

# **Does Universal Preschool Hit the Target? Program Access and Preschool Impacts**

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## **Abstract**

This paper studies the cost efficacy of universal over means-tested (targeted) programs, taking advantage of the rich diversity in state rules governing access to state-funded preschool in the U.S. Using age-eligibility rules for identification, I find that attending a state-funded universal preschool generates substantial immediate test score gains, particularly for low-income children. Gains for low-income children from attending targeted preschool are significantly smaller. These findings are robust to many specification checks, and cross-state differences in alternative care options, demographics, and other key features of the program environment cannot explain the difference in attendance impacts across program types. Impacts of universal public kindergarten and universal pre-K also look substantively similar within the same data, supporting an access interpretation. Benefit-cost ratios of universal programs are favorable despite their relatively high costs per low-income child.

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## I. Introduction

In the context of many public programs, key policy parameters involve not just how but *whom* – which populations should be eligible for benefits. This is evident in recent policy proposals at the federal level in the United States, which depart from the targeting characteristic of much U.S. policy to expand benefits to all individuals who meet broader eligibility criteria, even when many could be infra-marginal for the good or service in question. Central to the rhetoric behind such proposals, such as Medicare for All or universal child care, is that access to some services is a basic right, not a privilege for those who can afford it. Another rationale is that “programs for the poor are poor programs” – that means-tested programs end up underfunded due to lack of broad-based political support.

But can universal programs ever be justified on efficiency grounds? In theory, there are clear efficiency rationales for targeting: by targeting benefits on difficult-to-change characteristics correlated with low levels of human capital, policymakers can reduce moral hazard, keep costs down, and redistribute toward those most in need. On the other hand, the greater number – and political power – of stakeholders in universal programs might hold public goods providers more accountable, raising the productivity of public spending relative to a targeted program. Particularly in cases where there are direct interactions across program beneficiaries, universal access may also allow for human capital spillovers that increase the productivity of public spending for an implicit target population, such as disadvantaged children.

It is nevertheless difficult to gain empirical traction on this question; in the very least, it requires that the same kind of program be observed under widely different conditions of access, a situation that rarely arises in practice. Preschool education in the United States may provide a rare proving ground. Perhaps nowhere today is the variation in program access more striking: in

2015-16, not all states funded pre-kindergarten (pre-K) programs, and among the 43 states that did, there was great cross-state variation in eligibility rules. Some state programs are universal, serving all 4-year-olds that meet age-eligibility requirements; others are targeted, meaning that they are also means-tested or target enrollment based on other risk factors (Barnett et al., 2017).

In the first part of this paper, I take advantage of this rich cross-state variation in rules governing eligibility for state-funded pre-K to compare universal and targeted programs on the same basis, using the same data and research design. Despite a large literature on preschool education spanning disciplines, such an exercise has yet to be carried out. A mature body of research explores targeted preschool programs, most famously the federal Head Start program and the “model” preschool interventions of the distant past.<sup>1</sup> There is also emergent research on state-funded universal pre-K.<sup>2</sup> Both streams of literature tend to conclude that the benefits of preschool exceed the costs. Yet it is difficult to compare the findings for universal and targeted preschool programs directly due to differences across studies in methodology, outcomes, timing, and counterfactual enrollment patterns.<sup>3</sup>

I address this gap in the literature by working with survey data – the 2001 Birth Cohort of the Early Childhood Longitudinal Study (ECLS-B) – that span states where state-funded pre-K programs have different eligibility requirements and allow for credible estimation of the

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<sup>1</sup> Studies on Head Start include Currie and Thomas (1995), Garces, Thomas, and Currie (2002), Ludwig and Miller (2007), Deming (2009), Puma et al. (2010), Aizer and Cunha (2012), Carneiro and Ginja (2014), Bitler, Hoynes, and Domina (2014), Walters (2015), Kline and Walters (2016), Thompson (2018), Barr and Gibbs (2019), Anders, Barr, and Smith (2019), and Johnson and Jackson (2019). Regarding “model” interventions, see Heckman et al. (2010), Schweinhart et al. (2005), and recent reviews by Elango et al. (2016) and Almond, Currie, and Duque (2017). There are also stand-alone studies on targeted state pre-K in North Carolina (Ladd, Muschkin, and Dodge, 2014) and Tennessee (Lipsey et al., 2013, Lipsey, Farran, and Hofer, 2016).

<sup>2</sup> See, for example, Gormley and Gayer (2005), Fitzpatrick (2008), Cascio and Schanzenbach (2013), and Weiland and Yoshikawa (2013).

<sup>3</sup> Wong et al. (2008) estimate the short-term cognitive effects of pre-K attendance in 2004-05 in five states. Barnett et al. (2018) do a similar exercise in a more recent year for eight states. While the states differ some in terms of program access, these papers neither perform a formal analysis of the influence of access nor present estimates by family socio-economic status.

immediate gains from participation in universal and targeted programs alike. To estimate these gains, I take advantage of the large differences in state-funded pre-K eligibility and attendance among 4-year-olds that arise due to state rules governing minimum age at school entry. The pre-K evaluation literature features a number of studies exploiting this variation using a regression discontinuity (RD) design.<sup>4</sup> By contrast, I take a difference-in-differences (DD) approach, exploiting the larger gap in pre-K attendance rates of 4-year-olds across adjacent school entry cohorts in states with more robust state-funded pre-K programs. I thus use a comparison group to account for the direct effects of age on outcomes. The rich background characteristics available in the ECLS-B, including pretests, allow for useful tests of internal validity.

I find substantial positive effects of state-funded pre-K on the test scores of 4-year-olds in states with universal programs: universal pre-K eligibility (attendance) improves the average 4-year-old's standardized reading and math score by a significant 12 percent (60 percent) of a standard deviation. I cannot rule out equal effects of universal pre-K attendance by family income, but low-income children experience substantially larger test score gains.<sup>5</sup> Pre-K attendance impacts for children in states with targeted programs are significantly smaller. Effect sizes vary, but this basic set of results is robust to changes in the estimation sample, including changing the age range or the set of states considered. It also arises for another outcome – parent reports of their 4-year-old's kindergarten readiness – albeit less precisely. Supporting a causal interpretation, my preferred specification also does not yield similar patterns of impacts for a measure of mental development at age 2 or a host of other child observables.

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<sup>4</sup> The pre-K evaluation literature has looked to age-eligibility thresholds as a source of identifying variation since Gormley and Gayer's (2005) pioneering application of the RD design to Tulsa's pre-K program. (See also, for example, Wong et al. (2008) and Weiland and Yoshikawa (2013).) However, these RD studies have relied on district or state administrative data on public school *students*, precluding consistent estimates of the impacts of pre-K eligibility and attendance impacts (Lipsey et al., 2015).

<sup>5</sup> I define low-income as eligibility for free- or reduced-price lunch, since this is the modal income requirement for targeted programs. The substantive conclusions are however robust to alternative definitions.

A key feature of the universal and targeted pre-K programs under study is that the per-pupil costs are actually quite similar. The larger test score gains for universal programs alone thus suggest they are more cost-effective. But this conclusion could be hasty since some other characteristic of states with universal programs – rather than program access itself – could generate the same pattern of attendance impacts. For example, universal programs were relatively more likely to require small class sizes, which have been rigorously shown to improve early test performance (Krueger, 1999). States with universal programs may also have populations more likely to benefit from formal preschool in general, or universal programs may be more likely to draw their enrollees from informal or parental care. I rigorously explore these possibilities in the second part of the paper and find little supporting evidence. I also show that, consistent with access as a causal mechanism, the impacts of universal pre-K look quantitatively similar to those of universal public *kindergarten* within the ECLS-B, which I estimate by exploiting age-eligibility rules for kindergarten entry using an RD approach.

The evidence is thus consistent with universal pre-K being relatively cost-effective. In the third and final part of the paper, I monetize the test score gains in a tentative cost-benefit analysis. Even under conservative assumptions on key parameters like the magnitude of the association between early life test scores and earnings, universal pre-K delivers a benefit-to-cost ratio well above one, much like universal kindergarten. While less precise than the difference in test score effects of universal and targeted pre-K for low-income 4-year-olds, the magnitude of the difference in benefit-to-cost ratios across programs is substantial.

The paper proceeds as follows. The next section describes the landscape of state-funded preschool in the U.S. and the state-funded pre-K programs of study in this paper. Section III outlines the research design I employ to estimate the causal impact of these programs on age 4

test scores, and Section IV introduces the data and presents an exploratory assessment of whether the design’s identifying assumptions hold in the ECLS-B. Section V gives the main impact estimates for universal and targeted pre-K, along with a series of specification checks on these estimates and their difference. Section VI explores potential alternative explanations for the larger impacts of pre-K attendance in states with universal programs beyond universal access *per se*, and Section VII offers the cost-benefit analysis. Section VIII concludes.

## **II. Program Landscape**

There has been striking growth in public funding of preschool programs since the early 1980s. Figure 1 shows trends from 1968 through 2015 in the number of states funding pre-K programs (left axis) and in enrollment rates of 3- and 4-year-olds in the federal Head Start program and in any public preschool (right axis).<sup>6</sup> In the early 1980s, only four states funded pre-K programs; by 2015-16, this figure reached 43 states and the District of Columbia. Public preschool enrollment rates have risen alongside this increased state funding commitment. This is particularly the case for 4-year-olds, for whom enrollment in Head Start – the other primary provider of public preschool – has stagnated since the early 1990s. State-funded pre-K programs indeed focus on 4-year-olds: during 2015-16, 32% of 4-year-olds were enrolled, compared to 5% of 3-year-olds (Barnett et al., 2017).<sup>7</sup>

The 2001 birth cohort of the ECLS-B – this study’s focus – would have first aged into pre-K eligibility at age 4 in the fall of 2005, at the start of the 2005-06 school year. At this time (vertical line in Figure 1), state funding for pre-K was not that different than it’s been more

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<sup>6</sup> Data on public preschool enrollment rates by age are calculated from the October Current Population Survey (CPS) School Enrollment supplements. Head Start enrollment rates divide Head Start enrollments reported by the Head Start Bureau by cohort size estimates based on Census Bureau estimates for July 1, 2005. State funding dates were constructed from program narratives published by NIEER (Barnett et al., 2017).

<sup>7</sup> The line between state-funded pre-K and Head Start is sometimes blurred, as some states allow school districts to subcontract with Head Start centers to provide pre-K. The pre-K enrollment measure used in this paper takes into account this possibility, as described to follow.

recently: 38 states and Washington, D.C. funded programs. As has also been true in recent years, some programs had no eligibility requirements beyond age (universal programs), whereas others were also means-tested or used other risk factors, like low parental education, to determine eligibility (targeted programs). My main analysis focuses on 16 state pre-K programs where in 2005-06, there was an enrollment differential favoring 4-year-olds of at least 8 percentage points and a state-established date by which the youngest enrollees were to have turned age 4 that did not fall in the middle of a month, according to statistics and program narratives published by the National Institute for Early Education Research (NIEER) (Barnett et al., 2006).<sup>8</sup>

Given these selection criteria, these 16 state pre-K programs were unsurprisingly among the larger ones operating in 2005-06. In fact, Figure 2 shows that of the five states with the largest pre-K programs in terms of age 4 enrollment shares at that time – Florida, Georgia, Oklahoma, Texas, and Vermont – only Vermont is excluded from the analysis (due to a having locally-determined entry cutoff birthdate). The population-weighted average state-funded pre-K enrollment rate for 4-year-olds (gap between age 4 and age 3 enrollment rates) across these 16 states was 34.3 percent (32 percentage points) in 2005-06, compared to only 9.5 percent (5.7 percentage points) in the remaining 22 states with programs.

