The Effects of Public Pre-K for 3-year-olds on Early Elementary School Outcomes: Evidence from the DC Centralized Lottery

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This study examines the effects of universal public pre-kindergarten for 3-year-olds (Pre-K3) on later public education outcomes, including enrollment, school mobility, special education status, and in-grade retention from kindergarten through second grade. While universal pre-kindergarten programs typically target 4-year-olds, interest in expanding to 3-year-olds is growing. Using the centralized assignment lottery in the District of Columbia as the basis for a quasi-experimental design, we find that Pre-K3 students are more likely to persist in the public system and remain in the same school. These effects are strongest for residents of low-income neighborhoods and communities of color and for students enrolled in dual language programs. Overall, public Pre-K3 appears to stabilize children's early educational experiences, especially those starting furthest from opportunity.

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ABSTRACT

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Introduction

　　Public preschool is a leading policy remedy for advancing equitable access to enriching early learning opportunities (Yoshikawa et al., 2013). Although public investment in educational programming began at the federal level through the introduction of the Head Start program, more recently, states and localities across the nation have expanded investments in public programs that offer high-quality academic and social-emotional support to young children, especially for 4-year-old children from households with low incomes (Friedman-Krauss et al., 2023). These public investments stem from a robust literature demonstrating that pre-kindergarten can improve children's school readiness and later-life outcomes (Gray-Lobe, Pathak, & Walters, 2022), especially for children who are less likely to have exposure to high-quality early educational experiences in the absence of public preschool provision (Duncan & Magnuson, 2013). Nonetheless, few studies explore whether pre-kindergarten promotes continued participation in the public school system – an important issue for school districts and families alike (Gormley, Phillips, & Anderson, 2018; Weiland et al., 2019).

　　Alongside heightened investment, the landscape of publicly funded early education programs has rapidly evolved. Since the early 2000s, more states and localities have introduced *universal* preschool programming that allows children from all households—not just those facing difficulties paying for preschool—to enroll. Moreover, public preschool is increasingly being expanded downward toward 3-year-old children, giving some children the opportunity for exposure to an additional year of high-quality early education. The District of Columbia's (DC) universal public pre-kindergarten program leads the nation in access, enrolling 79 percent of DC's 3-year-old children – a high share of children relative to other

states (Friedman-Krauss et al., 2023). Although many studies have examined the impacts of public preschool programs for 4-year-old children (e.g., Chaudry et al., 2018), limited research to date has demonstrated impacts for universal 3-year-old pre-kindergarten (Pre-K3) programs despite their steadily growing popularity, in large part due to limited data availability and assignment procedures that complicate efforts to identify causal impacts of preschool participation.

This paper estimates the causal impacts of universal pre-kindergarten for 3-year-olds on later public education outcomes. In particular, we investigate whether school-based Pre-K3 students are more likely to persist in their enrollment in the DC public education system through second grade (e.g., instead of enrolling in private schools, public schooling options outside of DC, or being homeschooled). In addition, for the subset of students who persist in the public system, we evaluate whether school-based Pre-K3 affects special education classification, school mobility, and grade retention. We also investigate whether students furthest from opportunity – communities of color and communities with lower incomes –and students in particular Pre-K3 program types—Montessori and dual language programs— exhibit particularly large benefits from DC Pre-K3 participation on our outcomes of interest.

To address our research aims, we exploit the fact that DC uses a centralized admissions lottery to assign students to Pre-K3 programs that receive more applications than they have seats. By leveraging random variation generated by the deferred acceptance (DA) algorithm used by the DC lottery, we can identify causal impacts of school-based public Pre-K3 for the set of students for whom the lottery approximates a randomized controlled trial (Abdulkadiroğlu et al.,2017; Weiland et al.,2024). We leverage data on all applicants to the

DC Pre-K3 lottery from 2014 to 2017 and data on all students enrolled in DC public schools from 2014 to 2019.

To preview our results, we find that students enrolled in a DC public school-based Pre-K3 are 16.8 percentage points more likely to enroll in a DC public kindergarten program and 35.3 percentage points more likely to persist in the DC public education system between Pre-K4 and kindergarten. While estimated with less precision, this result largely holds through second grade and suggests that attending a public Pre-K3 program in DC substantially increases the chance of a student staying connected to the public system during early elementary school. We generally estimate larger effects for lottery applicants from communities of color and neighborhoods with lower incomes, highlighting the benefits of public Pre-K3 in facilitating secure attachment and the development of foundational academic and social skills among children from structurally marginalized backgrounds (Sandstrom and Huerta, 2013).

For the lottery applicants who later enroll in public kindergarten in DC, we find that attending Pre-K3 is associated with decreased school mobility and increased special education status in kindergarten. We do not find evidence that Pre-K3 enrollment is associated with grade retention in kindergarten (a rare event in the DC public education system). Finally, we find that students who get a seat in a Pre-K3 dual language program are more likely to stay in the DC public education system through kindergarten and less likely to switch schools from Pre-K4 to kindergarten compared to those who applied to dual language programs but did not get a dual language seat. We do not find comparable evidence for Pre-K3 Montessori programs.

The remainder of our paper is as follows. We begin by reviewing background literature relevant to our research questions and methods. Next, we describe the data sources and empirical method for identifying program effects. We then present our main findings as well as findings documenting the impacts of Montessori and dual language programs specifically. Finally, we discuss the findings and associated study limitations, suggest directions for future research, and offer takeaways for policymakers and practitioners.

Background

The effects of participation in public pre-kindergarten for children through elementary school have been well studied, particularly for 4-year-old children in the year before kindergarten (e.g., Bruhn & Emick, 2023; Chaudry et al., 2018; Phillips et al., 2017; Yoshikawa et al., 2013). Benefits include positive effects on language, literacy, and math at kindergarten entry; mixed effects on social-emotional skills in the short term; and improvement in longer-term outcomes like in-grade retention, special education placement, and persistence in public education systems (e.g., Camilli et al., 2010; Elango et al., 2015; Gormley, Phillips, & Anderson, 2018; Lipsey, Farran, & Durkin, 2018; McCoy et al., 2017; Watts, Duncan, & Rivas, 2019; Weiland et al., 2019). Lottery-based studies like ours typically focus on limited outcomes documented in administrative data (Weiland et al., 2024). Even in administrative data, public pre-kindergarten has shown a consistently high return on investment in reducing early disparities (e.g., Bartik et al., 2012; Magnuson & Duncan, 2016). The depth of the evidence base on public pre-kindergarten is unsurprising given heightened public investment over the last several decades (Friedman-Krauss et al., 2023), especially as a lever for increasing opportunity among children facing disadvantages propagated by structural racism and disinvestment (e.g., Magnuson & Waldfogel, 2016). As

such, a significant question for early education policy is whether and under what conditions public pre-kindergarten programs for 3-year-olds positively and equitably impact the populations they serve.

Although the preschool literature is less focused on elementary public school participation, the outcomes of elementary public school participation are particularly important to examine due to the recent instability in K-12 public school enrollment. Over the first two years of the COVID-19 pandemic, K-12 enrollment in U.S. public schools fell by more than 1.2 million students (Dee, 2023). The drop in enrollment was concentrated in the younger grades, with the steepest decline in kindergarten, about 340,000 students (Goldstein & Parlapiano, 2021). At the same time, evidence shows that K-12 homeschool enrollment increased by 30 percent between the 2019–20 and the 2021–22 school years (Dee, 2023). This rapid growth in homeschooling raises questions about the quality of the learning environments children are experiencing outside the public education system, especially given the differences in homeschooling requirements across the country (Home School Legal Defense Association, 2024). Additional questions concern the stability of educational experiences for students who have returned to the public education system, including issues of school mobility. Evidence suggests that school mobility increases the risk of poor achievement, behavior problems, and grade retention (Reynolds et al., 2009; Schwartz et al., 2017). It also poses financial and operational challenges for school districts grappling with declines in the population they serve.

Of note, very little evidence documents the efficacy of programs for 3-year-olds. This is concerning because the early childhood field has emphasized the need for robust early childhood infrastructure and public investment for the full birth-to-5 spectrum and because

efforts in New York City, Vermont, and recent federal proposals intend to meet that need (Chaudry et al., 2018). Few 3-year-olds nationally have access to public pre-kindergarten, even though economics, neuroscience, and developmental psychology theories and evidence suggest starting earlier may be more efficacious than investing in preschool at age 4 (Chaudry et al., 2018; Cunha & Heckman, 2007; Li et al., 2020). Moreover, very few studies use rigorous evaluation methods to assess the effects of these programs on educational outcomes. To our knowledge, only the Head Start Impact Study and National Early Head Start Research and Evaluation Project use experimental methods to assess the effects of means-tested programs for 3-year-olds (Love et al., 2005; Puma et al., 2010). Findings echo those of other studies that examine the additional benefit of starting preschool at younger ages: the 3-year-old pre-kindergarten year improves a range of short-term academic and longer-term noncognitive outcomes, and outcome persistence may depend on subsequent preschool sequencing and differentiated instruction (Ansari et al., 2019; Arteaga et al., 2014; Whitaker et al., 2023; Domitrovich et al., 2013).

The District of Columbia's Pre-K3 program is uniquely suited for large-scale impact evaluation. The alternative care arrangements for 3-year-olds are often tuition-based or time-consuming for parents, and the availability of Pre-K3 may be seen as an appealing and less expensive care option. By entering the public system earlier, families might get accustomed to a public school and may be less likely to switch schools in kindergarten. Parents might become familiar with the public system and involved with other families with children in the same cohorts. Children who enter the public education system at an early age might also be more likely to be identified as needing special education services and connect to the needed

resources before enrolling in the K-12 grades - potentially mitigating the need for continued services in later grades.

Study Context

The District of Columbia has offered funding for pre-kindergarten programs since the 1960s, but following the Pre-Kindergarten Enhancement and Expansion Amendment Act (the Act) of 2008, enrollment increased considerably. The Act authorized a 5-year strategic expansion plan to make pre-kindergarten "universally available" to children "for the two years before their eligibility for enrollment in kindergarten" (Pre-K Enhancement and Expansion Amendment Act, 2008). The Act makes pre-kindergarten available across the mixed delivery system, including in public schools and community-based organizations (CBOs). [1] The Act sets "high-quality content standards and program requirements" at the core of the investment. For example, the program operates on an academic year schedule for a minimum of 6.5 hours per day, five days a week, in all settings. In the District of Columbia Public Schools (DCPS), lead teachers are required to hold at least a BA, and assistant teachers must hold a Child Development Associate (CDA) or equivalent. The maximum class size for 3-year-olds is 16 (matching DC childcare standards). In 2022-23, DC Public Pre-kindergarten enrolled 5,929 3-year-olds, or 79% of the age group district-wide, and spent roughly $22,207 per child enrolled, the highest in the nation (NIEER 2023).

Although DC Public Pre-kindergarten serves 3- and 4-year-olds (in Pre-K3 and Pre-K4), we focused on school-based Pre-K3 for several reasons. First, DC is unique in its large-scale service provision for 3-year-olds. Evidence on Pre-K3 fills a critical gap in the existing literature and generates actionable insights for policymakers, practitioners, and researchers.

