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Kai Hong
Kacie Dragan
Sherry Glied

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ABSTRACT

Prior research suggests that high quality universal pre-kindergarten (UPK) programs can generate lifetime benefits, but the mechanisms generating these effects are not well-understood. In 2014, New York City made all 4-year-old children eligible for high-quality UPK programs that emphasized developmental screening. We examine the effect of this program on the health and healthcare utilization of children enrolled in Medicaid using a difference-in-regression discontinuity design that exploits both the introduction of UPK and the fixed age cut-off for enrollment. The introduction of UPK increased the probability that a child was diagnosed with asthma or with vision problems, received treatment for hearing or vision problems, or received a screening during the prekindergarten year. UPK accelerated the timing of diagnoses of vision problems. We do not find any increases in injuries, infectious diseases, or overall utilization. These effects are not offset by lower screening rates in the kindergarten year, suggesting that one mechanism through which UPK might generate benefits is that it accelerates the rate at which children are identified with conditions that could potentially delay learning and cause behavioral problems. We do not find significant effects of having a child who was eligible for UPK on mothers' health, fertility, or healthcare utilization.

Kai Hong
Robert F. Wagner Graduate School
of Public Service
New York University
295 Lafayette Street, 2nd Floor
New York, NY 10012
kai.hong@nyu.edu

Kacie Dragan
Robert F. Wagner Graduate School
of Public Service
New York University
295 Lafayette Street, 2nd Floor
New York, NY 10012
kacie.dragan@nyu.edu

Sherry Glied
Robert F. Wagner Graduate School
of Public Service
New York University
295 Lafayette Street, 2nd Floor
New York, NY 10012
and NBER
sherry.glied@nyu.edu

1. Introduction

A growing body of literature suggests that early childhood education improves lifetime outcomes, especially for disadvantaged children (Heckman, 2011; Muennig, 2015). In response, many states have expanded funding for pre-kindergarten programs. By the 2014-2015 academic year, 42 states and District of Columbia had established state funded pre-K programs serving 4-year-olds. Across the nation 1.2 million 4-year-old children, who account for about 30% of the total population of 4-year-old children, were enrolled in a state funded pre-K program (Barnett et al., 2016).

While evidence for the long-term benefits of preschool is strong, it is more challenging to identify how these benefits are achieved. Many studies find that pre-K programs improve children's academic skills (literacy, language and math), cognition, and test scores (Weiland and Yoshikawa, 2013; Gormley and Gayer, 2005; Fitzpartick, 2008; Lipsey et al., 2013; Wong et al., 2008; Cascio and Schanzenbach, 2013; Hill, Gormley, and Adelstein, 2015; Gormley, Phillips, and Gayer, 2008) in the short run, but often find these effects fade out over time. Studies also find that these programs increase the frequency of screenings for developmental delays and chronic conditions (Zigler, Piotrkowski, and Collins, 1994; Janvier et al., 2016), which may enable better outcomes in subsequent years. However, studies of early childhood programs also find that early exposure to other children may have deleterious effects. Some studies find that children who attended such programs may be more aggressive and have lower self-control at school entry (Magnuson, Ruhm, and Waldfogel, 2007; Baker, Gruber, and Milligan, 2008).

One of the greatest challenges to studies of pre-K programs has been the heterogeneity of program components and quality (D'Onise et al., 2015). Many of the programs that have generated evidence of long-term effects are of higher quality than the typical program in the field today. Current spending per child in pre-K averages only about $4,500 (Barnett et al., 2016, measured as 2015 dollars), less than half the $11,009 spent on public education per pupil across the US (U.S. Census Bureau, Annual Survey of School System Finances). Many high-quality programs are very small. Inconsistency in policy and program implementation, as well as the very small sample sizes of many of these evaluations, may be responsible for contradictory or null results (Cohen and Syme, 2013; D'Onise et al., 2015; Rossin-Slater, 2015).

The introduction of universal pre-kindergarten (UPK) in New York City, the nation's largest school system, offers an opportunity to assess how a high quality UPK program affects health outcomes in the short-run. The substantial size of the program; the design and financing of the program which suggest that it offers care of relatively high quality; and the timing of the roll-out make the NYC case a valuable case-study.

As with other US UPK programs, New York's program is currently voluntary. This means that enrolled children may differ from those whose parents choose other options. An analysis that does not take into account the endogeneity of enrollment is likely to lead to biased results (Gormley and Gayer, 2005; Lipsey et al., 2015). We overcome the threat of endogenous enrollment in pre-K programs by using an age-cutoff regression discontinuity design (RDD), coupled with a difference-in-differences analysis. We take advantage of the strict age cutoff for UPK eligibility in NYC, which is December 31st, and divide the population of children into a treatment group who were born before the cutoff date and a control group who were born after the cutoff date of birth. The regression discontinuity design addresses the endogeneity of participation, but the trajectory of development at early ages is so steep that children just below the cutoffs are likely to be quite different developmentally than those just above the cutoff. To address this concern, we adopt a difference-in-regression-discontinuity design (DRD), by which we identify the effect of UPK program as the difference between the estimated effects on health of an RDD around the age cutoff for the year before the UPK expansion and an RDD around the age cutoff for the year after the UPK expansion.[1]

Our study contributes to the literature in several ways. First, while most of the existing literature on UPK programs focuses on school readiness, we examine the effect of a high-quality UPK program on a range of short-run health outcomes during the pre-K year and in the Kindergarten year. We focus on low-income children who are enrolled in Medicaid, a group that is the target for most UPK programs.[2,3] Second, the large-scale UPK program in NYC, with clear guidance and regulation, provides us with evidence from a relatively homogenous, high-quality program, as well as a large data set. Third, we adopt a difference-in-regression-discontinuity design to identify plausibly causal effects.

We find that the NYC UPK program led to increases in rates of diagnosis of asthma and vision problems, to increased rates of screening for immunization or infectious disease, and to increased rates of treatment of hearing and vision problems. UPK eligibility (attendance) increased the probabilities of being diagnosed with asthma and vision problems by 1.3 (3.8) and 1.9 (5.6) percentage points respectively, and the probabilities of receiving treatment of hearing and vision problems and immunization or infectious disease screening by 0.9 (2.6), 2.2 (6.5) and 2.5 (7.4) percentage points respectively. Our findings indicate that UPK might work by accelerating the rate at which children are identified with conditions that could potentially delay learning and cause behavioral problems. By contrast, we do not find significant effects of a child's UPK

[1] Smith (2015) uses a similar approach to estimate the effects of a pre-K program on adult criminal activity.
[2] Zerpa (2016) examines the effects of pre-K programs on various health outcomes 1-8 years after pre-K, exploiting variation in the timing of the implementation of pre-K programs across states. She finds increases in health problems in the first four years after preschool for both boys and girls.
[3] Cascio (2017) studies the effects of pre-K programs on test scores for low-income children. She finds that universal pre-K programs have positive effects on reading and math scores of low-income 4 year olds, but pre-K programs targeted toward disadvantaged children have no effect on low-income children.

eligibility on mothers' health, fertility or healthcare system utilization.

2. Institutional Background and Data Description

NYC's UPK Program

Since 1998 New York City has had a publicly financed pre-K program for which all four-year-old in New York City are eligible. However, due to funding limitations, the program served only a small share of the eligible population. In 2013, NYC's pre-K program enrolled 19,483 children in full-day programs and 39,045 in part-day programs, accounting for just 18% and 37% of the total eligible population respectively (Potter, 2015).

In 2013, following the election of Mayor Bill de Blasio, New York City designed and implemented a universal pre-kindergarten policy called "Pre-K For All," with the goal of providing every child in New York City with a seat in a pre-kindergarten free of charge. The rollout of this UPK policy was to be completed in two stages: a portion of the seats would be made available in September 2014, and the policy would be fully implemented by September 2015 with a full-day pre-kindergarten seat available for each eligible child. Data from December 2015 indicate that NYC's UPK policy increased the number of eligible New York City children enrolled in full-day pre-kindergarten rapidly and substantially -- from 19,483 in September 2013 (the year prior to the UPK policy rollout) to 53,000 in September 2014 and 68,000 in September 2015, which is roughly the same number of students as are enrolled in public (district and charter) kindergarten, suggesting nearly universal take-up for the public school population (Potter, 2015).[4]

To be eligible for NYC's UPK program, a child must reside in New York City and be between

[4] According to the U.S. Census Bureau there are about 115,000 four-year olds in NYC. The 40% of 4- year olds outside the UPK program are children who may attend private or parochial pre-kindergartens or who do not attend a formal pre-kindergarten.

3 years and 8 months of age and 4 years and 8 months of age at the start of the academic year—that is, children born in 2010 were eligible to begin pre-K in 2014, and children born in 2011 were eligible to begin pre-K in 2015. The NYC Department of Education could not guarantee placement for all children in the 2014 phase. In 2015, in line with the goal of the policy, all applicants were guaranteed placement at an NYC pre-kindergarten, although the location was not necessarily their first choice.[5]

Institutions offering pre-K in NYC can be district schools, charter schools or NYC early childhood centers. All programs are required to comply with the licensing and permitting requirements of their Licensing Agency, the NYC Department of Buildings (DOB), and the Fire Department of New York (FDNY). All staff members must meet the health requirements of the Department of Health and Mental Hygiene (DOHMH) and the New York City Department of Education (NYCDOE), and meet all qualification and certification requirements. All students must be immunized in accordance with New York Public Health Law §2164 and the requirements of the NYC Department of Health and Mental Hygiene (DOHMH), which includes specific requirements about toileting training and sanitary practices such as handwashing. Adequate, safe, clean and well-maintained facilities, instructional materials and furniture are also required in and out of the classroom. There are also strict guidelines for class size and staff to student ratios. Class sizes are capped at 20, with one trained early childhood teacher and one program assistant in each class. Finally, all programs are required to use a valid and reliable developmental screening tool to identify students with potential developmental delays and English Language Acquisition support needs, and they must perform this screening within the first 45 days of enrollment. Note that all children enrolled in NYC public schools must undergo

[5] In 2015, about 70% of the applicants got their most preferred location and 82% were placed in one of their top three choices (Harris, 2015).

immunizations and clinician (not school) – administered developmental screenings prior to starting Kindergarten. In addition, the NYC UPK program cost more than twice as much per pupil as the national average and has been lauded for its exceptionally high quality (Kirp, 2016).

In the 2014-2015 academic year, among the 53,000 enrolled UPK students, 12.9% were Asian, 30.0% were black, 37.1% were Hispanic, 16.5% were white, and 3.5% belonged to other races. This pattern was similar to that of those enrolled in public kindergarten in NYC. About three-quarters of UPK students attended at a school/center that had more than three-fourths students receiving free and reduced-price lunch. About 67% of UPK students were enrolled in a program in a neighborhood with below-median average family income (Potter, 2015).

Data

Our data are drawn from the complete NYC Medicaid utilization files for academic years 2013-2014, 2014-2015, and 2015-2016. We focus on children who were born between January 2008 and December 2012, and were enrolled in Medicaid in September of each relevant academic year.[6] Figure 1 documents the time scheme of the observations related to the initial expansion of UPK in 2014. In the 2013-2014 academic year (pre-UPK), children born in 2008 were eligible for kindergarten, children born in 2009 were eligible for existing pre-K programs, and children born in 2010 and 2011 were too young to be eligible for pre-K. After the expansion, in academic year 2014-2015, children born in 2010 became eligible for the UPK program, while those born in 2011 were too young and those born in 2008 and 2009 were too old to be eligible for the UPK program. The timing of observations allows us to compare outcomes in academic year 2014-2015 between either 1) children born in 2009 and 2010 (panel (a) of Figure 1), or 2) children born in 2010 and 2011 (panel (b) of Figure 1).

[6] About 3-4% of the children who satisfy those conditions churned off and on Medicaid during the following academic year. In Appendix C, we show that such attrition is not a concern for our main findings.