Figure 2 also denotes (with square markers) which of these 16 states operated universal pre-K in 2005-06. The six universal states include Georgia and Oklahoma, which have the two longest-standing and most well-studied universal pre-K programs (Gormley and Gayer, 2005; Wong et al., 2008; Fitzpatrick, 2008, 2010; Cascio and Schanzenbach, 2013), whereas the targeted states (triangle markers) include Tennessee, the only state to date with a pre-K program

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<sup>8</sup> I do not consider all states with pre-K programs as treated due to constraints imposed by the ECLS-B and my empirical strategy. See Section III and Appendix A.

subjected to randomized evaluation (Lipsey et al., 2013; Lipsey, Farran, and Hofer, 2016).<sup>9</sup> Other states represented in Figure 2 had pre-K programs in 2005-06 but did not meet all of the criteria to be a treatment state. However, eight of these states (diamond markers) meet the criteria to be included in the comparison group, as described in Section III.

While greater political support for universal programs could translate into higher standards or higher per-pupil spending, this does not appear to have been the case at this time. Figure 2 shows no systematic relationship between universality and NIEER's 10-point metric of suggested minimum state pre-K standards, and in fact the targeted programs under study met slightly more of these requirements on average (Appendix Table 1). Average per-pupil state spending on pre-K was also about the same in 2005-06 for the universal and targeted programs under study, at \$3,500-\$3,600 (nominal dollars, population weighted).<sup>10</sup>

If not via greater per-pupil resources, how might universal pre-K deliver larger benefits than targeted pre-K, especially for the low-income children that both programs serve? Possible explanations include higher quality teachers<sup>11</sup> or higher academic expectations in universal pre-K classrooms,<sup>12</sup> peer effects, or perhaps a different mix of structural inputs for a given level of per-

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<sup>9</sup> Though universal states tend to have relatively high enrollment rates, the enrollment rate distributions of universal and targeted states overlap. This is expected: universality in this context means only that programs have no means-testing in the localities that provide them, not that they are provided in all localities within a state. Classifying states based on enrollment rates rather than mandated eligibility criteria delivers smaller and statistically insignificant group differences in test score impacts, as discussed in Appendix A.

<sup>10</sup> For most states, this figure represents only state contributions to pre-K. It therefore understates total spending, which could also be funded by local and federal revenue. I account for this possibility in the cost-benefit analysis of Section VII by taking K-12 per-pupil spending as an upper bound. K-12 spending is on average a bit higher in states with universal programs, at \$11,875 per pupil versus \$10,139 per pupil in states with targeted programs.

<sup>11</sup> Sabol et al. (2013) find that scores on the Classroom Assessment Scoring System (CLASS) do a better job than inputs (staff qualifications and class size) and learning environment (as measured by the Early Childhood Education Rating System – Revised, or ECERS-R) in predicting test score gains over the pre-K year. Exploiting random assignment of students to kindergarten teachers in a developing country, Araujo et al. (2016) find that kindergarten teachers with higher CLASS scores have higher value-added for reading and math scores. In a developing context, Araujo, Dormal, and Schady (2019) also show that infants and toddlers quasi-randomly assigned to caregivers with higher CLASS scores have better fine motor, communication, and problem-solving skills.

<sup>12</sup> If prompted to focus on relatively advanced material, teachers may accelerate the learning gains of most students. For example, Engel, Claessens, and Finch (2013) show the more time teachers spend on more advanced mathematics content, the more children gain in math scores over kindergarten year, regardless of demographics.



pupil spending. The universal programs under study actually on average imposed less teacher training than targeted ones, possibly in exchange for requiring smaller classes, lower staffing ratios, higher standards, and more comprehensive services (Appendix Table 1).

### **III. Empirical Strategy**

I am interested in the achievement impacts from attending state-funded pre-K programs, and the difference in these impacts between universal and targeted programs. At base, the parameters of interest are thus the attendance impacts of each program type. Causal estimates are difficult to obtain: A simple difference in the scores of attendees and non-attendees will be a biased estimate of the attendance effect, since attendance is voluntary, and there might not be state funding to serve all children who are eligible. Children who participate in state-funded pre-K may thus have unobserved characteristics that directly influence their achievement.

I bring an empirical approach to this identification problem that has similar motivations to that taken first in the pre-K evaluation literature by Gormley and Gayer (2005). At base, I wish to compare children who differ in their age eligibility for pre-K due to state rules governing age at school entry. Among 4-year-olds potentially served by a given pre-K program, those whose 4<sup>th</sup> birthdays were on or before the birthdate threshold to be eligible to attend (e.g., Sept. 1) should have a much higher probability of being currently enrolled in pre-K than children whose 4<sup>th</sup> birthdays were after it. If these two groups of children were on average similar along other dimensions, the difference in their test scores would be the causal effect of being age eligible for pre-K. Further, scaling this difference by the difference in their pre-K attendance rates would yield the causal effect of pre-K attendance.

One approach to making these two groups of 4-year-olds as similar as possible would be focus on children with birthdays right near the school entry threshold. In practice, however, the

ECLS-B precludes such a sharp comparison; even if information on exact birthday were available (it is not), there would be too few observations on a daily basis to generate informative estimates. In past applications using administrative data from specific states or school districts, researchers have addressed this issue by considering a wider range of birthdates around the cutoff, but also recognizing that children with birthdays on opposite sides no longer have the same potential on average. In fact, even if these two groups of children were to have similar unobservables, they differ along an observed dimension – age – that is strongly related to child development (e.g., Elder and Lubotsky, 2009). The RD solution is to assume that the test score effects of age or birthdate relative to the cutoff are smooth, or can be modeled with a polynomial function that is continuous through the cutoff.

The ECLS-B provides information on month of birth, not exact birthdate, and data on children across the U.S., not just in specific states or school districts. These data support an alternative, DD approach – a comparison of the test scores of 4-year-olds in adjacent school entry cohorts in states with the state-funded pre-K programs identified in Section II (the treatment states), versus other states.<sup>13</sup> I work with 17 such other, comparison states (Appendix Table 2). The comparison states had a state-established kindergarten entry cutoff birthdate in fall 2006 that was not in the middle of the month and either had: (1) no state-funded pre-K (9 states); or (2) state-funded pre-K enrollment rates that were too low or not different enough between 3- and 4-year-olds, according to NIEER, for me to consider them treatment states (the 8 states denoted with diamond markers in Figure 2).<sup>14</sup> Differences in the test scores of 4-year-olds across

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<sup>13</sup> In treatment states, cutoff birthdates for pre-K in fall 2005 are the same as those for kindergarten in fall 2006 (from Barnett, et al., 2007), so kids in adjacent pre-K entry cohorts are also in adjacent kindergarten entry cohorts.

<sup>14</sup> For the second group of states, it is impossible to detect a first stage using this empirical approach and the ECLS-B. Note that the 14 states with pre-K programs that are not included in the study (circles in Figure 2) had a cutoff birthdate for school entry that was either locally-determined or state-determined but in the middle of the month. All comparison states are listed in Appendix Table 2, and the selection process is further described in Appendix A.

adjacent school entry cohorts in the comparison states are intended to capture what *would* have happened for children in the treatment states in the absence of a state-funded pre-K program, due to aging or other factors.

Ignoring the distinction between universal and targeted programs for now to save on notation, the reduced-form DD model of interest that captures this idea is given by:

$$(1) \quad y_{is} = \theta \text{elig}_{is} \times \text{treat}_s + \sum_{m=-4}^7 \gamma_m \text{elig}_{is}^m + \alpha_s + v_{is},$$

where  $y_{is}$  is the age 4 (2005-06 academic year in the ECLS-B) test score of child  $i$  in state  $s$ , and  $\text{treat}_s$  is a dummy equal to one if  $s$  is a treatment state.  $\text{elig}_{is}$  is then a dummy equal to one if  $i$  is in the earlier (or older) entry cohort, set to enter kindergarten in fall 2006 rather than fall 2007 (and pre-K in fall 2005 rather than fall 2006 in treatment states). That is,  $\text{elig}_{is} = 1[\text{age}_{ki} - \text{age}_{ks}^* \geq 0]$ , where  $\text{age}_{ki}$  is child  $i$ 's age in months on September 1, 2006, and  $\text{age}_{ks}^*$  is the minimum age in months for kindergarten entry in state  $s$  on September 1, 2006.<sup>15</sup> Intuitively, if all states had August 31 or September 1 cutoff birthdates – and indeed 22 of the 33 states under study do –  $\text{elig}_{is}$  would equal one for all ECLS-B respondents born January through August 2001 and zero for those born September through December 2001.

Model 1 is a generalization of the simplest two (group)-by-two (period) difference-in-differences model that replaces the direct effects of period ( $\text{elig}_{is}$ ) and group ( $\text{treat}_s$ ) with fixed effects for single months of relative age (the  $\gamma_m$ , where  $\text{elig}_{is}^m = 1[\text{age}_{ki} - \text{age}_{ks}^* = m]$ ) and state fixed effects (the  $\alpha_s$ ), respectively.<sup>16</sup> In principle, I could estimate an alternative triple-difference model that also takes advantage of variation in the timing of school entry cutoffs across states.

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<sup>15</sup> Without exact birthday, I must include children who are eligible for kindergarten in fall 2006 (e.g., those turning 5 on September 1, 2006 in a state with a September 1 cutoff date) in the fall 2007 kindergarten cohort. If births are uniformly distributed across days, this should lead to a small attenuation bias in estimates of the eligibility impacts. Thus, I minimize attenuation bias by excluding states with cutoff dates closer to the middle of the month.

<sup>16</sup> Substituting a direct effect of  $\text{elig}_{is}$  for the vector  $\text{elig}_{is}^m$  in model 1 yields similar point estimates to those reported later in the paper, but with larger standard errors.

Such a model would allow for identification of month of birth effects on test scores separately from the effects of academic cohort (Cascio and Lewis, 2006) – and separately for treatment and comparison states – through inclusion of month of birth  $\times$   $treat_s$  fixed effects. This approach is however not possible in this application, since there is so little cross-state variation in the timing of entry cutoffs. That is, month of birth dummies and  $elig_{is}$  are highly collinear not just in subgroups of states (e.g., among universal states), but also in the full sample.<sup>17</sup> An upside of model 1, however, is that estimates are not vulnerable to the biases from heterogeneous treatment effects that arise in difference-in-differences settings that exploit variation in treatment timing (see, for example, de Chaisemartin and D’Haultfœuille, 2019; Goodman-Bacon, 2018).

The coefficient of interest in model 1 is the intent-to-treat (ITT) effect  $\theta$ , which captures how much more entry cohort, or pre-K eligibility, relates to the age 4 (2005-06 academic year) test scores of children in treatment states. But recall that the true parameter of interest is the impact of state-funded pre-K *attendance*, not eligibility. With data from the ECLS-B, I am able to produce estimates of the effects of the treatment on the treated (TOT) by instrumenting for state-funded pre-K attendance,  $prek_{is}$ , in the model

$$(2) \quad y_{is} = \beta prek_{is} + \sum_{m=-4}^7 \lambda_m elig_{is}^m + \delta_s + \varepsilon_{is}$$

with  $elig_{is} \times treat_s$ , using two-stage least squares (TSLS).

