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Differential Effects of Center and Non-center Childcare on Early Learning Outcomes

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Abstract I use longitudinal data from birth until start of kindergarten to examine the relationship between first use of non-parental childcare and learning outcomes at school entry. Childcare is classified into center care and non-center care. Knowledge of when children first enrolled in non-parental childcare, allows me to understand whether there are academic gains from attending center care, and if the timing of non-parental child care matters. I find that participation in center-based preschool programs is positively associated with higher mathematics and reading scores, especially at the preschool stage. On the other hand, enrollment into non-center care for the first time during preschool age is negatively associated with reading scores. A later switch to center care from non-center care shows improvement in math and reading scores.

Keywords: Cognitive achievement; Childcare; Preschool.

JEL Classification: D10, H75, I12, J2

1. Introduction

It is well recognized that infancy to kindergarten is a critical time for childhood cognitive development. Past studies have shown that accumulation of cognitive skills starts at a very early age (for example, Bedard and Dhuey, 2006; Burger, 2010; Doyle et al., 2009; Elder and Lubotsky, 2009; Heckman, 2008; Jenkins et al., 2016), and that being at the low end of the cognitive scale when starting school, is detrimental in the long run (Duncan et al., 2007). In addition to the direct effect of household income on children's health, which is generally found to be positive (for example, Blau, 1999; Case et al., 2002; Currie and Stabile, 2003), one of the early investments in child development is quality and quantity of non-parental childcare (for example, Baker et al., 2008; Berlinski et al., 2009; Bernal and Keane, 2011; Havnes and Mogstad, 2011; Loeb et al., 2007; Magnuson et al., 2007). There is also a large body of literature on the short-run and long-run effects of childcare on cognitive development (for instance, Arteaga et al., 2014; Bassok, 2010; Bernal and Keane, 2011; Fuller et al., 2017; Jenkins et al., 2016; Lee at al., 2014; Pilarz, 2017; Ruzek et al., 2014; Tarullo et al., 2010; Tucker-Drob, 2012). Thus, policies that subsidize childcare are meant to address financial constraints faced by many parents. Positive welfare effects are realized when these children are better prepared for the K-12 educational system, and thus have a better chance at school and professional success.

In this study, I examine the effect of timing of first use of non-parental care on mathematics and reading scores at kindergarten. I classify non-parental care as center based and non-center based

care. Center care includes state-funded prekindergarten programs, Head Start, and other private center care. Non-center care includes relative care and care provided by non-family member. Second, I examine the effect of a later change in the type of non-parental care – from center care to non-center care, or from non-center care to center care, on math and reading scores at school entry. I use data from all five waves of the Early Childhood Longitudinal Study – Birth Cohort surveys. Evaluating the effectiveness of policies that subsidize childcare is greatly complicated by selection, endogeneity, and measurement problems, as is recognized and addressed in the above-mentioned studies. I, too, address the issue of non-zero correlation between observed non-parental care choices and unobserved child or family characteristics by applying instrumental variables estimation method. The analyses presented in this paper seek to understand the singular effects of first and second choices of non-parental care from birth until school entry, as well as the cumulative effect of care choices on cognitive measures.

2. Data

The Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) is a nationally representative sample of about 10,700 children born in the United States in 2001, with oversampling from among some minority racial and ethnic groups, twins, and low birth weight children. The first wave of the survey was conducted when the average age of the sample children was approximately 9 months, and the second wave was conducted when they were around 2 years of age. The third wave was conducted between fall 2005 and spring 2006. A large number of the ECLS-B children were eligible to enter school in the 2006–2007 academic year. Henceforth, this group of children will be called the early cohort, while the remaining children form the late cohort. Thus, the third wave is largely representative of early cohort's preschool year. Similarly, the survey conducted between fall 2006 and spring 2007 is representative of the preschool year for the late cohort, and it represents the school year for the early cohort. The late cohort and those from the early cohort who delayed kindergarten entry were surveyed in a fifth and final wave, to coincide with the 2007–2008 school year. As per the guidelines of the National Center of Education Statistics regarding publishing results using the ECLS-B data, sample sizes have been rounded to nearest fifty throughout the article including the tables.

I limit analysis to households with at least one biological parent, which is a majority of the sample (over 99% in the first round of surveys). Due to attrition, approximately 8,950 children were surveyed in the fall 2005–spring 2006 wave, and 7,000 children were surveyed in the fall 2006–spring 2007 wave. A small number of children in this dataset (less than 1%) were diagnosed with Down's syndrome, Turner syndrome, and spina bifida. They were excluded from the analyses. I also excluded 850 households that delayed or expedited kindergarten enrollment of their children as these decisions could be driven by parents' (unobserved) concerns about children's relative position within a kindergarten cohort (Bassok and Reardon, 2013). Including children from these households would needlessly impose selection issues in the estimation process because the dependent variables in this study (cognitive measures) are observed at school entry. Very few households were single-father households, and they are excluded from the analyses. The exclusions, attrition through the survey waves, and incomplete data availability result in a sample of approximately 5,100 children in the multivariate regression analyses.

