health Capital and the Demand for Health.” Journal of Political Economy 80 (2): 223–55.

Hanushek, Eric A. 2010. “The Economic Value of Higher Teacher Quality.” CALDER Working Paper No. 56, 50.

Heckman, James J., Seong Hyeok Moon, Rodrigo Pinto, Peter A. Savelyev, and Adam Yavitz. 2010. “The Rate of Return to the HighScope Perry Preschool Program.” Journal of Public Economics 94 (1): 114–28. https://doi.org/10.1016/j.jpubeco.2009.11.001.

Heckman, James, Rodrigo Pinto, and Peter Savelyev. 2013. “Understanding the Mechanisms through Which an Influential Early Childhood Program Boosted Adult Outcomes.” American Economic Review 103 (6): 2052–86. https://doi.org/10.1257/aer.103.6.2052.

Jaffe. 2009. “Development, Interpretation, and Application of the W Score and the Relative Proficiency Index (Woodcock-Johnson III Assessment Service Bulletin No. 11).” Rolling Meadows, IL: Riverside Publishing. https://www.hmhco.com/~/media/sites/home/hmh-assessments/clinical/woodcock-johnson/pdf/wjiii/wj3_asb_11.pdf?la=en.

Johnson, Rucker C., and C. Kirabo Jackson. 2019. “Reducing Inequality through Dynamic Complementarity: Evidence from Head Start and Public School Spending.” American Economic Journal: Economic Policy 11 (4): 310–49. https://doi.org/10.1257/pol.20180510.

Kline, Patrick, and Christopher R. Walters. 2016. “Evaluating Public Programs with Close Substitutes: The Case of Head Start*.” The Quarterly Journal of Economics 131 (4): 1795–1848. https://doi.org/10.1093/qje/qjw027.

Kottelenberg, Michael J., and Steven F. Lehrer. 2013. “New Evidence on the Impacts of Access to and Attending Universal Childcare in Canada.” Working Paper. Working Paper Series. National Bureau of Economic Research. https://doi.org/10.3386/w18785.

Lubotsky, Darren, and Robert Kaestner. 2016. “Do `Skills Beget Skills’? Evidence on the Effect of Kindergarten Entrance Age on the Evolution of Cognitive and Non-Cognitive Skill Gaps in Childhood.” Economics of Education Review 53 (August): 194–206. https://doi.org/10.1016/j.econedurev.2016.04.001.

Magnuson, Katherine, and Greg J. Duncan. 2016. “Can Early Childhood Interventions Decrease Inequality of Economic Opportunity?” The Russell Sage Foundation Journal of the Social Sciences : RSF 2 (2): 123–41. https://doi.org/10.7758/RSF.2016.2.2.05.

Sawhill, Isabel V. 1999. “Kids Need an Early Start: Universal Preschool Education May Be the Best Investment Americans Can Make in Our Children’s Education – and Our Nation’s Future.” https://www.brookings.edu/articles/kids-need-an-early-start-universal-preschool-education-may-be-the-best-investment-americans-can-make-in-our-childrens-education-and-our-nations-future/.

Schiman, Cuiping. 2022. “Experimental Evidence of the Effect of Head Start on Mothers’ Labor Supply and Human Capital Investments.” Review of Economics of the Household 20 (1): 199–241.

Taryn Morrissey. 2020. “Addressing the Need for Affordable, High-Quality Early Childhood Care and Education for All in the United States.” Equitable Growth (blog). 2020. http://www.equitablegrowth.org/addressing-the-need-for-affordable-high-quality-early-childhood-care-and-education-for-all-in-the-united-states/.

Todd, Petra E., and Kenneth I. Wolpin. 2007. “The Production of Cognitive Achievement in Children: Home, School, and Racial Test Score Gaps.” Journal of Human Capital 1 (1): 91–136. https://doi.org/10.1086/526401.