For TSLS estimation of (2) to produce unbiased estimates of  $\beta$ , it must be the case that differences in unobserved determinants of outcomes across adjacent entry cohorts do not systematically differ between the treatment and comparison states, or  $elig_{is} \times treat_s$  is

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<sup>17</sup> As shown in Appendix Tables 1 and 2, 22 of 33 states (10 of the 16 treatment states and 12 of the 17 comparison states) require entering pre-kindergartners to be age 4 on August 31 or September 1. In addition, five more states (four treatment and one comparison) require pre-kindergartners to be age 4 only one month later, on September 30 or October 1. I show below that estimates of (1) when limited to states with August 31 or September 1 cutoffs are substantively similar to estimates of (1) on the full sample.

uncorrelated with  $\varepsilon_{is}$  conditional on the  $elig_{is}^m$  and state fixed effects. Identification also requires a significant first stage, or that  $elig_{is} \times treat_s$  significantly predicts pre-K attendance. The first-stage coefficients on the instrument will by (program) design differ in models that do not distinguish respondents by family income, making TSLS estimation of model 2 critical to comparing the benefits of universal and targeted programs. I begin by pooling respondents across the family income distribution. However, I quickly move to presenting estimates by family income, since targeted programs should only affect lower-income children.

Being able to estimate TOT impacts is one advantage of using the ECLS-B, as the administrative data used in previous RD applications have been restricted to students who enroll in public pre-K (Lipsey et al., 2015). But there are other advantages to these survey data. For example, the ECLS-B provides a rich set of baseline characteristics, including birth weight and earlier (age 2) outcomes, with which to evaluate the internal validity of the empirical approach, and data on alternative care and education options, allowing me to better understand the counterfactual to the state-funded program. The age 4 (2005-06) ECLS-B test is also designed to be age-appropriate and is administered before children attending pre-K would have progressed to kindergarten, limiting contamination from kindergarten exposure possibly present in past RD studies. The chief limitation of the ECLS-B is small sample size, or statistical power.

#### **IV. Data and Exploratory Analysis**

As discussed, the validity of my empirical approach rests on two assumptions. The first is that there is a first-stage relationship between eligibility and state-funded pre-K attendance, or that the interaction of school entry cohort and residence in a treated state,  $elig_{is} \times treat_s$ , predicts state-funded pre-K attendance in the 2001 birth cohort as of the 2005-06 academic year. The second is that this interaction does not predict unobserved correlates of test scores. In this

section, I provide some preliminary evidence that these assumptions are met and details on the construction of key variables and the estimation sample from the ECLS-B.

*A. State-funded Pre-K Attendance*

Administrative information on whether the ECLS-B respondents attended state-funded pre-K is unavailable. However, the survey provides detailed information on the care and education of respondents at age four (wave 3 of the survey, corresponding to 2005-06) from interviews with both parents and providers. While interviews of providers could in principle offer more reliable information, they were only administered to the one program, center, or person accounting for the *most* of a given child's non-parental care, and thus fail to pick up all cases of enrollment in state-funded pre-K. My base measure of pre-K attendance is therefore the parent report of a child attending free pre-K or free preschool. A limitation of this measure alone, however, is that parents whose children attended a state-funded pre-K program delivered via Head Start may have reported Head Start participation instead. In these cases – and in fact in all cases where the provider report signals public pre-K attendance when the parent report does not – I adjust my pre-K attendance variable upward accordingly. I code state-funded pre-K attendance in the provider interviews as public-school pre-K or another program (e.g., preschool or child care) sponsored by state or local government or school district. (See Appendix A.)

The first graph in Figure 3 Panel A shows pre-K attendance rates in 2005-06 by program type in one's state of residence (universal, targeted, comparison) and age relative to the minimum age for entering kindergarten the subsequent school year (in two-month intervals to reduce noise). Age is increasing along the horizontal axis, with the first two points representing ages of children who would not have been eligible for kindergarten in fall 2006 (or pre-K in fall 2005). The second graph in Figure 3 Panel A then shows the difference in means between each

of the two treatment groups and the comparison group, relative to what that difference was for children who just missed eligibility ( $-2 \leq age_{ki} - age_{ks}^* \leq -1$ ), adjusting for state and month of assessment fixed effects. Aside from age being grouped into intervals, this is a generalization of model 1, with pre-K attendance as the outcome. For now, the estimation sample includes *all* children, regardless of family income, who were resident in one of the 16 treatment or 17 comparison states in wave 3 of the ECLS-B and were 5 years old between 8 months before and 4 months after their state's kindergarten entry cutoff.<sup>18</sup>

Pooling across family income, the first-stage impacts of age-eligibility should be lower in states with targeted pre-K programs, where eligibility is also based on family income or other risk factors. This expectation is realized in the data. As shown in Panel A, all three groups of states exhibit similar, relatively low 2005-06 pre-K attendance rates among children who were not eligible to attend kindergarten in fall 2006 (or pre-K in 2005 in treatment states). However, pre-K attendance rates between treatment and comparison states diverge for children age-eligible to start pre-K in fall 2005, and the extent of divergence is greater for children in universal programs, as anticipated. As shown in the second graph, the regression-adjusted DD estimates for these age-eligible children are statistically significant.

Columns 1 and 3 in Table 1 Panel A give mean pre-K attendance rates among age-ineligible children in treatment states (i.e., eligible for pre-K in fall 2006, not fall 2005). Columns 2 and 4 show the first-stage DD estimates that correspond to the second subpanel in

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<sup>18</sup> I make this restriction since August 31/September 1 is the modal cutoff date in the sample (see Appendix Tables 1 and 2). I additionally restrict attention to children with non-missing preschool-age cognitive assessments administered in September or later and non-missing demographic and background characteristics. These additional restrictions lead to a loss of very few observations. There are 5,100 observations in the sample overall; 1,750 of these children reside in states with targeted programs; 1,150 reside in states with universal programs; and 2,250 reside in the comparison states. Reported sample sizes are rounded to the nearest 50, per IES rules to protect confidentiality of ECLS-B respondents.

Figure 3 Panel A, i.e., subgroup-specific coefficients (standard errors) on  $elig_{is} \times treat_s$  from model 1, which includes fixed effects for state of residence and single months of age relative to the threshold, with  $prek_{is}$  as the dependent variable.<sup>19</sup> The estimated gap in 2005-06 pre-K enrollment rates between the 2006 and 2007 kindergarten cohorts was 21.1 percentage points higher in states with universal pre-K programs than in the comparison states (column 2). For targeted states, on the other hand, this gap amounted to 11.4 percentage points (column 4). The difference in these estimates is statistically significant (column 5).<sup>20</sup>

#### B. *Demographic and Background Characteristics*

Table 1 Panel B gives ineligible means and analogous DD estimates for demographic and background characteristics in the full sample. In addition to basic demographics – age at assessment (in months) and indicators for sex (female) and race (non-Hispanic black and Hispanic) – I construct indicators for low birth weight (birth weight < 2,500 grams), for low maternal education (at or below a high school degree), for a language other than English being spoken in the home, for the presence of both biological parents in the household, and for low family income. I define low-income as eligibility for free or reduced-price lunch (family income  $\leq$  185% of the federal poverty line (FPL)), since it is the modal eligibility criterion for the targeted states under consideration and thus the best available way to stratify the analysis.<sup>21</sup>

If the TSLS estimates are identified,  $elig_{is} \times treat_s$  should have little predictive power

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<sup>19</sup> As in Figure 3, I cluster standard errors on state of residence-by-month of birth (the level of the treatment) and weight the analysis using sampling weights appropriate for analyses using data from the first and third waves of the ECLS-B. The model also includes dummies for month-by-year of the wave 3 assessment.

<sup>20</sup> Reassuringly, the universal-targeted gap in first-stage coefficient estimates ( $21.1/11.4 = 1.85$ ) is proportionally similar to the universal-targeted gap in the difference in age 4 and age 3 state funded pre-K participation rates reported by NIEER for 2005-06 ( $41.2/23.1 = 1.78$ ).

<sup>21</sup> The eligibility criterion is relevant for five targeted states – Texas, Maryland, Louisiana, Colorado, and Tennessee – which together account for 56 (69) percent of 4-year old population (state-funded pre-K enrollment) in the states with targeted programs listed in Appendix Table 1. The remaining states have different income requirements (Michigan, Kansas) or no income requirements, but risk factor requirements that correlate strongly with income (Illinois, South Carolina, Virginia). I test the sensitivity of my conclusions to the definition of poverty below.



with regard to these observed correlates of test scores, just as it should have little predictive power for unobservables. For the most part, the coefficient estimates in the even columns are not statistically significant. There are exceptions, however. Most notably, children who are age-eligible for universal preschool are significantly less likely to be low-income; this leads me to reject the test of joint significance on the DD coefficients (including this variable, the  $p$ -value on joint test is 0.01; excluding it, it is 0.32; column 2).<sup>22</sup> This phenomenon is also evident, but to a lesser extent, among children in targeted states (column 4). For both subsamples, the DD coefficient for age in months is also negative and (marginally) statistically significant, but small.

These findings, and the fact that some of these coefficients are large even if not statistically significant, suggest the importance of including these background variables as controls in the analysis. They also suggest the importance of seeking additional ways to validate the research design. I do so below both in considering prior (age 2) cognitive test scores as an outcome, and in testing for “impacts” of eligibility among ineligible students, the idea being that such analyses will only turn up significant coefficients if there is confounding by unobservables. It is important to note, however, that poverty and age are balanced for the *difference* in estimates between universal and targeted states, as demonstrated by the triple difference (DDD) estimates in column 5, and it is the difference in program effects that is the focal point of the paper. In addition, among low-income children, who are also the focal group under study, there is balance on observables for universal and targeted programs alike (Appendix Table 3).

## **V. Effects of Pre-K Eligibility on Preschool-Age Test Scores**

### *A. Baseline Estimates*

I focus the analysis of outcomes on cognitive test scores from the third (preschool-age)

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<sup>22</sup> This is more likely an artifact of sampling variation than of explicit sorting (Dickert-Conlin and Elder, 2010).

wave of the ECLS-B. The preschool-age cognitive assessment included math and reading components and was designed to test both for developmental (age-based) milestones and for knowledge and skills considered important for school readiness and early school success (see Appendix A). I standardize test scores to have a mean of zero and a standard deviation of one in the comparison states and calculate average scores across reading and math as an unweighted mean of these standardized scores. Test administration was concentrated during the fall of the 2005-06 school year, however, possibly raising concerns that not enough time would have elapsed for children's scores to reflect pre-K. In my robustness analysis, I therefore consider an alternative outcome at preschool-age – an indicator for whether a parent reports concern over a child's readiness for kindergarten. This measure captures variation across program types in parental perceptions of likely impacts of pre-K attendance, not just on academic preparation for kindergarten but also behavioral and social preparation as well.<sup>23</sup>

Mean preschool-age test scores for the ineligible subsample in treatment states, shown in column 2 of Table 2, are negative not because universal or targeted states are negatively selected, but rather because there is a strong age gradient in test scores in all states. This is evident in the first graph in Figure 3 Panel B: for comparison states, where the age gradient is least likely to reflect pre-K by design,<sup>24</sup> average reading and math test scores rise about 80% of a standard deviation between the relatively youngest and relatively oldest children in the estimation sample. There is thus significant variation in early test performance based solely on (relative) age, holding constant family background. This (relative) age gradient in test scores provides a useful

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<sup>23</sup> The ECLS-B provides one socio-emotional assessment at age 4 – the “two bags task.” I analyzed this assessment in an earlier version of this paper, but the estimates were uninformative.

<sup>24</sup> The age gradient in comparison states could, however, reflect other characteristics of these states besides their relative lack of state-funded pre-K programs. Fortunately, treatment and comparison states have similar observable demographic and background characteristics on average. See Appendix A.

benchmark to which to compare the estimated impacts of pre-K attendance.

