

Supplemental Online Appendix for Jenkins et al. (2024)

In search of dynamic complementarities between early and later education: Evidence from North Carolina's pre-k and K-12 school funding reforms

A. Additional data details

Of the 1,918,794 births appearing in our records during this period, 1,425,408 were matched as attending a public school in NC in any grade and year (74.29% of children born in NC during this period). Non-matches occurred because of migration out of state, private school attendance, or errors in the matching process. The matched group was slightly more likely than the unmatched group to have a mother who is single, native-born, and non-White. Importantly, match rates were not systematically related to county funding allocations, alleviating concerns of biased sample selection (see Ladd et al., 2014, for more details about the matching process). Students who attended a charter school or with incomplete birth record information were excluded from analyses. This results in an analysis sample of 1,055,206 with complete data.

Appendix Table 1 displays the descriptive statistics for both our full analysis sample, and by DSSF treatment status (pilot-high PPE treatment; nonpilot-low PPE treatment), also including key district and county characteristics. Of note, about 30% of the children in our sample were Black and 5% were Hispanic. Mothers were about 26 years old at the time of the child's birth, and about 23% of mothers had less than a high school level of education. Median family income (in 2019 dollars) across the 100 counties and 18 years of data was approximately \$67,000 per year. Students in districts receiving high-level DSSF funding (pilot) were more likely to be Black or Native American.

APPENDIX TABLE 1: STUDY DESCRIPTIVE CHARACTERISTICS

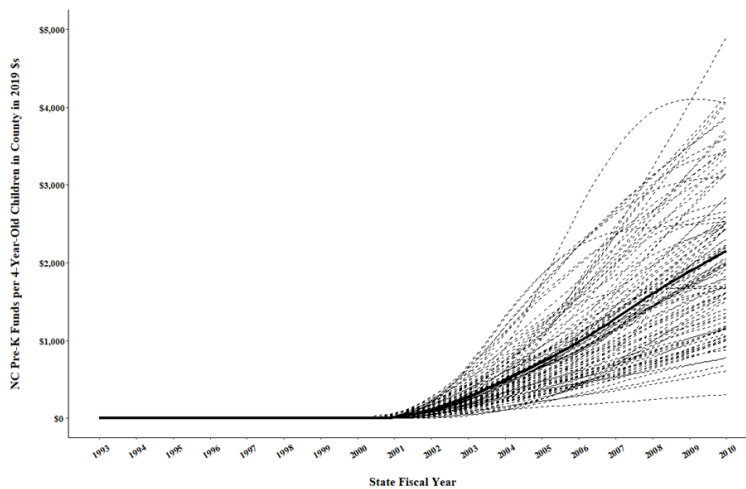
	Full sample				DSSF Pilot/high PPE treatment Districts				DSSF Nonpilot/low PPE treatment Districts			
	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max
Key Funding Variables												
DSSF-induced PPE (\$000s)	0.03	0.05	0	0.39	0.16	0.13	0	0.39	0.02	0.02	0	0.09
District PPE excluding DSSF \$ (\$000s)	9.76	0.96	7.95	22.27	10.29	1.33	8.55	22.27	9.72	0.92	7.95	19.98
District PPE (\$000s)	9.79	0.97	7.95	22.53	10.44	1.37	8.6	22.53	9.74	0.92	7.95	20.04
Years exposed to DSSF	1.94	2.36	0	6	2.43	2.58	0	6	1.9	2.33	0	6
NCPK funding (000s)	0.27	0.48	0	4.41	0.37	0.7	0	4.32	0.26	0.46	0	4.41
Child Birth Record Characteristics												
BR: Extremely low birth weight	0		0	1	0		0	1	0		0	1
BR: Very low birth weight	0.01		0	1	0.01		0	1	0.01		0	1
BR: Low birth weight	0.07		0	1	0.08		0	1	0.07		0	1
BR: High birth weight	0.1		0	1	0.07		0	1	0.1		0	1
BR: Mother's Ed <12 years (1 = Yes)	0.23		0	1	0.31		0	1	0.23		0	1
BR: Mother marital status	0.66		0	1	0.47		0	1	0.67		0	1
BR: Mother immigration	0.08		0	1	0.05		0	1	0.08		0	1
BR: Mother age in year	25.97		10	54	24.42		12	47	26.09		10	54
BR: No father information	0.14		0	1	0.25		0	1	0.13		0	1
BR: First born	0.43		0	1	0.41		0	1	0.44		0	1
BR: Mother black	0.3		0	1	0.49		0	1	0.28		0	1
BR: Mother native American	0.02		0	1	0.16		0	1	0.01		0	1
BR: Mother Asian	0.01		0	1	0		0	1	0.01		0	1
BR: Mother Hispanic	0.06		0	1	0.05		0	1	0.06		0	1
BR: Mother other race	0		0	1	0		0	1	0		0	1
Child is Black	0.3		0	1	0.49		0	1	0.28		0	1
Child is Native American	0.02		0	1	0.16		0	1	0.01		0	1
Child is Asian	0.01		0	1	0		0	1	0.01		0	1
Child is Hispanic	0.05		0	1	0.04		0	1	0.06		0	1
Child is mixed race	0.03		0	1	0.02		0	1	0.03		0	1
Male	0.5		0	1	0.5		0	1	0.5		0	1
Quarter of Birth Year	2.47	1.07	1	4	2.49	1.08	1	4	2.47	1.07	1	4
County Characteristics												
Percent of births from Black mothers	26.29	14.64	0	81	41.57	18.12	0	81	25.14	13.67	0	81
Percent of births from Hispanic mothers	7.05	11.32	0	100	5.91	12.26	0	100	7.13	11.24	0	100
Percent of births from mothers (<12 yrs in Ed)	22.51	6.57	7.28	48.84	28.27	6.21	7.28	48.84	22.07	6.39	7.28	48.84
Number of births in county and year (Log)	7.48	1.07	3.09	9.46	6.81	0.91	3.09	9.44	7.53	1.07	3.09	9.46