Figure 1: Timing of Observations

(a) Oldest children (born on January 1st, 2010)

	Academic year			
	2013-2014		2014-2015	
Birthdate	01/01/2008 - 12/31/2008	01/01/2009 - 12/31/2009	01/01/2009 - 12/31/2009	01/01/2010 - 12/31/2010
Grade	K	PK[(a)]	K	UPK
Average age	5	4	5	4

Expansion of UPK

(b) Youngest children (born on December 31st, 2010)

	Academic year			
	2013-2014		2014-2015	
Birthdate	01/01/2009 - 12/31/2009	01/01/2010 - 12/31/2010	01/01/2010 - 12/31/2010	01/01/2011 - 12/31/2011
Grade	PK[(a)]	-	UPK	-
Average age	4	3	4	3

Expansion of UPK

Note: (a) There were existing pre-K programs (non-universal) in NYC before the expansion in 2014.

We exclude children who were not eligible for NYC's pre-K program because of residency.[7] In total there are 65,678, 64,221, 65,863, 65,085, 65,082, 65,587, 64,739, 65,127, 64,431, 64,917 and 65,791 children who were enrolled in Medicaid during the follow-up period and were born in 2008 (for the 2013-2014 academic year), 2008 (for the 2014-2015 academic year), 2009 (for the 2013-2014 academic year), 2009 (for the 2014-2015 academic year), 2009 (for the 2015-2016 academic year), 2010 (for the 2013-2014 academic year), 2010 (for the 2014-2015 academic year), 2010 (for the 2015-2016 academic year), 2011 (for the 2014-2015 academic year), 2011 (for the 2015-2016 academic year) and 2012 (for the 2015-2016 academic year) respectively.

Table 1 summarizes the background and health/utilization indicators for these children for the

[7] To be eligible for NYC's pre-K program, a child needs the proof of residency when apply. The proof has to be recent within 60 to 90 days, depending on the document (utility bill, lease agreement, property tax bill, etc.). In our sample, we only include the children who lived in NYC from March through September of the year when the children became eligible.

academic years (September – June) corresponding to Figure 1, for both rollouts in 2014 and 2015. We focus on health outcomes that are most likely to be affected by UPK. These include injuries and infectious diseases, which may increase because of exposure to other children; immunizations and infectious disease screenings and regular checkups, which may be required for school attendance; and diagnosis and treatment of chronic conditions that may be initially identified by UPK staff (asthma, hearing and vision problems, developmental delays, ADHD, anxiety disorder). We also include a measure of overall Medicaid expenditures, to capture other diagnoses and conditions.

There are no striking differences in the observed demographic characteristics across the three cohorts. The treatment group (children born in 2010) and the control group (children born in either 2009 or 2011) for the initial UPK expansion in 2014 differ in several health and utilization indicators during academic year 2014-2015, after the introduction of UPK. However, many of these differences also exist in the prior year (before UPK). There are some marked differences among children by age. For example, older children are more likely to be diagnosed with asthma, vision problems and mental problems (ADHD and anxiety disorders) and to receive treatments for vision problems, and are less likely to be diagnosed with hearing problems, developmental delay and to have had a routine checkup.

Table 1: Descriptive Statistics of Demographic Variables, Health and Healthcare Utilization Indicators

Average age when the indicator is measured	3	3	3	4	4	4	5	5	5	6	6
Academic year when the indicator is measured	2013-2014	2014-2015	2015-2016	2013-2014	2014-2015	2015-2016	2013-2014	2014-2015	2015-2016	2014-2015	2015-2016
Birth year	2010	2011	2012	2009	2010	2011	2008	2009	2010	2008	2009
Demographics											
Male (%)	51.4	51.2	51.4	51.5	51.6	51.3	51.0	51.5	51.5	51.3	51.4
Race/Ethnicity (%)											
Black	21.5	20.3	18.8	21.9	20.6	19.6	21.9	20.8	19.9	21.0	20.0
White	16.8	17.0	16.8	16.6	16.6	16.4	16.1	16.5	16.1	16.1	16.0
Asian	10.9	11.5	12.1	11.1	11.1	11.4	11.6	11.5	11.0	11.6	11.4
Hispanic	33.8	31.5	28.3	34.3	32.5	29.7	34.6	33.0	30.8	33.4	31.3
Other	3.0	3.3	3.7	2.7	3.3	3.5	3.0	3.0	3.6	3.2	3.2
Health and healthcare utilization indicators											
Recorded Diagnoses (%)											
Asthma	12.5	12.8	12.5	13.4	14.8	14.6	14.5	14.8	15.2	14.4	13.7
Infectious disease	50.1	53.3	53.0	50.0	53.6	54.4	50.0	52.1	52.1	46.2	46.8
Injury	14.9	14.8	14.5	13.8	13.9	13.9	13.5	13.5	13.3	12.9	12.3
Hearing problems	4.3	4.3	4.1	4.1	4.2	4.1	3.4	3.4	3.6	2.9	2.9
Vision problems	5.0	4.9	5.6	10.5	11.8	13.3	15.1	15.3	15.3	16.8	17.0
ADHD	1.4	1.5	1.8	2.4	2.6	2.7	4.5	4.8	4.9	6.4	6.5
Anxiety disorder	0.5	0.6	0.6	1.0	1.1	1.2	1.8	2.2	1.9	2.9	2.7
Development delay	9.7	10.3	11.9	7.2	7.9	9.6	6.3	8.1	8.8	8.5	9.1
Treatment for Sensory Problems (%)											
Hearing problems	3.2	5.1	5.1	3.4	5.6	6.0	3.2	3.2	3.2	2.9	2.8
Vision problems	9.0	8.8	8.4	14.9	16.3	16.5	20.1	19.9	19.0	22.1	21.3
Routine and primary care (%)											
Routine checkup	68.8	70.0	63.2	66.9	67.3	59.9	58.3	59.4	53.6	57.7	50.8
Immunization or screening (%)											
Immunization or infectious disease screening	37.9	44.4	48.4	40.2	48.0	52.2	31.4	35.8	39.1	31.4	34.3
Aggregate Utilization											
Total Medicaid cost ($)	1588 (10728)	1747 (11170)	2099 (15339)	1370 (6827)	1771 (11016)	2069 (12660)	1593 (11243)	1557 (8061)	1964 (12796)	1776 (14544)	1847 (9136)
Sample size	65,587	64,431	65,791	65,863	64,739	64,917	65,678	65,085	65,127	64,221	65,082

Note: Standard deviations for the continuous variables are shown in parentheses. The omitted baseline category of race is declined/unknown. It increases slightly for each cohort because the completeness and accuracy of the race variable in Medicaid data increases with the age of the patient.
Asthma was defined as having one or more diagnoses of asthma during the pre-K year.
Common infectious diseases included flu, pneumonia, strep throat and related throat infections such as tonsillitis, the common cold, ear infections, and bacterial or viral conjunctivitis.
Hearing problems included all types of hearing impairment and loss (neural or conductive).
Vision problems included all types of vision impairment or loss (e.g., problems with perception or clarity).
Injury measures any damage due to external causes, including fractures, strains, sprains, bruises, open wounds, crush injuries, burns, and poisonings.
ADHD measures a clinical ADHD diagnosis or closely related condition, including conduct disorder, obsessive-compulsive behavior, and over-activity.
Anxiety disorder is a clinical adjustment or anxiety disorder diagnosis, including generalized anxiety disorder, any phobia, acute stress reaction, and post-traumatic stress disorder.
Development delay is a clinical developmental disorder diagnosis, including intellectual disabilities, autism, selective mutism, and dyslexia.
Routine checkup measures any routine medical examination (i.e., an annual or semi-annual physical exam), with or without abnormal findings.
Hearing treatment includes speech or hearing therapy related to poor hearing, insertion of ear drainage tubes, prescription and maintenance of hearing aids and cochlear implants, and procedures to correct abnormalities in the inner and outer ear affecting hearing (e.g., impacted cerumen, damaged middle ear structures, etc.).
Vision treatment includes prescription and maintenance of corrective lenses, vision therapy to improve binocular function, visual processing, and myopia, and surgery to correct muscular, retinal, lens, or corneal problems affecting vision (e.g., strabismus, detached retina, pediatric cataracts, etc.).
Immunization or infectious disease screening captures any visit involving an immunization or screening for any infectious disease.
The definitions are consistent with AHRQ's Clinical Classifications Software (CCS) system of categorizing diagnoses. Source: https://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccsfactsheet.jsp#what.

3. Analytical Framework

For children born in 2009 and 2010, the relationship between our 2014-2015 outcome measures and the introduction of UPK can be modeled as:

$$y_i = \alpha + \beta 1\{DOB_i \geq c\} + e_i, \quad (1)$$

where y_i is the health outcome of child i during academic year 2014-2015; $1\{DOB_i \geq c\}$ is an indicator of eligibility for UPK, which equals 1 if child i's date of birth DOB_i is after the age cutoff c (December 31st, 2009), α is the intercept, and e_i is the error term. β is the intent-to-treat (ITT) effect of the introduction of UPK on health and utilization indicator y_i.

The unobserved determinants of the health outcome may be correlated with child's age, as indicated in Table 1. If that is the case, a simple OLS estimation of equation (1) leads to a biased estimate of β. To address this problem, we take advantage of the UPK eligibility rules in an age-cutoff RDD approach. To be eligible for the pre-K program starting in September, children must be at least 3 years and 8 months old at the beginning of that year. For example, only children who were born from January 1st, 2010 to December 31st, 2010 were eligible to participate in UPK in September 2014. We keep in the sample children who were born in a small window close to the cutoff of December 31st, e.g., a 60-day bandwidth, and estimate the following (sharp) RDD:

$$y_i = \alpha + \beta 1\{DOB_i \geq c\} + f(DOB_i - c) + e_i, \quad (2)$$

where $f(DOB_i - c)$ is a linear piecewise function and $f(DOB_i - c) = \gamma_1(DOB_i - c) + \gamma_2 1\{DOB_i \geq c\}(DOB_i - c)$. All other parameters are defined in the same way as equation (1). β is the ITT effect of UPK on health and utilization indicator y_i for children who were born at the cutoff.

An alternative approach to this problem would be to use a difference-in-differences (DID) approach. We estimate the following DID by adding outcomes in the 2013-2014 academic year for children born in 2008 and 2009 as the baseline:[8]

$$y_{it} = \alpha + \theta 1\{DOB_i \geq c_t\}1\{t = 2014\} + \rho_1 1\{DOB_i \geq c_t\} + \rho_2 1\{t = 2014\} + \varepsilon_{it}, \quad (3)$$

where subscript t indicates academic year, y_{it} is the health and utilization indicator, which is measured during the 2013-2014 academic year for children born in 2008 and 2009, and during the 2014-2015 academic year for children born in 2009 and 2010. $1\{t = 2014\}$ is an indicator for the 2014-2015 academic year. It equals one if the observation comes from the 2014-2015 academic year (post-UPK). The indicator equals to zero if the observation comes from the 2013-2014 academic year before the UPK expansion (pre-UPK).[9]

The ITT effect of the UPK is identified as θ in equation (3), which is the difference between the average effects of UPK on the 2010 cohort (compared with the 2009 cohort) and the 2009 cohort (compared with the 2008 cohort). To interpret θ as a causal effect, we make a "common trend" assumption: without the expansion of UPK, the observed differences in the 2014-2015 academic year between children born in 2010 and 2009 would be the same as the differences in the 2013-2014 academic year between children born in 2009 and 2008.