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[1] CBOs accounted for 7% of seats in the 2022-23 school year (OSSE, 2023). Those seats are made available outside the lottery and are part of the comparison group, a limitation we return to below.

Second, different from CBOs, school-based enrollment is organized around a common lottery, My School DC, which provides a sound basis for causal inference. Third, DCPS and public charter schools offer the vast majority of seats in the program, making them the typical Pre-K3 experience.

In addition to estimating the main effects of Pre-K3, we also investigate the effects of attending a Montessori or dual-language Pre-K3 program. We focus on Montessori and dual-language programs for practical and conceptual reasons. On the practical side, these two program types are identifiable in the lottery and enrollment data over the full analysis period and receive a sizable number of applications every year. During the analysis period, there were 14 Pre-K3 Montessori programs and 20 dual-language programs in the DC Pre-K3 public school system. Montessori programs are defined as programs with the term Montessori in their title with varying adaptions of the method and have not necessarily been certified by any organization. Dual-language programs offer dual-language education in English, Spanish, Hebrew, and Mandarin. Both Montessori and dual language programs may be schoolwide or may exist as distinct tracks in schools with other offerings.

On the empirical side, substantial bodies of evidence document the effect of both program types in Pre-K4. A recent meta-analysis of 32 studies found that Montessori programs had positive effects on a wide-ranging set of academic and nonacademic outcomes, though academic effects from random assignment studies and public Montessori programs were indistinguishable from chance (Randolph et al., 2023). Dual language programs have a similarly robust evidence base, with positive impacts for dual language learners and native English speakers demonstrated on a host of academic outcomes (Barnett et al., 2007; Partika et al., 2021; Raikes et al., 2019).

Data

　　We used data from three different sources to answer our research questions. First, we

obtained data from the My School DC Lottery, which provided information on all

applications[2] to DC public Pre-K3 between 2014 and 2017. We restricted the period to focus

on kindergarten outcomes between 2016 and 2019 (before the COVID-19 pandemic). My

School DC conducted a matching process to link lottery applicants with public school

enrollment data and provided us with unique student identifiers that track students as they

progress through the DC public education system. Lottery data also included information

used in the lottery to assign applicants to seats, such as ranked choices, school priorities, and

random lottery draws. Like many school application systems, lottery data were intentionally

sparse in an effort to reduce the administrative burden of applications and improve the equity

of take-up. For instance, our data included the gender of student applicants and whether

applications were completed in English or Spanish, but it lacked other socioeconomic

characteristics. Because the data included applicants' home addresses, we used a secure

geocoder to identify the census block associated with their residence and then merge it with

publicly available data on community characteristics (described below). Finally, the data

contained information on whether a student was matched to a Pre-K3 program or placed on

one or more waitlists.

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[2] Throughout the paper, we refer to applications as the forms submitted to My School DC that generate the school choice data we observe. Applications also include a limited set of family and child characteristics. When referring to characteristics provided in application data, we refer to these as characteristics of applicants, though we recognize that sometimes these data describe children (e.g., gender) and other times describe families (e.g., residential address).

The second dataset used for this study was public school enrollment data maintained by the DC Office of the State Superintendent of Education (OSSE). It included information on all students enrolled in DC public schools from 2014 to 2019. The data contained students' unique student identifiers, which we then used to identify whether a Pre-K3 applicant enrolled in a DC public Pre-K3 program or later enrolled in DC public Pre-K4, kindergarten, first grade, or second grade. The data also included information on the school of enrollment and whether the student is classified with a special education status. We exclude from the analysis the few students who applied to the Pre-K3 lottery but eventually enrolled in a Pre-K4 program in the same year.

Finally, we used 2010 U.S. Census data to obtain census block-level economic and demographic statistics. Using the geocoded information on the residence of pre-kindergarten applicants, we defined applicants of communities of color as those residents of census blocks where the majority of residents (i.e., more than 50%) are people of color.[3] Additionally, we characterized applicants of communities with lower incomes as residents of census blocks whose median income is lower than $85,000, which was smaller than the median income of all families in DC ($101,722, Census 2022), but close to the median census block household income of applicants in our evaluation sample.[4] We chose this threshold to ensure we have sample sizes that provide us with enough power to estimate treatment effects for applicants from communities with lower-income. Residents in Wards experiencing disadvantage are

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[3] In Table A1 we further validate this measure by looking at the racial composition of students from communities of color who end up enrolling in the DC public system for whom we observe their race and ethnicity (about 82% of all Pre-K3 applicants). Among this group, we find that 91.2% of applicants of communities of color are people of color. We also find that 90.5% of applicants of color are residents of communities of color. However, this relationship between a person of color and being a resident of a community of color tends to be slightly weaker for applicants in the evaluation sample of the study.

[4] The median census block household income for the sample of all applicants is $81,152.

those in Wards 5,7 and 8, which are the wards with the highest poverty rates in DC (DC Health Matters 2023).

More than 19,000 students applied to the My School DC Pre-K3 Lottery between 2014 and 2017 (Table 1), representing about 60.7% of all 3-year-olds in DC. Among these applicants, 80.1 percent ended up enrolling in a public school for Pre-K3. An additional 1.9 percent of applicants enrolled in Pre-K3 in public community-based organizations (CBOs), which were not part of the lottery, and about 18 percent of applicants did not enroll in the DC public pre-kindergarten program. Nearly half of the student applicants were females (49.6 percent), and 4.4 percent submitted their applications in Spanish. Most applicants were coming from majority-Black census tracks. About 76% of all applications of a typical student went to oversubscribed programs (Table A2). Due to progressive policy implementation and public school building capacity constraints, there were no Pre-K3 programs in several of the communities with the highest incomes and where a greater number of residents who are white reside in DC during our period of analysis (with program offerings spread throughout all of DC's eight wards with the exception of Ward 3).

We focused on two main outcomes available for all Pre-K3 lottery applicants. The first outcome was an indicator of whether a Pre-K3 applicant eventually enrolled in kindergarten in a DC public school.[5] In other words, we followed all Pre-K3 applicants over time and identified those who eventually enrolled in a DC public kindergarten before 2019.[6] The second outcome was a measure of persistence in the DC Public system. This outcome

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[5] In the analysis, students who withdraw from a public school before October 5th are not considered enrolled in that academic year.
[6] We also create analogous measures for 1st—and 2nd-grade enrollment before 2019 to estimate the effect on later grades.

indicated whether the Pre-K3 applicant later enrolled in a school-based Pre-K4 program and public kindergarten in the DC public education system before 2019.[7]

We also evaluated the effect of Pre-K3 on three additional outcomes that are only available for Pre-K3 applicants who later enroll in DC public kindergarten. These outcomes were measured for 71% of our analytical sample.[8] First, we identified Pre-K3 applicants classified as students receiving special education services in kindergarten. Second, we created a school mobility outcome, which was an indicator of whether the student attended two different schools in DC between Pre-K4 and kindergarten.[9] Third, following OSSE, we defined a student as retained in grade if they attended kindergarten in a DC public school for two consecutive years.

Empirical Method

To estimate the effect of Pre-K3 enrollment on enrollment outcomes, we exploit the centralized lottery used by DC to match applicants to programs. DC uses a deferred acceptance (DA) algorithm to assign students to schools. The DA algorithm is referred to as a "school lottery" because oversubscribed schools - i.e., schools that received more applications than open seats - use a random lottery to determine which student gets a seat.

The system is "centralized" because parents use a shared infrastructure to submit their ranked list of preferred schools. Additionally, applicants' lottery numbers are common across all schools. Finally, schools set priorities over applicants, determining the order in which they admit applicants and overriding lottery numbers. Typical priority rules include sibling priorities and in-boundary resident preferences.

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[7] We also measure persistence in the public system between Pre-K4 and 1st and 2nd grades.
[8] Since we will later demonstrate that treated applicants are more likely to enroll in DC kindergarten, our estimated effects on these secondary outcomes are subject to attenuation bias.
[9] The indicator equals zero for students who did not attend Pre-K4 in the DC public system.

The DA algorithm is a dynamic and iterative process (Gale and Shapely, 1962). Before each lottery run, applicants submit their ranked school lists, and schools submit their priority rules. First, applicants are assigned a random lottery number, and schools determine their seat capacities. Next, a student's application goes to the most preferred school, which has not rejected it. If the school of application is undersubscribed, the program preliminarily accepts the applicant. If the school is oversubscribed, three different outcomes can occur. If the student has a lower priority level than the last student admitted by the school, their application is rejected. If the student has a higher priority status than the marginal student, their application is preliminarily accepted. If the student has the same priority level as the marginal student, the lottery number determines who is admitted to the school. The process continues in subsequent rounds until all students have been assigned to a school or until no further changes occur.

The Deferred Acceptance Assignment Score Method[10]

To identify the effect of Pre-K enrollment on later outcomes by exploiting the DA algorithm, we rely on the method developed by Abdulkadiroglu, Angrist, Narita, and Pathak (2017). The basic idea of the design is that the lottery creates numerous naturally occurring randomized experiments in school assignments for a set of applicants. Unlike previous approaches that use the number of applicants randomized to their first choice or first lottery, this research design leverages all random variation generated by the school lottery (Weiland et al.,2024).

The key insight of Abdulkadiroglu et al. (2017) is that applicants with the same ranked list and priority status should have the same chance of a match. Abdulkadiroglu et al. (2017)

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[10] In a companion brief (Monarrez et al., 2020), we provide a more in-depth explanation of the implementation of the deferred acceptance (DA) method using the DC centralized lottery.

show that the probability of obtaining a seat - which is based on the applicant's ranked choices and priority status - is a sufficient control to ensure that treated-untreated comparisons identify causal effects. The estimated probability of each student obtaining a match is called the DA assignment score or propensity score.[11] In the main specification of the paper, we use a formulaic approach to estimate DA assignment scores – as defined in Abdulkadiroglu et al. (2017).

Our evaluation sample is restricted to applicants with a non-degenerate risk of being unmatched at the end of the lottery run (i.e., whether they are matched depends on their lottery number). Due to an excess supply of seats in the lottery, most Pre-K3 applicants have a guaranteed chance of a match, while others will remain unmatched regardless of their lottery draw. For about 24% of applicants from 2014 through 2017, the random lottery draw determines their match with Pre-K3, placing them in our evaluation sample in a setup akin to a randomized controlled trial (Table 1). Applicants in our evaluation sample are more likely to come from census blocks with a higher median household income and higher education levels. They are also more likely to come from communities with a greater share of the population who are white and a smaller share of the population who are Black. Because of the progressivity of the Pre-K program in DC, more Pre-K3 seats are offered in communities with low incomes and communities of color, making residents of these locations more likely to have a guaranteed match.

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[11] Despite the similar names, the "DA propensity score" method carries a higher degree of credibility than the more commonly used propensity score matching method. The former is based on the random assignment to treatment (considered the "gold standard" of causal inference) driven by the lottery. The DA propensity score ensures that we compare individuals with a similar "risk" of being treated. We use the "DA assignment score" terminology to avoid confusion between the two methods.