County population (log)	11.73	0.99	8.24	13.56	11.02	0.84	8.24	13.53	11.79	0.99	8.24	13.56
Estimated Median Family Income (\$2019)	67489.2	13098.8	33501.3	101574	56004.6	12473.3	33501.3	101574	68357.5	12730.3	33501.3	101574
% of SNAP recipients	0.07	0.04	0.02	0.24	0.13	0.05	0.02	0.24	0.07	0.03	0.02	0.24
% of population enrolled in Medicaid	0.14	0.06	0.03	0.34	0.22	0.08	0.03	0.34	0.13	0.05	0.03	0.34
District Characteristics												
Number of Schools	51.84	48.79	2	175	20.31	14.1	3	43	54.23	49.64	2	175
Total Students	36791.2	41175	544	153534	11142.2	8579.7	585	24996	38730.5	42006	544	153534
Total Special ED IEP Students	4733.02	5128.79	77	20270	1705	1521.89	77	4463	4961.98	5231.89	78	20270
% of Economically Disadvantaged students	46.95	13.67	0	93.45	70.3	10.76	42.17	93.45	45.19	12.16	0	88.8
Sample size	1055206				74178				981028			

Notes: BR= Birth Record derived variable

NC Pre-K funding: We use the level of NC Pre-K funding (per 4-year-old child) in the county in a year as our operationalization of early educational investment. Funding was allocated annually to each of the 100 NC counties to support classroom-based slots for eligible children (i.e., the program did not fund separate preschool programs). Funding began in pilot counties in fiscal year 2002 and varied in the number of counties and dollars per student across years (Ladd et al., 2014). In the first year, 34 of 100 counties received funds. In the second year, 57 counties were added, and in the third year all 100 counties received at least some funds.