United States Department of Health and Human Services, Administration for Children and Families., Office of Planning, Research and Evaluation, Michael Puma, Stephen Bell, Ronna Cook, and Camilla A. Heid. 2018. “Head Start Impact Study (HSIS), 2002-2008 with Center Analysis File [United States]: Version 2.” ICPSR - Interuniversity Consortium for Political and Social Research. https://doi.org/10.3886/ICPSR36968.V2.

U.S. Department of Health and Human Services,. 2010a. “Head Start Impact Study: Final Report.” 2010. https://www.acf.hhs.gov/opre/report/head-start-impact-study-final-report.

———. 2010b. “Head Start Impact Study: Final Report, Executive Summary.” 2010. https://www.acf.hhs.gov/opre/report/head-start-impact-study-final-report-executive-summary.

Table 1. ITT Estimates of Randomization and IV Estimates of Any Preschool Attendance on Child Outcomes Three-year-old Cohort

	Age Three		Age Four	
PPVT	ITT	IV	ITT	IV
Randomized to Treatment	6.44**		3.36**	
	(1.44)		(1.66)	
Any Preschool at Age Three		12.47**		6.26**
		(2.77)		(2.91)
Number of Observations	1777	1693	1727	1624
Control Standard Deviation	38	38	42	42
Woodcock-Johnson Spelling				
Randomized to Treatment	2.93**		1.39	
	(1.05)		(1.20)	
Any Preschool at Age Three		5.72**		3.08
		(1.93)		(2.20)
Number of Observations	1784	1700	1730	1627
Control Standard Deviation	22.6	22.6	26.3	26.2
Woodcock-Johnson Applied				
Randomized to Treatment	5.12**		3.64**	
	(1.39)		(1.11)	
Any Preschool at Age Three		10.20**		6.85**
		(2.42)		(2.00)
Number of Observations	1765	1684	1717	1615
Control Standard Deviation	30	30	25	25
Woodcock-Johnson Oral Comp.				
Randomized to Treatment	0.02		1.19*	
	(0.60)		(0.68)	
Any Preschool at Age Three		0.16		2.11*
		(1.16)		(1.22)
Number of Observations	1751	1664	1724	1624
Control Standard Deviation	14.5	14.5	16.3	16.4
Woodcock-Johnson Word				
Randomized to Treatment	6.47**		4.03**	
	(1.48)		(1.38)	
Any Preschool at Age Three		12.60**		6.94**
		(2.60)		(2.48)
Number of Observations	1783	1699	1729	1626
Control Standard Deviation	24.0	24.0	29.4	29.4
Kline Walters Index				
Randomized to Treatment	0.20**		0.10**	
	(0.04)		(0.04)	
Any Preschool at Age Three		0.39**		0.19**
		(0.07)		(0.06)
Number of Observations	1748	1666	1714	1612
Control Standard Deviation	0.88	0.88	0.90	0.90

Notes: Sample limited to observations with non-missing dependent variable and covariates. Baseline covariates include indicator variables for whether child is female, child's race, child lived with both biological parents, had limited English proficiency, had special needs, and whether child's baseline preacademic skills was in the lowest quartile, primary care giver age, indicator variables for whether mom is a recent immigrant, mother's race, teen mom, marital status, education, household risk indicators, and urban. All regressions also include child age (in weeks), weeks at assessment since September 01, 2002, and center fixed effects. Standard errors are clustered by center. * $p < 0.10$; ** $p < 0.05$

Table 2. ITT Estimates of Randomization and IV Estimates of Any Preschool Attendance on Child Outcomes Four-year-old Cohort