The remaining curves in Figure 3 Panel B show how the existence of a robust state-funded pre-K program affects this age gradient in preschool-age test scores. There is a clear and relatively sustained divergence between the average test performance of age-eligible children in universal pre-K states relative to the comparison group (subpanel 1). The relative gains in test performance are statistically significant for the two youngest groups of children in the eligible cohort (subpanel 2). While there is some suggestion of such gains for targeted programs, the effect dies out more quickly, and even turns negative for the oldest children in the sample. Combined with the evidence for pre-K attendance in Panel A, these figures are consistent with children gaining more in the short-term from pre-K attendance in states with universal programs. Supporting this inference, the divergence in scores between universal states and the comparison group did not already begin among children who were not yet age-eligible for school (i.e., there is no pre-existing upward trend).

Table 2 presents the corresponding first-stage and reduced-form (model 1) estimates of the impacts of pre-K eligibility and IV and OLS (model 2) estimates of the impacts of pre-K attendance on preschool-age test scores. I show estimates without and then with controls for the demographic and background characteristics in Table 1 Panel B, separately for universal (Panel A) and targeted (Panel B) programs. Though the additional controls have little impact on first-stage estimates, they more moderately impact the reduced-form and IV estimates. With controls I reject the null that attending a targeted pre-K program has the same effect as attending a universal pre-K program, as shown in Panel C ( $p=0.046$ ). The IV estimated impact of attending pre-K in a universal state also remains substantial, at a marginally statistically significant 0.57 standard deviations – about 70% of the impact that the average child would expect from a full

year of aging. This estimate is very different from its OLS counterpart (-0.07 standard deviations), which suggests negative selection into pre-K attendance.

#### *B. Heterogeneity by Family Income*

I prefer estimates from a sample including children regardless of family income as a starting point, since I cannot perfectly replicate the other eligibility rules for targeted programs in the ECLS-B. Table 3 presents estimates applying arguably the best available consistent definition, which cuts the sample by eligibility for free- or reduced-price lunch, based on the preferred specification with the additional controls; group-specific means and balance tests are provided in Appendix Table 3. This cut of the data produces income gaps in achievement like those that have been seen in other data (Table 3 column 2) (Reardon 2011). First-stage impacts of age-eligibility for pre-K (column 1) are also essentially the same for low-income children regardless of whether a program is universal or targeted (0.226 versus 0.223) but are only evident for children who are not low income in states with universal programs (0.189 versus 0.037), as expected. Appendix Figure 1 provides transparent graphical evidence of these first-stage impacts.

For low-income children, estimated test score gains from pre-K are strikingly different for states with universal versus targeted programs. Indeed, although it remains possible that universal pre-K (Panel A) leads to equivalent gains across the two family-income groups ( $p=0.118$  for the reduced-form and  $p=0.191$  for IV),<sup>25</sup> the estimates for universal programs shown in Table 2 and Figure 3 were clearly driven by the low-income subsample. Age-eligibility for pre-K raises the preschool-age test scores of low-income children in universal states by a

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<sup>25</sup> Finding larger effects of pre-K attendance for low-income children is consistent with a framework where higher-income children have relatively high-quality care and education options in the absence of universal pre-K and with much existing evidence on universal preschools both in the U.S. and worldwide (Cascio, 2015; Elango et al., 2016).

significant 0.263 standard deviations (Panel A, column 3). By contrast, it reduces the test scores of low-income children in targeted states by an insignificant 0.018 standard deviations ( $p=0.02$  on the difference; Panel C).<sup>26</sup> Figure 4 suggests that this basic insight also holds when I divide the sample by quintiles of a socio-economic status (SES) index provided by the ECLS-B, derived from factor analysis on parental education, parental occupation, and family income: Test score gains from pre-K in universal states are concentrated in the two bottom quartiles of this index (Panel B) despite positive impacts on pre-K attendance across the income distribution (Panel A).

Returning to Table 3, the IV estimates imply that pre-K attendance raises the preschool-aged test scores of low-income children in universal states by 1.16 standard deviations and lowers them by 0.08 standard deviations in targeted states. Previous research suggests that universal programs should have larger effects, but this is a larger difference in attendance effects than we might expect to see based on prior literature. For example, recent estimates suggest that the earliest years of (universal) elementary education raise test performance by up to 1 standard deviation (e.g., Anderson et al., 2011; Fitzpatrick, Grissmer, and Hastedt, 2011), much like the IV estimate for universal pre-K.<sup>27</sup> However, the average child in the present study has had just a few months of pre-K exposure, not a full school year. Likewise, existing estimates for targeted state-funded pre-K programs and Head Start are substantially smaller than those found for elementary education (and universal pre-K). However, though a recent evaluation of the

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<sup>26</sup> Estimation of a model that substitutes a “universal” dummy for the *treat<sub>it</sub>* in model 1 and limits the estimation sample to treated states implies that pre-K eligibility yields a relative test score gain (for universal programs) of 0.259 standard deviations (s.e.=0.009,  $p=0.01$ ). There is thus some precision to be gained from dropping comparison states and focusing on the universal-targeted difference in effects. However, such an approach precludes estimation of the attendance impacts of each type of program.

<sup>27</sup> Fitzpatrick, Grissmer, and Hastedt (2011) find that one year of kindergarten or first grade raises reading and math scores by about 1 standard deviation, using on variation in assessment dates in the original kindergarten cohort of the ECLS (ECLS-K). Applying an RD design to exploit age eligibility rules also in the ECLS-K, Anderson et al. (2011) find that a year of early elementary school exposure raises math scores by 0.75 standard deviations.

Tennessee Voluntary Pre-K program ultimately delivered negative effects (Lipsey, et al., 2013; Lipsey, Farran, and Hofer, 2016), these estimates have typically been positive.<sup>28</sup>

It could be the case that the existing evaluation literature understates the expected difference in attendance impacts between universal and targeted pre-K programs – and not just due to differences in methodology, outcomes, timing, and counterfactual enrollment patterns across studies. For example, while the attendance impacts of universal pre-K seem quite large given just a few months of exposure, other research suggests that learning may decelerate over the school year (Kuhfeld and Soland, 2020), as well as points out the same intervention typically yields larger test score gains at younger ages (Cascio and Staiger, 2012). The Tennessee program also scores higher on NIEER’s quality checklist than the average targeted state in the present study (Appendix Table 1). That said, the limited statistical power afforded by the ECLS-B means that I am more confident in there being a difference in impacts between universal and targeted programs – and in the impacts of universal programs in particular being positive – than I am in their magnitudes.

Figure 5 presents graphs of the test score impacts of pre-K by family income in an analogous way to Figure 3 Panel B. The concentration of positive impacts of universal pre-K among the youngest eligible students is now even more evident (Panel A). Separate analyses of the subcomponents of the test (Appendix Figures 2 and 3) reveals that performance on the math subcomponent is responsible for this pattern; effects on reading scores are more sustained. Moreover, estimating the preferred model separately for the standardized reading and math scores, as done in Panels B and C of Table 4 for the full sample (Appendix Table 4 for the low-

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<sup>28</sup> For example, using randomized variation in Head Start attendance from the Head Start Impact Study, Kline and Walters (2016) estimate that one year of Head Start attendance raises the average of standardized reading and math scores by around 0.25 standard deviations. An evaluation of the Tennessee program also found short term effects of attendance around a third of a standard deviation (Lipsey, Farran, and Hofer, 2016).

income subsample), reveals universal pre-K effects that are much more precisely estimated for reading scores. Pre-existing trends in reading scores are also relatively similar across the three groups of states (Appendix Figure 2), lending greater credibility to those findings.

### *C. Specification Checks*

The estimates presented thus far suggest that children attending pre-K in states with universal programs experience larger early test score gains than children attending pre-K in states with targeted programs, and the difference is more pronounced for the low-income children who would likely meet eligibility criteria for either type of program. But these findings could still be an artifact of the research design, estimation sample, or choice of outcome. In this section, I assess the robustness of the basic set of results to these decisions.

In Table 4 Panel D, I first consider impacts of pre-K attendance on a test of mental development at age 2 (or in wave 2 of the ECLS-B), before children would have been eligible for pre-K.<sup>29</sup> Performance on this test is neither significantly affected by pre-K attendance nor significantly different across states with universal and targeted programs ( $p=0.613$ ), suggesting limited contamination by unobservables. The estimates for age 4 test impacts are also similar when age 2 scores are included as controls (Appendix Table 5).<sup>30</sup>

In Table 4 Panel E, I then consider an alternative outcome at age 4 – an indicator for whether a parent reports that their child is not ready for kindergarten. Mirroring the estimates for test scores, the parents of children attending pre-K in states with universal programs are less

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<sup>29</sup> The wave 2 cognitive assessment is the Bayley Short Form-Research Edition (based on the Bayley Scales of Infant Development, 2<sup>nd</sup> Edition). Results with Bayley motor scores as an outcome show a similar pattern as those for mental scores and so are omitted for brevity. The model in Panel D also includes age of assessment and dummies for month-by-year of assessment in the relevant wave, in addition to the controls of the baseline model, and is weighted by sampling weights appropriate for inclusion of that wave.

<sup>30</sup> Controlling for age 2 scores in the full sample has no appreciable effect on the estimates for universal programs but raises estimates for targeted programs to an extent that the gap in IV estimates across program types is no longer statistically significant ( $p=0.178$ ). The difference in IV estimates for low-income children does, however, remain marginally significant with these controls included ( $p=0.055$ ).

likely to express concern over their kindergarten readiness. The estimates are more pronounced among lower-income parents (Appendix Table 4), but as was also the case with test scores, I cannot rule out that they are identical across income groups ( $p=0.35$ ). Unlike in the test score case, however, I also cannot rule out that the IV estimates are the same across program types for low-income children ( $p=0.22$ ), though the evidence is slightly more suggestive for a reduction in concern over *academic* readiness for kindergarten in particular ( $p=0.17$ ; Appendix Table 6). Similar findings do not arise for parent reports of concern over school readiness on other margins (Appendix Table 6), suggesting that the relative benefits of universal pre-K may be primarily academic. But the relative lack of statistical power makes all of these complementary estimates suggestive at best.

I consider several changes to the estimation sample in Table 5, returning to the original test score outcome. I considered a wider age span for eligible children in the baseline estimation sample (8 months) than for ineligible children (4 months) to improve statistical power, but possibly at the expense of greater bias. Limiting estimation to children with birthdays within four months of the age-eligibility threshold (Panel B), who are more similar to one another along some but not all dimensions (Appendix Table 7), actually generates more positive estimates for the impacts of pre-K eligibility and attendance, enough so that I am less confident that the IV estimates differ between universal and targeted states in the full sample ( $p=0.197$ ). However, I remain reasonably confident in this conclusion for low-income children, even in this restricted sample ( $p=0.060$ ; Appendix Table 8). In Panel C, I approach this concern in a different way, maintaining the full sample, but controlling directly for interactions between  $treat_s$  and  $elig_{is}^{4-5}$  and  $elig_{is}^{6-7}$  (i.e., indicators for the oldest relative age groups in the sample). This alternative model only exploits variation in eligibility within 4 months of the threshold but maintains the full



sample to identify coefficients on the controls. The findings are similar.

The two remaining changes to the estimation sample represented in Table 5 make it more, then less, expansive. Adding treatment states may further help limit the influence of idiosyncratic state samples, since the ECLS-B is not designed to be state-representative. With this in mind, I expand the sample to include children in the two targeted states (Arkansas and North Carolina) and one universal state (Maine) with middle of the month birthdate cutoffs, as long as their birthdate is not in the cutoff month (to minimize misclassification). Results are not much changed (Panel D). Further, limiting attention to the 10 treatment states (5 universal, 5 targeted) and 12 comparison states with cutoff birthdates on August 31 or September 1 – thus focusing on the largest subsample where eligibility and month of birth are collinear – barely changes the IV estimates in the full sample (Panel E). Moreover, in both the full sample and the low-income subsample (Appendix Table 8), state-funded pre-K attendance in universal states continues to yield significantly larger test score gains.