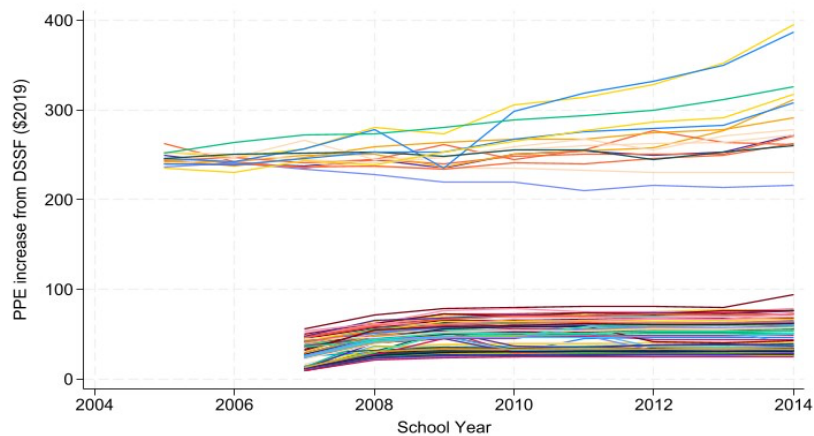
The per-child NC Pre-K funding level for each county over time displayed in Figure 1. This level is computed as the actual total number of dollars allocated to the county in a year divided by the estimated number of 4-year-old children living in that county in that fiscal year, without regard to the funding amount allocated to each funded child (i.e., our measure does not differentiate between children who did and did not directly participate in the program). The per-child dollar allocations for each of the 100 counties across each of the birth cohorts included in the study were matched to specific children based on their county of residence at birth. The average per-child NC Pre-K investment from state allocations across all of the years when the program was operating in our study (2002 through 2010) was about \$1,064 per 4-year-old child in a county. This illustrates the within-county variation identifying the NC Pre-K funding effect.



APPENDIX FIGURE 1. COUNTY-LEVEL ALLOCATIONS OF NC PRE-K FUNDING, PER 4-YEAR OLD

DSSF Funding: NCDPI makes publicly available the record of district-by-year allocations of funding from the DSSF program. We merged this information with the school district universe,

whereby we calculated the DSSF-induced per-pupil expenditure (PPE) increases, converted to thousands of dollars. This figure is the key treatment variable of interest, termed “dosage” by JJ. Figure 2 illustrates *dosage* for each district across the study time period. The clustering of time series around \$250 and then \$50 represent the pilot and non-pilot districts, respectively. In 2005, the DSSF funding differed very little across districts participating in the pilot program, but by 2014, the highest-funded districts received approximately \$400 in additional funds per child, whereas the lower-funded pilot districts were receiving just over \$200 per child. In contrast, the non-pilot districts had very little change in their funding amounts over time, as we observed substantial stability in the small funding increase for non-pilot districts after the rollout of the program.



APPENDIX FIGURE 2. DISTRICT-LEVEL ALLOCATIONS OF DSSF FUNDING, PER-PUPIL

Districts were permitted to use funds on items drawn from a “menu of proven strategies,” including recruiting and retaining teachers via bonuses, teacher mentorship and professional development, reducing class sizes, and equipment upgrades (see Henry et al. 2010, for more detail; authors do not have access to school-level expenditure data).

Paired with this treatment variable is the calculation of the corresponding number years in which each child was exposed to DSSF-enhanced funding at their elementary school, termed “exposure.” This measure is calculated as the difference between the student’s school entry date (at age 5) and the district’s first DSSF treatment year. *Exposure* has a maximum value of 6, whereby children entering a DSSF-treated school in kindergarten could benefit from the treatment for a total of 6 years prior to the end of fifth grade when our outcome is measured.

For robustness, we created alternative forms of DSSF treatment: 1) a 6-year rolling average of DSSF-induced PPE increases (capturing the years of elementary school one could be exposed to the enhanced funding, which closely matches the operationalization used by JJ), using DSSF treatment period only, and; 2) dichotomous indicators of treatment from the pilot phase (I), and the statewide phase (II).

District and School Characteristics: District- and school-level information come from NCDPI administrative records housed at NCERDC. County-level covariates are derived from several sources (e.g., NC Division of Public Health). Details on variable definitions are available in the appendix.

Birth County Characteristics: Our analyses included a host of time-varying county characteristics matched to each child's observation by their year of birth. These measures were derived from aggregating information from all birth records in a given county and year, and from the NC Office of State Budget Management: percent births to non-Hispanic Black mothers, percent births to Hispanic mothers, percent births to low-education mothers, total population (log), number of births (log), proportion of population receiving SNAP, proportion of population receiving Medicaid, and median family income (in 2019 dollars). We also include the county-level allocations for the state's Smart Start program, which allocates modest funds to counties to support early childhood well-being in a variety of ways (see Ladd et al, 2014, for more detail).