Table 1 provides descriptive statistics of all individual-level and household-level variables used in this study. The primary dependent variables are mathematics and reading scores at school entry. Theta scores or *z*-scores, constructed by the ECLS-B administrators, reflect latent ability in math and reading skills. They can be used to interpret children's skill levels relative to their peers. I convert the *z*-scores into standardized *t*-scores that have mean 50 and standard deviation of 10 (based on the full sample distribution). Regression coefficients can then be divided by 10 to translate them into effect sizes. The average math score at school entry was 56.4 and the average reading score was 56.6. The cognitive measures are from wave IV (V) for children who were eligible to enter school or entered school in fall 2006 (2007). Generally, if a child is 5 years or older on the day of the cut-off, he/she is eligible to enter kindergarten in the upcoming school year; however, kindergarten entrance age varies from state to state. The school entrance cut-off dates are obtained from the Education Commission of the States, 2005. Some states have no specific cut-off date, some states have cut-off dates in the middle of a month (for instance, August 15 in Alaska), some states have cut-off dates at the end of a month (for instance, September 30 in Nevada), some states have cut-off dates at the start of a month (for instance, July 1 in Indiana), and finally, some states let local school districts decide entrance age-eligibility conditions. If children were not enrolled in kindergarten in wave IV, parents were asked to report their local school district eligibility criteria, i.e., if their children were age-eligible to enroll in kindergarten.

The primary independent variables are first use of center based and non-center based childcare since birth until school entry. Non-parental childcare is categorized into center care and non-center care. Center care includes state-funded prekindergarten programs, Head Start, and other private center-based care. Non-center care includes relative care and care provided by non-family member. Non-center care could be provided either at child's home or at caregiver's home. Many households combined center care and non-center care within a single wave. For instance, a child could be enrolled in a center care part-time, and then cared for by a relative before being handed over to the parent(s). When multiple childcare settings were used, the ECLS-B data recorded which care setting was considered primary by the parent.

To identify the first use of center care and non-center care, I compare the choice of primary care across waves. This allows me to create categorical variables of first use of each type of non-parental care, if any. Each variable has four categories – whether non-parental care began around 9-month of age (i.e., wave I) which is assigned a value '1', or around 2-year (i.e., wave II) which is assigned a value '2', or at preschool stage which is assigned a value '3', or non-parental care was not used at all which is assigned a value '0'. Since some ECLS-B children were born in the first half of 2001 and some in the latter half, waves III and IV represent the preschool age depending on school eligibility. It is possible that among those who first chose non-center based care (say, in wave I), some later switched to center based care (say, in wave II). In this scenario, the categorical variable 'first use of non-center care' is assigned a value '1' and, the categorical variable 'first use of center care' is assigned a value '2'. Around 30% of the households never used any center-based childcare, while 42% never used any non-center care. Approximately 52% of the ECLS-B households first used non-center care in waves I and II, and almost a similar percentage used center care for the first time at preschool age. Among all who used non-center care as a first non-parental care type, 32.2% moved to center care later but before school entry. Conversely, only 2.7% of those who went to center care first, switched to non-center care later.

In this sample, the average kindergarten starting age was 65.3 months. Male and female children were equally represented in the ECLS-B sample. Almost 40% of the children were white non-Hispanic, followed by 20% Hispanic, 16% black non-Hispanic, and 12% Asian non-Hispanic children. Remaining children were categorized as 'other races'. Approximately 71% of the households reported living in dense urban areas. Around 70% of the households were married households. Parent's education was recorded as a categorical variable. An average of 4.6 indicates that the average education level of ECLS-B mothers was 'some college'. ECLS-B mothers' age, on average, was 33 years at child's school entry. Around 73% of mothers worked before birth of the ECLS-B sample child. Almost 18% of the sample children had a neonatal intensive care unit (NICU) stay. On an average, there were 2.6 children per household, and 2.1 adults per household.

While childcare inputs are important determinants of early cognitive achievement, goods inputs, such as nutrition, health care, books and other educational resources, are likely to be equally important to cognitive development. Thus, human capital production models usually include some measure of cumulative household income. In the ECLS-B surveys, annual household income was reported on a categorical scale, and summing them across all waves to calculate a cumulative measure is neither meaningful nor easy to interpret. I use interval regressions to impute a continuous income measure to self-reported categorical income (Stewart, 1983; Violato et al., 2011) and to improve interpretation of the results. Regressors in the interval regressions consist of parent-level characteristics – educational attainment, employment status, age, race, and occupation, along with household-level variables – number of earners in the household, number of adults in the household, number of children in the household, and rural or urban residency. Two panel-data interval regression models are estimated – one for two-parent households and another for single-mother households, and the results are shown in Appendix A. Average estimated income and standard deviation of estimated income corresponding to each category of observed income are shown in Appendix B. Overall, the average cumulative household income across all four waves is estimated to be $300,000.