In our setting, the RDD and the DID approaches alone may not work well. Even children within a small neighborhood around the cutoff can be quite different because of the steep developmental trajectory at early ages, making the RDD approach problematic, since health outcomes may not go across the cutoff smoothly. The common trend assumption in the DID approach may not hold as there could be other relevant policy changes at the same time as UPK expansion. To address these possibilities, we combine the RDD approach with the DID approach

[8] We don't add the outcomes in the 2013-2014 academic year for the same cohorts (the children born in 2009 and 2010) as the baseline because we want to have the outcomes measured at the same age in the treatment or control group. This makes the two "differences" comparable.
[9] Equivalently, the indicator $1\{t = 2014\}$ also indicates that the comparison is between the child born in 2009 and 2010, which uses the outcomes measured in the 2014-2015 academic year.

to get a difference-in-regression-discontinuity design (DRD). The DRD approach accounts for the potential relative pre-existing differences at the cutoff of the standard RDD and other policy changes. Specifically, we estimate the following DRD:

$$y_{it} = \alpha + \theta 1\{DOB_i \geq c_t\}1\{t = 2014\} + \rho_1 1\{DOB_i \geq c_t\} + \rho_2 1\{t = 2014\} + \rho_3(DOB_i - c_t) + \rho_4 1\{DOB_i \geq c_t\}(DOB_i - c_t) + \rho_5 1\{t = 2014\}\{DOB_i \geq c_t\}(DOB_i - c_t) + \varepsilon_{it}, \quad (4)$$

where all of the variables are defined in the same way as equation (3). Using the DRD specification, we estimate the effects of UPK at two cutoffs simultaneously ($\theta + \rho_1$ for the cutoff of December 31st, 2009, and ρ_1 for the cutoff of December 31st, 2008). The ITT effect of UPK is identified as θ in equation (4) as the difference between these two effects at the eligibility cutoffs. We can now interpret θ as a causal effect under a much weaker "common trend" assumption: without the expansion of UPK, the observed differences in the 2014-2015 academic year between children born in a small neighborhood around December 31st, 2009, would be the same as the differences in the 2013-2014 academic year between children born in a small neighborhood around December 31st, 2008. [10] It seems very plausible that this common trend holds when we restrict the comparison to the children with ages around the cutoffs.

The effect identified by equation (4) as described above is the effect for the oldest children relative to their cohorts in the same grade, as they are the only group that were eligible for UPK after the expansion in 2014 (see panel (a) of Figure 1). The other three groups were too old to be eligible for UPK in the 2014-2015 academic year. We can also obtain the effect for the youngest children relative to their cohorts in the same grade by estimating the same equation (4) but using the outcomes in the 2013-2014 academic year for the children born in 2009 and 2010, and the outcomes in the 2014-2015 academic year for the children born in 2010 and 2011. The estimated

[10] Alternatively, the assumption can be interpreted from the RDD perspective: conditional on pre-existing differences in health outcomes, all health determinates (observed or unobserved) except for the eligibility status, evolves smoothly with respect to age (birth date) around the cutoff.

effect is the effect for the youngest children relative to their cohorts in the same grade because again they are the only group that were eligible for UPK in the 2014-2015 academic year (see panel (b) of Figure 1). Finally, we can also pool the estimation samples together to obtain the averaged total effect for the oldest and the youngest children, by adding a sample fixed effect to equation (4). The specification is the following:

$$y_{it} = \alpha + \theta 1\{DOB_i \geq c_t\}1\{t = 2014\} + \rho_1 1\{DOB_i \geq c_t\} + \rho_2 1\{t = 2014\} + \rho_3 (DOB_i - c_t) + \rho_4 1\{DOB_i \geq c_t\}(DOB_i - c_t) + \rho_5 1\{t = 2014\}\{DOB_i \geq c_t\}(DOB_i - c_t) + d_i + \varepsilon_{it}, \quad (5)$$

where d_i is the sample fixed effect indicating that the observation comes from the sample for the oldest children, corresponding to panel (a) in Figure 1. All other variables and parameters are the same as equation (4).

4. Empirical Results

Graphical Analysis

In Appendix A, Figure A1 illustrates how health outcomes and healthcare utilization in the 2013-2014 and the 2014-2015 academic years change by age relative to the cutoffs, which are December 31st, 2008 for children born in 2008 and 2009 (before the UPK expansion), and December 31st, 2009 for children born in 2009 and 2010 (after the UPK expansion), respectively. We observe discontinuities in most of the examined health outcomes and healthcare utilizations, but for most outcomes we also observe similar patterns before the UPK expansion.[11]

[11] For example, compared with children around the cutoff who are ineligible for the UPK expansion in 2014, marginally eligible children are more likely to be diagnosed with asthma, hearing and vision problems, and to get treatment for hearing and vision problems. They are less likely to get injury and to be diagnosed with ADHD and anxiety disorder.

Difference-in-Regression-Discontinuity Design

The DRD approach allows for the existence of differences before the treatment, and imposes a "common trend" assumption that such difference would remain the same if the treatment had not been implemented, but only for the children around the cutoffs.[12] We estimate equations (4) and (5) using children born in a 120-day window around the cutoff.[13] Table 2 report the estimation results for both the oldest and the youngest children, and the pooled sample.[14]

We find few impacts of UPK on health diagnoses and utilization indicators with three exceptions. Eligible children are about 2 percentage points more likely to have a diagnosis of vision problems recorded, for both the oldest children and the youngest children. They are more likely to have had a diagnosis of asthma recorded (1.3 percentage points for the oldest children, 2.1 percentage points for the youngest children). They are more likely to receive treatment for hearing problems (about 1 percentage point) and vision problems (about 2 percentage points for both the oldest and the youngest children). They are also more likely to have had an immunization or infectious disease screening (5.4 percentage points for the oldest children, 2.9 percentage points for the youngest children).

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[12] For the purpose of comparison, we conduct conventional regression discontinuity design (RDD) and difference-in-differences (DID) approaches in Appendix B.

[13] We also check that whether our results are sensitive to model choice by re-estimating the model using a logit model for binary outcomes. While not shown here, the results from this alternative specification are largely consistent with our main results. The estimation results from the logit model are available upon request.

[14] A potential threat to the common trend assumption of DRD would be perfect manipulation of birth date. It may be possible in a few cases for parents to choose whether a baby is delivered on December 31st or January 1st, but very few Medicaid parents are likely to have manipulated birthdate in this way. We formally examine whether there is any evidence of manipulation by displaying the distribution of birthdate observed in our data. Figure A2 in Appendix A is a histogram that shows the distributions of children by date of birth around the four cutoffs (December 31st of 2008, 2009, 2010 and 2011). There is clearly no evidence of manipulation around the cutoffs. The date of birth follows an approximately uniform distribution within the 120-day window around the cutoff.

Table 2: Impacts of UPK on Four-year-old Health and Healthcare Utilization Indicators

	The oldest			The youngest			Pooled
	before expansion (a)	after expansion (b)	(b)-(a) (main) (c)	before expansion (d)	after expansion (e)	(e)-(d) (main) (f)	main
Recorded Diagnoses							
Asthma	-0.024*** (0.009)	-0.011 (0.010)	0.013 (0.012)	0.012 (0.009)	0.033*** (0.009)	0.021* (0.012)	0.013** (0.006)
Infectious disease	-0.063*** (0.014)	-0.046*** (0.014)	0.017 (0.017)	0.036*** (0.013)	0.039*** (0.013)	0.002 (0.017)	0.006 (0.008)
Injury	-0.012 (0.009)	-0.016* (0.009)	-0.005 (0.012)	0.012 (0.010)	0.010 (0.009)	-0.002 (0.012)	-0.003 (0.006)
Hearing problems	0.001 (0.005)	0.001 (0.005)	-0.001 (0.007)	-0.001 (0.006)	-0.007 (0.006)	-0.005 (0.007)	-0.001 (0.003)
Vision problems	-0.037*** (0.009)	-0.015* (0.009)	0.021* (0.011)	0.023*** (0.007)	0.044*** (0.008)	0.021** (0.009)	0.019*** (0.005)
ADHD	-0.017*** (0.005)	-0.012** (0.005)	0.005 (0.006)	0.002 (0.004)	0.005 (0.004)	0.003 (0.005)	0.003 (0.003)
Anxiety disorder	-0.007** (0.003)	-0.007** (0.003)	0.000 (0.004)	0.006** (0.003)	0.003 (0.003)	-0.003 (0.003)	-0.002 (0.002)
Development delay	-0.003 (0.007)	-0.013* (0.007)	-0.011 (0.009)	0.014* (0.007)	0.026*** (0.008)	0.013 (0.009)	0.000 (0.004)
Treatment for Sensory problems							
Hearing problems	-0.003 (0.005)	0.010* (0.006)	0.013* (0.007)	0.001 (0.005)	-0.000 (0.006)	-0.001 (0.007)	0.009*** (0.003)
Vision problems	-0.048*** (0.010)	-0.029*** (0.010)	0.020 (0.013)	0.027*** (0.009)	0.047*** (0.009)	0.021* (0.011)	0.022*** (0.006)
Routine care							
Routine checkup	0.027** (0.013)	0.031** (0.013)	0.004 (0.016)	0.001 (0.012)	-0.011 (0.012)	-0.012 (0.014)	-0.008 (0.007)
Immunization or screening							
Immunization or infectious disease screening	0.006 (0.013)	0.060*** (0.013)	0.054*** (0.017)	-0.013 (0.013)	0.016 (0.013)	0.029* (0.017)	0.025*** (0.008)
Aggregate Utilization							
Total Medicaid cost (ln$)	-0.076 (0.061)	-0.109* (0.060)	-0.033 (0.077)	0.178*** (0.061)	0.188*** (0.060)	0.010 (0.074)	0.008 (0.035)
Sample size	42,709			42,410			85,119

Note: The specification estimated in the table is equation (4) for the oldest and youngest children, and equation (5) for the pooled sample. Only children within the 120-day window are included. Robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% level, respectively.

5. Robustness checks and Interpretations

Robustness Checks with Alternative Bandwidths and Specifications

In our main analysis, we use a 60-day bandwidth around the cutoff. We also check whether our results are robust to alternative bandwidths: 15 days, 30 days, 90 days, 120 days, outcome-specific IK optimal bandwidth (Imbens and Kalyanaraman, 2011) and CCT optimal bandwidth (Calonico, Cattaneo, and Titiunik, 2014). In Appendix D, Table D1 presents the estimation results of the total effects from different bandwidths. Overall our estimated effects are robust to the choice of bandwidth. We also check whether our main results are robust to different specifications. We re-estimate equation (5) controlling for quadratic or cubic piece-wise polynomial of the forcing variable, for both local and global estimations. The results are presented in Table D2 in Appendix D. Overall, our main results, are robust to model specifications. Finally, we check to see whether our results hold over a full year (rather than an academic year). These results are presented in Table D3 in Appendix D. Again, the results are robust to this alternative specification. In Table D3 we also check whether our results hold for the first half (September to December) of an academic year. Overall the results are robust, except for smaller (but still significant) effects on vision problems and treatments and an insignificant effect on hearing treatment.

Heterogenous Effects by Gender and Ethnicity

The existing literature suggests that boys and girls benefit differently from pre-K programs (Zerpa, 2016). The effects of pre-K may also differ by ethnicity. To explore potential heterogeneous effects by gender and ethnicity, we re-estimate the main model by demographic groups separately. Table 3 summarizes the estimation results for the pooled sample.

Notably, the findings for immunizations and screenings hold similarly for boys and girls and are statistically comparable across all race/ethnicity groups. By contrast, diagnoses of asthma are concentrated among boys and among Hispanics. Treatment of vision problems increases for both boys and girls, and more among Hispanics than among other groups, while the effect of UPK on treatment for hearing problems is greater among boys and Whites.