To address the difference in representation of our evaluation sample, we will also show estimated effects of Pre-K3 for specific groups with characteristics closer to the overall population of applicants. As expected, students from our evaluation sample are more likely to apply to more competitive, oversubscribed programs than the average applicant (Table A2). Nonetheless, we could not identify much difference in program quality – defined by Classroom Assessment Scoring System (CLASS) Pre-K scores on Classroom Organization, Emotional Support, and Instructional Support domains -for ranked programs of applicants from our evaluation sample and the overall population of the applicants.[12]

Within the evaluation sample, we find a balance in pre-application characteristics between the applicants matched to a Pre-K3 program and those not matched to any program once we account for differences in their DA assignment score (Table A3). Of 22 pre-application characteristics, only two are statistically unbalanced between the treatment and control groups at the 5% level (with a joint F-test=0.99, p-value=0.47). This level of imbalance is expected by chance in a randomized controlled experiment, supporting the assumption that within our analysis, treatment operates as a random assignment conditional on DA assignment scores. We also include the rich set of pre-application controls - listed below - to address the remaining imbalance in pre-treatment characteristics between the two groups and improve the precision of our estimations.

Lottery Compliance and Instrumental Variable Approach

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[12] The classroom, emotional, and instructional support scores are based on the Classroom Assessment Scoring System (CLASS) used to assess the quality of experiences children attending DC Pre-K programs receive in their learning environment. CLASS observations provide information on practices and classroom features important for improving classroom interactions that matter most for children's outcomes. CLASS overall and domain scores (Emotional Support, Classroom Organization, and Instructional Support) were computed by OSSE and transmitted to the research team through our data-sharing agreement.

From a policy perspective, we are especially interested in the causal impact of enrolling in the Pre-K program and less so in the impact of being matched to the program. The next step in estimating the impact of Pre-K3 is to examine how random variation in match status translates to random variation in Pre-K3 enrollment. Applicants unmatched in the lottery can subsequently gain a seat off a waitlist when families matched through the lottery decide not to enroll at a given school. Likewise, families offered a seat can decline to participate in the program (e.g., because they choose to keep their child in a private preschool or with family, friends, or neighbors, or because they move away from DC).[13]

To recover the effect of Pre-K3 enrollment on outcomes, we use an instrumental variables approach. In the first stage, we estimate the effect of being matched to a Pre-K3 program on the likelihood of enrolling in a Pre-K3 program. We restrict the sample to those in the evaluation sample and control for application year-fixed effects, the interaction of DA assignment scores and year-fixed effects, and a set of applicant characteristics.

$$Enroll_{it} = \alpha Matched_{it} + \gamma_t + \pi\, AScore_i \times \gamma_t + \delta X_i + e_{it}$$

where $Enroll_{it}$ is an indicator for whether the applicant i to the Pre-K3 lottery in year t enrolled in a DC school-based Pre-K3 program in year t. $Matched_{it}$ is an indicator for whether the applicant was matched to a Pre-K3 program in the lottery. γ_t are application year-fixed effects and $AScore_i$ is the estimated DA assignment score.[14] Finally, X_i includes the number of programs ranked by the applicant, whether the applicant submitted their application in Spanish, whether the applicant is male, Ward of residence of the applicant

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[13] In the jargon of randomized experiments, this indicates a considerable amount of non-compliance in our experiment.
[14] Throughout the analysis, we will use DA scores using the formula calculations. But the main results are generally robust if we use frequency or simulated calculations.

fixed effects, and census block characteristics of the applicant: median income, share of the population by race and ethnicity, and share of adult population by education level.

In the second stage of the instrumental variable regression, we use the predicted enrollment from the first stage to estimate the effect of Pre-K3 on later enrollment outcomes:

$$Y_{it+\tau} = \beta \widehat{Enroll}_{it} + \gamma_t + \theta AScore_i \times \gamma_t + \rho X_i + u_{it}$$

where Y_{it+x} is an enrollment outcome of applicant i measured τ years after the lottery. All the other variables in the model are defined in the first stage. The interpretation of the coefficient β is the effect of Pre-K3 enrollment on later outcomes among applicants who comply with the lottery result.

Results

We find that students enrolled in Pre-K3 are more likely to persist in the public education system to kindergarten. In the reduced form model, which estimates intent to treat effects - we estimate that students matched by chance to a DC Pre-K3 program are 4 percentage points more likely to enroll in DC public kindergarten (Table 2). In the two-stage least squares model, the first stage shows that being matched to a Pre-K3 program increases the likelihood of enrollment in a Pre-K3 program by 22.6 percentage points among applicants in the evaluation sample. The second stage shows that enrollment in a Pre-K3 public program derived from a positive lottery draw increases the likelihood of enrollment in DC public kindergarten by 16.8 percentage points (or 25 percent).

The results are even stronger for the likelihood of enrollment in public Pre-K4 and kindergarten (persistence in the DC public system). We estimate that being matched to a DC Pre-K3 program increases the likelihood of enrollment in Pre-K4 and kindergarten by 8.2 percentage points. The two-stage least square model shows that students enrolled in a DC

Pre-K3 program are 35 percentage points (62.9 percent) more likely to enroll in a DC public Pre-K4 and kindergarten program. We interpret this result as evidence that enrolling a 3-year-old in Pre-K3 increases families' desire and ability to keep their children in the public system.

We also find suggestive evidence that students enrolled in Pre-K3 are more likely to be classified as students receiving special education services in kindergarten. The reduced form model shows that among children enrolled in a DC public kindergarten, those matched by chance to the DC Pre-K3 program are 2.5 percentage points more likely to be classified as a student receiving special education services (Table 2). From the two-stage least square model, we find that enrollment in a Pre-K3 public program increases the likelihood of being classified as a student receiving special education services by 11.5 percentage points among DC public kindergarten students. This result suggests that by enrolling in a public Pre-K3 program, students have more interactions with the public education system, which may lead to earlier diagnosis for special needs and the necessary support from an early age.

We also find that Pre-K3 enrollment is negatively associated with school mobility. Students who attended a DC Pre-K3 program are 17.8 percentage points less likely to switch schools from Pre-K4 to kindergarten within the DC public system. We interpret this finding as evidence that Pre-K3 families might decide to keep their children in the public school where they are assured a seat via the lottery through kindergarten. Finally, we do not find any evidence that enrolling in a Pre-K3 program impacts kindergarten retention. One potential explanation for the null effects is that retention in kindergarten is uncommon in DC, with only 1.0% of students in the comparison group retained.

Impact Heterogeneity

Next, we investigate whether enrollment in a DC Pre-K program has stronger effects on specific groups of students. We estimate larger effects of Pre-K3 on kindergarten enrollment for applicants from neighborhoods with lower incomes (median income is lower than $85,000), communities of color (more than 50 percent of the population are people of color), and residents of wards that are disadvantaged (residents of wards 5,7, and 8). Applicants from communities of color who enroll in a Pre-K3 program by chance are 26.7 percentage points more likely to be enrolled in a DC public kindergarten than applicants from the same communities who did not attend a Pre-K3 program (Figure 1, Panel A). In the same way, attending a public pre-K3 program increases the likelihood of enrollment in a DC public kindergarten by 35.5 percentage points for applicants from communities with lower incomes and 30.5 percentage points for applicants from wards that are disadvantaged. While these effects are measured with lower precision due to the smaller sample sizes, we tend to find greater effects of Pre-K3 on kindergarten among students who are more structurally marginalized. Finally, we do not find substantively different effects for male and female applicants.

We also find that applicants from communities with lower incomes are more likely to persist in the DC public system between Pre-K4 and kindergarten (Figure 1, Panel B). Applicants from those communities who enroll in Pre-K3 are 36.7 percentage points more likely to enroll in Pre-K4 and kindergarten public programs. We also estimate positive effects for applicants from communities of color and Wards that are disadvantaged. Overall, the results suggest that public Pre-K3 may have stronger positive effects on early elementary

public school enrollment for students who start their educational journeys furthest from opportunity.

Applicants from communities of color who enroll in a Pre-K3 program also have a greater chance of being classified as students receiving special education services in DC public kindergarten (Figure 1, Panel C) and a lower chance of switching schools in kindergarten (Figure 1, Panel D). However, these results must be interpreted cautiously due to the smaller sample size and weaker instruments for these groups (Table A4).

Do Enrollment Effects Persist after Kindergarten?

While the main focus of this study is whether enrollment in Pre-K3 impacts kindergarten outcomes, we also investigate whether these findings persist to first and second grade. To that end, we make further restrictions on the application years. For the first-grade analysis, we restrict the sample to DC Pre-K3 lottery applicants between 2014 and 2016, which represent 3,323 applicants in the evaluation sample (Table A5), and for the second-grade analysis, we restrict the sample to DC Pre-K3 lottery applicants between 2014 and 2015, which represent 2,161 applicants in the evaluation sample.

We estimate a positive effect of Pre-K3 enrollment on first and second-grade enrollment (Figure 2). The effect sizes are in the same order of magnitude as those for kindergarten enrollment – between 12 and 11 percentage points. However, these effects are estimated with less precision due to smaller evaluation samples, and we cannot reject null effects at the 5% significance level. We also find positive and statistically significant effects of Pre-K3 enrollment on persistence in the public system to first and second grades (Table A5). Students who, by chance, are admitted and enrolled in a Pre-K3 program are 22 percentage points more likely to be in the public system from Pre-K4 to second grade. In other words,

access to Pre-K3 programs increases children's attachment to public education for many years. We do not find any evidence that Pre-K3 enrollment impacts a student receiving special education supports, school mobility, or grade retention in the first and second grades. One potential interpretation is that students not enrolled in Pre-K3 eventually catch up with treated students in these dimensions as they progress in the public system. Nonetheless, future work can benefit from more post-COVID enrollment data to understand better the effects of public Pre-K3 in DC through second grade and beyond.

The Effect of Montessori and Dual Language Pre-K3 programs on Kindergarten Outcomes

To this point, we have explored the impact of all Pre-K3 programs on outcomes of interest. Our final set of analyses acknowledges that DC Public Pre-kindergarten is a large and diverse initiative with a variety of program offerings. These offerings reflect the work of advocates, administrators, and families with young children who sought out program types such as Montessori, Reggio Emilia, blended learning (in-person and digital content), arts integration, the Schoolwide Enrichment Model, and extended day schedules. We now turn to the question of whether particular types of Pre-K3 have stronger effects on kindergarten enrollment outcomes than others. We focus on Montessori and dual language programs, which receive a sizeable number of applications every year.

In each analysis, we restrict the sample to applicants to Montessori and dual language Pre-K3 programs in DC, respectively. Between 2014 and 2017, 5,352 students applied to a Montessori (Table A6), and 8,395 students applied to a dual language Pre-K program (Table A8). Like in the main analysis, we restrict the sample to students whose lottery numbers determine their enrollment in those programs. We estimate for each student applying to a Montessori (dual language) program their program-specific DA assignment score, which is

the likelihood of getting matched to a Montessori (or dual language) program in the lottery. We further restrict the sample to applicants whose program-specific DA assignment score is between above zero and below 1. After this restriction, there are 2,204 applicants in the Montessori evaluation sample and 3,054 applicants in the dual language evaluation sample.