3. Econometric Framework

Following Leibowitz (1974), I apply the human capital production framework to estimate cognitive achievement as a function of individual-level characteristics and investments in children in the formative years. In this study, I focus on a specific type of early investment – first use of non-parental childcare. The relationship between non-parental care and child's cognitive ability at kindergarten entry, A_i, is described as follows:

$$A_i = \alpha_0 + \alpha_C C_i + \alpha_N N_i + \alpha_X X_i + \varepsilon_i \quad (1)$$

Subscript i denotes individual. For the early cohort, math and reading scores are from the fourth wave of the ECLS-B surveys, and for the late cohort they are from the fifth wave. First use of center and non-center based care are denoted by C and N, respectively. They are categorical variables, each with four categories. A value of '0' denotes that a specific non-parental care was not used in any wave prior to school entry. Values '1', '2', and '3', denote that the first use of care was in the first wave, second wave, and preschool wave, respectively. For the early cohort, wave III is the preschool wave, while for the late cohort it is wave IV. Note that data from all waves are used to construct these two variables.

As mentioned before, it is possible that some families move their children to another non-parental care that is different from their first choice. For this reason, both C and N variables in equation (1) could take non-zero values simultaneously. For instance, if a child is first enrolled into non-center care in wave I, and then moved to center care in the preschool wave, then $N=1$ and $C=3$. A variation of the estimating equation (1) that combines C and N variables into mutually exclusive categories, and adds a second choice of non-parental care is as follows:

$$A_i = \alpha_0 + \alpha_F F_i + \alpha_{SC} SC_i + \alpha_{SN} SN_i + \alpha_X X_i + \varepsilon_i \quad (2)$$

Here, F has seven categories. A value of '1' denotes that the first use of non-parental care is a non-center care in wave I, '2' denotes that the first use is non-center care in wave II, '3' denotes that the first use is non-center care in preschool wave, '4' denotes that the first use of non-parental care is a center care in wave I, '5' denotes that the first use is center care in wave II, '6' denotes that the first use is center care in preschool wave, and '0' denotes that no non-parental care is used prior to school entry. SC takes the value '1' to denote switch to center care from non-center care, and the value '0' denotes that either center care is used throughout until school entry or that no non-parental care is used prior to school entry. Similarly, SN denotes switch to non-center care from center care.

In both equations (1) and (2), the vector X includes child, mother, and household characteristics. Child's gender and race, any NICU stay, and if mother worked pre-birth are time-invariant. Child's age at the time of assessment of math and reading scores following school entry is used. Cumulative household income is estimated using income data from each wave. I use data from the school entry wave for the remaining characteristics, which include the number of children and adults in the household, urban area residency, mother's age, mother's education, and mother's marital status.

The error term, ε, includes unobservable factors, such as child's innate ability, household's taste for goods, household's taste for childcare, in addition to any random noise and measurement error. In the model specification (1), non-zero correlations between the primary independent variables (i.e., the demand for childcare) and the error term exist if the demand for childcare are correlated with any unobserved child or family characteristic, such as ability or parents' attachment to labor market. In this case, estimated effects of the suspect endogenous variables on mathematics and reading scores using ordinary least squares (OLS) regression are likely to be biased. On the other hand, if the care choices and the timing of first use non-parental care are independent of the error term, then OLS regressions will produce unbiased, consistent, and efficient estimates.

All potentially endogenous variables in equation (1) or equation (2) are categorical. In an instrumental variables estimation, which is commonly used when non-zero correlation between explanatory variables and the error term is suspected, a nonlinear first stage may be a "forbidden regression" and may not yield consistent estimators (Angrist and Pischke, 2008). One alternative is to apply a three-stage estimation process, where nonlinear fitted values are obtained first, and then the usual two-stage least squares model is estimated where the nonlinear fitted values are used as instruments (Angrist and Pischke, 2008; Newey, 1990). This technique could be used for endogenous dummy variables, so that a probit model is estimated to obtain nonlinear fitted values.

I reduce the number of categories in the first use variables in equation (2) by suppressing the timing of entry to non-parental care and only using the information on whether a specific type of care was used or not. In other words, the four primary (and potentially endogenous) independent dummy variables are – whether first use was center care or not, whether first use was non-center care or not, whether later changed to center care or not, and whether later changed to non-center care or not.

The additional exogenous variables in the first stage of probit estimations are state-level data that are expected to be correlated with the demand for non-parental care. These instruments include women's average hourly wage rates, pre-kindergarten expenditures per enrollee, Head Start expenditures per enrollee, average cost of center-based childcare per child, average cost of non-center-based childcare per child, and child-to-teacher ratio. Appendix C presents the complete list of state-level instruments.

4. Estimation Results and Discussion

I examine the effect of first use of non-parental childcare, as a primary source of childcare, on cognitive achievement at kindergarten entry. There are two dependent variables, to proxy for cognitive achievement – standardized mathematics and reading scores. Several variations, based on how the independent variables are measured, are estimated using OLS technique. The results are shown in Table 2.