	Age Four		Age Five	
PPVT	ITT	IV	ITT	IV
Randomized to Treatment	4.22**		-0.28	
	(1.65)		(1.78)	
Any Preschool at Age Four		9.29**		-2.09
		(3.62)		(3.70)
Number of Observations	1448	1368	1346	1253
Control Standard Deviation	40	40	43	43
Woodcock-Johnson Spelling				
Randomized to Treatment	2.67**		-1.50	
	(1.28)		(1.46)	
Any Preschool at Age Four		5.48**		-3.46
		(2.74)		(3.01)
Number of Observations	1452	1372	1346	1253
Control Standard Deviation	25	25	28	28
Woodcock-Johnson Applied				
Randomized to Treatment	2.23*		-0.58	
	(1.23)		(1.28)	
Any Preschool at Age Four		4.31*		-1.43
		(2.61)		(2.62)
Number of Observations	1442	1361	1344	1251
Control Standard Deviation	28	28	21	21
Woodcock-Johnson Oral Comp.				
Randomized to Treatment	-0.70		-1.36*	
	(0.75)		(0.81)	
Any Preschool at Age Four		-1.52		-3.05*
		(1.61)		(1.68)
Number of Observations	1425	1346	1344	1251
Control Standard Deviation	18	18	19	19
Woodcock-Johnson Word				
Randomized to Treatment	5.13**		-1.61	
	(1.43)		(1.77)	
Any Preschool at Age Four		11.28**		-4.09
		(2.99)		(3.69)
Number of Observations	1450	1370	1345	1252
Control Standard Deviation	27	27	35	35
Kline Walters Index				
Randomized to Treatment	0.12**		-0.03	
	(0.04)		(0.04)	
Any Preschool at Age Four		0.26**		-0.09
		(0.08)		(0.08)
Number of Observations	1435	1354	1344	1251
Control Standard Deviation	0.88	0.88	0.85	0.85

Notes: Same with Table 1.

Table 3. Estimates of Depreciation and Presence of Dynamic Complementarity

	Panel A. Three-year-old Cohort		Panel B. Four-year-old Cohort	
PPVT	Value Added	IV	Value Added	IV
Lagged Outcome	0.50**	0.50**	0.65**	0.64**
	(0.03)	(0.03)	(0.03)	(0.03)
Randomized to Treatment	0.34		-3.64**	
	(1.42)		(1.56)	
Any Preschool at Age Three (Four)		0.58		-7.49**
		(2.53)		(3.25)
Number of Observations	1663	1591	1313	1242
Control Standard Deviation	41	41	42	42
Woodcock-Johnson Spelling				
Lagged Outcome	0.46**	0.46**	0.39**	0.40**
	(0.03)	(0.03)	(0.03)	(0.03)
Randomized to Treatment	0.14		-3.00**	
	(1.11)		(1.36)	
Any Preschool at Age Three (Four)		0.62		-6.49**
		(2.04)		(2.82)
Number of Observations	1668	1598	1315	1244
Control Standard Deviation	26	26	28	28
Woodcock-Johnson Applied				
Lagged Outcome	0.37**	0.37**	0.36**	0.36**
	(0.03)	(0.03)	(0.03)	(0.03)
Randomized to Treatment	1.91**		-1.55	
	(0.93)		(1.13)	
Any Preschool at Age Three (Four)		3.29**		-3.20
		(1.68)		(2.34)
Number of Observations	1637	1571	1305	1233
Control Standard Deviation	25	25	21	21
Woodcock-Johnson Oral Comp.				
Lagged Outcome	0.51**	0.49**	0.57**	0.56**
	(0.03)	(0.03)	(0.04)	(0.04)
Randomized to Treatment	1.00		-1.31*	
	(0.64)		(0.74)	
Any Preschool at Age Three (Four)		1.78		-2.73*
		(1.14)		(1.54)
Number of Observations	1635	1565	1291	1220
Control Standard Deviation	16	16	18	18
Woodcock-Johnson Word				
Lagged Outcome	0.51**	0.51**	0.55**	0.57**
	(0.03)	(0.03)	(0.03)	(0.03)
Randomized to Treatment	0.63		-5.24**	
	(1.24)		(1.56)	
Any Preschool at Age Three (Four)		0.52		-11.16**
		(2.30)		(3.25)
Number of Observations	1666	1596	1313	1242
Control Standard Deviation	29	29	35	35
Kline Walters Index				
Lagged Outcome	0.62**	0.62**	0.65**	0.66**
	(0.03)	(0.03)	(0.03)	(0.03)
Randomized to Treatment	-0.02		-0.14**	
	(0.03)		(0.03)	
Any Preschool at Age Three (Four)		-0.04		-0.28**
		(0.05)		(0.07)
Number of Observations	0.88	0.88	1300	1228
Control Standard Deviation	1623	1554	0.84	0.84

Notes: For the three-year-old cohort, the variable is "Any Preschool at Age Three." For the four-year-old cohort, the variable is "Any Preschool at Age Four." Additional notes are located under Table 1.