In the program-specific analysis, the treatment groups are defined as applicants who enroll in a Montessori (dual language) public Pre-K3 program, and the comparison group is those who applied to those programs but ended up not enrolling there. Among those in the Montessori evaluation sample, 25% enrolled in a DC Pre-K3 Public Montessori, 46% enrolled in other school-based DC Pre-K3 public program, 2% enrolled in CBOs, and 27% did not enroll in any DC public program (Table A6). Among those in the dual language evaluation sample, 30% enrolled in a DC Pre-K3 Public dual language program, 41% enrolled in other school-based DC Pre-K3 public program, 3% enrolled in CBOs, and 26% did not enroll in any DC public program (Table A8).[15] For applicants in the program-specific evaluation sample, once we account for differences in their program-specific DA assignment scores, we find a balance in pre-application characteristics between those matched to a Pre-K3 Montessori program and those not matched to the program (Table A7). The same balance is observed among applicants matched to a dual-language program and those not matched (Table A9)

Main Results

Among those in the program-specific evaluation sample, being matched to a Montessori Pre-K3 program increases the chances of enrolling in a Montessori DC Pre-K3 by 49

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[15] Within the evaluation samples, we have a fair balance in pre-application characteristics between the applicants matched to a Pre-K3 Montessori (dual language) program and those not matched to that program once we account for differences in their program-specific DA assignment scores (Tables A7 and A9, respectively).

percentage points once we account for differences in their program-specific DA assignment scores (Table 3). Nonetheless, we find no evidence that students who, by chance, get a seat in a Pre-K3 Montessori program are more likely to stay in the DC public education system compared to those who applied to the same programs but did not get a Montessori seat. We estimate small and non-significant effects of Montessori enrollment on kindergarten enrollment and persistence in the DC public education system. We also do not find evidence that Montessori enrollment is associated with changes in school mobility, special education status in kindergarten, or grade retention. In other words, attending a Montessori Pre-K3 program has very little impact on early elementary school enrollment.

To better understand these results, we descriptively compare the outcomes of applicants in the treatment group (enrollment in Montessori Pre-K3) to the outcomes of applicants in different counterfactual conditions that make up the comparison group (Figure A1). While Montessori students are more likely to persist in the DC public system than those not enrolled in any DC public Pre-K program, there is no significant difference in this outcome in relation to students enrolled in other school-based program types. In the same way, Montessori Pre-K3 students are as likely as other school-based students to move schools in kindergarten. One potential explanation for this finding is that families seek a Montessori education while their children are in Pre-K but show no special preference for Montessori education in the early elementary grades. As a result, students enrolled in Montessori programs are as likely to leave the public system later or move schools as any other school-based Pre-K3 student.

On the contrary, dual language Pre-K3 enrollment increases the likelihood of persistence in the DC public education system and decreases school mobility in kindergarten more than

other program types (Table 4). First, being matched to a dual-language Pre-K3 program increases the likelihood of enrollment in a dual-language Pre-K3 program by 43.7 percentage points among those in the evaluation sample. In addition, students enrolled in a dual language Pre-K3 program are 11.6 percentage points more likely to enroll in a DC public Pre-K4 and kindergarten program in relation to the comparison group. Students attending a dual language Pre-K3 program are also 24.6 percentage points less likely to switch schools from Pre-K4 to kindergarten in relation to those in the comparison group. We do not find a significant impact of dual language Pre-K3 enrollment on our other outcomes.

Further descriptive statistics show that compared to students attending other school-based DC Pre-K programs, dual language Pre-K3 students are more likely to persist in the public system and stay within the same school (Figure A2). We interpret this as evidence that once applicants gain a spot in a highly desirable dual language school, families choose to stay in this educational model.

Discussion

This study leveraged data from DC's centralized school assignment lottery to generate new evidence on the effects of starting school at age 3. We find that students who enroll, by chance, in a DC public school for Pre-K3 are more likely to persist in the public education system through kindergarten and less likely to switch schools. These findings mirror similar results from lottery-based and quasi-experimental studies of universal preschool in Boston and Tulsa (Gormley, Phillips, & Anderson, 2018; Weiland et al., 2019). The effects are strongest for students living in communities of color and communities with low incomes and for schools in dual language programs. Consistent with past research (McCoy et al., 2017), we also find that students who enroll, by chance, in a DC public school for Pre-K3 are more

likely to be assigned as receiving special education services in kindergarten. Students of Pre-K3 dual language programs are more likely to stay in the DC public education system through kindergarten and are less likely to switch schools from Pre-K4 to kindergarten. We do not find comparable evidence for Pre-K3 Montessori programs.

Before unpacking the study findings, we raise several limitations that inform our interpretation and discussion of implications. Two limitations concern threats to external validity. The first is a unique study context. DC launched Pre-K3 through the Pre-K Enhancement and Expansion Act of 2008 and began the My School DC centralized assignment lottery in 2014. As a result, our treatment reflects a mature preschool program administered at scale. Although enrollments continued to climb during the study period, most program expansions occurred before 2014 (Friedman-Krauss et al., 2023). By contrast, we leverage data from the first four cohorts of My School DC. Lottery applications grew through the study period as outreach and family engagement efforts evolved (Greenberg et al., 2020). Study findings may not necessarily generalize to the early years of a new preschool initiative or settings with more established lotteries.

In addition, the DA approach produces generalizability concerns in the preschool context (Weiland et al., 2023). Like other lottery-based methods, our analytic framework trades internal validity for external validity by restricting the experimental sample to applicants facing risk in the lottery. The experimental sample is 24% of all applicants over the study period, and these applicants live in communities that are whiter, more educated, and more affluent than other applicants and DC's population of young children as a whole (Table 1; Monarrez et al., 2020). The average applicant from our sample differs from the average applicant to the lottery, but the evaluation sample represents the students who would likely

benefit from more seats in their desired programs. We partially address this limitation—a serious one given the longstanding equity goals of early education in the US—through sample disaggregation and analysis. However, the exclusion of applicants who do not face risk in the lottery remains an important limitation that could be addressed in future research.

Additionally, two limitations concern potential threats to internal validity. First, in centering our analysis on the My School DC lottery, we exclude community-based organizations offering public pre-kindergarten in DC but not participating in the lottery. Like many jurisdictions, DC offers universal preschool through a mixed-delivery system. Nearly 30 community-based organizations offered 5% of seats in the system during the study period (OSSE, 2023). Because these organizations do not allocate seats through DC's centralized assignment lottery but rather enroll students on-site, they are included in the study control group. It is, therefore, possible that our findings underestimate the true effects of Pre-K3.

Finally, as with many studies that use school district administrative data, we acknowledge that our analysis is limited by looking at school enrollment outcomes for applicants who later enroll in the DC public education system (Table A10). We observe kindergarten school outcomes, such as special education services status, for about 72% of Pre-K3 applicants in our evaluation sample who end up enrolling in a public DC kindergarten – with a higher rate for those matched to a Pre-K3 program than those unmatched (75% vs 66%). While guidance from the IES What Works Clearinghouse suggests we are within tolerable attrition rates under liberal attrition standards, we interpret the results of school outcomes with caution.

Implications

Despite the limitations described above, our findings have a wide range of applicability for early childhood education and early elementary school policy. This study demonstrates

that Pre-K3 improves public school persistence, benefiting students, families, and school systems. For older students, a large body of evidence shows that school mobility increases the risk of poor achievement, behavior problems, and grade retention (e.g., Reynolds et al., 2009; Schwartz et al., 2017). Because Pre-K3 substantially reduces movement between schools and school systems (or to private options), it can potentially stabilize children's early educational experiences. Early educational stability, in turn, can facilitate secure emotional attachment and the development of foundational academic and social skills (Chaudry & Sandstrom, 2020; Sandstrom & Huerta, 2013). Although we find no impact of Pre-K3 on grade retention in this study, retention is exceedingly rare in DC's early elementary grades (Table 2). Tracking focal cohorts into the later elementary and secondary grades may uncover latent effects.

The benefits of educational stability that accrue to students can also foster family well-being. A recent review of the literature demonstrates that instability in child care and early education is common and often disruptive to parents' ability to work and families' financial health (Chaudry & Sandstrom, 2020). However, DC Public Pre-kindergarten bypasses many of the changes that are common in counterfactual settings. Schools that offer Pre-K3 are not subject to the churn of the childcare market, nor do they have the tuition, co-payment, and eligibility certification requirements of other options for 3-year-olds (Weiland et al., 2021). Instead, Pre-K3 is free for all DC residents due to stable, permanent funding. This investment raised maternal labor force participation by 10 percentage points to the level of mothers of school-age children, with the greatest increases accruing to mothers who were unmarried, had less than a high school degree, and were experiencing poverty (Malik, 2018). In DC, where residents are facing gentrification and residential displacement due to rising housing

costs (Hyra, 2017), it is not surprising that communities of color and communities with low incomes see the greatest persistence benefits of Pre-K3 (Figure 1).

Finally, for school systems, Pre-K3 offers a clear policy solution to the problem of declining enrollment. Addressing declining enrollment and restoring the financial health of public school systems were, in fact, goals of the initial design of DC Public Pre-kindergarten (Watson, 2010). These goals have renewed importance in the wake of the COVID-19 pandemic. Public school enrollments have not yet recovered, and questions remain about the educational quality and long-term civic consequences of homeschooling and other alternative learning environments (Dee, 2023; Goldstein & Parlapiano, 2021). As federal pandemic relief fades, low enrollment may soon force difficult choices about teacher layoffs and school closures (Burtis & Goulas, 2023). With expanded public investment in Pre-K3, those difficult choices could become improved educational opportunities for students, families, and school systems.

Conclusion

As policy interest in expanding public preschool grows, this study establishes new evidence on the effects of starting school at age 3. This study demonstrates that Pre-K3 can boost public school persistence and stabilize school systems and their youngest students. Given the implications of study findings for pandemic recovery, following students through third grade and focusing on cohorts who attended Pre-K3 during the pandemic are key priorities for future research.

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Table 1

Descriptive Statistics

	All Applicants	**Evaluation Sample**
Applicant Characteristics		
# Programs Ranked	5.55	6.19
Spanish Applications	4.4%	5.2%
Female	49.6%	48.8%
Census Block Average Characteristic		
Median HH Income	$81,460.84	$107,582.96
HS or Less	35.3%	24.1%
Some College	19.9%	14.7%
Bachelors	20.6%	26.1%
Graduate	24.2%	35.1%
Asian	2.6%	4.1%
Black	57.2%	36.7%
Hispanic	10.9%	13.0%
Multiracial	3.8%	4.5%
White	24.6%	41.0%
Ward of Residence		
Ward 1	10.0%	15.5%
Ward 2	3.7%	7.5%
Ward 3	2.7%	6.2%
Ward 4	15.2%	20.0%
Ward 5	14.8%	13.0%
Ward 6	16.2%	22.9%
Ward 7	17.0%	7.8%
Ward 8	19.6%	5.6%
No Ward	0.6%	1.2%
PK3 Enrollment		
DC Public School	80.1%	64.3%
CBOs	1.9%	2.6%
Not Enrolled in DC Public Program	18.1%	33.1%
# Applicants	19,059	4,561

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data, and 2010 US census data.
Note: The evaluation sample consists of those who applied to a PK3 program between 2014 and 2017 and were impacted by the lottery (DA score >0 & DA score <1).