I estimate equation (1) in models I and II, and equation (2) in models III and IV. In model I, the primary independent variables are first use of center care and first use of non-center care. Each has four categories – 9-month, 2-year, preschool, or never used center (or non-center) care. 'Never used' is the comparison category in the estimations. All children are included in this analysis, and switching to a different form of non-parental care is allowed but inherently absorbed in the first use variables. In other words, it is possible that a child could have first entered into a non-center care in, say, wave I, and then moved to center care in, say, wave II. In this illustration, first use of center care will take the value '2' while first use of non-center care will take the value '1'.

In model II, I exclude all children who switch to a different form of non-parental care after their first choice to have a better understanding of the association between cognitive measures and the type and timing of non-parental care enrollment. In model III, I again include all children. This is the preferred model. There are three primary independent variables – type and timing of first use of non-parental childcare, if later switched to center care from non-center care, and if later switched to non-center care from center care. Comparing the findings from models I and II can help in understanding the cumulative effect of first and second choices of non-parental care. Comparing the results of models I and III can shed light on the significance of timing of a later choice of non-parental care, after accounting for the effects of the first choice. Model IV converts the seven-category variable F in equation (2) into two dummy variables – whether first use is center care or not, and whether first use is non-center care or not. The primary purpose of estimating model IV is to be able to make comparisons between OLS estimators and results from instrumental variables estimation.

In model I, where I do not explicitly account for later changes, the estimated coefficients corresponding to first use of center care are positive and statistically significant, while the estimated coefficients corresponding to first use of non-center care are insignificant. Irrespective of when children are first enrolled in center care, there is a positive relationship between cognitive measures and center care use, with about a 0.1 standard deviation shift compared to not using center care at all. Those who switched to another form of non-parental care, after first choosing center or non-center care, are excluded in model II. This results in a loss of 39% of the sample. However, upon doing so, the importance of acknowledging the cumulative effect of first and second non-parental care choices are revealed. In model II, the estimated coefficients of center care are smaller, while the estimated coefficients of non-center care are larger. Additionally, only reading scores are statistically significantly affected by the first choice of non-parental care.

One explanation for the smaller effect sizes of center care in model II could be that the categories of center care and non-center care are now mutually exclusive. In this model, if the variable C takes a non-zero value, then N has to be zero, and vice-versa. Previously, both variables could take non-zero values simultaneously. Thus, the current analysis could be capturing more accurate effect of center care on cognitive measures. The previous analysis could be capturing a pure effect and any additional benefit of center care when children move to center care after enrolling into non-center care first, which is 32% of the sample. In case of non-center care, the current analysis could be capturing larger negative effects of non-center care among children who have never been exposed to center care prior to school entry. Non-center care, as a first form of non-parental care, during the preschool stage is associated with a 0.1 standard deviation decrease in reading scores at school entry compared to if non-center care was not used at all. On the other hand, first use of center care during the preschool stage is associated with a 0.1 standard deviation increase in reading scores at school entry.

In model III, equation (2) is estimated. Results are similar to those obtained in model II, with additional information on the explicit association between cognitive measures and a transition from the first choice of non-parental care to a different setting. That a later switch to center care from non-center care has a positive and statistically significant coefficient lends support to previous findings that either first use of center care at preschool age or a later switch to center care from early use of non-center care could be beneficial in terms of improvement in math and reading scores.

The OLS results from model IV largely agree with previous findings, except that when timing of first use of non-parental care is suppressed, the estimated coefficient of non-center care is not statistically significant. The instrumental variables estimation results for model IV are shown in Table 3. The two first use variables are estimated using a bivariate probit model, and the remaining two indicator variables are estimated using univariate probit models. Results from the bivariate and univariate probit regression models and joint χ^2-statistics for the state-level instruments are presented in Appendix D. While the first stage joint test statistics for state-level instruments are statistically significant at 99% confidence level, it appears that only child-to-teacher ratio in center care and average price of non-center care are statistically significant in estimating choice of non-parental care. The predicted values of first use variables and later changes in non-parental care settings are then used as instruments in a two-stage least squares estimation of math and reading scores. Note that there are as many instruments as suspect endogenous regressors. Thus, there is

no test for overidentifying restrictions. Rejection of the null hypothesis in the under-identification test indicates that the equation is identified, or that the excluded instruments are relevant. The endogeneity test statistic in each equation is small – it is not statistically significant in the math equation and statistically significant only at 90% confidence level in the reading equation. Thus, the specified endogenous regressors could be treated as exogenous variables. The magnitude of the estimated coefficients of the suspect endogenous regressors using instrumental variables method are larger than their OLS counterparts, which suggest that the observed relationship between non-parental care choices and cognitive measures are not driven by omitted variables such as children's innate ability and other unobserved family characteristics (Angrist and Pischke, 2008). Based on these findings, I conclude that the standard OLS estimated coefficients in model III may be used to understand the association between first and second use of non-parental care and cognitive measures at school entry.

Remaining regressors shown in Tables 2 and 3 are assumed to be exogenous. Using results from model III in Table 2, I note that higher cumulative household income, child's age at school entry, urban area residency, mother's education, that mother worked pre-birth, and living in married household are associated with higher mathematics and reading scores. Larger household size, in terms of larger number of children and adults, is negatively associated with cognitive measures. Statistically significant differences exist between gender and among race categories. Boys have lower scores than girls. Black non-Hispanic children have lower math scores than white non-Hispanic children; Hispanic children have lower math and reading scores; and, Asian non-Hispanic children have higher scores than white non-Hispanic children. Finally, any NICU stay, a proxy for infant health, is negatively associated with mathematics and reading scores.