Table 4. ITT Estimates of Randomization and IV Estimates of Any Preschool Attendance – Non-cognitive Outcomes

	Panel A. Three-year-old Cohort			
	Age Three		Age Four	
Total Problem Behavior Score	ITT	IV	ITT	IV
Randomized to Treatment	-0.68**		-0.60**	
	(0.18)		(0.18)	
Any Preschool at Age Three		-1.27**		-1.12**
		(0.33)		(0.33)
Number of Observations	1743	1708	1683	1582
Control Standard Deviation	3.74	3.74	3.87	3.86
Social Competencies Score				
Randomized to Treatment	0.05		0.03	
	(0.07)		(0.07)	
Any Preschool at Age Three		0.10		0.07
		(0.12)		(0.12)
Number of Observations	1742	1707	1683	1582
Control Standard Deviation	1.39	1.39	1.31	1.31
Social Skills and Positive Approach to Learning Score				
Randomized to Treatment	0.11		0.01	
	(0.09)		(0.08)	
Any Preschool at Age Three		0.21		0.04
		(0.16)		(0.15)
Number of Observations	1743	1708	1683	1582
Control Standard Deviation	1.71	1.71	1.69	1.69
	Panel B. Four-year-old Cohort			
	Age Four		Age Five	
Total Problem Behavior Score	ITT	IV	ITT	IV
Randomized to Treatment	-0.11		0.29	
	(0.20)		(0.20)	
Any Preschool at Age Four		-0.23		0.55
		(0.43)		(0.43)
Number of Observations	1423	1371	1333	1242
Control Standard Deviation	3.48	3.48	3.51	3.53
Social Competencies Score				
Randomized to Treatment	0.02		-0.01	
	(0.07)		(0.08)	
Any Preschool at Age Four		0.03		-0.04
		(0.16)		(0.16)
Number of Observations	1424	1372	1334	1242
Control Standard Deviation	1.21	1.21	1.05	1.05
Social Skills and Positive Approach to Learning Score				
Randomized to Treatment	-0.13		-0.04	
	(0.09)		(0.08)	
Any Preschool at Age Four		-0.27		-0.12
		(0.20)		(0.17)
Number of Observations	1424	1372	1334	1242
Control Standard Deviation	1.59	1.59	1.46	1.47

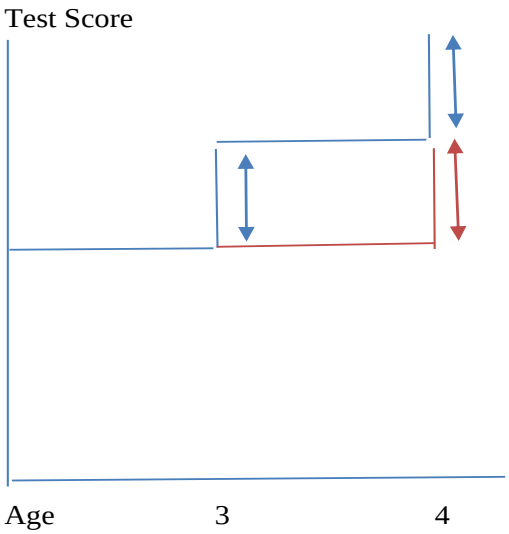
Notes: Same with Table 2.