Child and Family Characteristics: Derived from the matched birth and school records, we included the following child characteristics as covariates in our analyses: the infant's quarter of birth (as fixed effects), sex, birthweight (extremely low [$<1000\text{g}$], very low [$1000-<1500\text{g}$], low [$1500-<2500\text{g}$], normal [$2500-<4500\text{g}$], high [$<4500\text{g}$]; from World Health Organization, 2004), a single exhaustive and mutually exclusive categorical indicator for race/ethnicity (non-Hispanic Black, non-Hispanic Native American, non-Hispanic Asian, non-Hispanic Mixed race, non-Hispanic White, and Hispanic). We also controlled for mother characteristics including: marital status (married = 1), years of education, age at child's birth (years), primipara (yes = 1), race (Black, Native American, Asian, White, other race), ethnicity (Hispanic or not Hispanic), and immigration status (1=yes). Finally, we also controlled for whether a father was present at birth (no=1).

District and School Characteristics. District- and school-level information come from NCDPI administrative records housed at NCERDC. County-level covariates are derived from several sources (e.g., NC Division of Public Health).

Federal, State, and Local Per-Pupil Expenditures. Per-pupil funding was calculated at the school district level (for all grades K–12, in 2019 dollars) for each school year, financed by the federal, state, and local governments, in thousands. Combined, these form our district total PPE measure. We further constructed a PPE measure from non-DSSF sources, calculated as the total PPE minus the DSSF-induced PPE.

Student-Teacher Ratio. The total number of students in the student’s elementary school (defined as the school in which the child was enrolled in fifth grade), across all grades, divided by the total number of teachers (including special education teachers), across all grades, for each school year. A higher ratio would imply larger average class size.

National Board-Certified Teachers. The proportion of teachers in the school holding a National Board Certification (NBC), across all grades, converted to 10 percentage-point units to ease interpretability of coefficients.¹

Inexperienced Teachers. The proportion of teachers in the student’s elementary school, across all grades, who have less than three years of teaching experience. converted the measure into 10 percentage-point units.

Teacher Turnover. This measure captures the proportion of classroom teachers in the student’s elementary school who left the school in a given year, calculated by dividing the total number of teachers across all grades who left the school in the past year by the total number of teachers in the school, converted into 10 percentage-point units.

¹ Note that the source of these data changed over time: NCDPI school report card data for 2002-2005, NCDPI administrative records for 2006-2018, and interpolated from school-level averages for 1998-2001.

B. Additional analysis details

The timing of both treatments across the cohorts considered in our study, and the total years of exposure, is shown in Appendix Table 2.

APPENDIX TABLE 2: TREATMENT EXPOSURE BY COHORT

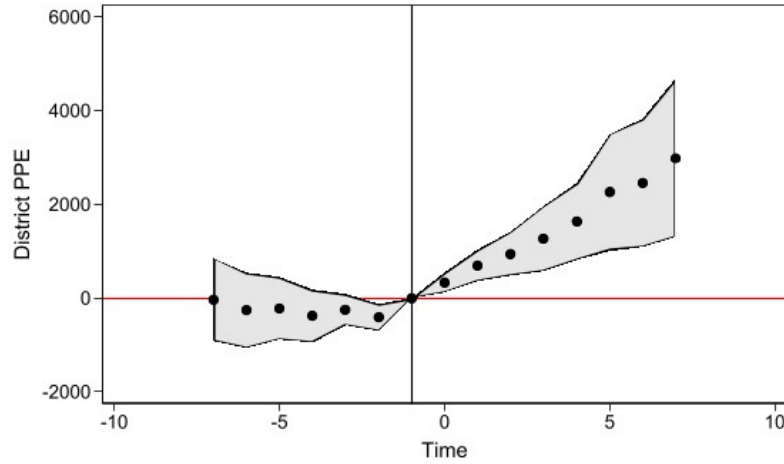
5 th grade year	DSSF status	NC Pre-K status	DSSF Years Exposed (Pilot)	DSSF Years Exposed (Statewide)
2001	-	-	0	0
2002	-	-	0	0
2003	-	-	0	0
2004	-	-	0	0
2005	DSSF pilot	-	1	0
2006	DSSF pilot	-	2	0
2007	DSSF	-	3	1
2008	DSSF	NCPK early	4	2
2009	DSSF	NCPK early	5	3
2010	DSSF	NCPK	6	4
2011	DSSF	NCPK	6	5
2012	DSSF	NCPK	6	6
2013	DSSF	NCPK	6	6
2014	DSSF	NCPK	6	6