5. Conclusion

I use a novel longitudinal dataset to examine the relationship between first use of non-parental care and children's cognitive achievement at kindergarten entry. Participation in center-based care, which typically have standard curriculum, is positively associated with early cognitive outcomes. The positive association between center care and cognitive achievement holds irrespective of child's age when center care is first used, but the effect size and statistical significance depends on the sample considered in the analysis – only consider those children who continued in center care throughout since first entry or also include those who switched into center care from a first choice of non-center care. Among those children who do not later switch to non-center care, the positive effect of center care on math and reading scores is realized at around preschool age. First use of non-center care at preschool age is associated with lower reading scores compared to not using non-center care at all. A later switch to center-based care from non-center care, shows gains in math and reading scores. The ECLS-B dataset does not have the necessary information to examine geographic distribution of center-based to explore accessibility issues. However, given the statistically significant positive effect of center-based care on learning outcomes, it is worthwhile to investigate why more children are not enrolled in center-based preschool programs.

Endnotes

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Violato, M., Petrou, S., Gray, R., Redshaw, M. 2011. Family income and child cognitive and behavioural development in the United Kingdom: Does money matter?' *Health Economics*, 20(10), 1201-1225.

Table 1: Descriptive statistics, low-income households (*N* = 5,950†)

Variables	Definition	Mean (SD) or Percentage†
Math score	Standardized t-scores of mathematics z-scores with mean 50 and standard deviation of 10	56.42 (7.79)
Reading score	Standardized t-scores of reading z-scores with mean 50 and standard deviation of 10	56.62 (8.05)
First use of center care:		
Never	Center care was never used	29.69%
9-month	Center care was first used in wave I	8.07%
2-year	Center care was first used in wave II	9.86%
Preschool	Center care was first used in wave III for early cohort and wave IV for late cohort	52.39%
First use of non-center care:		
Never	Non-center care was never used	42.35%
9-month	Non-center care was first used in wave I	42.22%
2-year	Non-center care was first used in wave II	10.23%
Preschool	Non-center care was first used in wave III for early cohort and wave IV for late cohort	5.20%
Later change to center care	Among those who first chose non-center care, the percentage who later changed to center care	32.24%
Later change to non-center care	Among those who first chose center care, the percentage who later changed to non-center care	2.74%
Cumulative income	Total household income cumulated from birth until school entry (in $100,000)	3.08 (4.07)
Child's age (months)	Average age of child at the time of assessment (approximately at school entry)	65.32 (3.76)
Gender	Whether child is male	49.87%
Race and ethnicity:	Child's race and ethnicity	
White non-Hispanic	Child is white non-Hispanic	39.95%
Black non-Hispanic	Child is black non-Hispanic	15.76%
Hispanic	Child is Hispanic	20.55%
Asian non-Hispanic	Child is Asian non-Hispanic	11.84%
Other races non-Hispanic	Child belongs to any other race or is multiracial and is non-Hispanic	11.89%
Married households	Percentage of households with married mother	69.98%

Mother's education	Mother's level of educational attainment of parent(s); measured on a 1 (8^{th} grade or below) to 9 (doctorate or professional degree) scale; e.g. 3 indicates 'High School diploma or equivalent'	4.61 (1.97)
Mother's age	Mother's age, in years	33.32 (6.39)
Number of adults	Total number of members residing in the household who are 18 years of age or older	2.08 (0.74)
Number of children	Total number of members residing in the household who are less than 18 years old	2.58 (1.16)
Urban area residency	If household resides in an urban cluster	70.94%
Mother worked pre-birth	Percentage of mothers who worked before birth of child in the sample	72.60%
NICU stay	If as newborn stayed in NICU	17.87%

† Following the guidelines of National Center of Education Statistics (NCES) regarding publishing results using ECLS-B data, sample sizes have been rounded to nearest 50. The sample size of 5,950 represents the number of children for whom mathematics and reading scores were available

Table 2: OLS estimated effects of first use of center and non-center care on mathematics and reading scores