Table 5. Estimates of Depreciation and Presence of Dynamic Complementarity – Non-cognitive Outcomes

	Panel A. Three-year-old Cohort		Panel B. Four-year-old Cohort	
Total Problem Behavior Score	Value Added	IV	Value Added	IV
Lagged Outcome	0.43**	0.42**	0.47**	0.47**
	(0.03)	(0.03)	(0.03)	(0.03)
Randomized to Treatment	-0.35*		0.33*	
	(0.18)		(0.18)	
Any Preschool at Age Three (Four)		-0.62*		0.68*
		(0.32)		(0.38)
Number of Observations	1622	1582	1296	1240
Control Standard Deviation	3.86	3.86	3.54	3.54
Social Competencies Score				
Lagged Outcome	0.32**	0.32**	0.37**	0.37**
	(0.04)	(0.04)	(0.04)	(0.04)
Randomized to Treatment	0.03		-0.03	
	(0.07)		(0.07)	
Any Preschool at Age Three (Four)		0.05		-0.06
		(0.11)		(0.14)
Number of Observations	1621	1581	1296	1240
Control Standard Deviation	1.31	1.31	1.05	1.05
Social Skills and Positive Approach to Learning Score				
Lagged Outcome	0.32**	0.32**	0.25**	0.25**
	(0.04)	(0.04)	(0.04)	(0.04)
Randomized to Treatment	-0.03		-0.04	
	(0.08)		(0.08)	
Any Preschool at Age Three (Four)		-0.05		-0.09
		(0.14)		(0.16)
Number of Observations	1622	1582	1296	1240
Control Standard Deviation	1.69	1.69	1.47	1.47

Notes: For the three-year-old cohort, the variable is "Any Preschool at Age Three." For the four-year-old cohort, the variable is "Any Preschool at Age Four." Additional notes are located under Table 1.

Appendix to "Do Preschool Investments Fadeout or Result in Dynamic Complementarities? An Assessment Using the Head Start Impact Study"



Appendix Figure 1

Notes: The difference-in-differences approach can be shown graphically, as in Appendix Figure 1, and is useful to elucidate the nature of the "reverse" experiment. At the end of the first year of participation (age three in Appendix Figure 1), the test score of the treated group increases due to any preschool attendance, which is consistent with the empirical evidence from the HSIS. At the end of the second year (age four), the test scores of both the treated and control groups increase due to any preschool attendance during the second period. It is important to recognize that the treated group's test score at age four reflects preschool attendance at both ages three and four —they receive two years of this type of investment. As drawn in Appendix Figure 1, the difference-in-differences is approximately zero, which assumes that the effect of preschool attendance at age three is approximately the same as it is at age four, and that there is zero depreciation and no dynamic complementarities. If there were dynamic complementarities, then the increase in test scores at age four would be larger for the treated than control group. If there was depreciation, which is assumed to be zero in Appendix Figure 1, then the test scores of both the treated and control groups would decline from age three to age four.

Appendix Table 1. Summary Statistics at Baseline (Fall 2002)