Table 2

The Effect of DC Public School PK3 Program Enrollment on Kindergarten Outcomes

Outcome	Unmatched Mean	First Stage	Reduced Form	2SLS	N
Panel A - Evaluation Sample					
Kindergarten enrollment in the DC Public system	66.3%	0.226***	0.0379**	0.168**	4,561
		(0.017)	(0.0160)	(0.0672)	
Persistence in the DC Public System	56.1%		0.0819***	0.353***	
			(0.0166)	(0.0654)	
Panel B - Evaluation sample & Enrolled in DC Public KG					
Kindergarten Special Education	7.7%	0.221***	0.0253**	0.115**	3,247
		(0.018)	(0.0122)	(0.0556)	
Moved to a new DC Public School	24.7%		-0.0393**	-0.178**	
			(0.0178)	(0.0814)	
Retained in grade	1.0%		-0.00648	-0.0294	
			(0.00423)	(0.0190)	

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data

Note: The evaluation sample consists of those who applied to a PK3 program between 2014 and 2017 and were impacted by the lottery (DA score >0 & DA score <1). The unmatched mean is the outcome mean for applicants in the evaluation sample not matched to a PK3 program in the lottery. The first stage, reduced form and 2SLS regressions control for DA scores interacted with year fixed-effect, # schools ranked, Spanish application, gender, Ward fixed effects, census block characteristics (median income, % population by race and ethnicity, % adult population by education level). *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3

The Effect of DC Public Schools Montessori PK3 Program Enrollment on Kindergarten Outcomes

| Outcome	Unmatched Mean	First Stage	Reduced Form	2SLS	N
Panel A - Montessori Evaluation Sample					
Kindergarten enrollment in the DC Public system	72.1%	0.492***	-0.000921	-0.00187	2,204
		(0.025)	(0.0246)	(0.0496)	
Persistence in the DC Public System	66.1%		0.0267	0.0544	
			(0.0257)	(0.0509)	
Panel B - Montessori Evaluation Sample & Enrolled in DC Public KG					
Kindergarten Special Education	7.9%	0.554***	0.0116	0.0209	1,592
		(0.028)	(0.0180)	(0.0320)	
Moved to a new DC Public School	25.0%		-0.0224	-0.0404	
			(0.0277)	(0.0494)	
Retained in grade	0.8%		-0.00286	-0.00516	
			(0.00522)	(0.00933)	

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data
Note: The Montessori evaluation sample consists of those who applied to a Montessori PK3 program between 2014 and 2017 and were impacted by the lottery (Montessori DA score >0 & Montessori DA score <1). The unmatched mean is the outcome mean for applicants in the Montessori evaluation sample not matched to a PK3 Montessori program in the lottery. The first stage, reduced form and 2SLS regressions control for Montessori DA p-scores interacted with year fixed=effect, # schools ranked, Spanish application, gender, Ward fixed effects, census block characteristics (median income, % population by race and ethnicity, % adult population by education level). *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4

The Effect of DC Public School Dual Language PK3 Program Enrollment on Kindergarten Outcomes

Outcome	Unmatched Mean	First Stage	Reduced Form	2SLS	N
Panel A - Dual Language Evaluation Sample					
Kindergarten enrollment in the DC Public system	74.5%	0.437***	0.00602	0.0138	3,054
		(0.024)	(0.0218)	(0.0493)	
Persistence in the DC Public System	66.6%		0.0506**	0.116**	
			(0.0232)	(0.0507)	
Panel B - Dual Language Evaluation Sample & Enrolled in DC Public KG					
Kindergarten Special Education	8.4%	0.519***	-0.00550	-0.0106	2,281
		(0.026)	(0.0161)	(0.0309)	
Moved to a new DC Public School	26.8%		-0.128***	-0.246***	
			(0.0220)	(0.0426)	
Retained in grade	0.5%		-0.00349	-0.00674	
			(0.00260)	(0.00498)	

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data
Note: The dual language evaluation sample consists of those who applied to a dual language PK3 program between 2014 and 2017 and were impacted by the lottery (dual language DA score >0 & dual language DA score <1). The unmatched mean is the outcome mean for applicants in the dial language evaluation sample not matched to a PK3 dual language program in the lottery. The first stage, reduced form and 2SLS regressions control for dual language DA p-scores interacted with year fixed=effect, # schools ranked, Spanish application, gender, Ward fixed effects, census block characteristics (median income, % population by race and ethnicity, % adult population by education level). *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Figure 1

The Effect of DC Public School PK3 Program Enrollment on Kindergarten Outcomes by Applicant Characteristics
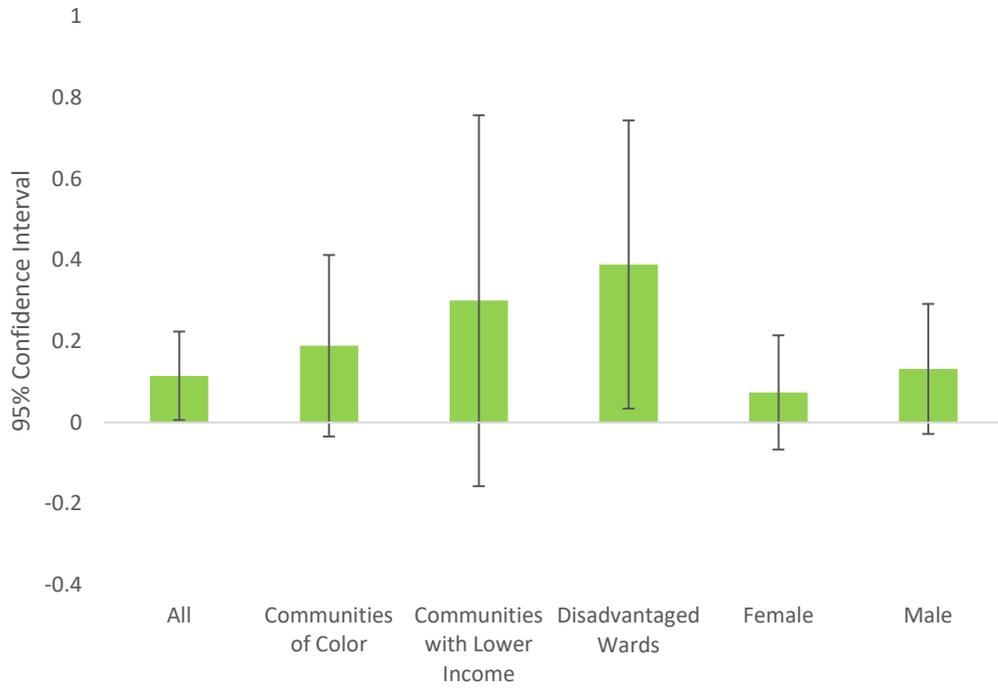
Panel A - Effect of PK3 Program Enrollment on Kindergarten enrollment in the DC Public system
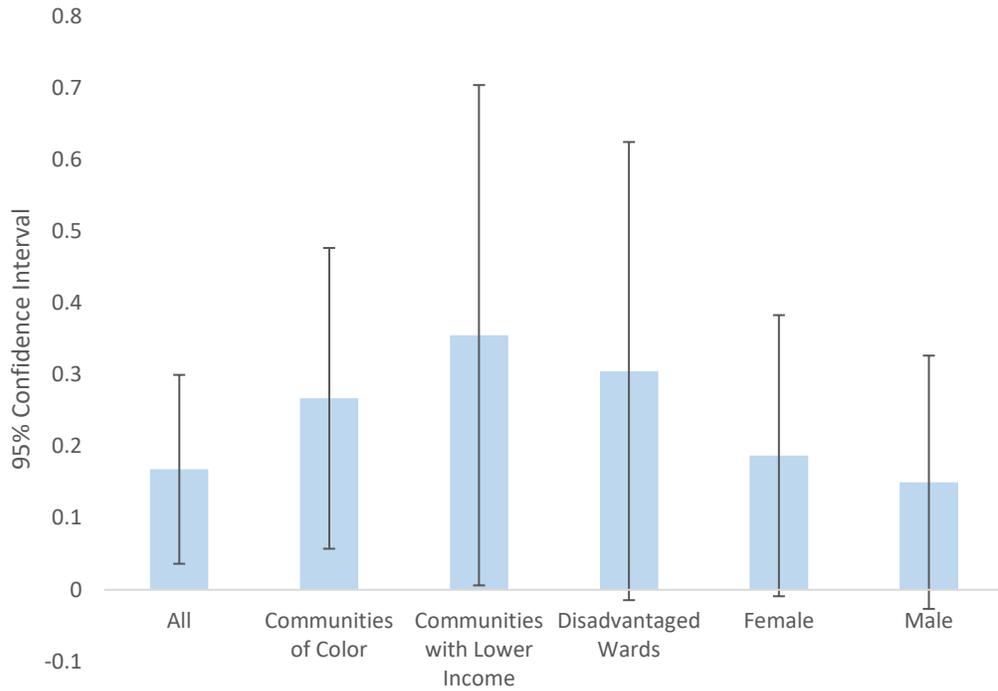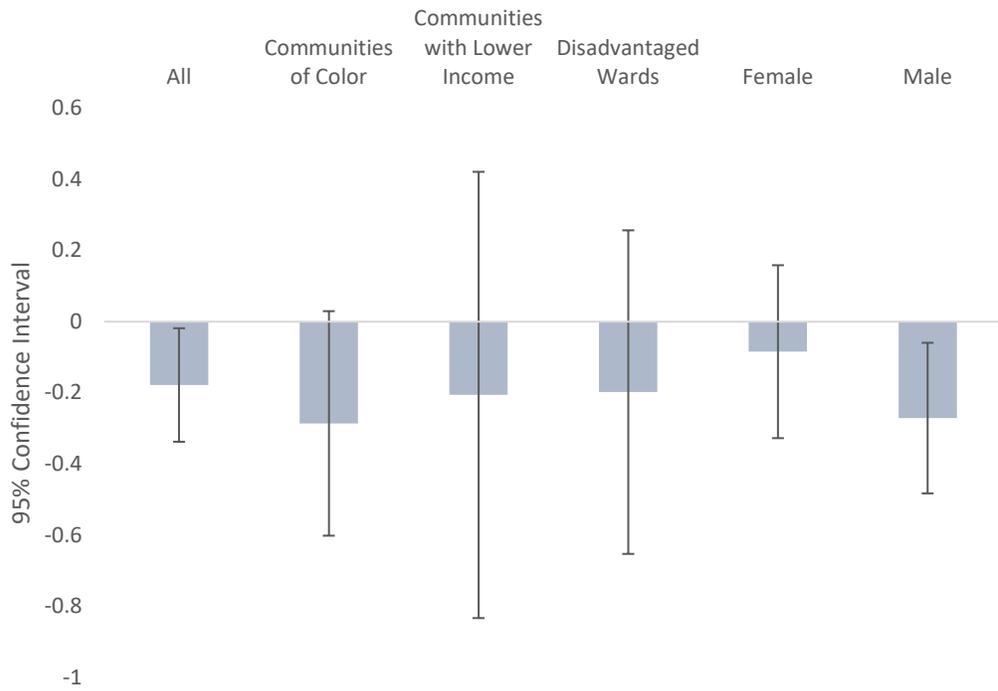