Variables	Model I		Model II		Model III		Model IV	
	Math	Reading	Math	Reading	Math	Reading		
First non-center care								
9-month	–0.258	–0.222	–0.333	–0.492	–0.512	–0.526		
	(0.225)	(0.238)	(0.442)	(0.464)	(0.434)	(0.449)		
2-year	–0.184	0.073	–1.059	–0.637	–0.518	–0.336		
	(0.342)	(0.348)	(0.692)	(0.686)	(0.525)	(0.529)		
Preschool	–0.122	–0.979	–0.240	–1.488	–0.349	–1.510		
	(0.505)	(0.544)	(0.668)	(0.688)**	(0.671)	(0.688)**		
First center care								
9-month	0.793	1.433	0.134	0.398	0.413	0.885		
	(0.420)*	(0.448)***	(0.578)	(0.599)	(0.554)	(0.574)		
2-year	0.829	1.418	0.560	1.024	0.621	1.002		
	(0.347)**	(0.362)***	(0.636)	(0.636)	(0.607)	(0.612)		
Preschool	1.009	1.415	0.715	0.988	0.796	1.152		
	(0.234)***	(0.247)***	(0.407)*	(0.421)**	(0.405)**	(0.418)***		
First non-center care							–0.468	–0.648
							(0.421)	(0.431)
First center care							0.733	1.101
							(0.396)*	(0.405)***
Later non-center care					0.422	0.486	0.169	0.298
					(0.641)	(0.722)	(0.566)	(0.651)
Later center care					1.058	1.462	1.039	1.625
					(0.278)***	(0.297)***	(0.267)***	(0.281)***
Assessment age	0.061	0.089	0.081	0.094	0.061	0.091	0.060	0.090
	(0.026)**	(0.026)***	(0.033)**	(0.035)***	(0.026)**	(0.026)***	(0.025)**	(0.026)***
Cumulative income	0.472	0.447	0.544	0.491	0.473	0.449	0.470	0.450
(‘000,000)	(0.050)***	(0.052)***	(0.067)***	(0.067)***	(0.050)***	(0.052)***	(0.049)***	(0.052)***
Male child	–0.436	–1.160	–0.258	–0.960	–0.430	–1.147	–0.432	–1.160
	(0.188)**	(0.199)***	(0.243)	(0.259)***	(0.188)**	(0.199)***	(0.188)**	(0.199)***

Black non-Hispanic	–1.863	–0.476	–1.848	–0.235	–1.869	–0.467	–1.891	–0.476
	(0.320)***	(0.340)	(0.455)***	(0.483)	(0.319)***	(0.340)	(0.318)***	(0.339)
Hispanic	–1.925	–1.494	–1.858	–1.534	–1.923	–1.493	–1.931	–1.475
	(0.280)***	(0.304)***	(0.346)***	(0.380)***	(0.280)***	(0.304)***	(0.280)***	(0.303)***
Asian non-Hispanic	2.266	2.651	1.540	2.230	2.264	2.646	2.271	2.647
	(0.334)***	(0.355)***	(0.435)***	(0.468)***	(0.335)***	(0.355)***	(0.335)***	(0.355)***
Other race	–0.319	–0.117	–0.304	–0.019	–0.330	–0.128	–0.337	–0.132
	(0.327)	(0.336)	(0.419)	(0.437)	(0.327)	(0.336)	(0.327)	(0.336)
Number of children	–0.509	–0.721	–0.524	–0.771	–0.512	–0.729	–0.509	–0.725
	(0.085)***	(0.089)***	(0.102)***	(0.109)***	(0.085)***	(0.089)***	(0.084)***	(0.089)***
Number of adults	–0.278	–0.337	–0.437	–0.377	–0.272	–0.327	–0.267	–0.332
	(0.150)*	(0.156)**	(0.194)**	(0.202)*	(0.150)*	(0.156)**	(0.150)*	(0.156)**
Lives in dense urban area	0.761	0.531	1.107	0.787	0.758	0.516	0.757	0.519
	(0.223)***	(0.237)**	(0.284)***	(0.307)**	(0.223)***	(0.238)**	(0.223)***	(0.238)**
Mother's education	0.721	0.815	0.754	0.926	0.725	0.822	0.722	0.821
	(0.064)***	(0.066)***	(0.083)***	(0.087)***	(0.064)***	(0.067)***	(0.064)***	(0.067)***
Mother's age (yr)	0.022	–0.010	0.034	–0.010	0.023	–0.009	0.023	–0.010
	(0.018)	(0.019)	(0.022)	(0.024)	(0.018)	(0.019)	(0.018)	(0.019)
Mother worked pre-birth	0.713	0.634	0.618	0.489	0.727	0.656	0.698	0.653
	(0.233)***	(0.245)**	(0.280)**	(0.299)	(0.233)***	(0.246)***	(0.231)***	(0.242)***
Mother is married	1.164	1.331	1.461	1.687	1.152	1.315	1.165	1.324
	(0.252)***	(0.268)***	(0.331)***	(0.352)***	(0.253)***	(0.268)***	(0.252)***	(0.267)***
NICU stay	–2.258	–1.127	–2.368	–1.348	–2.251	–1.113	–2.243	–1.118
	(0.263)***	(0.263)***	(0.327)***	(0.343)***	(0.263)***	(0.263)***	(0.263)***	(0.263)***
Constant	47.557	46.813	45.690	46.077	47.677	46.918	47.743	47.014
	(1.825)***	(1.855)***	(2.357)***	(2.427)***	(1.842)***	(1.863)***	(1.839)***	(1.858)***
R^2	0.26	0.24	0.26	0.25	0.26	0.24	0.26	0.24
N	5,100	5,100	3,100	3,100	5,100	5,100	5,100	5,100

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Robust standard errors are shown in parentheses.