Table 3: Impacts of UPK on Four-year-old Health and Healthcare Utilization Indicators by Gender and Ethnicity, Pooled Sample

	By gender (a)		By ethnicity (b)			
	Boy	**Girl**	**White**	**Black**	**Asian**	**Hispanic**
Recorded Diagnoses						
Asthma	0.020** (0.008)	0.006 (0.007)	0.006 (0.010)	0.005 (0.013)	0.000 (0.015)	0.031*** (0.010)
Infectious disease	-0.003 (0.011)	0.015 (0.011)	-0.006 (0.018)	0.011 (0.016)	-0.035 (0.022)	0.036*** (0.014)
Injury	0.002 (0.008)	-0.008 (0.007)	-0.011 (0.014)	-0.004 (0.011)	-0.031* (0.017)	0.013 (0.010)
Hearing problems	0.002 (0.005)	-0.005 (0.004)	0.026*** (0.009)	-0.007 (0.005)	-0.006 (0.009)	-0.007 (0.006)
Vision problems	0.019*** (0.007)	0.019*** (0.007)	-0.004 (0.011)	0.009 (0.010)	0.016 (0.015)	0.036*** (0.009)
ADHD	0.004 (0.004)	0.001 (0.003)	-0.010** (0.005)	0.002 (0.006)	0.002 (0.006)	0.010* (0.005)
Anxiety disorder	0.000 (0.003)	-0.005** (0.002)	-0.002 (0.003)	-0.002 (0.003)	-0.002 (0.004)	-0.002 (0.004)
Development delay	0.006 (0.007)	-0.006 (0.005)	0.007 (0.009)	-0.010 (0.009)	-0.009 (0.011)	0.010 (0.008)
Treatment for sensory problems						
Hearing problems	0.014*** (0.005)	0.003 (0.004)	0.019** (0.009)	0.008 (0.006)	0.013 (0.011)	0.004 (0.006)
Vision problems	0.014* (0.008)	0.032*** (0.008)	0.015 (0.015)	0.013 (0.011)	0.003 (0.019)	0.035*** (0.010)
Routine and primary care						
Routine checkup	-0.003 (0.010)	-0.014 (0.010)	-0.025 (0.019)	-0.006 (0.016)	-0.009 (0.020)	-0.006 (0.012)
Routine dental exam	-0.008 (0.011)	-0.013 (0.011)	-0.049** (0.019)	0.005 (0.016)	-0.005 (0.024)	0.005 (0.014)
Immunization or screening						
Immunization or infectious disease screening	0.026** (0.011)	0.023** (0.011)	0.028 (0.018)	0.031* (0.017)	0.008 (0.023)	0.014 (0.014)
Aggregate Utilization						
Total Medicaid cost (ln$)	0.034 (0.050)	-0.021 (0.050)	-0.062 (0.081)	0.014 (0.084)	0.001 (0.100)	0.110* (0.058)
Sample size	43,948	41,171	14,021	18,261	9,514	28,410

Note: The specification estimated in the table is equation (5) with the children in the 120-day window. Robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% level, respectively.

Effect of the Expansion in 2015

In 2015 there was a smaller, second expansion of UPK. The number of enrollees increased from 53,000 in September 2014 to 68,000 in September 2015. We next test the robustness of our results using this second year expansion. Figure 2 shows the timing of observations for the 1st-year effect in 2015, which is similar with Figure 1 for the 1st-year effect in 2014. We use the same specification to estimate the effects of the 1st-year effect in 2015, except that we continue to compare to the non-universal pre-K before the expansion in 2014.

Figure 2: Timing of Observations, 1st-Year Effect in 2015

(a) Oldest children (born on January 1st, 2011)

	Academic year			
	2013-2014		2015-2016	
Birthdate	01/01/2008 - 12/31/2008	01/01/2009 - 12/31/2009	01/01/2010 - 12/31/2010	01/01/2011 - 12/31/2011
Grade	K	PK(a)	K	UPK
Average age	5	4	5	4

Expansion of UPK

(b) Youngest children (born on December 31st, 2011)

	Academic year			
	2013-2014		2015-2016	
Birthdate	01/01/2009 - 12/31/2009	01/01/2010 - 12/31/2010	01/01/2011 - 12/31/2011	01/01/2012 - 12/31/2012
Grade	PK(a)	-	UPK	-
Average age	4	3	4	3

Expansion of UPK

Note: (a) There were existing pre-K programs (non-universal) in NYC before the expansion in 2014.

Table 4 summarizes the estimated effects for the oldest, youngest and pooled samples. We find some variation in effects – asthma is no longer significant, while infectious disease diagnoses increase. The effects on immunizations and screening, diagnosis of vision problems, and treatment of hearing and vision problems, however, remain quite consistent across the two years and are larger in magnitude in the second comparison (where more students are enrolled in UPK). Taking into account that the second expansion enrolled more students, the TOT effects are also consistent across the two years, as shown later in section 7.

Table 4: Impacts of UPK on Four-year-old Health and Healthcare Utilization Indicators, Second Expansion

	The oldest	The youngest	Pooled
Recorded diagnoses			
Asthma	0.005 (0.012)	0.003 (0.012)	0.005 (0.006)
Infectious disease	0.021 (0.017)	0.015 (0.017)	0.017** (0.008)
Injury	-0.007 (0.012)	-0.012 (0.012)	-0.000 (0.005)
Hearing problems	-0.007 (0.006)	0.002 (0.007)	-0.002 (0.003)
Vision problems	0.028** (0.012)	0.020** (0.010)	0.024*** (0.005)
ADHD	-0.002 (0.006)	-0.004 (0.005)	-0.003 (0.003)
Anxiety disorder	0.002 (0.004)	-0.004 (0.003)	-0.001 (0.002)
Development delay	-0.014 (0.009)	0.001 (0.010)	-0.004 (0.004)
Treatment for sensory problems			
Hearing problems	0.033** (0.007)	0.003 (0.007)	0.016*** (0.003)
Vision problems	0.032** (0.013)	0.026** (0.011)	0.027*** (0.006)
Routine and primary care			
Routine checkup	-0.003 (0.016)	-0.010 (0.015)	-0.010 (0.007)
Immunization or screening			
Immunization or infectious disease screening	0.038** (0.017)	0.003 (0.017)	0.020*** (0.008)
Aggregate Utilization			
Total Medicaid cost (ln$)	-0.017 (0.080)	-0.037 (0.078)	0.007 (0.037)
Sample size	43,264	42,412	85,676

Note: The specification estimated in the table is equation (4) for the oldest and youngest children, and equation (5) for the pooled sample. Only children within the 120-day window are included. standard errors are shown in parentheses. **, and *** indicate statistical significance at 5% and 1% level, respectively.

6. Effects over Time

Virtually all children enrolled in UPK who remain living in NYC progress to Kindergarten a year later. Asthma and hearing and vision problems tend to be chronic conditions. In the absence of UPK, children might have been diagnosed with these conditions a year later, when they entered kindergarten. To assess these possibilities, we follow the oldest children and analyze whom we can follow through their entry into kindergarten in the 2015-2016 academic year, the year following UPK.

Timing of Treatments of Sensory Problems

UPK may help accelerate identification and treatment sensory problems that affect children's learning and developments at an earlier stage. Specifically, we model the hazard of first treatment by the following Cox proportional hazards model:

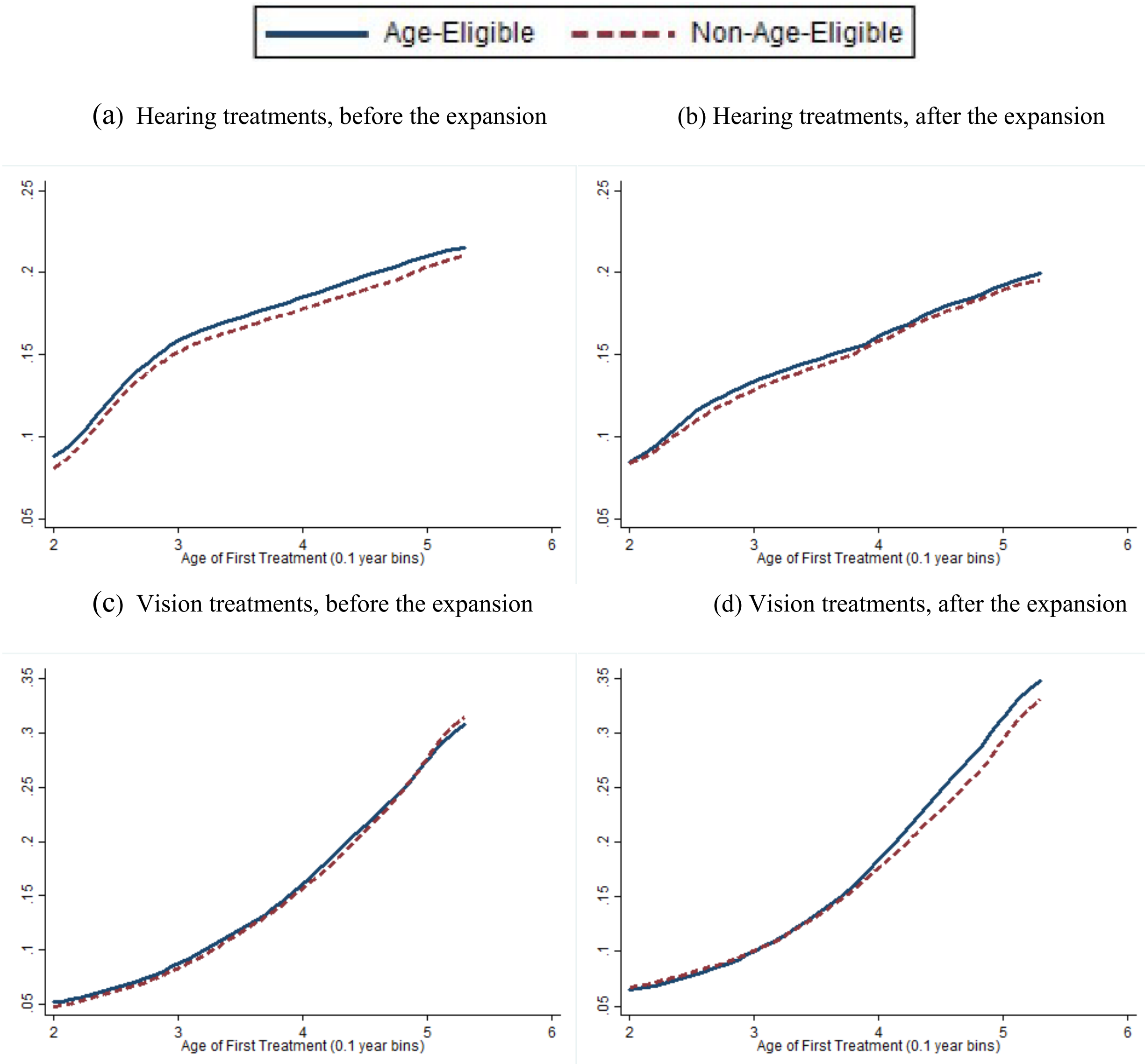
$$h(\tau_{it}) = h_0(\tau)g(DOB_i - c_t), \quad (6)$$

where $h(\tau_{it})$ is the hazard of the first treatment at age τ, $h_0(\tau)$ is the baseline hazard that is left unspecified, and $g(DOB_i - c_t) = exp(\theta 1\{DOB_i \geq c_t\}1\{t = 2014\} + \rho_1 1\{DOB_i \geq c_t\} + \rho_2 1\{t = 2014\} + \rho_3(DOB_i - c_t) + \rho_4 1\{DOB_i \geq c_t\}(DOB_i - c_t) + \rho_5 1\{t = 2014\}\{DOB_i \geq c_t\}(DOB_i - c_t) + d_i)$. All the variables and parameters in $g(DOB_i - c_t)$ are the same as equation (5).[15]

θ is the effect of UPK on the hazard of the first treatment of sensory problems. In our sample, the most common treatments of hearing problems are removing impacted cerumen (40%) and speech/hearing therapy (28%), and the major treatments of vision problems are eye exam to evaluate problems (55%) and purchase of frames (26%). Figure 3 compares the estimated Nelson-Aalen cumulative hazard of first treatment for the age-eligible and non-age-eligible groups, before and after the expansion of UPK.

[15] A detailed discussion about incorporating RDD to a survival analysis framework can be found in Bor et al., (2014). The Cox proportional hazards model does not allow for omitting important explanatory variables, no matter whether they are endogenous or not. In Appendix E we re-estimate the impact via accelerated failure-time (AFT) models that allow for omitted explanatory variables. The results show that our findings are robust to omitted explanatory variables.

Figure 3: Cumulative Hazard of First Treatment of Hearing and Vision Problems



(a) Hearing treatments, before the expansion

(b) Hearing treatments, after the expansion

(c) Vision treatments, before the expansion

(d) Vision treatments, after the expansion

Note: The polynomial lines represent local mean smoothing of the estimated Nelson-Aalen cumulative hazard of the first treatment, starting from 2-year old and using a bandwidth of 0.1 years. We do not have hazard of the first treatment for the total sample after age 5.3 because thereafter the data for the youngest children becomes unavailable.