Panel B - Effect of PK3 Program Enrollment on Persistence in the DC Public system
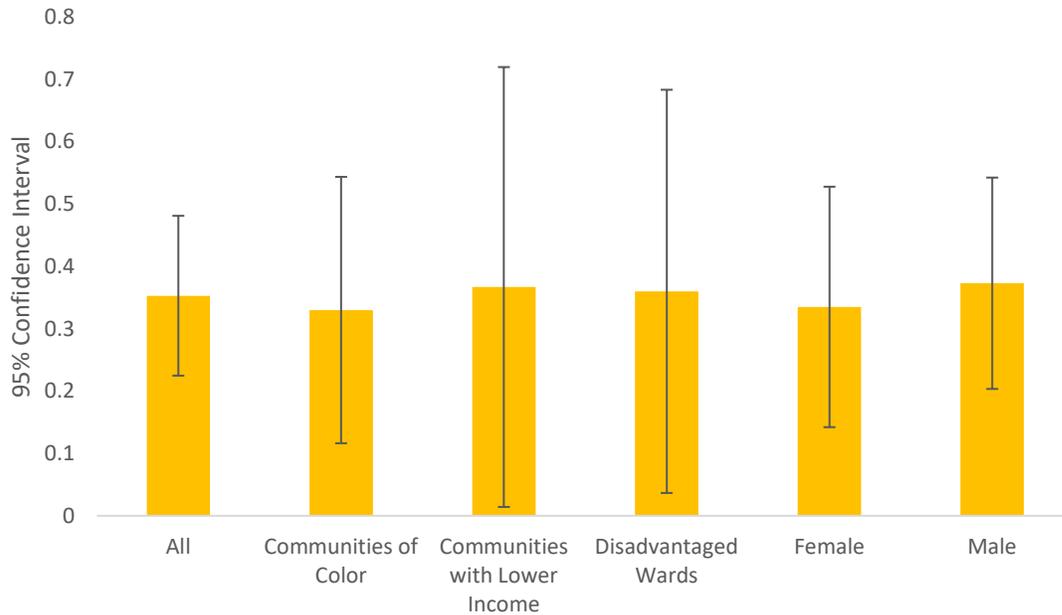
Panel C - Effect of PK3 Program Enrollment on Kindergarten Special Education

Panel D - Effect of PK3 Program Enrollment on Moved to a Different School in Kindergarten

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data, and 2010 US census data.

Note: In Panel A and B, the sample is restricted to those in the evaluation sample. In Panel B, the sample is restricted to the evaluation sample and students enrolled in DC Public Kindergarten. We report estimated coefficients and 95% confidence from the 2SLS using the same model reported in Table 2. Communities of color are census blocks where more than 50% of the population identifies as people of color. Communities with lower income are census blocks with a median income lower than 85 thousand dollars. Disadvantaged wards are residents of wards 5,7, and 8. Regression results are presented in Table A4.

Figure 2

Effect of PK3 Program Enrollment on Later Enrollment in a DC Public System
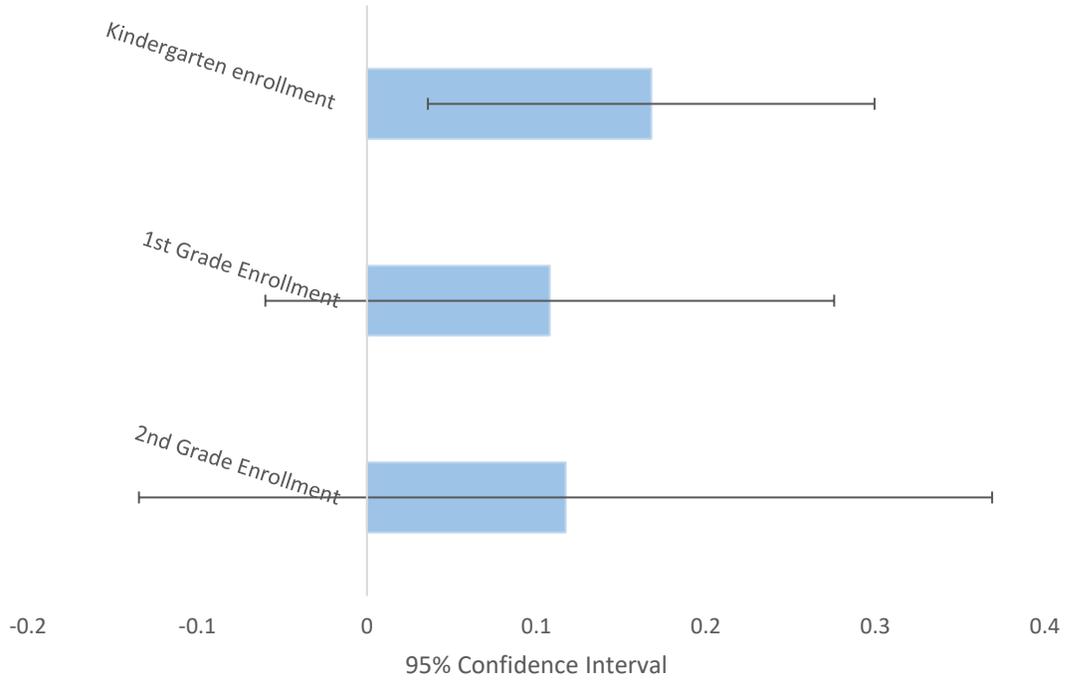
Note: The sample is restricted to the evaluation sample. We restrict the sample to DC PK3 lottery applicants between 2014 and 2017 for kindergarten enrollment. For 1st Grade enrollment, we restrict the sample to DC PK3 lottery applicants between 2014 and 2016. For 2nd Grade enrollment, we restrict the sample to DC PK3 lottery applicants between 2014 and 2015. We report estimated coefficients and 95% confidence from the 2SLS using the same model reported in Table 2. Regression results are presented in Table A5.

Online Supplementary Files

Appendix A: Supplemental Tables and Figures

Table A1

People of Color vs Communities of Color Analysis

	All Applicants	Evaluation Sample
Unknown race or ethnicity	18.1%	33.1%
Among applicants with a known race or ethnicity		
Racial and ethnic distribution of applicants from communities of color		
American Indian or Alaskan Native	0.2%	0.1%
Asian	1.1%	2.4%
Black or African American	72.9%	49.4%
Hispanic/Latino	14.5%	22.7%
Native Hawaiian or other Pacific Islander	<0.1%*	<0.1%*
Two or more races	2.3%	3.4%
Not reported	<0.1%*	<0.1%*
White	8.8%	22.0%
Applicants of color residence		
Community of color	90.5%	78.5%
Other communities	9.5%	21.5%
# Applicants	15,617	3,052

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data

Note: Applicants with an unknown race are applicants who we do not later see enrolled in the DC Public System. The evaluation sample consists of those who applied to a PK3 program between 2014 and 2017 and were impacted by the lottery (DA score >0 & DA score <1). Communities of color are census blocks where more than 50% of the population identifies as people of color. Applicants of color are those identified as American Indian or Alaskan Native, Asian, Black or African American, Hispanic/Latino, Native Hawaiian or other Pacific Islander, and two or more races.

*Point estimation not reported in accordance with disclosure rules from the DC Office of the State Superintendent of Education

Table A2

Descriptive Statistics – Programs

	All Applicants	Evaluation Sample
Program Characteristics (Means)		
Average Ratio of Applications to Seats Available	5.43	7.70
% Oversubscribed programs	76.2%	>99.9%*
Classroom Support Score	5.77	5.78
Emotional Support Score	5.98	6.01
Instructional Support Score	2.88	2.89
% Dual Language	16.3%	26.5%
% Montessori	5.4%	8.2%
Ward of Program		
Ward 1	11.0%	17.1%
Ward 2	8.3%	12.0%
Ward 3	<0.1%*	<0.1%*
Ward 4	14.4%	16.7%
Ward 5	19.0%	21.2%
Ward 6	18.2%	26.0%
Ward 7	12.5%	3.5%
Ward 8	16.6%	3.4%
# Applicants	19,059	4,561

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data, and 2010 US census data.

Note: The evaluation sample consists of those who applied to a PK3 program between 2014 and 2017 and were impacted by the lottery (DA score >0 & DA score <1). Oversubscribed programs are those with # applicant > # seats.

 *Point estimation not reported in accordance with disclosure rules from the DC Office of the State Superintendent of Education

Table A3

Comparison of Characteristics Between Treatment and Comparison Groups

| | Matched to a DC Public School PK3 Program | | Statistical Difference Test P-value | |
	No	Yes	No controls	DA Scores x Year Fixed-Effects
Applicant Characteristics				
# Programs Ranked	5.93	6.39	0.00	0.95
Spanish Applications	5.1%	5.2%	0.94	0.41
Female	48.6%	48.9%	0.81	0.49
Census Block Average Characteristic				
Median HH Income	$110,309.18	$105,442.04	0.00	0.08
HS or Less	23.4%	24.5%	0.05	0.07
Some College	14.7%	14.7%	0.95	0.14
Bachelors	26.2%	26.1%	0.89	0.06
Graduate	35.7%	34.6%	0.05	0.13
Asian	3.9%	4.2%	0.13	0.02
Black	35.5%	37.6%	0.02	0.17
Hispanic	13.2%	12.8%	0.39	0.02
Multiracial	4.5%	4.4%	0.34	0.50
White	42.0%	40.2%	0.03	0.04
Ward of Residence				
Ward1	14.7%	16.2%	0.15	0.81
Ward2	8.2%	6.9%	0.10	0.69
Ward3	7.8%	5.0%	0.00	0.60
Ward4	19.2%	20.6%	0.22	0.09
Ward5	14.9%	11.6%	0.00	0.83
Ward6	20.7%	24.6%	0.00	0.07
Ward7	7.8%	7.8%	0.98	0.09
Ward8	4.6%	6.5%	0.00	0.15
No Ward	1.9%	0.6%	0.00	0.06
# Observations	2,020	2,541		

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data, and 2010 US census data**.**

Note: Sample restricted to the evaluation sample. Statistical differences test with no controls are t-tests for differences in the mean. Statistical differences test with controls come from linear regression controlling for DA scores interacted with year-fixed effects.