## **VI. Interpretation**

It may be tempting to conclude that universal access is itself the driver of the generally robust finding of larger effects of pre-K attendance in states with universal programs. However, whether a pre-K program is universal or not is not randomly assigned; state contexts, pre-K programs and populations differ along other dimensions. In this section, I attempt to rule out leading alternative explanations – differences in counterfactual care, other pre-K characteristics (specifically maximum class size), and demographics in states with universal programs. I also present additional evidence consistent with an access interpretation: The estimates for universal pre-K look much like what one finds for universal *kindergarten*, at age 5, within the ECLS-B.

### *A. Differences in the Counterfactual?*

Existing literature suggests that if universal pre-K attendees were drawn less from other center-based care and more from informal or parental care, we would see relatively large test score effects of universal pre-K, all else constant.<sup>31</sup> I estimate the reduced-form impact of age-eligibility for pre-K and the IV effect of pre-K attendance for a mutually-exclusive set of alternative care options – Head Start, other center-based care, informal non-parental care, and parental care.<sup>32</sup> For additional statistical power, I also combine Head Start and other center-based care as “formal care” and informal non-parental and parental care as “informal care.”

The IV estimates for the full sample (Appendix Table 9) imply that approximately 90% of targeted pre-K attendees were drawn from informal care, versus 46% of universal pre-K attendees. The difference is not surprising: Universal programs serve higher-income children, for whom formal care or education in the absence of state-funded pre-K is relatively common. More telling are findings for the low-income subsample, where the difference in estimated attendance effects across program types is most pronounced. Table 6 shows substitution patterns that are more similar across program types in this sample, with point estimates implying that about 35% of low-income pre-K attendees would have otherwise attended Head Start and about 15% would have otherwise been in informal, non-parental care. But parental care was a more likely alternative in the targeted case, so that 70% of low-income targeted pre-K attendees would have otherwise been in informal care, compared to 55% of low-income universal pre-K attendees.<sup>33</sup> Though the difference is not statistically significant ( $p=0.66$ ), this suggests the estimated gap in pre-K attendance effects across program types is actually *lower* than it would be with a constant

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<sup>31</sup> In re-analyses of data from the Head Start Impact Study, Feller et al. (2016) and Kline and Walters (2016) find that Head Start has much smaller impacts on children who would have otherwise been in center-based care.

<sup>32</sup> The reduced-form DD coefficients therefore add up to zero across all categories, including the first-stage DD coefficient for pre-K. Reassuringly, reported Head Start enrollment rates for low-income children in universal and targeted states (at 12%) are quite similar to what they are in the administrative data.

<sup>33</sup> These figures for program substitution are similar to those found for the recent Head Start Impact Study (Feller et al., 2016; Kline and Walters, 2016).

counterfactual. It therefore does not provide strong evidence against the conclusion that universal programs outperform targeted ones.

#### B. *Differences in Other Characteristics of Programs or Populations?*

As noted in Section II, though universal and targeted programs look similar in the aggregate in terms of available resources and the overall number of minimum standards to which they are held, the two types of programs differ in how funds are allocated or which standards are emphasized on average, and it might be these differences in resource allocation that are driving the differential in estimated effects across states with different pre-K access. Of particular interest is that the universal programs under study prioritize smaller class sizes, which in early education have been convincingly shown to produce higher immediate test scores (Krueger, 1999). With the important caveat that the decision to require small class sizes could be endogenous to the access decision itself, I can investigate whether the difference in reduced-form and IV estimates across universal and targeted states is robust to allowing for heterogeneity in pre-K impacts by this program dimension. Using a similar approach, I can also explore robustness to regression-adjusting for heterogeneity in pre-K impacts by the demographic and background characteristics in Table 1 Panel B.<sup>34</sup>

<sup>34</sup> Specifically, I begin with the triple-difference reduced-form model:

$$y_{isp} = \theta_{UT} \text{elig}_{is} \times \text{treat}_s \times \text{uni}_s + \theta_T \text{elig}_{is} \times \text{treat}_s + \theta_D \text{elig}_{is} \times \text{treat}_s \times C_s + \delta \text{elig}_{is} \times C_s + \sum_{p=0}^1 \sum_{m=-4}^7 \gamma_{mp} \text{elig}_{is}^m \times P_p + \alpha_{sp} + \sum_{p=0}^1 (x_{is} \times P_p) \pi_p + \omega_{isp},$$

where  $\text{uni}_s$  and  $\text{treat}_s$  represent, respectively, a dummy for whether  $s$  is a universal (treated) state and a dummy for whether  $s$  is a treatment state at all (universal *or* targeted), and  $C_s$  the number of class size standards (out of two possible) that the state program requires. All of the controls are interacted with an indicator for the estimation sample,  $P_j = 1[j=p]$ , with  $p=1$  for the universal pre-K estimation sample and  $p=0$  for targeted pre-K estimation sample. Excluding the interactions with the class size variable ( $\text{elig}_{is} \times \text{treat}_s \times C_s$  and  $\text{elig}_{is} \times C_s$ ),  $\theta_{UT}$  is then the difference in the reduced-form DD estimates for universal and targeted pre-K programs presented in Table 2, and  $\theta_T$  is the baseline reduced-form DD estimate for targeted programs. Of interest is then estimation with the class size interactions included, which adjusts estimates of  $\theta_{UT}$  for the correlation between a state program offering universal access and the program requiring small classes. The coefficients on  $\text{prek}_{is}$  and  $\text{prek}_{is} \times \text{uni}_s$  in the structural model of interest are estimated using TSLS with  $\text{elig}_{is} \times \text{treat}_s \times \text{uni}_s$  and  $\text{elig}_{is} \times \text{treat}_s$  as excluded instruments. The model with demographic heterogeneity replaces  $C_s$  with  $X_i$ , where  $X_i$  is one of the characteristics in Table 1 Panel B. I also estimate version of this model including multiple characteristics simultaneously.

Table 7 Panel A presents the difference in reduced-form (columns 1 and 4) and IV (columns 2 and 5) estimates across universal and targeted programs from the model with additional controls, along with estimates of the coefficients capturing how class size standards influence the effect of pre-K eligibility (columns 3 and 6), both for the full sample and for the low-income subsample.<sup>35</sup> The universal-targeted difference in reduced-form estimates shrinks somewhat, as pre-K eligibility has a greater impact on test scores when class sizes are required to be small, as anticipated. But the difference in IV estimates remains at least as large in both samples as it was at baseline. The estimates in Table 7 Panel B similarly show demographic heterogeneity in the impacts of pre-K exposure in the expected direction: Effects of pre-K eligibility tend to be larger (and are often statistically significant) for more disadvantaged populations, like children of mothers with no more than a high school degree. However, the populations of universal and targeted states are similar enough that this has no large impact on the conclusion that universal programs outperform targeted ones.

### *C. Comparison to the Impacts of Kindergarten Using an Alternative Approach*

To provide further evidence consistent with an access interpretation, I examine whether the test score impacts from attending universal public *kindergarten* look substantively similar to those from attending universal pre-K in the ECLS-B.<sup>36</sup> The fourth (kindergarten-age) wave of the ECLS-B also included math and reading cognitive assessments, again largely administered in the fall of the academic year, which I standardized and aggregated in a similar fashion to the preschool assessments. It also included information on grade of enrollment and whether the

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<sup>35</sup> With reference to the reduced-form model presented in the prior footnote, columns 1 and 4 present estimates of  $\theta_{UT}$ , and columns 3 and 6 present estimates of  $\theta_D$ .

<sup>36</sup> As earlier noted, the magnitude of the impacts of universal pre-K attendance in the preferred model appears comparable to that of universal early education more generally, but the relevant studies (Anderson, et al., 2011; Fitzpatrick, Grissmer, and Hastedt, 2011) used a different data source, the ECLS-K.

school was public or private (if applicable).

To carry out this analysis, however, I must rely on a different empirical approach than that earlier in the paper. In particular, since universal kindergarten is available in public schools across all states, I can only exploit age-eligibility rules using an RD model in the reduced-form, given by:

$$(3) \quad y_{is} = \tilde{\theta} \text{elig}_{is} + f(\text{relage}_{is}; \tilde{\lambda}) + \tilde{\alpha}_s + \varpi_{is}.$$

$f(\text{relage}_{is}; \tilde{\lambda})$  represents some smooth function, with parameter vector  $\tilde{\lambda}$ , of the difference between child  $i$ 's age in months on September 1, 2006 and the minimum required age in state  $s$  on that date for kindergarten entry, i.e.,  $\text{relage}_{is} = \text{age}_{ki} - \text{age}_{ks}^*$ . For simplicity and because it is a good fit to the data (see Appendix Figure 4), I specify the smooth function in age relative to the cutoff as linear within  $\pm$  four months of the entry age threshold, with a different slope among those eligible for public kindergarten. I produce estimates of the impacts of K attendance by substituting a smooth function of the same form as in model 3 for the unrestricted eligibility effects in model 2, then estimating that model using TSLS with  $\text{elig}_{is}$  as an instrument for  $\text{prek}_{is}$ .

Estimates for the full sample of states considered in the main analysis are given in Table 8. Underlying models also include as controls the demographic and background variables in Table 1 Panel B, as well as age and dummies for month-by-year of assessment during the wave 4 interview. There is a strong first-stage relationship between age-eligibility for kindergarten and public kindergarten attendance in 2006-07: On average, a child just barely eligible was 66 percentage points more likely to be enrolled in the full sample (column 1).<sup>37</sup> The marginal child in the full sample also scored a significant 0.38 standard deviations higher on the kindergarten-

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<sup>37</sup> Notably, this estimate is considerably lower than the *average* kindergarten enrollment rate of age-eligible children. This is to be expected given the commonly-found extent of non-compliance with entry-age regulations, but lack of information on exact birthday in the ECLS-B may attenuate this estimate further. I also find a low first-stage coefficient on the instrument for pre-K attendance relative to the levels of pre-K attendance reported by NIEER.

age reading and math tests (column 2). Point estimates are much more similar across income in this case, and the implied effect of public kindergarten attendance in the sample overall – 57% of a standard deviation (column 3) – is essentially the same as what I found for universal pre-K (Table 2).<sup>38</sup>

## VII. Cost-Benefit Analysis

As laid out in Section II, per-pupil costs of the universal and targeted pre-K programs under study are similar. However, the attendance impact for the average child eligible to attend a universal program – approximately 0.6 standard deviations (Table 2) – greatly exceeds the attendance impact for the average (low-income) child eligible for a targeted program – approximately -0.08 standard deviations (Table 3). While the findings thus suggest a more favorable benefit-to-cost ratio for universal programs, it is useful to formalize this calculation.

Table 9 Panel A presents estimates of the benefit-to-cost ratio for each program type.<sup>39</sup> Only per-pupil state outlays for pre-K are available, so I make two conservative assumptions regarding total per-pupil spending that are well above the state contribution. The marginal social benefit of universal pre-K attendance, measured as the present discounted value of the expected earnings gains from the increase in test scores, is 39% higher than the per-pupil cost of K-12 schooling (Panel A, row 1). It is 85% higher than the per-pupil cost of K-12 schooling net of the social savings from substitution from other public and private centers. These ratios are not statistically different than one but are close to significantly different from those for targeted pre-K programs (column 3), as seen in column 4. Using Head Start to approximate program outlays (Panel A row 2) considerably increases these ratios for universal pre-K. The 3.52 benefit-to-cost

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<sup>38</sup> However, substitution from alternative care is also more common than in the universal pre-K case: 73% switch from other formal center-based care (Appendix Table 10).