Panel (a) and (b) compare the cumulative hazard of the first treatment of hearing problems. We find little effect of the introduction of UPK on the pattern of hearing treatment of age-eligible children relative to non-eligible children. Panel (c) and (d) compare the cumulative hazard of the first treatment of vision problems. Before the expansion there is almost no difference in the hazard between the age-eligible and non-age-eligible groups. After the expansion, there is still no initial difference in treatment until about age 4 (the entry age for UPK), after which we observe significantly higher hazard for the eligible children. Overall UPK significantly increases the hazard of the first treatment of vision problems between ages 4 and 5. Details about the survival analysis can be found in Appendix E.[16]

Utilization During the Kindergarten Year

Utilization of diagnostic and treatment services in the pre-kindergarten year may be offset by lower rates of use of these services during the kindergarten year. To assess this, we directly examine utilization of services in the kindergarten year (second year effects of UPK). Figure 4 shows the timeline for the analysis of the second-year effects. Again, as in panel (a) of Figure 1, children born after January 1st, 2010 are the only group that is eligible for the expanded UPK. All the outcomes are measured in the second year after the UPK year, so the children are in either grade 1 or kindergarten, and aged 6 or 5.[17]

Figure 4: Timing of Observations, Second-Year Effect

	Academic year			
	2014-2015		2015-2016	
Birthdate	01/01/2008 - 12/31/2008	01/01/2009 - 12/31/2009	01/01/2009 - 12/31/2009	01/01/2010 - 12/31/2010
Grade	1	K	1	K
Average age	6	5	6	5

Expansion of UPK (Second Year)

There is considerable persistence in diagnoses from the UPK to the kindergarten year. Table 5 shows the persistence of diagnoses in the UPK cohort and the control cohort.

[16] While not shown there, the effect of UPK between age 5 and 6, which is basically for the oldest children, is not statistically significant for either hearing or vision treatments.

[17] We can't estimate second-year effect for the youngest children because in their case the comparison group, which was too young to be eligible for the UPK at the time of expansion, has become eligible for pre-K.

Table 5: Fraction of Children with a Diagnosis Recorded in the Kindergarten Year by whether They have the Same Diagnosis recorded in the Pre-K Year

	Outcome in Pre-K Year			
	Yes		No	
Outcome in Kindergarten Year	**2009 Cohort (non-eligible) (a)**	**2010 Cohort (eligible) (b)**	**2009 Cohort (non-eligible) (c)**	**2010 Cohort (eligible) (d)**
Recorded Diagnosis (%)				
Asthma	65.5	67.5	7.1	6.5
Infectious disease	67.9	66.6	37.7	34.0
Injury	22.9	19.7	13.3	12.0
Hearing problems	25.5	27.8	2.6	2.1
Vision problems	42.6	41.9	11.9	11.7
ADHD	51.3	49.7	4.0	3.4
Anxiety disorder	31.3	24.5	1.8	1.6
Development delay	53.6	51.0	5.3	4.7
Treatment for sensory problems (%)				
Hearing problems	25.6	16.6	2.9	2.3
Vision problems	50.0	46.2	14.3	13.7
Routine and primary care (%)				
Routine checkup	69.5	59.5	47.1	41.6
Immunization or screening (%)				
Immunization or infectious disease screening	53.2	51.3	26.1	26.5

Note: The table shows the percentage of children with the corresponding diagnose in kindergarten year, among the children in the 120-day window with the same diagnose in pre-K year. For example, among all children born in November and December of 2009 with (without) asthma in pre-K year (2013-2014 academic year), 65.5% (7.1%) were diagnosed with asthma in kindergarten year (2014-2015 academic year).

Table 6 present the estimation results for the second academic year in kindergarten. We observe no offsetting reductions in the diagnosis of asthma, hearing or vision problems and any immunization or infectious disease screening over the total sample. We next estimate the same DRD model for those children who had diagnoses or treatments in the pre-K year to assess whether earlier diagnoses were more likely to be spurious or offset under the UPK regime. We find evidence that treatment of hearing problems diagnosed in the pre-K year is more likely to continue among the children exposed to UPK, and that children who had an immunization or screening service in pre-K under the UPK regime were less likely to have one in the subsequent year, but we find no other offsetting reductions in diagnosis or treatment in this group.

Table 6: Second Year Impacts of UPK

	First-Year Effect (a)	Second-Year Effect (b)	
	The oldest	Total – oldest cohort	Have diagnosis in pre-K year
Recorded Diagnoses			
Asthma	0.013 (0.012)	0.008 (0.013)	0.037 (0.045)
Infectious disease	0.017 (0.017)	0.001 (0.018)	-0.024 (0.024)
Injury	-0.005 (0.012)	0.019 (0.012)	0.008 (0.037)
Hearing problems	-0.001 (0.007)	0.001 (0.006)	-0.018 (0.077)
Vision problems	0.021* (0.011)	-0.007 (0.012)	-0.034 (0.050)
ADHD	0.005 (0.006)	-0.002 (0.008)	-0.029 (0.106)
Anxiety disorder	0.000 (0.004)	0.003 (0.005)	-0.049 (0.142)
Development delay	-0.011 (0.009)	-0.007 (0.010)	-0.039 (0.064)
Treatment for sensory problems			
Hearing problems	0.013* (0.007)	0.000 (0.006)	0.128* (0.068)
Vision problems	0.020 (0.013)	-0.003 (0.013)	0.027 (0.044)
Routine and primary care			
Routine checkup	0.004 (0.016)	-0.005 (0.018)	-0.010 (0.020)
Immunization or screening			
Immunization or infectious disease screening	0.054*** (0.017)	0.014 (0.017)	-0.050* (0.027)
Aggregate Utilization			
Total Medicaid cost (ln$)	-0.062 (0.077)	-0.182** (0.082)	-
Sample size	42,709	39,535	-

Note: The specification estimated in the table is equation (4). Only children within the 120-day window are included. Robust standard errors are shown in parentheses. *, and *** indicate statistical significance at 10% and 1% level, respectively.

7. Implied Treatment-on-Treated (TOT) Effect

Our analyses provide estimates of the ITT effect of UPK, which provides insights about the effect of UPK policy. In comparing these results with prior studies of the effects of early childhood education, it is useful to construct TOT estimates, which measure the effect of participation in UPK. We are not able to directly estimate the TOT effect because we do not have actual enrollment data, but we can calculate the approximate TOT effects implied by our estimated ITT effect using enrollment information from other sources.

The TOT effect can be calculated by dividing the estimated ITT effect by the change in the pre-K enrollment rate of four-year-old children enrolled in Medicaid during the first year after the UPK expansion. The overall change in the pre-K enrollment rate for NYC from 2013-2014 to 2014-2015 was about 32% (Potter, 2015). The increase is likely to have been larger for our sample of Medicaid enrollees: one estimate shows the change in the pre-K enrollment rate for the bottom two quintiles of the household income distribution between 2013 and 2014 was about 34% (University of California, Berkeley. Institute of Human Development, 2015). Using this figure, our TOT estimate suggests that for those compliers who would attend UPK if eligible and would not attend UPK if not eligible, attending UPK increases the probability of being diagnosed with asthma by 3.8 percentage points, the probability of being diagnosed with vision problems by 5.6 percentage points, and the likelihood of receiving an immunization or infectious disease screening by 7.4 percentage points. The probabilities of receiving hearing and vision treatments increase by 2.6 and 6.5 percentage points among those attending UPK. Relative to the baseline rates reported in Table 1, these constitute treatment increases of 63% and 45% respectively.

For the second expansion in 2015, the change in the pre-K enrollment rate for the bottom two quintiles of the household income distribution between 2013 and 2015 was about 51% (Shapiro and Cheney, 2015; University of California, Berkeley. Institute of Human Development, 2015). Our TOT estimate suggests that the 2015 expansion increases the probability of vision problem diagnosis, receiving hearing treatment and vision treatment by 4.7, 3.1 and 5.3 percentage points, respectively. The 2015 expansion increases the probability of receiving immunization and infectious disease diagnosis by 3.9 and 3.3 percentage points.

8. Effect on Mothers' Health

A potential channel for the UPK to affect children's health is mothers' health. The existing literature provides some evidence about how early child care affects maternal health and well-being. The introduction of subsidized universal child care in Quebec, Canada, led to worse parental health (Baker, Gruber, and Milligan, 2008; Brodeur and Connolly, 2013; Kottelenberg and Lehrer, 2013), higher maternal depression and lower-quality parental relationships (Baker, Gruber, and Milligan, 2008; Kottelenberg and Lehrer, 2013). Using data from the Child Care and Development Fund (CCDF) in the United States, Herbst and Tekin (2014) find that mothers who receive child care subsidies report lower health and are more likely to have mental health problems such as anxiety and depression. A study on public day care in Germany found that it led to worse maternal physical condition (Kröll and Borck, 2013), higher family life satisfaction (Schober and Stahl, 2016; Schober and Schmitt, 2013) and higher fertility (Bauernschuster, Hener, and Rainer, 2013).

We adopt the same age-eligibility difference-in-regression discontinuity design (DRD, equation (5)) to analyze the impact of a child's UPK eligibility on indicators of mothers' health, fertility and health care utilization. The estimate results are presented in Table 7. We report results separately for all mothers, and also for those for whom the UPK eligible child is the youngest in the household. Overall we do not find significant effects of UPK on mothers whose children are eligible, except for a weak positive effect on the probability of MD visit for the mothers whose eligible children are not the youngest in the household.

Table 7: Impacts of UPK on Maternal Health, Fertility, and Healthcare Utilization Indicators, Pooled Sample

	All Children	Youngest Children	Non-Youngest Children
Recorded Diagnoses			
Anxiety disorder	-0.001 (0.004)	0.002 (0.006)	-0.006 (0.006)
Depression or related mood disorder	-0.000 (0.005)	-0.003 (0.006)	0.003 (0.007)
Fertility			
Contraception	0.002 (0.008)	0.001 (0.010)	0.003 (0.013)
Pregnancy	-0.003 (0.008)	-0.001 (0.009)	-0.008 (0.015)
Aggregate Utilization			
MD visit	0.004 (0.009)	-0.008 (0.011)	0.023* (0.013)
MD visit for chronic disease	0.003 (0.009)	-0.005 (0.012)	0.013 (0.014)
ED visit	-0.007 (0.007)	-0.008 (0.009)	-0.008 (0.012)
Hospitalization	-0.007 (0.006)	-0.001 (0.005)	-0.019 (0.014)
Prescription	-0.003 (0.004)	-0.004 (0.006)	-0.002 (0.006)
New prescription	-0.003 (0.004)	-0.004 (0.006)	-0.001 (0.006)
Total Medicaid cost (ln $)	0.036 (0.052)	-0.001 (0.065)	0.080 (0.086)
Sample size	56,382	34,625	21,757

Note: The specification estimated in the table is equation (5) for the pooled sample. Only children within the 120-day window are included. Robust standard errors are shown in parentheses. * indicates statistical significance at 10% level.

9. Conclusion

Existing studies find that pre-K is an effective way to boost children's development, especially cognition and academic performance (Weiland and Yoshikawa, 2013; Gormley and Gayer, 2005; Fitzpartick, 2008; Lipsey et al., 2013; Wong et al., 2008; Cascio and Schanzenbach, 2013; Hill, Gormley, and Adelstein, 2015; Gormley, Phillips, and Gayer, 2008). This evidence supports the premise that a pre-K program's key outcome is to increase readiness for kindergarten and the schooling that follows (Pianta, Cox, and Snow, 2007). Our study examines another potential channel through which pre-K may boost long-term academic, social, and economic life chances through the early detection and treatment of sensory problems and other chronic conditions such as asthma that could interfere with a child's ability to thrive in academic settings.

This study used Medicaid data from New York City to estimate the effect of UPK eligibility on short-run health and healthcare utilization outcomes. Using a difference-in-regression-discontinuity design, we find that children who were eligible for the UPK program were more likely to have been diagnosed with asthma and vision problems, and to have had treatments for hearing or vision problems and an immunization or screening for an infectious disease during the pre-K year. Relative to baseline rates for these outcomes, our TOT effects show a more than doubling of rates of hearing and vision treatments. We find no offsetting reductions in diagnosis or treatment rates during the subsequent kindergarten year, suggesting that these screenings are catching problems earlier than would otherwise have been the case. In contrast to many papers in the literature which find negative effects of publicly-subsidized childcare on mother's health, we do not find significant effects – either positive or negative – of UPK on mothers' health, fertility or health care utilization.