Both NCPK and DSSF were targeted treatments, such that resources were differentially allocated to communities with higher levels of economic disadvantage and lower maternal education. This is evident in the county, and district descriptive statistics in Tables 1. Watts and colleagues (2023) show that NCPK investments are conditionally exogenous; controlling for county-level demographic characteristics (those shown in Table 1), the relationship between NCPK funding and 5th grade achievement is robust to possible confounders (e.g., Head Start availability, county time trends; reproduced in Appendix Table 3).

Henry and colleagues (2010) demonstrate the conditional exogeneity of DSSF funding receipt, showing a clear discontinuity in PPE between the 16 most disadvantaged counties—as measured by an index of socioeconomic need—and the next 16 counties.

We further demonstrate the exogeneity of treatment assignment using an event study approach. Shown in Appendix Figure 3, there were no differences in the pre-trends of district spending based

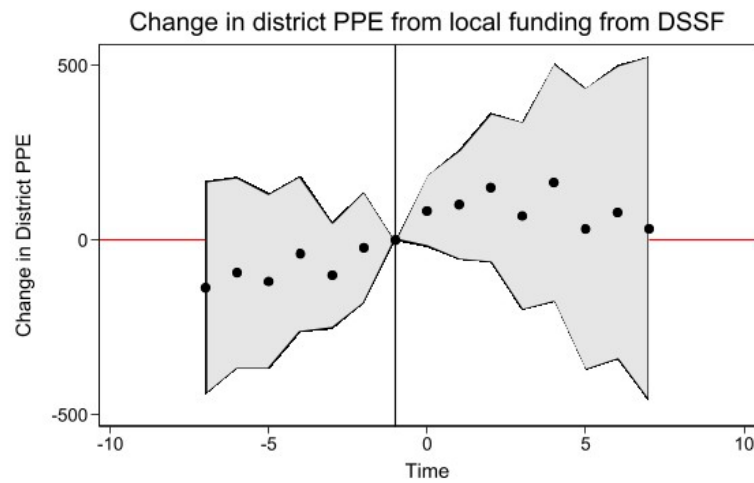
on DSSF receipt (90% confidence intervals shown) prior to the DSSF program implementation. Post-treatment, there exists a clear increase in PPE.