<sup>39</sup> See table notes and Appendix B for a description of assumptions over key parameter values.

ratio in the most favorable (yet still conservative) scenario for universal pre-K is both greater than one and greater than the corresponding ratio for targeted programs. It is also larger than the (highly significant) benchmark estimate for kindergarten programs, of 2.96 (column 1).

Through it is customary to present benefit-to-cost ratios for early educational programs, the marginal value of public funds (MVPF) – or the ratio of a program beneficiary’s willingness to pay for the program out of his/her own income to government costs net of fiscal externalities – provides a means of using causal estimates from program evaluation for social welfare analysis (Hendren, 2016). I thus also present estimates of the MVPF of each program, making a small adaptation to the MVPF formula used by Kline and Walters (2016) in their re-evaluation of the Head Start Impact Study to accommodate the contemporaneous private benefits (to families) of universal programs. Specifically, the MVPF in the present context pins the marginal program beneficiary’s willingness to pay to both their net-of-tax earnings gains from program participation and the reduction in their family’s immediate out-of-pocket childcare expenses.

In particular, for program  $j$ , the MVPF is given by

$$MVPF^j = \frac{(1-\tau)p\hat{\beta}_{TSLs}^j + \phi_j^V S_j^V}{\phi_j^j - \phi_j^B S_j^B - \tau p\hat{\beta}_{TSLs}^j},$$

where  $\hat{\beta}_{TSLs}^j$  is the TSLS estimate of the effect of attending program  $j$  on test scores (in standard deviation units),  $p$  is the predicted change in discounted lifetime earnings with a one standard deviation test score increase, and  $\tau$  represents the marginal tax rate. The first numerator term is thus the present discounted value of the net-of-tax private earnings gains from participation for the marginal program  $j$  attendee. The second is then the private transfer from program substitution – the product of the marginal private program cost,  $\phi_j^V$ , and the likelihood of switching from a private center to program  $j$ ,  $S_j^V$ . The denominator subtracts the marginal fiscal

savings from substitution across public programs,  $\varphi_j^B S_j^B$ , and the marginal discounted value of future tax revenues,  $\tau p \hat{\beta}_{TSLs}^j$ , from marginal government outlays for program  $j$ ,  $\varphi_j^j$ . It thus captures the predicted cost to government of the marginal child's attendance, net of the fiscal externalities from public program substitution and the additional tax revenue.<sup>40</sup>

The MVPF estimates in Table 9 Panel B are noisier than those for the benefit-to-cost ratios but show a similar pattern to the estimates in Panel A. Estimates of the MVPF are larger for universal pre-K and when program outlays are set equal to per-pupil Head Start spending. Indeed, in that case, the MVPF of universal pre-K is 4.27. This estimate is much higher than that seen for a number of redistributive policies (Hendren, 2016), or even for Head Start (Kline and Walters, 2016). However, I have more confidence in the conclusion that the MVPF of universal pre-K truly differs from that of targeted pre-K under the assumption of higher (K-12) costs.

But comparing the MVPFs of universal and targeted programs would only be truly meaningful for a welfare analysis if they served the same populations. Put differently, if these programs both only served low-income children, we could then draw the further conclusion that universal pre-K is the more desirable policy. While most of the true beneficiaries of universal pre-K appear to be low-income children, I cannot rule out that higher-income children gain and so cannot draw this conclusion. Estimates of the MVPF for universal pre-K should therefore be helpful reference points for future work where monetary returns of universal pre-K attendance are measured in other data or perhaps more directly. By the same reasoning, however, my findings do not provide a strong case for targeted *state-funded* pre-K programs: The MVPF for targeted, state-funded pre-K programs is significantly lower than that for the federally-funded

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<sup>40</sup> The benefit-to-cost ratios presented in Table 9 Panel A can be represented by this notation. The first, gross-cost estimate is given by  $p \hat{\beta}_{TSLs}^j / \varphi_j^j$ . The second, net-cost estimate is given by  $p \hat{\beta}_{TSLs}^j / (\varphi_j^j - \varphi_j^B S_j^B - \varphi_j^V S_j^V)$ .



Head Start program (Kline and Walters, 2016), which serves essentially the same income group.

## **VIII. Conclusion**

This paper has presented new estimates of the impacts of preschool education in the U.S., and by harnessing the benefits of observing children from across the country in an underused longitudinal survey, moved the literature forward in meaningful ways. First, I have presented comparable estimates of the immediate cognitive test score impacts of both universal and targeted pre-K, based not only on the same data but also the same research design. I have found evidence that the benefits from attending state-funded pre-K in a state with a universal program exceed those from attending state-funded pre-K in a state with a targeted (means-tested) program – not just overall but especially for the low-income children that both types of programs serve. I also attempted to rule out alternative explanations – beyond pre-K access – for the differences in pre-K attendance impacts across these two groups of states. Throughout, my empirical approach addressed limitations of prior pre-K evaluations exploiting age-eligibility rules for identification. Most notably, survey data from the ECLS-B supported estimation of valid TOT effects and incorporation of new tests of internal validity.

The constellation of evidence is consistent with universal pre-K delivering greater benefits to the population it serves, relative to the costs, than targeted pre-K. In other words, there may be an efficiency-related justification for choosing a universal program over a targeted one, at least in the context of state-funded pre-K. The fact that universal pre-K delivers short-term benefits similar to universal kindergarten suggests that it looks considerably more like public education than targeted pre-K. Public education being perhaps the one investment in children that has the most political support in U.S., political economy considerations may be important for understanding universal pre-K's relative success.

This study has limitations. Though short-term cognitive test score gains from educational intervention predict impacts on adult outcomes like earnings (Chetty et al., 2011) – an idea that I use in the cost-benefit analysis – the findings in this paper only pertain to short-term cognitive effects for one birth cohort. Estimating the impacts of universal and targeted pre-K on longer-term outcomes, once the programs are mature enough to do so, would resolve uncertainty over whether the test score impacts documented here truly manifest in better outcomes over the longer term. Even looking at short-term outcome for more than one cohort would be helpful, if only because the present estimates are noisier than would be ideal. To my knowledge, however, the ECLS-B is the only dataset currently available in the U.S. to carry out this analysis.

In addition, while the findings of this paper provide a concrete example of a public program where universal eligibility may raise cost efficacy, the implications might not extend to situations where public goods are not directly provided by the government, or even beyond early education. Given the idiosyncratic features of policy debates over access, it is important to study the impacts of eligibility rules on the output and productivity of other public programs directly.

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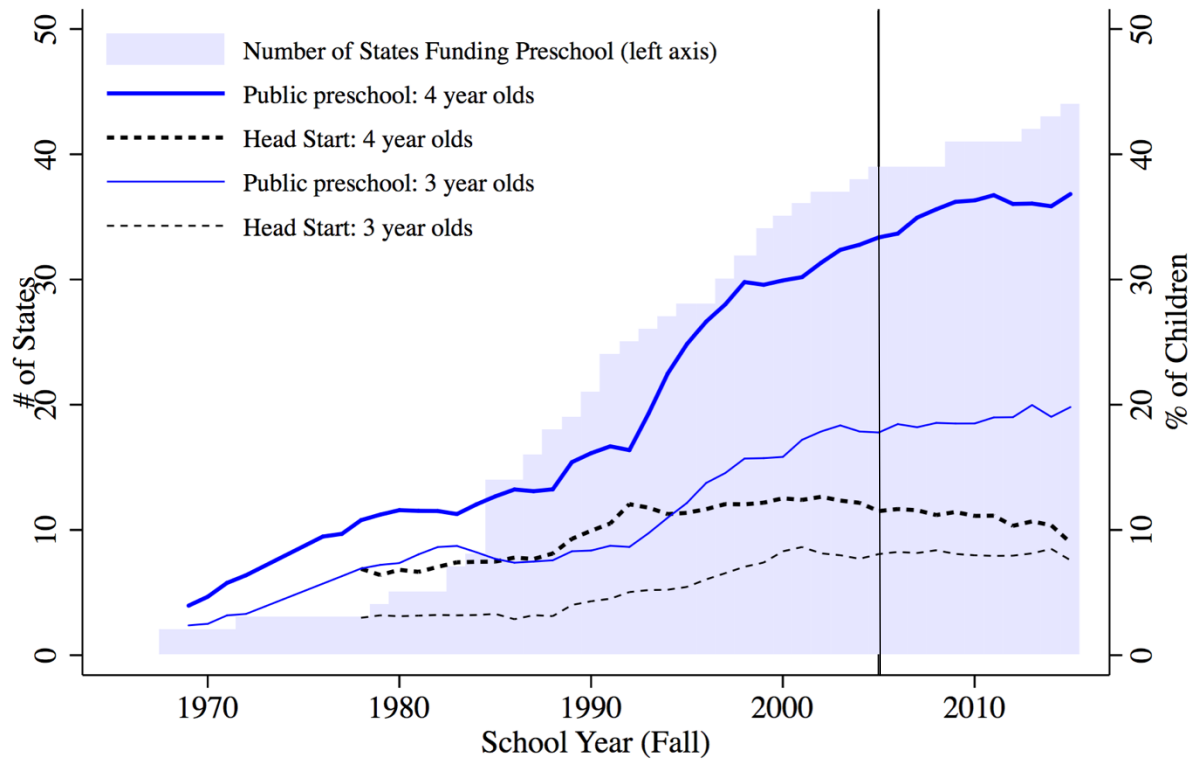
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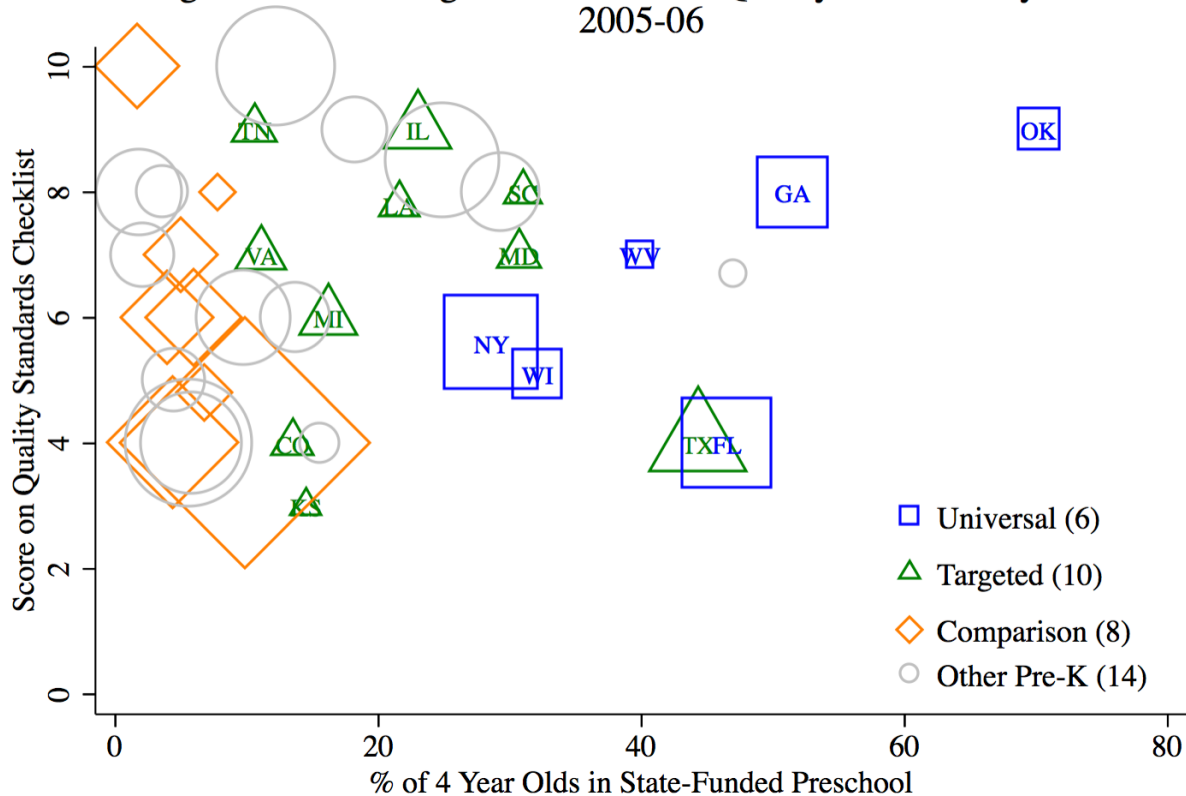
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Figure 1. Trends in Public Preschool Enrollment Rates and Pre-K Funding: 1968-2015