Our findings provide insight into one potential pathway through which pre-K could eventually lead to positive long-run outcomes, which is a process not yet well-understood. To date, research on the effects of pre-K attendance has largely followed two threads. The first has shown that many of the short-run cognitive advantages that children attending pre-K enjoy disappear within the first years of elementary school, as the children who did not attend pre-K "catch up" to those who did (Duncan and Magnuson, 2013; Magnuson, Ruhm, and Waldfogel, 2007). The second thread has demonstrated that, despite this, certain long-term advantages of pre-K attendance persist into adolescence and adulthood – for example, increased likelihood of obtaining a job or securing higher earnings, and decreased likelihood of teen pregnancy or depression (Heckman, 2011; Muennig, 2011). That is, while the cognitive benefits of pre-K may not persist in the long-term, some of the behavioral or social benefits do. Our findings provide evidence for one avenue by which pre-K might lead to these long-term advantages: by diagnosing and treating chronic health problems early in children's educational trajectories, they might develop skills that enable them to take advantage of the educational opportunities to a greater extent, cope with challenges, feel less frustrated or overwhelmed in the classroom, and communicate with peers and educators more effectively. If a young student's health conditions are well-managed—particularly sensory problems that could impede learning—then the child may have the chance to develop successful long-term learning strategies or problem-solving capacities in comparison to a child who remains burdened by undetected or poorly-managed conditions early in their education.

One of our most robust findings in this study pertains to the increases in the diagnosis and treatment of vision and hearing problems. Vision problems are prevalent among children in poor urban environments (Gould and Gould, 2003) and are correlated with low academic performance at exams (Krumholtz, 2000). In a literature review, Basch (2011) asserts that school-based vision screening is an effective approach to detect and treat vision problems that are highly and disproportionately prevalent among school-aged urban minority youth. In our sample, about 85% of the vision treatments are for refraction evaluations or glasses fittings, which help children see clearly. Untreated vision problems may also lead to social or emotional problems (Zaba, 2001; Johnson et al., 1996). In an academic context, students may become frustrated or unable to engage in a classroom setting to the fullest extent. Poor eyesight is incompatible with a learning environment, and in the long-run, untreated poor eyesight and the associated low educational attainment have negative impacts on quality of life and economic standing (Polack et al., 2008;

Rein, et al. 2006). The proactive diagnosis and treatment of vision problems among pre-K children may provide them with early advantages for succeeding in social environments that in turn shape their life down the line.

In general, hearing problems are likely to be diagnosed before ages 3-4, which is prior to the age at which the children would start pre-K. Although our results show no impact on diagnosis of hearing problems, we do find that the UPK policy leads to higher probability of receiving treatment for hearing problems. Prior research has suggested that hearing problems may negatively impact academic performance, self-esteem, and social functioning (Daud et al., 2010; American Speech-Language-Hearing Association, 2017; Theunissen et al, 2014) and that early intervention is essential for closing the developmental gap (Mellon et al., 2009). In fact, students who are treated for hearing problems in childhood and receive school-based support can develop communication skills on par with or above their healthy peers by adolescence (Eriks-Brophy et al., 2012). Our results support the idea that pre-K enhances children's chances for accessing such treatments and interventions earlier than they otherwise might, which can close this developmental gap as early as possible.

While more research on long-term effect of pre-K program is called for, we argue that future studies should also be conducted in fields outside of education. For instance, our use of health utilization and outcome data in this study provided an opportunity to understand how detection and treatment of medical problems may play a role in the success of children eligible for pre-K programs. In turn, these findings may help bridge the gap in the current understanding of how pre-K imparts social and economic benefits many years later. This study does have limitations, particularly in our ability to generalize outside of the NYC Medicaid population. All subjects in this analysis came from low-income families enrolled in the Medicaid program, and it is possible that UPK eligibility would lead to different outcomes for children in other economic situations, such as the uninsured or privately-insured. Further, our intent-to-treat design provides a conservative estimate of effect size, as we do not know which specific children actually attended pre-K. Rather, we only know who was eligible to attend, and therefore children who did not actually participate in the expansion have been included here. While we did use available enrollment estimates to calculate TOT estimates, future studies could continue to investigate the effects of actual pre-K attendance and exploit other sources of variation – such as the varying quality of the programs offered – in estimating the effect of UPK policies on young children.

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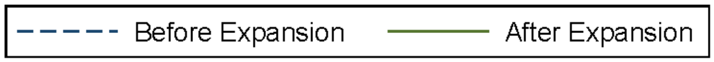
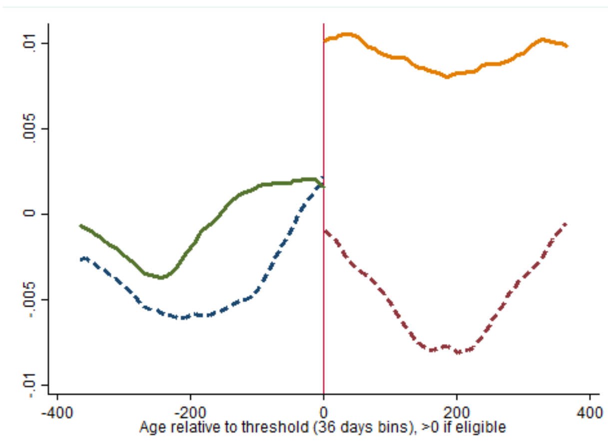
Appendix

A. Graphic Analysis

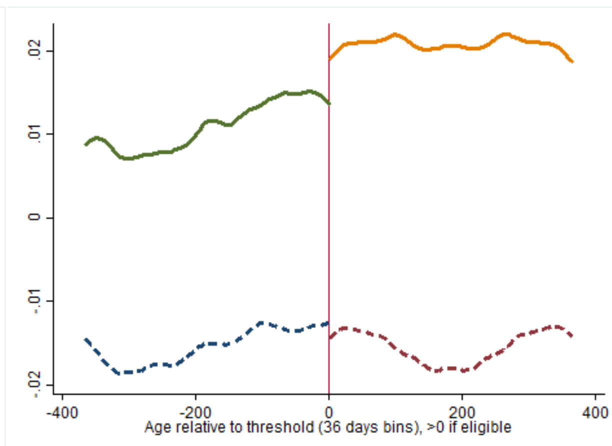
Figure A1: Health and Healthcare Utilization by Age Relative to Cutoff, Pooled Sample