Table 3: IV estimated effects of first use of center and non-center care on mathematics and reading scores

Variables	Math	Reading
First non-center care	4.343 (5.315)	–3.479 (5.874)
First center care	6.046 (5.597)	4.935 (6.161)
Later non-center care	8.165 (11.092)	2.847 (11.850)
Later center care	2.089 (2.763)	5.476 (2.892)*
Assessment age	0.052 (0.032)	0.117 (0.035)***
Cumulative income ($100,000)	0.433 (0.087)***	0.467 (0.091)***
Male child	–0.502 (0.210)**	–1.292 (0.226)***
Black non-Hispanic	–2.651 (0.941)***	–0.619 (0.992)
Hispanic	–1.902 (0.361)***	–1.031 (0.390)***
Asian non-Hispanic	1.928 (0.433)***	2.653 (0.464)***
Other race	–0.575 (0.449)	–0.325 (0.467)
Number of children	–0.387 (0.181)**	–0.751 (0.192)***
Number of adults	–0.218 (0.225)	0.101 (0.242)
Lives in dense urban area	0.798 (0.353)**	0.139 (0.381)
Mother's education	0.575 (0.179)***	0.765 (0.192)***
Mother's age (yr)	0.050 (0.037)	–0.020 (0.040)
Mother worked pre-birth	0.228 (0.714)	1.354 (0.758)*
Mother is married	1.372 (0.599)**	0.797 (0.652)
NICU stay	–2.060 (0.323)***	–0.802 (0.336)**
Constant	42.799 (5.411)***	43.787 (5.774)***
R^2	0.19	0.15
Under-identification test: $\chi^2(1)$	10.12***	9.95***
Endogeneity test: $\chi^2(4)$	1.05	8.24*
N	4,600	4,600

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Robust standard errors are shown in parentheses.

Appendix A: Interval regression results

Variables	Two-parent households	Single-mother households
Mother's age	0.031*** (0.002)	0.014*** (0.002)
Father's age	0.006*** (0.001)	
Both/self, Black non-Hispanic	–0.276*** (0.022)	–0.456*** (0.037)
Both/self, Hispanic	–0.218*** (0.019)	–0.190*** (0.042)
Both/self, Asian, non-Hispanic	–0.121*** (0.022)	0.021 (0.094)
Both/self, Other races, non-Hispanic	–0.280*** (0.040)	–0.466*** (0.079)
Multiple race-ethnicity	–0.122*** (0.025)	–0.066 (0.056)
Dense urban residency	0.125*** (0.013)	0.180*** (0.031)
Number of earners	0.153*** (0.010)	0.333*** (0.015)
Mother works full-time	0.108*** (0.009)	0.346*** (0.027)
Father works full-time	0.157*** (0.017)	
Mother has HS degree only	–0.232*** (0.022)	–0.300*** (0.048)
Mother did some college	–0.009 (0.013)	–0.056 (0.041)
Mother has college degree	0.201*** (0.020)	0.407*** (0.064)
Mother studied beyond college	0.328*** (0.025)	0.598*** (0.093)
Father has HS degree only	–0.177*** (0.019)	
Father did some college	–0.003 (0.012)	
Father has college degree	0.146*** (0.020)	
Father studied beyond college	0.274*** (0.026)	
Mother's occupation score†	0.005*** (0.0004)	0.011*** (0.001)
Father's occupation score†	0.006*** (0.0005)	
Constant	8.605*** (0.050)	8.513*** (0.098)
Panels	7,000	2,150

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

†According to https://nces.ed.gov/statprog/handbook/ecls_keyconcepts.asp, "In the ECLS-B, each parent's occupation was scored using the average of the 1989 GSS [General Social Survey] prestige scores for the 2000 census occupational category codes covered by the ECLS-B occupation."

Appendix B: Comparison of observed and predicted household income

Observed income (categorical variable)	Predicted income, deflated to 2001$: Average within category (standard deviation)
1: $5,000 or less	3,463.08 (295.16)
2: $5,001 to $10,000	7,164.33 (433.70)
3: $10,001 to $15,000	11,676.91 (592.84)
4: $15,001 to $20,000	16,297.82 (809.58)
5: $20,001 to $25,000	20,957.93 (1,046.28)
6: $25,001 to $30,000	25,666.65 (1,262.26)
7: $30,001 to $35,000	30,213.61 (1,540.25)
8: $35,001 to $40,000	34,978.82 (1,697.64)
9: $40,001 to $50,000	41,675.83 (2,088.47)
10: $50,001 to $75,000	56,687.03 (2,921.98)
11: $75,001 to $100,000	79,873.87 (3,974.42)
12: $100,001 to $200,000	123,157.10 (7,498.25)
13: $200,001 or more	274,345.71 (617,308.10)