APPENDIX FIGURE 3. EVENT STUDY PLOT OF TOTAL DISTRICT PER-PUPIL EXPENDITURES RELATIVE TO DSSF IMPLEMENTATION

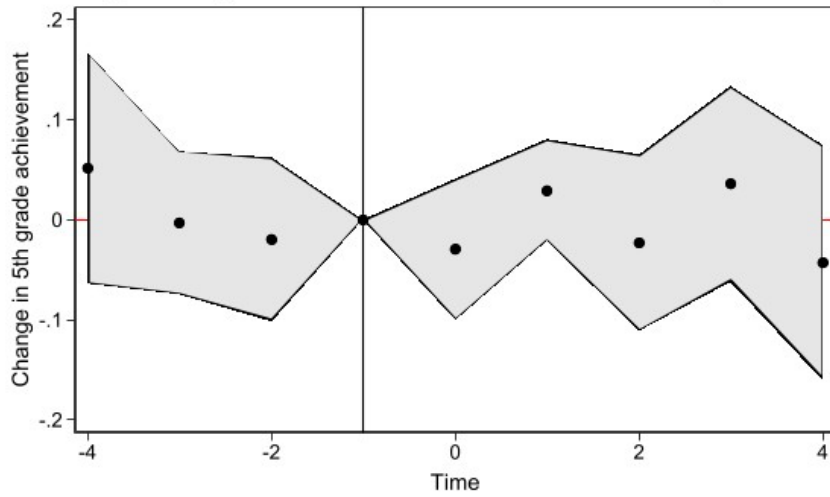
NOTES: 90% CONFIDENCE INTERVALS SHOWN

Henry et al. (2010) also demonstrate that no alternative treatments occurred at the cutoff between the 16 pilot districts (lowest SES), and the next-highest-scoring 16 districts on the scale of economic disadvantage. Because we use both DSSF treatment allocations in our study (pilot and statewide), we further show that higher SES districts did not allocate more local funds as supplements to “catch-up” with DSSF pilot districts. An event study plot shown in Appendix Figure 4 demonstrates that local contributions to PPE did not change concurrently with the DSSF court-ordered allocations.



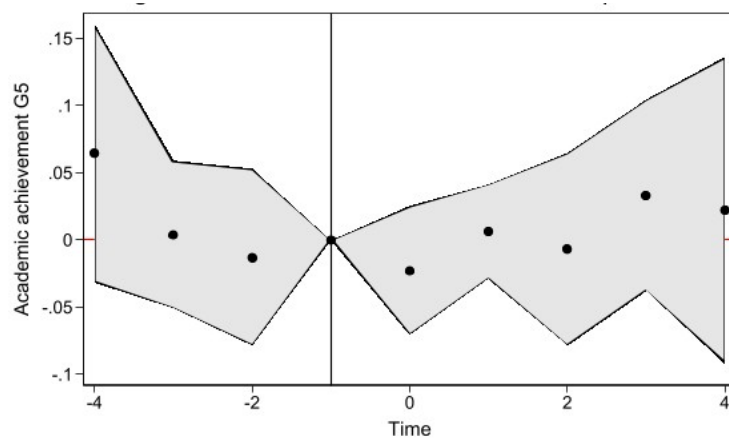
APPENDIX FIGURE 4. EVENT STUDY PLOT OF CHANGES IN LOCAL PPE FUNDING RELATIVE TO DSSF IMPLEMENTATION

C. Additional results



APPENDIX FIGURE 5. EVENT STUDY PLOT OF 5TH GRADE ACADEMIC ACHIEVEMENT RELATIVE TO DSSF IMPLEMENTATION

Notes: District-level data.



APPENDIX FIGURE 6. EVENT STUDY PLOT OF 5TH GRADE ACADEMIC ACHIEVEMENT RELATIVE TO DSSF IMPLEMENTATION USING STUDENT-LEVEL DATA

APPENDIX TABLE 3. SENSITIVITY OF EFFECTS OF NC PRE-K FUNDING ON ACADEMIC ACHIEVEMENT (FROM WATTS ET AL., 2023)

	Academic Achievement in 5 th Grade				
	(1)	(2)	(3)	(4)	(5)
NC Pre-K funding (\$000s)	0.030** (0.011)	0.033** (0.010)	0.011 (0.011)	0.026 (0.017)	0.031** (0.011)
Child and family controls	X		X		X
County controls	X	X			X
Smart Start funding					X
Time trends				X	
HS and EHS saturation					X
Fixed-effects	X	X	X	X	X
Observations	1,207,576	1,207,576	1,207,576	1,207,576	1,207,576

Notes: NC Pre-K funding operationalized as thousands of dollars in Watts et al, 2023, whereas the current study uses hundreds of dollars. Standard errors in parentheses and clustered at the county-level. + p<.10 * p<.05 ** p<.01 *** p<.001. Fixed effects= county and cohort. Child and family covariates include: child's sex (male), child's race and ethnicity (Black, Native American, Asian, Hispanic, Mixed race), child's birth weight (extremely low, very low, low, high), mother's education (less than high school), mother's marital status (married), mother's immigration status, mother's age (in years), whether a father was present at birth, first born status, mother's race and ethnicity (Black, Native American, Asian, Hispanic, other race). County covariates include: percent of births to Black mothers, percent of births to Hispanic mothers, percent of births to low-education mothers, number of births (log), total population (log), median family income, percent of population receiving food stamps, percent of population enrolled in Medicaid. HS=Head Start. EHS=Early Head Start. "Saturation" refers to the percentage of children, by age, in each county, that participated in either HS or EHS.