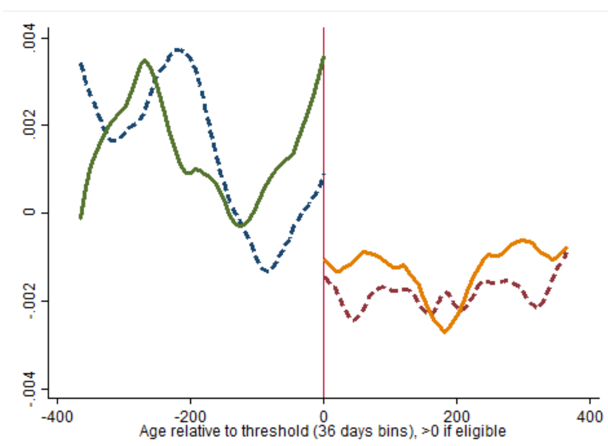
(a) Asthma



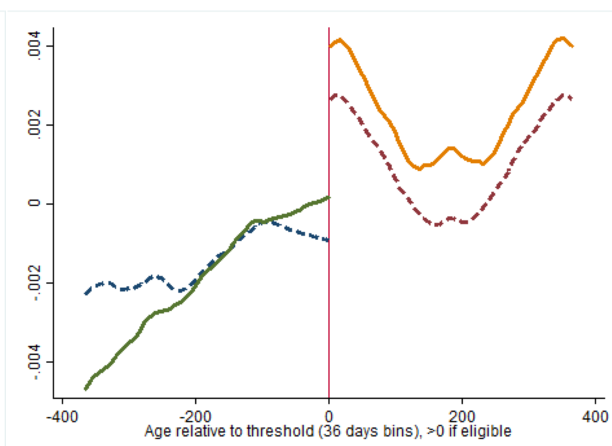
(b) Infectious disease



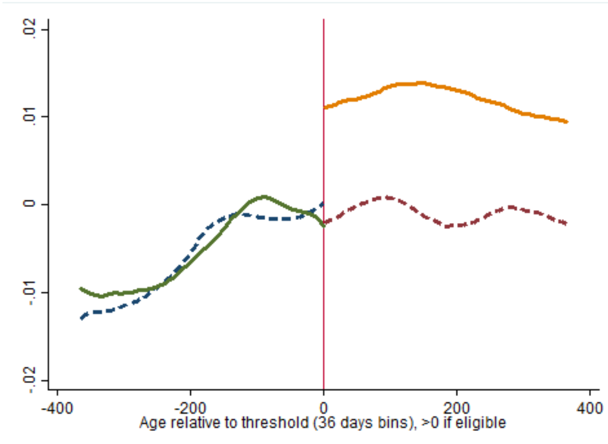
(c) Injury



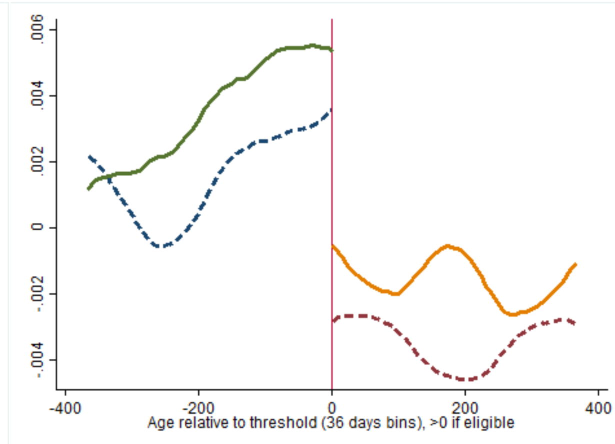
(d) Hearing problems



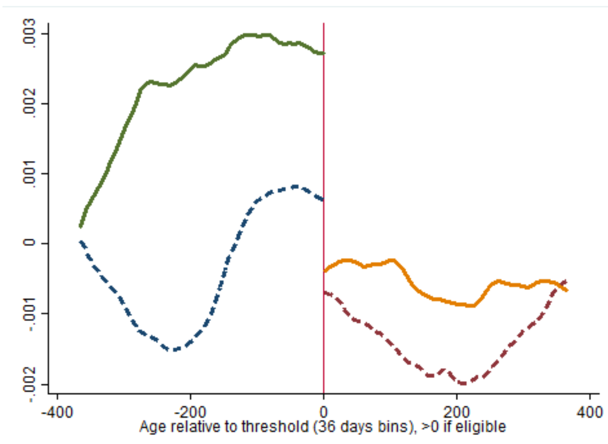
(e) Vision problems



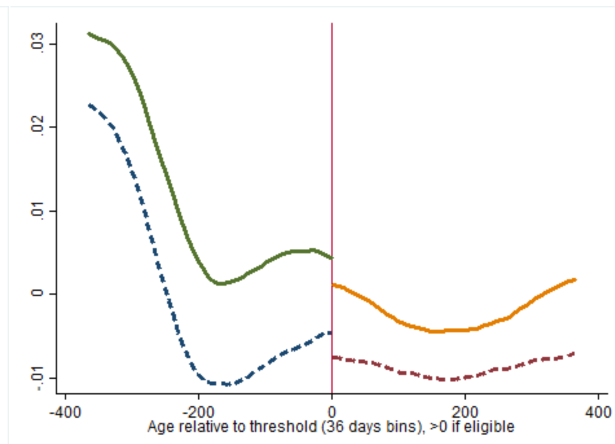
(f) ADHD



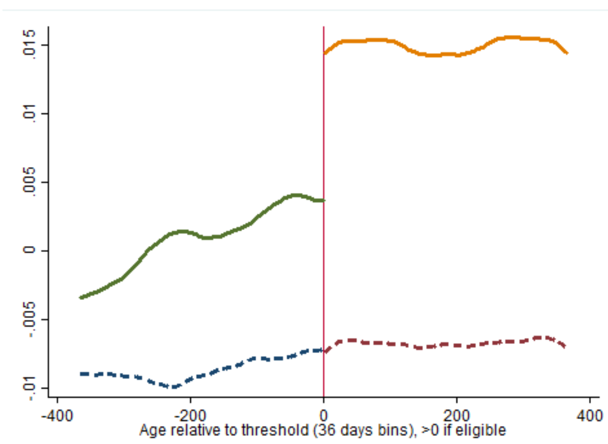
(g) Anxiety disorder



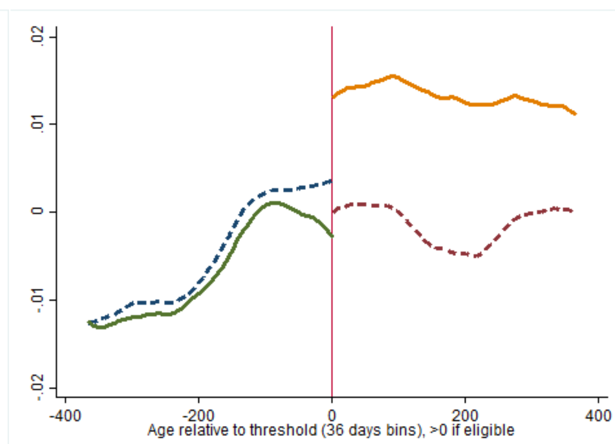
(h) Development delay



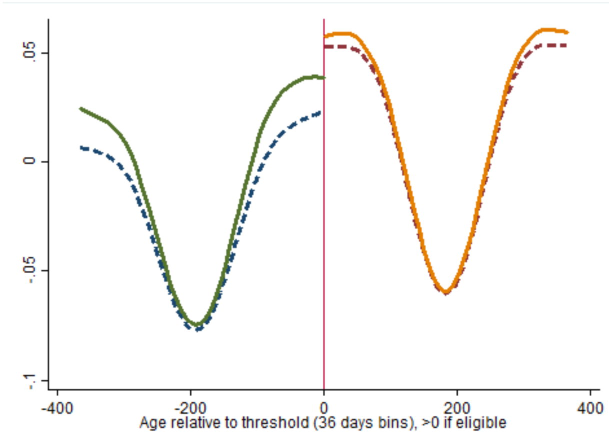
(i) Hearing treatment



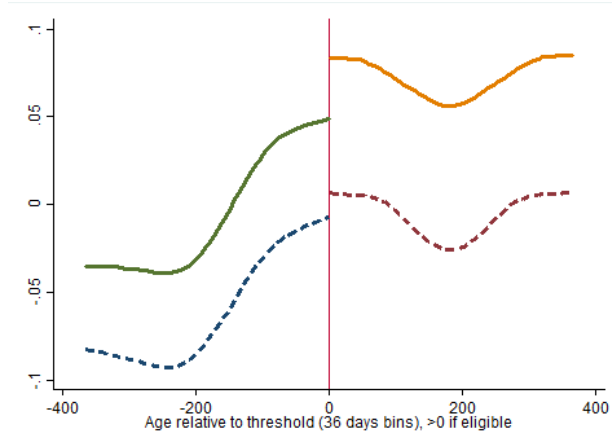
(j) Vision treatment



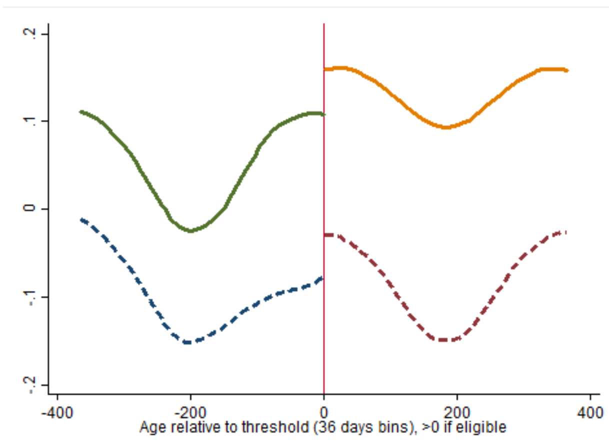
(k) Routine checkup



(l) Immunization or infectious disease screening



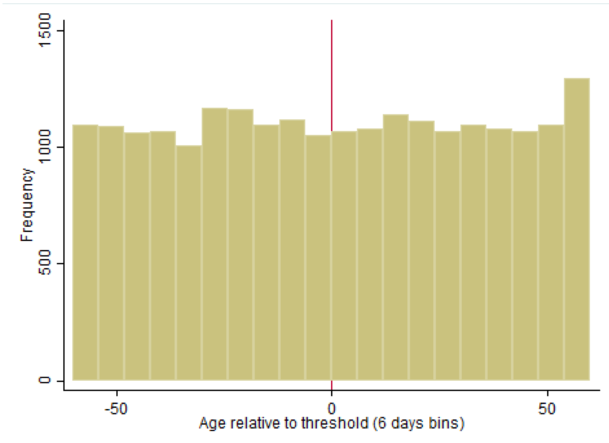
(m) Total Medicaid cost (ln$)



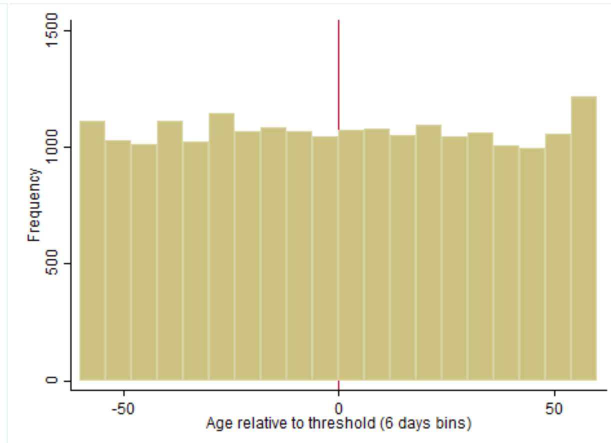
Note: The outcomes before (after) the expansion are the health and healthcare utilization indicators measured in the 2013-2014 (2014-2015) academic year, conditional on age relative to the cutoff of December 31st, 2008 (2009). The polynomial lines represent local mean smoothing of residuals from a regression of the outcome or utilization on fixed effects that indicates whether the observation is in the sample for the oldest children, conditional on age and using a bandwidth of 36 days.

Figure A2: Distribution of Children by Birthdate around Cutoffs

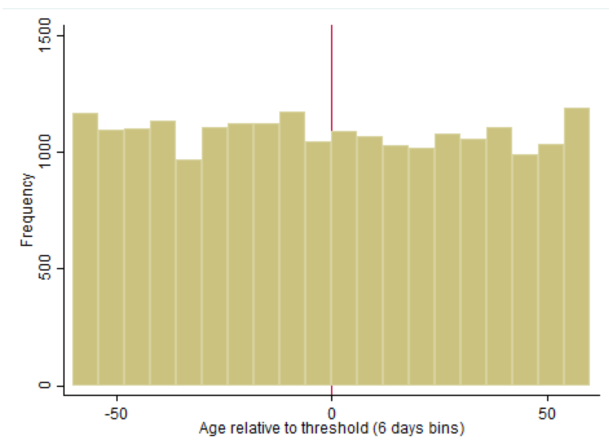
(a) December 31st, 2008



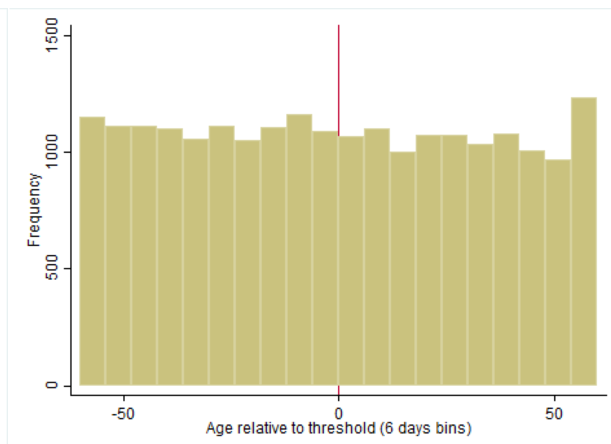
(b) December 31st, 2009



(c) December 31st, 2010



(d) December 31st, 2011



Note: The children within the window of 120 days are included. Each bin represents 6 days.

B. Regression Discontinuity Design and Difference-in-Differences

An RDD produces unbiased estimates of the effects of the pre-K program on subsequent children's health if there is no perfect manipulation of date of birth. The relevant histograms that check whether there is any evidence of manipulation around the cutoffs used for RDD are in Figure A2. There is clearly no evidence of manipulation around the cutoffs of December 31st, 2009 and December 31st, 2010.

The internal validity of the RDD requires that no relevant variables other than the treatment jump at the cutoff. As suggested by Figure A1, and later shown in Section 4 there are systematic differences in pre-existing health and utilization indicators before the UPK expansion. As a result, a straightforward RDD may not estimate a plausible causal impact of the eligibility of the pre-K program, let alone simple OLS estimations.

The DID approach allows for the existence of observed differences before the treatment, and imposes a "common trend" assumption that such difference would remain the same if the treatment had not been implemented, from a perspective of yearly average.

The estimation results from the OLS estimation (equation (1)), RDD approach (equation (2)) and DID approach (equation (3)) for the pooled sample are reported in Table B1. Despite the concerns regarding reliability, the estimated effects from the standard RDD using local linear estimation are largely consistent with Figure A1. The main results from DRD are substantially different from the results from the OLS, RDD and DID estimations.

Table B1: Impacts of UPK on Four-year-old Health and Utilization Indicators, OLS, RDD and DID, Pooled Sample

	OLS	RDD	DID	DRD (main)
Recorded Diagnoses				
Asthma	0.010*** (0.001)	0.010** (0.004)	0.011*** (0.002)	0.013** (0.006)
Infectious disease	0.010*** (0.002)	0.002 (0.006)	0.010*** (0.003)	0.006 (0.008)
Injury	-0.003* (0.001)	-0.004 (0.004)	0.001 (0.002)	-0.003 (0.006)
Hearing problems	0.004*** (0.001)	0.002 (0.002)	0.002 (0.001)	-0.001 (0.003)
Vision problems	0.017*** (0.001)	0.015*** (0.003)	0.013*** (0.002)	0.019*** (0.005)
ADHD	-0.005*** (0.001)	-0.005** (0.002)	0.000 (0.001)	0.003 (0.003)
Anxiety disorder	-0.003*** (0.000)	-0.003** (0.001)	-0.002*** (0.001)	-0.002 (0.002)
Development delay	-0.013*** (0.001)	-0.000 (0.003)	-0.005*** (0.002)	0.000 (0.004)
Treatment for sensory problems				
Hearing problems	0.014*** (0.001)	0.009*** (0.002)	0.012*** (0.001)	0.009*** (0.003)
Vision problems	0.020*** (0.001)	0.016*** (0.004)	0.017*** (0.002)	0.022*** (0.006)
Routine and primary care				
Routine checkup	0.026*** (0.002)	0.016*** (0.005)	-0.007*** (0.003)	-0.008 (0.007)
Immunization or screening				
Immunization or infectious disease screening	0.079*** (0.002)	0.034*** (0.006)	0.024*** (0.003)	0.025*** (0.008)
Aggregate Utilization				
Total Medicaid cost (ln$)	0.081*** (0.009)	0.051** (0.025)	0.067*** (0.013)	0.008 (0.035)
Sample size	258,994	42,316	521,985	85,119

Note: The OLS estimation fits the whole sample of two-year window with equation (1). The RDD estimation fits the 120-day window with equation (2). The DID estimation fits the whole sample of two-year window with equation (3). The DRD estimation fits the sample of 120-day window with equation (5). Robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% level, respectively.

C Attrition from NYC Medicaid

One possible concern for our findings is that some eligible children become ineligible for Medicaid during academic year 2014-2015. The free pre-K program allows the household to reallocate resources, e.g., by increasing maternal labor supply.[18] The following increased household income may lead the children becomes ineligible for Medicaid, thus leaving our sample. In this scenario, the estimation in this paper may underestimate (or overestimate) the benefit (harm) from the pre-K program.