Table A4

The Effect of DC Public School PK3 Program Enrollment on Kindergarten Outcomes by Applicant Characteristics

Panel A - Effect of PK3 Program Enrollment on Kindergarten enrollment in the DC Public system
Outcome: Kindergarten enrollment in the DC Public system

Sample	All	Communities of Color	Communities with Lower Income	Disadvantaged Wards	Female	Males
Enrolled in a DC Public School PK3 Program	0.168**	0.267**	0.355**	0.305*	0.187*	0.150*
	(0.0672)	(0.107)	(0.178)	(0.163)	(0.100)	(0.0901)
Observations	4,561	2,552	1,561	1,207	2,224	2,337
Unmatched Dep Var Mean	66.3%	73.2%	74.1%	70.2%	66.4%	66.3%
Kleibergen-Paap F-statistic	185.8	64.96	22.55	27.23	84.02	99.56

Panel B - Effect of PK3 Program Enrollment on Persistence in the DC Public System
Outcome: Persistence in the DC Public System

Sample	All	Communities of Color	Communities with Lower Income	Disadvantaged Wards	Female	Males
Enrolled in a DC Public School PK3 Program	0.353***	0.330***	0.367**	0.360**	0.335***	0.373***
	(0.0654)	(0.109)	(0.180)	(0.165)	(0.0984)	(0.0865)
Observations	4,561	2,552	1,561	1,207	2,224	2,337
Unmatched Dep Var Mean	56.1%	65.8%	65.3%	64.5%	57.7%	54.6%
Kleibergen-Paap F-statistic	185.8	64.96	22.55	27.23	84.02	99.56

Panel C - Effect of PK3 Program Enrollment on Kindergarten Special Education
Outcome: Persistence in the DC Public system

Sample	All	Communities of Color	Communities with Lower Income	Disadvantaged Wards	Female	Males
Enrolled in a DC Public School PK3 Program	0.115**	0.189*	0.300	0.389**	0.0740	0.132
	(0.0556)	(0.114)	(0.233)	(0.181)	(0.0718)	(0.0817)
Observations	3,247	1,978	1,228	910	1,594	1,653
Unmatched Dep Var Mean	7.7%	9.4%	9.7%	9.3%	4.9%	10.3%
Kleibergen-Paap F-statistic	154.7	46.19	12.44	25.81	65.80	88.01

Panel D - Effect of PK3 Program Enrollment on Moved to a Different School in Kindergarten
Outcome: Persistence in the DC Public System

Sample	All	Communities of Color	Communities with Lower Income	Disadvantaged Wards	Female	Males
Enrolled in a DC Public School PK3 Program	-0.178**	-0.286*	-0.206	-0.198	-0.0844	-0.271**
	(0.0814)	(0.161)	(0.320)	(0.232)	(0.124)	(0.108)
Observations	3,247	1,978	1,228	910	1,594	1,653
Unmatched Dep Var Mean	24.7%	27.1%	28.7%	30.6%	23.7%	25.7%
Kleibergen-Paap F-statistic	154.7	46.19	12.44	25.81	65.80	88.01

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data.

Note: In Panel A and B, the sample is restricted to those in the evaluation sample. In Panel B, the sample is restricted to the evaluation sample and students enrolled in DC Public KG. We report estimated coefficients and 95% confidence from the 2SLS using the same model reported in Table 2. Communities of color are census blocks where more than 50% of the population identifies as people of color. Communities with lower income are census blocks with a median income lower than 85 thousand dollars. Disadvantaged wards are residents of wards 5,7 and 8. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A5

Effect of PK3 Program Enrollment on Later Outcomes in a DC Public System

Panel A - Effect of PK3 Program Enrollment on Later enrollment in the DC Public system

Outcome	Kindergarten enrollment	1st Grade Enrollment	2nd Grade Enrollment
Enrolled in a DC Public School PK3 Program	0.168**	0.108	0.117
	(0.0672)	(0.0856)	(0.128)
Observations	4,561	3,323	2,161
Dep var mean	66.3%	63.8%	61.4%
Kleibergen-Paap F-statistic	185.8	126.6	58.85
Sample	DC PK3 lottery applicants between 2014 and 2017	DC PK3 lottery applicants between 2014 and 2016	DC PK3 lottery applicants between 2014 and 2015

Panel B - Effect of PK3 Program Enrollment on Persistence in the DC Public System

Outcome	Persistence to Kindergarten	Persistence to 1st Grade	Persistence to 2nd Grade
Enrolled in a DC Public School PK3 Program	0.353***	0.271***	0.223*
	(0.0654)	(0.0841)	(0.128)
Observations	4,561	3,323	2,161
Dep var mean	56.1%	53.3%	51.5%
Kleibergen-Paap F-statistic	185.8	126.6	58.85
Sample	DC PK3 lottery applicants between 2014 and 2017	DC PK3 lottery applicants between 2014 and 2016	DC PK3 lottery applicants between 2014 and 2015

Panel C - Effect of PK3 Program Enrollment on Later Special Education

Outcome	Special Ed in Kindergarten	Special Ed in 1st Grade	Special Ed in 2nd Grade
Enrolled in a DC Public School PK3 Program	0.115**	0.0979	0.206
	(0.0556)	(0.0814)	(0.140)
Observations	3,247	2,259	1,406
Dep var mean	7.7%	10.5%	11.5%
Kleibergen-Paap F-statistic	154.7	88.91	37.13
Sample	DC PK3 lottery applicants between 2014 and 2017 & Enrolled in DC Public KG	DC PK3 lottery applicants between 2014 and 2016 & Enrolled in DC Public 1st grade	DC PK3 lottery applicants between 2014 and 2015 & Enrolled in DC Public 2nd grade

Panel D - Effect of PK3 Program Enrollment on Moved to a Different School

Outcome	Moved to a Different DC Public School in Kindergarten	Moved to a Different DC Public School in 1st Grade	Moved to a Different DC Public School in 2nd Grade
Enrolled in a DC Public School PK3 Program	-0.178**	-0.0834	-0.0467
	(0.0814)	(0.0908)	(0.107)
Observations	3,247	2,259	1,406
Dep var mean	24.7%	14.9%	7.8%
Kleibergen-Paap F-statistic	154.7	88.91	37.13
Sample	DC PK3 lottery applicants between 2014 and 2017 & & Enrolled in DC Public KG	DC PK3 lottery applicants between 2014 and 2016 & Enrolled in DC Public 1st grade	DC PK3 lottery applicants between 2014 and 2015 & Enrolled in DC Public 2nd grade

Panel E - Effect of PK3 Program Enrollment on Retention

Outcome	Retained in Kindergarten	Retained in 1st Grade	Retained in 2nd Grade
Enrolled in a DC Public School PK3 Program	-0.0294	0.0375	0.00990
	(0.0190)	(0.0304)	(0.0121)
Observations	3,247	2,259	1,406
Dep var mean	1.0%	0.5%	0.2%
Kleibergen-Paap F-statistic	154.7	88.91	37.13
Sample	DC PK3 lottery applicants between 2014 and 2017 & Enrolled in DC Public KG	DC PK3 lottery applicants between 2014 and 2016 & Enrolled in DC Public 1st grade	DC PK3 lottery applicants between 2014 and 2015 & Enrolled in DC Public 2nd grade

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data

Note: Sample restricted to the evaluation sample. For kindergarten enrollment, we restrict the sample to DC PK3 lottery applicants between 2014 and 2017. For 1st Grade enrollment, we restrict the sample to DC PK3 lottery applicants between 2014 and 2016. For 2nd Grade enrollment, we restrict the sample to DC PK3 lottery applicants between 2014 and 2015. Models are estimated using 2SLS using the same model reported in Table 2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A6
Descriptive Statistics – Montessori Applicants

	All Montessori Applicants	Montessori Evaluation Sample
Applicant Characteristics		
# Programs Ranked	8.76	9.00
Spanish Applications	1.0%	0.9%
Female	49.4%	48.4%
Census Block Average Characteristic		
Median HH Income	$97,171.72	$99,903.12
HS or Less	28.8%	26.9%
Some College	17.7%	17.2%
Bachelors	24.0%	25.5%
Graduate	29.5%	30.5%
Asian	3.0%	3.4%
Black	49.0%	47.0%
Hispanic	9.1%	9.8%
Multiracial	4.5%	4.7%
White	33.6%	34.3%
Ward of Residence		
Ward 1	7.4%	8.3%
Ward 2	2.3%	2.8%
Ward 3	2.4%	3.0%
Ward 4	13.5%	15.7%
Ward 5	20.5%	25.0%
Ward 6	26.6%	22.9%
Ward 7	17.4%	12.2%
Ward 8	8.6%	7.4%
No Ward	1.1%	2.2%
PK3 Enrollment		
DC Pre-K3 Public Montessori	15.5%	25.1%
Other School-based DC Pre-K3 Public Program	62.7%	45.9%
CBOs	1.4%	1.8%
Not Enrolled in DC Public Program	20.4%	27.3%
# Applicants	5,352	2,204

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data.
Note: The Montessori evaluation sample consists of those who applied to a Montessori PK3 program between 2014 and 2017 and were impacted by the lottery (Montessori DA score >0 & Montessori DA score <1).

Table A7

Treatment and Comparison Groups, Montessori

	Matched to a Montessori DC Public School PK3 Program		Statistical Difference Test P-value	
	No	Yes	No controls	Montessori DA Scores X Year Fixed-Effects
Applicant Characteristics				
# Programs Ranked	9.09	8.66	0.01	0.75
Spanish Applications	1.0%	0.4%	0.19	0.07
Female	47.4%	51.9%	0.09	0.07
Census Block Average Characteristic				
Median HH Income	$100,574.10	$97,447.91	0.23	0.48
HS or Less	26.6%	27.7%	0.26	0.16
Some College	17.0%	18.0%	0.05	0.61
Bachelors	25.6%	25.1%	0.38	0.24
Graduate	30.8%	29.2%	0.08	0.32
Asian	3.4%	3.4%	0.85	0.30
Black	46.4%	49.0%	0.10	0.18
Hispanic	9.8%	10.0%	0.64	0.65
Multiracial	4.7%	4.5%	0.42	0.78
White	34.9%	32.3%	0.06	0.21
Ward of Residence				
Ward 1	8.0%	9.5%	0.30	0.21
Ward 2	3.0%	2.1%	0.26	0.59
Ward 3	3.1%	2.9%	0.83	0.74
Ward 4	15.0%	18.0%	0.11	0.41
Ward 5	24.9%	25.2%	0.91	0.11
Ward 6	24.1%	18.4%	0.01	0.37
Ward 7	12.0%	13.0%	0.54	0.63
Ward 8	7.4%	7.6%	0.85	0.52
No Ward	2.2%	2.3%	0.87	0.88
# Observations	1,720	484		

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data**.**

Note: The sample is restricted to the Montessori evaluation sample. Statistical differences test with no controls are t-tests for differences in the mean. Statistical differences test with controls come from linear regression controlling for Montessori DA scores interacted with year-fixed effects.

Table A8

Descriptive Statistics, Dual Language Program Applicants

	All DLP Applicants	DLP Evaluation Sample
Applicant Characteristics		
# Programs Ranked	7.90	8.31
Spanish Applications	6.3%	6.2%
Female	48.7%	48.2%
Census Block Average Characteristic		
Median HH Income	$99,627.98	$102,680.69
HS or Less	27.3%	26.1%
Some College	16.3%	15.9%
Bachelors	24.9%	25.5%
Graduate	31.5%	32.6%
Asian	3.6%	3.9%
Black	42.5%	39.0%
Hispanic	13.8%	14.8%
Multiracial	4.4%	4.5%
White	34.9%	37.0%
Ward of Residence		
Ward 1	17.3%	21.4%
Ward 2	4.2%	3.4%
Ward 3	4.3%	4.9%
Ward 4	21.2%	22.9%
Ward 5	17.7%	20.5%
Ward 6	18.9%	14.6%
Ward 7	8.9%	6.5%
Ward 8	6.6%	4.7%
No Ward	0.9%	1.0%
PK3 Enrollment		
DC Pre-K3 Public DLP	24.2%	30.0%
Other School-based DC Pre-K3 Public Program	52.2%	40.7%
CBOs	2.6%	3.5%
Not Enrolled in DC Public Program	21.0%	25.7%
# Applicants	8,395	3,054

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data
Note: The dual language evaluation sample consists of those who applied to a Dual Language PK3 program between 2014 and 2017 and were impacted by the lottery (Dual Language DA score >0 & Dual Language DA score <1).