	Three-year-old Cohort		Four-year-old Cohort	
	Control	Treated	Control	Treated
Baseline Characteristics				
Child is female	0.53	0.52	0.48	0.49
Child's Hispanic	0.33	0.33	0.44	0.43
Child is Black	0.34	0.37	0.21	0.22
Child lived with both biological parents	0.48	0.50	0.54	0.51
Child had limited English proficiency	0.14	0.12	0.07	0.07
Child had special needs	0.09	0.13	0.12	0.14
Child's baseline preacademic skills was in the lowest quartile	0.23	0.24	0.25	0.24
Primary care giver's age	28.47	29.13	29.64	29.36
Mom is a recent immigrant	0.17	0.16	0.24	0.22
Mom is Hispanic	0.31	0.32	0.43	0.42
Mom is Black	0.33	0.37	0.21	0.22
Teen Mom	0.19	0.14	0.17	0.18
Mom is married	0.45	0.44	0.49	0.45
Mom is never married	0.40	0.42	0.34	0.36
Mom has a high school or lower degree	0.69	0.69	0.76	0.72
Household risk index (moderate risk)	0.21	0.19	0.20	0.21
Household risk index (high risk)	0.09	0.09	0.09	0.08
Center is in urban areas	0.81	0.82	0.86	0.85
Cognitive Outcomes at baseline				
PPVT	231 [38]	230 [36]	272 [38]	269 [40]
Woodcock-Johnson Spelling	334 [25]	335 [24]	357 [24]	359 [25]
Woodcock-Johnson Applied	366 [28]	368 [27]	391 [23]	390 [24]
Woodcock-Johnson Oral Comp.	434 [13]	433 [13]	446 [14]	445 [14]
Woodcock-Johnson Word	293 [22]	294 [23]	306 [25]	308 [26]
Kline Walters Index	-0.018 [0.74]	-0.025 [0.73]	0.052 [0.76]	0.026 [0.80]
Non-cognitive Outcomes at baseline				
Total problem behavior score	6.3 [3.7]	5.9 [3.4]	6.4 [3.6]	6.1 [3.8]
Social competencies score	10.8 [1.5]	10.8 [1.4]	10.9 [1.3]	10.8 [1.4]
Social skills and positive approach to learning score	12.2 [1.8]	12.3 [1.7]	12.4 [1.7]	12.3 [1.7]
Sample Size	637	1147	522	930

Notes: Summary statistics reported are means and standard deviations in brackets. Sample is limited to observations with non-missing dependent variable (Woodcock-Johnson Spelling) in 2003 and baseline covariates. There are 1784 children in the three-year-old cohort (637 in the control group and 1147 in the treatment group) and 1452 in the four-year-old cohort (522 in the control group and 930 in the treatment group).

Appendix Table 2. Mean and Standard deviation of outcomes by Year

	Panel A. Three-year-old Cohort			
	Age Three		Age Four	
	Control	Treated	Control	Treated
PPVT	252 [38]	258 [33]	298 [42]	301 [36]
Woodcock-Johnson Spelling	344 [23]	347 [21]	375 [26]	378 [26]
Woodcock-Johnson Applied	373 [30]	377 [27]	399 [25]	402 [21]
Woodcock-Johnson Oral Comp.	436 [14]	435 [14]	446 [16]	446 [16]
Woodcock-Johnson Word	301 [24]	307 [25]	330 [29]	334 [28]
Kline Walters Index	0.005 [0.88]	0.203 [0.78]	0.005 [0.90]	0.118 [0.78]
Total problem behavior score	6.4 [3.7]	5.7 [3.4]	5.8 [3.8]	5.1 [3.4]
Social competencies score	10.9 [1.4]	11.0 [1.3]	11.1 [1.3]	11.2 [1.3]
Social skills and positive approach to learning score	12.4 [1.7]	12.5 [1.7]	12.6 [1.7]	12.7 [1.5]
	Panel B. Four-year-old Cohort			
	Age Four		Age Five	
	Control	Treat	Control	Treat
PPVT	290 [40]	294 [36]	335 [43]	334 [40]
Woodcock-Johnson Spelling	368 [25]	371 [24]	425 [28]	414 [28]
Woodcock-Johnson Applied	393 [28]	396 [25]	427 [21]	427 [20]
Woodcock-Johnson Oral Comp.	444 [18]	443 [18]	458 [19]	456 [19]
Woodcock-Johnson Word	319 [27]	324 [28]	379 [35]	377 [32]
Kline Walters Index	0.015 [0.89]	0.142 [0.82]	0.038 [0.85]	0.003 [0.80]
Total problem behavior score	5.9 [3.5]	5.8 [3.8]	4.9 [3.5]	5.1 [3.7]
Social competencies score	11.1 [1.2]	11.1 [1.3]	11.2 [1.05]	11.2 [1.2]
Social skills and positive approach to learning score	12.6 [1.6]	12.5 [1.7]	12.8 [1.4]	12.7 [1.5]

Notes: Summary statistics reported are means and standard deviations in brackets. Sample is limited to observations with non-missing dependent variable and covariates.