We examine the potential impact of pre-K eligibility on two indicators of Medicaid attrition. One is whether the children went off and then back on Medicaid (cycling), and the other is the number of months on Medicaid. The results are shown in Table C1. During the pre-K year, the eligible children are more likely to leave Medicaid and come back later, but they do not stay on Medicaid for shorter time. The effect of being eligible for the pre-K program on number of months on Medicaid is almost zero. For the kindergarten year, we do not find any significant effect on Medicaid attrition. Overall there is not much evidence of higher attrition rate in the treatment group.

Table C1: Impacts of UPK on Medicaid Attrition Indicators

	First Year	**Second Year**
Going off and then back on Medicaid	0.008*** (0.003)	0.006 (0.005)
Number of months on Medicaid	0.000 (0.024)	0.039 (0.047)
Sample size	85,119	42,252

Note: The specification estimated in the table is equation (5) for the first year and equation (4) for the second year, with the children in the 120-day window. Robust standard errors are shown in parentheses. *** indicate statistical significance at 1% level.

[18] The existing literature on the effect of preschool program on maternal labor supply provides us a mixed picture. While Berlinski, Galiani, and McEwan (2011) find positive effect of preschool attendance of the youngest children on maternal labor supply in Argentina, Fitzpatrick (2010) finds little effect of the pre-K program in the US. In this paper, we may expect a positive effect of the pre-K program on maternal labor supply because the mothers in our sample are from low-income backgrounds.

D Robustness Checks with Alternative Bandwidths and Specifications

Table D1: Impacts of UPK on the Four-year-old Health and Healthcare Utilization Indicators, Various Bandwidths, Pooled Sample

	60-day (main) (a)	15-day (b)	30-day (c)	90-day (d)	120-day (e)	IK Optimal (f)	CCT Optimal (g)
Recorded Diagnoses							
Asthma	0.013** (0.006)	0.027** (0.011)	0.019** (0.008)	0.012*** (0.005)	0.012*** (0.004)	0.011*** (0.003)	0.011*** (0.004)
Infectious disease	0.006 (0.008)	0.021 (0.016)	0.011 (0.011)	0.006 (0.006)	0.006 (0.006)	0.006 (0.005)	0.006 (0.006)
Injury	-0.003 (0.006)	0.009 (0.011)	0.003 (0.008)	-0.003 (0.004)	-0.002 (0.004)	-0.000 (0.002)	-0.001 (0.004)
Hearing problems	-0.001 (0.003)	-0.002 (0.006)	-0.004 (0.004)	-0.000 (0.003)	0.000 (0.002)	0.000 (0.002)	0.000 (0.002)
Vision problems	0.019*** (0.005)	0.022** (0.010)	0.023*** (0.007)	0.016*** (0.004)	0.014*** (0.003)	0.013*** (0.003)	0.015*** (0.004)
ADHD	0.003 (0.003)	0.006 (0.005)	0.006 (0.004)	0.001 (0.002)	-0.000 (0.002)	-0.001 (0.002)	0.000 (0.002)
Anxiety disorder	-0.002 (0.002)	-0.001 (0.004)	-0.001 (0.003)	-0.002 (0.001)	-0.002 (0.001)	-0.002* (0.001)	-0.002 (0.001)
Development delay	0.000 (0.004)	-0.001 (0.009)	0.003 (0.006)	-0.001 (0.003)	-0.002 (0.003)	-0.003 (0.003)	-0.003 (0.003)
Treatment for sensory problems							
Hearing problems	0.009*** (0.003)	0.003 (0.006)	0.007 (0.004)	0.010*** (0.003)	0.010*** (0.002)	0.010*** (0.002)	0.010*** (0.002)
Vision problems	0.022*** (0.006)	0.020* (0.011)	0.023*** (0.008)	0.019*** (0.005)	0.018*** (0.004)	0.018*** (0.003)	0.017*** (0.004)
Routine and primary care							
Routine checkup	-0.008 (0.007)	-0.007 (0.014)	-0.006 (0.010)	-0.012** (0.006)	-0.013** (0.005)	-0.012** (0.005)	-0.013** (0.006)
Immunization or screening							
Immunization or infectious disease screening	0.025*** (0.008)	0.041*** (0.015)	0.039*** (0.011)	0.022*** (0.006)	0.021*** (0.005)	0.022*** (0.006)	0.022*** (0.006)
Aggregate Utilization							
Total Medicaid cost (ln$)	0.008 (0.035)	0.018 (0.071)	0.027 (0.050)	-0.003 (0.029)	0.000 (0.025)	0.021 (0.022)	0.014 (0.026)
Sample size	85,119	21,016	42,456	127, 264	170,612	-	-

Note: The specification estimated in the table is equation (5) with the children in the corresponding windows. The IK and CCT optimal bandwidths and the corresponding sample sizes for each outcome are available upon request. Robust standard errors shown in parentheses. *, **, and *** indicate statistical significance at 10%, 5% and 1% level, respectively.

Table D2: Impacts of UPK on the Four-year-old Health and Healthcare Utilization Indicators, Various Specifications, Pooled Sample

	Local Regression (60-day window)			Global Parametric Regression	
	Linear (main) (a)	**Quadratic (b)**	**Cubic (c)**	**Quadratic (d)**	**Cubic (e)**
Recorded Diagnoses					
Asthma	0.013** (0.006)	0.015** (0.007)	0.015** (0.007)	0.012*** (0.002)	0.012*** (0.002)
Infectious disease	0.006 (0.008)	0.006 (0.010)	0.006 (0.010)	0.011*** (0.004)	0.011*** (0.004)
Injury	-0.003 (0.006)	-0.003 (0.007)	-0.003 (0.007)	0.001 (0.002)	0.001 (0.002)
Hearing problems	-0.001 (0.003)	-0.003 (0.004)	-0.003 (0.004)	0.002 (0.001)	0.002 (0.001)
Vision problems	0.019*** (0.005)	0.020*** (0.006)	0.020*** (0.006)	0.013*** (0.002)	0.013*** (0.002)
ADHD	0.003 (0.003)	0.004 (0.003)	0.004 (0.003)	0.000 (0.001)	0.000 (0.001)
Anxiety disorder	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002** (0.001)	-0.002** (0.001)
Development delay	0.000 (0.004)	0.000 (0.005)	0.000 (0.005)	-0.005*** (0.002)	-0.005*** (0.002)
Treatment for sensory problems					
Hearing problems	0.009*** (0.003)	0.008* (0.004)	0.007* (0.004)	0.012*** (0.001)	0.012*** (0.001)
Vision problems	0.022*** (0.006)	0.022*** (0.007)	0.022*** (0.007)	0.018*** (0.003)	0.018*** (0.003)
Routine and primary care					
Routine checkup	-0.008 (0.007)	-0.006 (0.009)	-0.006 (0.009)	-0.008** (0.003)	-0.008** (0.003)
Immunization or screening					
Immunization or infectious disease screening	0.025*** (0.008)	0.034*** (0.010)	0.034*** (0.009)	0.024*** (0.003)	0.024*** (0.003)
Aggregate Utilization					
Total Medicaid cost (ln$)	0.008 (0.035)	0.002 (0.043)	0.001 (0.043)	0.074*** (0.016)	0.074*** (0.016)
Sample size	85,119	85,119	85,119	521,985	521,985

Note: The specification estimated in the table is equation (5) with the children in the corresponding windows. Robust standard errors shown in parentheses. **, and *** indicate statistical significance at 1% and 5% level, respectively.

Table D3: First Year Impacts of UPK, Full Year and Half Academic Year, Pooled Sample

	Academic Year (main) (a)	Full Year (b)	Half Academic Year (September to December) (c)
Recorded Diagnoses			
Asthma	0.013** (0.006)	0.012** (0.006)	0.011** (0.005)
Infectious disease	0.006 (0.008)	0.004 (0.008)	-0.012 (0.007)
Injury	-0.003 (0.006)	-0.001 (0.006)	0.002 (0.004)
Hearing problems	-0.001 (0.003)	0.000 (0.003)	-0.001 (0.002)
Vision problems	0.019*** (0.005)	0.019*** (0.005)	0.008*** (0.003)
ADHD	0.003 (0.003)	0.002 (0.003)	0.001 (0.002)
Anxiety disorder	-0.002 (0.002)	-0.003 (0.002)	-0.001 (0.001)
Development delay	0.000 (0.004)	0.001 (0.005)	0.001 (0.003)
Treatment for sensory problems			
Hearing problems	0.009*** (0.003)	0.008** (0.003)	-0.001 (0.002)
Vision problems	0.022*** (0.006)	0.026*** (0.006)	0.007** (0.004)
Routine and primary care			
Routine checkup	-0.008 (0.007)	-0.009 (0.007)	0.003 (0.007)
Immunization or screening			
Immunization or infectious disease screening	0.025*** (0.008)	0.022*** (0.008)	0.021*** (0.007)
Aggregate Utilization			
Total Medicaid cost (ln$)	0.008 (0.035)	0.007 (0.033)	-0.004 (0.042)
Sample size	85,119	85,119	85,119

Note: The specification estimated in the table is equation (5) for the pooled sample. Only children within the 120-day window are included. Robust standard errors are shown in parentheses. **, and *** indicate statistical significance at 5% and 1% level, respectively.

E Survival Analysis of the First Treatment of Hearing and Vision Problems

The Cox model adopted in the main analysis is semi-parametric without specifying the baseline hazard (which is the hazard for the ineligible children before the expansion). It is sensitive to omitted covariates, and assumes that the UPK works by multiplying the baseline hazard by a constant. Alternatively, we model the hazard of first treatment by a parametric accelerated failure-time (AFT) model, which allows for omitted covariates and an effect to accelerate or decelerate the survival time of no treatment by some constant. Specifically, we have the following AFT model:

$$log(\tau_{it}) = \alpha + \theta 1\{DOB_i \geq c_t\}1\{t = 2014\} + \rho_1 1\{DOB_i \geq c_t\} + \rho_2 1\{t = 2014\} + \rho_3(DOB_i - c_t) + \rho_4 1\{DOB_i \geq c_t\}(DOB_i - c_t) + \rho_5 1\{t = 2014\}\{DOB_i \geq c_t\}(DOB_i - c_t) + d_i + \varepsilon_{it}, \quad \text{(E1)}$$

where τ_{it} is the survival time (age of the first treatment) and ε_{it} is the error term. θ is the effect of UPK on the survival time (until the first treatment). We examine two types of AFT models: Weibull and loglogistic. Both satisfy the general features of an AFT model discussed above. The Weibull AFT model assumes that ε_{it} follows an extreme-value distribution and the loglogistic AFT assumes that ε_{it} follows a logistic distribution. The latter also allows for a non-monotonic hazard function with respect to time.

Table E1 summarizes the estimated effects on the hazard of the first treatment (the Cox model) and the estimated effects on survival time until the first treatment (AFT models). The results are robust to various model settings and consistent with Figure 3.

Table E1: Impacts of UPK on Four-year-old First Treatment of Hearing and Vision Problems, Pooled Sample

	Cox model		Weibull AFT model		Loglogistic AFT model	
Age	**2-4**	**4-5**	**2-4**	**4-5**	**2-4**	**4-5**
Treatments for sensory problems						
Hearing problems	0.039 (0.048)	-0.035 (0.089)	-0.055 (0.070)	0.040 (0.101)	-0.063 (0.071)	0.041 (0.101)
Vision problems	0.048 (0.043)	0.201*** (0.044)	-0.035 (0.032)	-0.204*** (0.045)	-0.036 (0.033)	-0.210*** (0.046)

Note: The specification estimated in the table is equation (6) for the Cox model and equation (E1) for the Weibull AFT model and the loglogistic AFT model, with the children in the 120-day window. Because of the data limitation, hazard and survival time are measured starting from age 2. The sample sizes are 85,044 for hearing problems and 80,074 for vision problems. Robust standard errors are shown in parentheses. ** and *** indicates statistical significance at 5% and 1% level, respectively.