SOURCE: Data on public preschool enrollment rates by age are 3-year moving averages calculated from the 1968-2016 October Current Population Survey (CPS) School Enrollment supplements. Head Start enrollment rates divide Head Start enrollments reported by the Head Start Bureau by cohort size estimates based on annual (as of July 1) national age-specific population estimates from the Census Bureau. State funding dates were constructed from program narratives published by the National Institute for Early Education Research (Barnett et al., 2017).

Figure 2. Prekindergarten Access and Quality Standards by State:  
2005-06

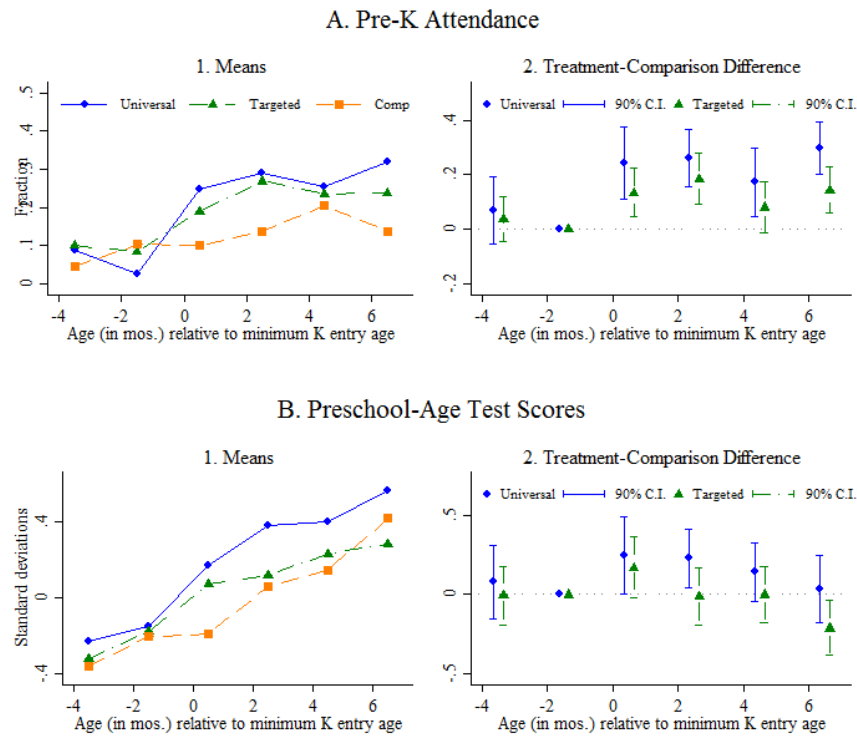


NOTE: Dot sizes represent the size of the state's 4-year-old population. The quality standards checklist (vertical axis) has 10 points, one for each of 10 program standards: 1 point for comprehensive early learning standards, 4 points for teacher training and credentialing requirements (teacher has BA, specialized training in pre-K, assistant teacher has Child Development Associate or equivalent, at least 15 hours of in-service training annually), 2 points for staffing ratios (maximum class size no larger than 20, staff-child ratio 1:10 or better), 2 points for comprehensive services (vision, hearing, health, and one support service, at least one meal provided), and 1 point for a site visit requirement. To qualify as "treated," a state must have had in 2005-06 a state-established date by which the youngest pre-kindergartners were to have turned age 4 that did not fall in the middle of a month and a pre-K enrollment differential favoring 4-year-olds (over 3-year-olds) of at least 8 percentage points. "Universal" treated states are ones that met these criteria and had no eligibility requirements beyond age; "targeted" treated states are ones that met these criteria and had additional eligibility requirements based on family income or other risk factors. (See Appendix Table 1.) Comparison states did not surpass the pre-K enrollment threshold to be a treated state but did have a state-established date by which the youngest enrollees were to have turned age 4 that did not fall in the middle of a month. Not all comparison states are represented in the figure, as some did not have pre-K programs in 2005-06. (See Appendix Table 2.)

SOURCE: Barnett et al. (2006).

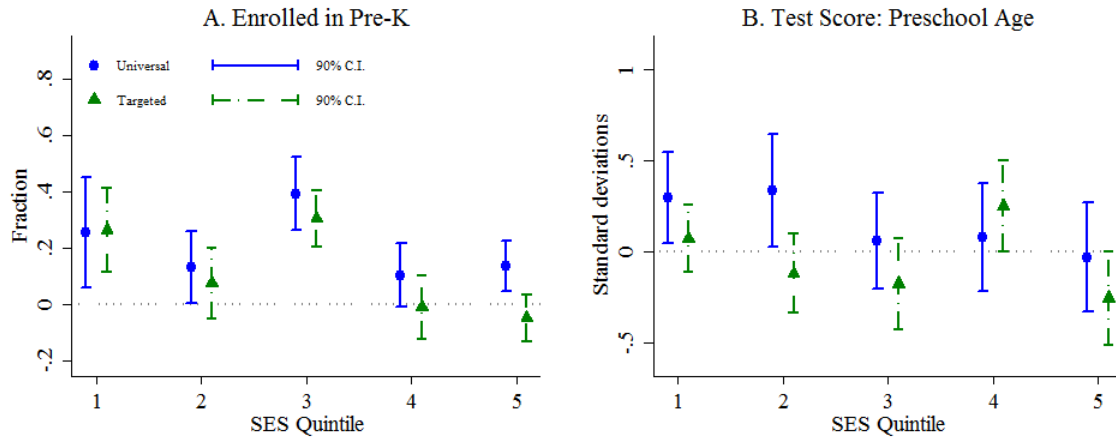


Figure 3. Pre-K Attendance and Test Scores by Age and State Program Type



NOTE: Data are from the ECLS-B. Estimation sample is restricted to respondents with non-missing values of key variables resident in one of the analysis states at wave 3, born with 4 months after and 8 months before that state's cutoff birthdate for kindergarten entry, and assessed during the 2005-06 school year. Panel A corresponds to pre-K attendance in 2005-06 (wave 3, when ECLS-B respondents were 4 years of age); Panel B corresponds to average standardized reading and math scores in 2005-06. Subpanel 1 of each panel plots average values of the dependent variable by age relative to the minimum age for kindergarten entry (2-month bins) for treated states with universal pre-K programs, treated states with targeted pre-K programs, and comparison states; see notes to Table 1 or Appendix Tables 1 and 2 for lists of states. The dots in subpanel 2 of each panel represent, separately for treatment states with universal programs and treatment states with targeted programs, the coefficients on interactions between a treatment dummy and a series of dummies for age relative to the minimum age for kindergarten entry (2-month bins) from a regression that allows for direct effects of each of these (sets of) variables in addition to month x year of assessment dummies and state fixed effects. The interaction with the dummy for missing eligibility by 1 to 2 months is omitted for identification. Capped vertical lines represent 90% confidence intervals, with standard errors clustered on state by month of birth.

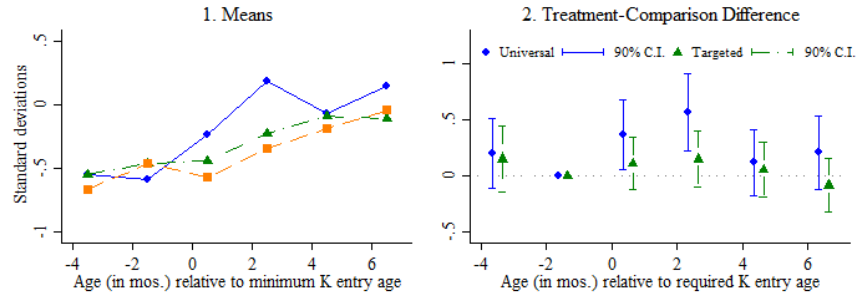
Figure 4. Eligibility Effects on Pre-K Attendance and Test Scores, by State Program Type and SES Quintile



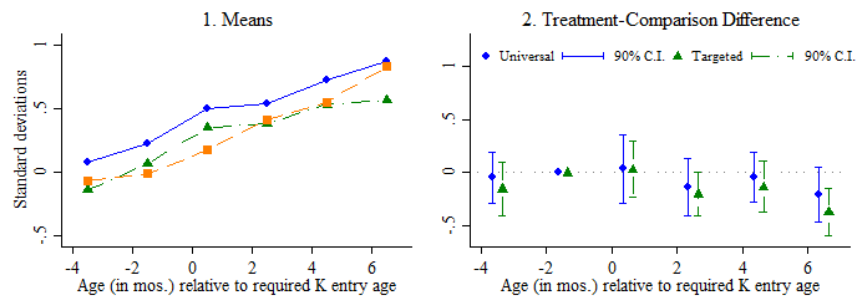
NOTE: Data are from the ECLS-B. Estimation sample is restricted to respondents with non-missing values of key variables resident in one of the analysis states at wave 3, born with 4 months after and 8 months before that state's cutoff birthdate for kindergarten entry, and assessed during the 2005-06 school year. Each dot in each panel represents an estimate of  $\theta$  in model 1 restricting attention to children in states with universal or targeted programs (in both cases relative to the same group of comparison states) in the designated quintile of the ECLS-B index for socio-economic status (SES). The SES index is measured contemporaneously with outcomes (in wave three, or 2005-06) and is derived from a factor analysis of parental education, parental occupation, and family income. The underlying regression also includes indicators for month x year of assessment and the demographic and background characteristics listed in Table 1, Panel B. The capped vertical lines represent 90% confidence intervals, with standard errors clustered on state by month of birth.

Figure 5. Pre-K Eligibility and Test Scores by Age, State Program Type, and Poverty Status

A. Low-Income ( $\leq 185\%$  FPL)



B. Not Low-Income ( $> 185\%$  FPL)



NOTE: Data are from the ECLS-B. Estimation sample is restricted to respondents with non-missing values of key variables resident in one of the analysis states at wave 3, born with 4 months after and 8 months before that state's cutoff birthdate for kindergarten entry, and assessed during the 2005-06 school year. The dependent variable in each panel is average standardized reading and math scores during wave 3, when respondents were 4 years of age. Panel A corresponds to respondents who were eligible for free- or reduced-price lunch in 2005-06; Panel B corresponds to respondents who were not. Subpanel 1 of each panel plots the average standardized test score by age relative to the minimum age for kindergarten entry (2-month bins) for treated states with universal pre-K programs, treated states with targeted pre-K programs, and comparison states; see notes to Table 1 or Appendix Tables 1 and 2. The dots in subpanel 2 of each panel represent, separately for treatment states with universal programs and treatment states with targeted programs, the coefficients on interactions between a treatment dummy and a series of dummies for age relative to the minimum age for kindergarten entry (2-month bins) from a regression that allows for direct effects of each of these (sets of) variables in addition to month x year of assessment dummies and state fixed effects. The interaction with the dummy for missing eligibility by 1 to 2 months is omitted for identification. Capped vertical lines represent 90% confidence intervals, with standard errors clustered on state by month of birth.