Table A9

Descriptive Statistics – Programs

	Matched to a Dual Language DC Public School PK3 Program		Statistical Difference Test P-value	
	No	Yes	No controls	Dual Language DA P-scores X Year Fixed-Effects
Applicant Characteristics				
# Programs Ranked	8.46	7.90	0.00	0.73
Spanish Applications	5.7%	7.6%	0.07	0.60
Female	48.3%	47.9%	0.86	0.75
Census Block Average Characteristic				
Median HH Income	$101,457.20	$101,925.40	0.96	0.79
HS or Less	26.0%	26.3%	0.72	0.34
Some College	16.1%	15.2%	0.03	0.37
Bachelors	25.5%	25.3%	0.68	0.52
Graduate	32.4%	33.2%	0.24	0.28
Asian	3.8%	4.2%	0.01	0.06
Black	40.1%	35.8%	0.00	0.09
Hispanic	14.3%	16.0%	0.00	0.72
Multiracial	4.5%	4.5%	0.66	0.99
White	36.4%	38.7%	0.02	0.18
Ward of Residence				
Ward 1	17.9%	31.4%	0.00	0.01
Ward 2	3.7%	2.4%	0.06	0.95
Ward 3	5.3%	3.8%	0.10	0.83
Ward 4	22.6%	23.4%	0.64	0.74
Ward 5	22.5%	14.9%	0.00	0.41
Ward 6	14.9%	13.5%	0.33	0.20
Ward 7	6.9%	5.2%	0.10	0.61
Ward 8	4.8%	4.5%	0.70	0.81
No Ward	1.1%	0.6%	0.22	0.79
# Observations	2,248	806		

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data, and 2010 US census data**.**
Note: The sample is restricted to the dual language evaluation sample**.** Statistical differences test with no controls are t-tests for differences in the mean. Statistical differences test with controls come from linear regression controlling for dual language DA scores interacted with year-fixed effects.
 *Point estimation not reported in accordance with disclosure rules from the DC Office of the State Superintendent of Education

Table A10
Attrition Rate

	% of missing at KG Enrollment					
	Unmatched Pre-K3 program	Matched Pre-K3 program	Difference	P-Value	Adjusted Difference*	P-Value
	33.7%	25.0%	-8.71%	0.000	-3.56%	0.029
# of Students	2,020	2,541				

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data
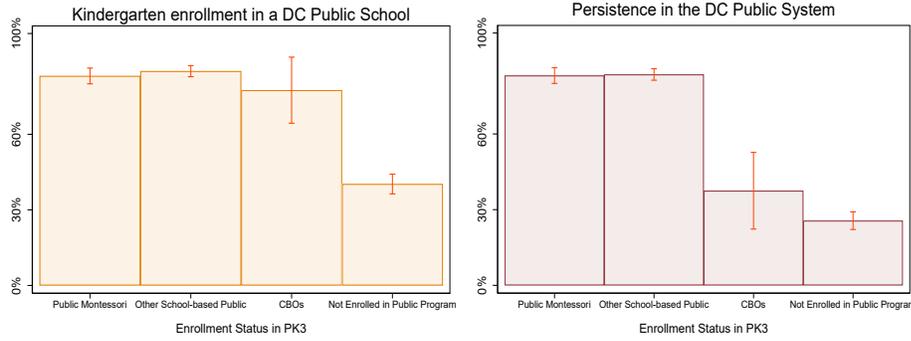
Note: The evaluation sample consists of those who applied to a PK3 program between 2014 and 2017 and were impacted by the lottery (DA score >0 & DA score <1).

Adjusted Difference - Statistical differences test with controls come from linear regression controlling for DA scores interacted with year fixed effects.
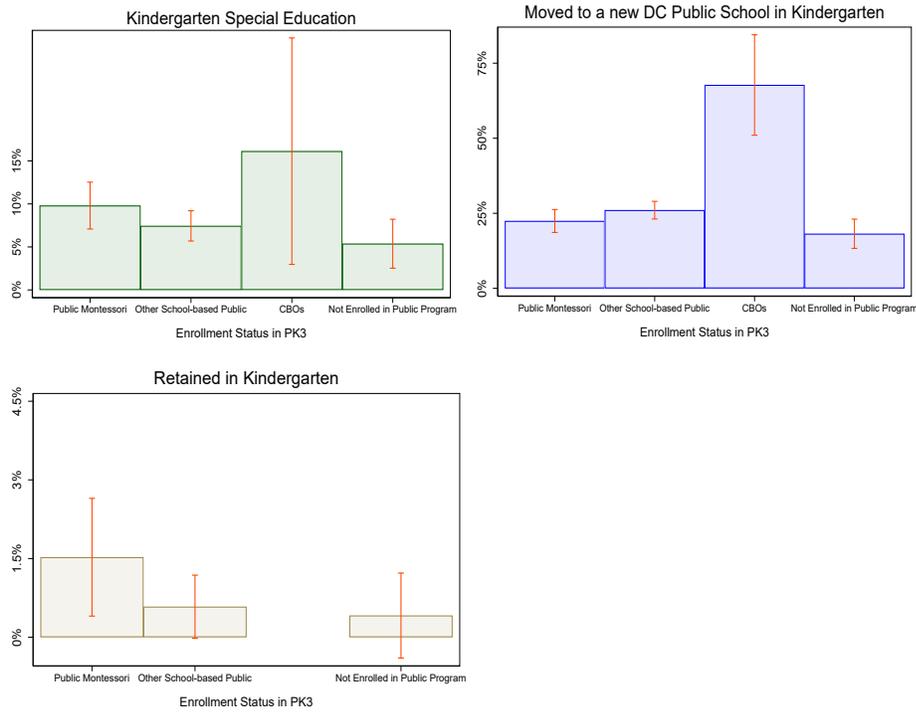
Figure A1

Descriptive Statistics on Montessori Counterfactuals

Panel A - Montessori Evaluation Sample

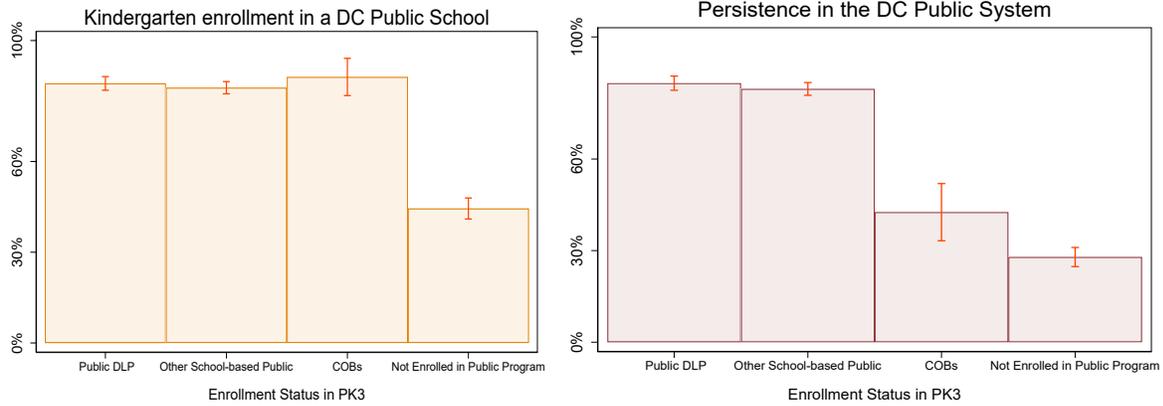Panel B - Montessori Evaluation Sample & Enrolled in KG DC Public Program

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 US census data**.**
Note: The Montessori evaluation sample consists of those who applied to a Montessori PK3 program between 2014 and 2017 and were impacted by the lottery (Montessori DA score >0 & Montessori DA score <1). % Retained in Kindergarten among CBOs students is not reported in accordance with disclosure rules from the DC Office of the State Superintendent of Education.
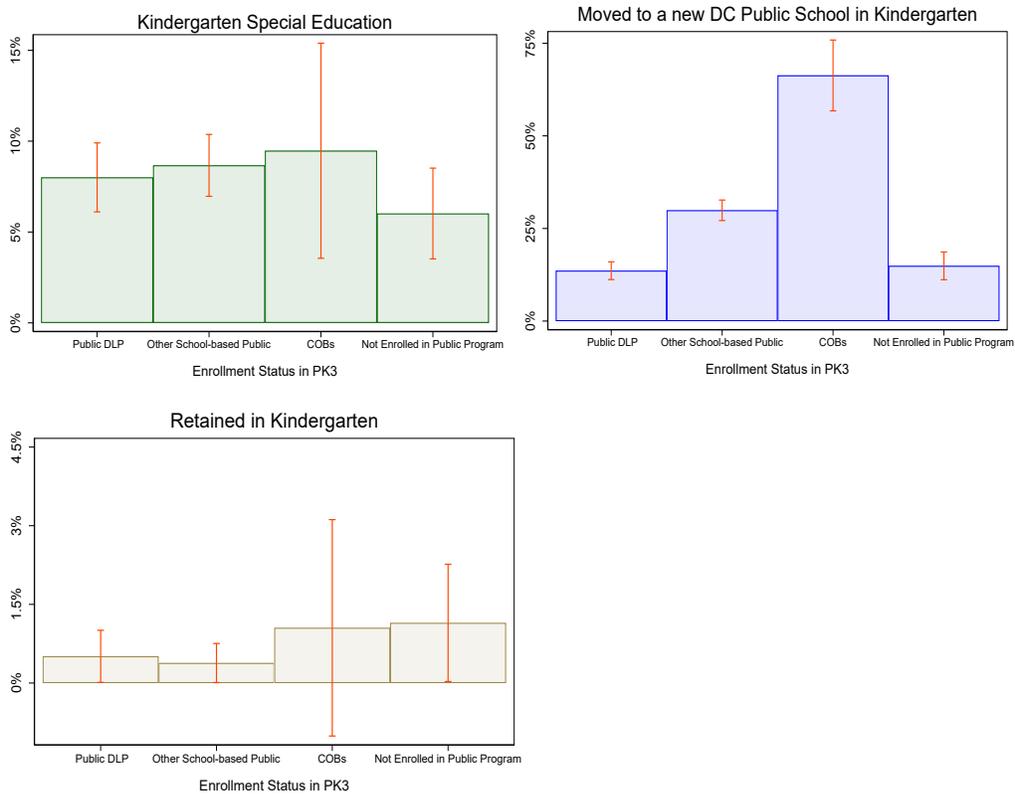
Figure A2

Descriptive Statistics on Dual Language Counterfactuals

Panel A - Dual Language Evaluation Sample

Panel B - Dual Language Evaluation Sample & Enrolled in KG DC Public Program

Source: Author's calculations using 2014-15 to 2017-18 MSDC administrative lottery data, OSSE enrollment data and 2010 census data
Note: The dual language evaluation sample consists of those who applied to a dual language PK3 program between 2014 and 2017 and were impacted by the lottery (dual language DA score >0 & dual language DA score <1).