Appendix C: List of state-level instruments

State-level variables	Source	Description
Women's wage rate	Bureau of Labor Statistics	Women's earnings as a percentage of men's earnings, multiplied to mean hourly wage across all occupations
Child-to-teacher ratio	Child Care Licensing Study	Number of children per teacher in center care for 9-month, 2-year, 3-year and 4-year old cohorts
Pre-kindergarten expenditures per enrollee	National Institute for Early Education Research	State expenditure (excluding CCDF funding) per child enrolled in state pre-kindergarten initiative. It is set as zero if a state did not have any public-funded pre-kindergarten program.
Head Start expenditures per enrollee	National Institute for Early Education Research	State expenditure on Head Start divided by the number of children in Head Start
Average cost of center-based child care per child	National Association of Child Care Resource and Referral Agencies	Cost of center care for a child, averaged at the state-level, and varying by age of child
Average cost of non-center-based child care per child	National Association of Child Care Resource and Referral Agencies	Cost of non-center based care for a child, averaged at the state-level, and varying by age of child

Appendix D: First-stage bivariate probit and univariate probit regression results for IV estimation

Variables	First center	First non-center	Later center	Later non-center
Wage (wave III)	–0.036 (0.033)	0.037 (0.033)	0.017 (0.031)	0.026 (0.074)
Wage (wave II)	–0.014 (0.054)	–0.017 (0.053)	–0.024 (0.050)	–0.119 (0.078)
Wage (wave I)	0.064 (0.052)	–0.031 (0.052)	0.015 (0.049)	0.001 (0.067)
Ratio (wave III)	0.055 (0.013)***	–0.052 (0.013)***	–0.007 (0.013)	0.059 (0.026)**
Ratio (wave II)	–0.015 (0.013)	0.012 (0.012)	0.021 (0.012)*	–0.087 (0.027)***
Ratio (wave I)	0.025 (0.033)	–0.028 (0.033)	–0.073 (0.034)**	0.043 (0.066)
HS expenditure (wave IV)	–0.006 (0.010)	0.013 (0.010)	0.013 (0.010)	–0.005 (0.021)
HS expenditure (wave III)	–0.003 (0.010)	–0.008 (0.010)	–0.007 (0.010)	0.025 (0.021)
Pre-k expend. (wave IV)	0.0001 (0.002)	0.002 (0.002)	0.004 (0.002)*	–0.0002 (0.004)
Pre-k expend. (wave III)	0.001 (0.002)	–0.003 (0.002)	–0.003 (0.002)	0.0001 (0.004)
Center price (wave II)	–0.008 (0.007)	0.004 (0.007)	0.006 (0.006)	–0.002 (0.008)
Center price (wave I)	0.005 (0.006)	–0.001 (0.006)	–0.008 (0.006)	–0.005 (0.006)
Non-center price (wave III)	0.016 (0.007)**	–0.005 (0.007)	–0.007 (0.006)	–0.006 (0.011)
Non-center price (wave II)	0.013 (0.010)	–0.013 (0.010)	–0.010 (0.010)	0.014 (0.014)
Non-center price (wave I)	–0.019 (0.008)**	0.010 (0.008)	0.016 (0.008)**	–0.005 (0.012)
Assessment age	–0.008 (0.005)	0.011 (0.005)**	0.005 (0.005)	0.005 (0.011)
Cumulative income	–0.021 (0.010)**	0.044 (0.010)***	0.050 (0.009)***	–0.005 (0.020)
Male child	0.016 (0.036)	0.001 (0.036)	0.015 (0.036)	–0.081 (0.073)
Black non-Hispanic	–0.227 (0.064)***	0.403 (0.064)***	0.456 (0.060)***	0.207 (0.112)*
Hispanic	–0.199 (0.059)***	0.220 (0.056)***	0.096 (0.057)*	–0.031 (0.128)
Asian non-Hispanic	–0.149 (0.066)**	0.160 (0.066)***	0.156 (0.066)**	0.004 (0.161)
Other race	–0.004 (0.062)	0.022 (0.061)	0.066 (0.061)	0.238 (0.113)**
Number of children	0.008 (0.016)	–0.056 (0.016)***	–0.067 (0.016)***	–0.021 (0.032)
Number of adults	–0.191 (0.030)***	0.187 (0.029)***	–0.003 (0.026)	–0.114 (0.052)**
Lives in dense urban area	0.170 (0.043)***	–0.205 (0.043)***	–0.127 (0.044)***	–0.007 (0.089)
Mother's education	0.012 (0.012)	0.032 (0.012)***	0.068 (0.012)***	0.058 (0.027)**
Mother's age (yr)	0.011 (0.003)***	–0.015 (0.003)***	–0.011 (0.003)***	–0.028 (0.008)***
Mother worked pre-birth	–0.396 (0.043)***	0.539 (0.042)***	0.398 (0.043)***	0.156 (0.083)*
Mother is married	0.237 (0.049)***	–0.335 (0.048)***	–0.140 (0.047)***	–0.245 (0.093)***

NICU stay	–0.086 (0.048)*	0.113 (0.048)**	–0.007 (0.047)	–0.204 (0.103)**
Constant	–0.212 (0.0434)	–0.164 (0.431)	–1.114 (0.435)**	–1.375 (0.907)
Joint χ^2-test	205.46***	31.55***	32.84***	
N	5,100	5,550	5,550	