**Table 1. Descriptive Statistics and Balance Tests on Key Variables, by Program Type: Full Sample**

	Universal		Targeted		Uni - Tar
	Ineligible Mean [sd]	DD Coef. (se)	Ineligible Mean [sd]	DD Coef. (se)	DDD Coef. (se)
	(1)	(2)	(3)	(4)	(5)
<u>A. Treatment variable</u>					
Pre-kindergarten <sup>a</sup>	0.052	0.211 (0.047)	0.091	0.114 (0.033)	0.097 (0.048)
<u>B. Background characteristics</u>					
Age in months <sup>a</sup>	48.525 [3.160]	-0.099 (0.060)	48.235 [3.316]	-0.093 (0.051)	-0.006 (0.055)
Female	0.463	0.078 (0.046)	0.521	-0.007 (0.044)	0.085 (0.047)
Black non-Hispanic	0.206	0.042 (0.033)	0.201	0.026 (0.029)	0.015 (0.035)
Hispanic	0.196	-0.034 (0.039)	0.255	-0.021 (0.033)	-0.014 (0.036)
Low birth weight	0.074	0.022 (0.014)	0.079	0.015 (0.012)	0.007 (0.014)
Maternal education $\leq$ HS <sup>a</sup>	0.445	0.022 (0.042)	0.468	-0.031 (0.045)	0.053 (0.042)
Both biological parents in HH <sup>a</sup>	0.704	-0.052 (0.038)	0.692	0.045 (0.035)	-0.097 (0.041)
Non-English at home <sup>a</sup>	0.152	-0.010 (0.031)	0.160	-0.008 (0.026)	-0.002 (0.030)
Family income $\leq$ 185% FPL <sup>a</sup>	0.473	-0.092 (0.043)	0.451	-0.064 (0.043)	-0.028 (0.045)
<u>C. p-value: joint test for background chars.</u>					
All background characteristics		0.01		0.17	0.26
Excluding poverty		0.32		0.40	0.27
Observations <sup>b</sup>	300	3,400	400	3,950	7,350

<sup>a</sup> Measured at preschool age, or in 2005-06 (wave 3 interview).

<sup>b</sup> rounded to the nearest 50, per IES guidelines.

NOTE: Odd-numbered columns give means for respondents in treatment states ineligible for pre-K in 2005-06 [standard deviations for non-binary variables]. Even-numbered columns give DD coefficients (standard errors) on the interaction between a dummy for being eligible for pre-K in 2005-06 and a dummy for residing in a treatment state (*elig x treat*) from a separate regression that also includes dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07. Treatment states are those with state-funded pre-K programs focused much more on 4-year-olds than 3-year-olds and statewide minimum age at pre-K entry cutoffs not in the middle of the month; treatment states with universal programs are FL, GA, NY, OK, WI, and WV, and treatment states with targeted programs are CO, IL, KS, LA, MI, MD, SC, TN, TX, and VA. Comparison states have statewide age at kindergarten entry regulations with kindergarten entry cutoffs not in the middle of the month; some comparison states have relatively small pre-K programs (AL, CA, DE, MO, NM, OH, OR, WA), while others lack pre-K programs (AK, HI, ID, IN, MS, ND, RI, SD, UT). A child is deemed eligible for K in 2006-07 if he/she turned age 5 in time to start K in fall 2006, given his/her date of birth and the kindergarten entry age regulations in effect in 2006-07 reported by Barnett et al. (2007). Sample is limited to children who turn age 5 between 4 months after and 8 months before the cutoff date and who are assessed during the 2005-06 school year. Means and regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Table 2. Impacts of State-funded Pre-K on Preschool-Age Test Scores**

	Pre-K:	Test Score (Average Reading and Math):			
	First Stage	Ineligible Mean	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)	(5)
<u>A. Universal (N=3,400)</u>					
No additional controls	0.211 (0.047)	-0.183	0.144 (0.081)	0.682 (0.389)	-0.168 (0.057)
With additional controls <sup>a</sup>	0.211 (0.047)		0.120 (0.065)	0.569 (0.315)	-0.069 (0.048)
<u>B. Targeted (N=3,950)</u>					
No additional controls	0.114 (0.033)	-0.235	-0.009 (0.069)	-0.076 (0.594)	-0.232 (0.049)
With additional controls <sup>a</sup>	0.118 (0.034)		-0.044 (0.060)	-0.373 (0.513)	-0.093 (0.042)
<u>C. <i>p</i>-value on Universal-Targeted Difference (N=7,350)</u>					
No additional controls	0.045		0.071	0.185	0.227
With additional controls <sup>a</sup>	0.057		0.012	0.046	0.609

<sup>a</sup> Additional controls include all demographic and background characteristics in Table 1 Panel B: age at assessment, dummies for female, Hispanic, black non-Hispanic, low birth weight, non-English at home, mom has high school degree or less, both biological parents in household, and low-income.

NOTE: The first stage and RF (ITT) (reduced form (intent-to-treat)) columns in Panels A and B give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The IV (TOT) (instrumental variables (treatment on treated)) and OLS columns in Panels A and B give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Table 3. Impacts of State-funded Pre-K on Preschool-Age Test Scores, by Poverty Status**

	Pre-K: First Stage (1)	Test Score (Average Reading and Math):			
		Ineligible Mean (2)	RF (ITT) (3)	IV (TOT) (4)	OLS (5)
<u>A. Universal</u>					
Low-income (N=1,550)	0.226 (0.062)	-0.572	0.263 (0.107)	1.160 (0.544)	-0.037 (0.055)
Not low-income (N=1,850)	0.189 (0.047)	0.165	0.007 (0.102)	0.038 (0.530)	-0.079 (0.077)
<i>p</i> -value on difference	0.550		0.118	0.191	0.635
<u>B. Targeted</u>					
Low-income (N=1,750)	0.223 (0.051)	-0.497	-0.018 (0.102)	-0.082 (0.450)	-0.015 (0.051)
Not low-income (N=2,200)	0.037 (0.037)	-0.018	-0.066 (0.080)	no f.s.	-0.174 (0.079)
<i>p</i> -value on difference	0.002		0.732		0.107
<u>C. <i>p</i>-value on Universal-Targeted Difference</u>					
Low-income	0.996		0.02	0.032	0.728
Not low-income	0.001		0.461	n.a.	0.255

NOTE: A child is considered low income if his (preschool-age or 2005-06) family income is at or below 185% FPL, the threshold for eligibility for reduced-price lunch and the modal income-eligibility criterion for the targeted programs under study. The first stage and RF (ITT) (reduced form (intent-to-treat)) columns in Panels A and B give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The IV (TOT) (instrumental variables (treatment on treated)) and OLS columns in Panels A and B give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all demographic and background characteristics listed in Table 1 Panel B except the low-income indicator. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth. "no f.s." means "no first stage." "n.a." means "not applicable."

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Table 4. Sensitivity of Estimated Effects of Pre-K to the Choice of Outcome**

	Pre-K:	Test Scores		
	First Stage	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)
<u>A. Baseline</u>				
Universal (N=3,400)	0.211	0.120	0.569	-0.069
	(0.047)	(0.065)	(0.315)	(0.048)
Targeted (N=3,950)	0.118	-0.044	-0.373	-0.093
	(0.034)	(0.060)	(0.513)	(0.042)
<i>p</i> -value on difference	0.057	0.012	0.046	0.609
<u>B. Reading score only</u>				
Universal (N=3,400)	0.211	0.135	0.639	-0.036
	(0.047)	(0.064)	(0.328)	(0.047)
Targeted (N=3,950)	0.118	-0.037	-0.314	-0.100
	(0.034)	(0.067)	(0.564)	(0.045)
<i>p</i> -value on difference	0.057	0.007	0.054	0.214
<u>C. Math score only</u>				
Universal (N=3,400)	0.211	0.106	0.500	-0.102
	(0.047)	(0.082)	(0.378)	(0.058)
Targeted (N=3,950)	0.118	-0.051	-0.432	-0.087
	(0.034)	(0.067)	(0.587)	(0.047)
<i>p</i> -value on difference	0.057	0.061	0.102	0.786
<u>D. Mental score (age 2)<sup>a</sup></u>				
Universal (N=3,350)	0.211	0.005	0.023	-0.062
	(0.046)	(0.069)	(0.326)	(0.051)
Targeted (N=3,950)	0.115	0.035	0.299	-0.081
	(0.034)	(0.068)	(0.610)	(0.051)
<i>p</i> -value on difference	0.049	0.613	0.556	0.643
<u>E. = 1 if parent reports not ready for K (age 4)</u>				
Universal (N=3,400)	0.207	-0.091	-0.440	0.003
	(0.047)	(0.046)	(0.231)	(0.025)
Targeted (N=3,950)	0.114	-0.036	-0.315	-0.021
	(0.033)	(0.036)	(0.343)	(0.023)
<i>p</i> -value on difference	0.053	0.261	0.712	0.327

<sup>a</sup> Additional controls include age at assessment and dummies for month x year of assessment in wave 2 of the ECLS-B, and panel weights incorporate observation in wave 2.

NOTE: The first stage and RF (ITT) columns give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The IV (TOT) and OLS columns give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all demographic and background characteristics listed in Table 1 Panel B. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Direct Child Assessments" [collection at 24 mos., 48 mos.], "Parent-Guardian Interviews" and "Early Care and Education Providers" [collection at 48 mos.]

**Table 5. Sensitivity of Estimated Effects of Pre-K on Test Scores to Estimation Sample**

	Pre-K:	Test Scores		
	First Stage	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)
<u>A. Baseline</u>				
Universal (N=3,400)	0.211 (0.047)	0.120 (0.065)	0.569 (0.315)	-0.069 (0.048)
Targeted (N=3,950)	0.118 (0.034)	-0.044 (0.060)	-0.373 (0.513)	-0.093 (0.042)
<i>p</i> -value on difference	0.057	0.012	0.046	0.609
<u>B. Sample +/- 4 months from threshold<sup>a</sup></u>				
Universal (N=2,000)	0.226 (0.054)	0.203 (0.075)	0.900 (0.350)	-0.050 (0.071)
Targeted (N=2,350)	0.129 (0.039)	0.042 (0.068)	0.321 (0.527)	-0.067 (0.056)
<i>p</i> -value on difference	0.091	0.024	0.197	0.808
<u>C. Identification +/- 4 months from threshold<sup>b</sup></u>				
Universal (N=3,400)	0.218 (0.055)	0.220 (0.074)	1.007 (0.377)	-0.066 (0.047)
Targeted (N=3,950)	0.143 (0.039)	0.040 (0.070)	0.278 (0.488)	-0.092 (0.042)
<i>p</i> -value on difference	0.191	0.015	0.104	0.587
<u>D. Expanded sample (+ middle of month cutoffs)<sup>c</sup></u>				
Universal (N=3,450)	0.212 (0.045)	0.127 (0.065)	0.600 (0.314)	-0.046 (0.048)
Targeted (N=4,250)	0.118 (0.032)	-0.020 (0.059)	-0.170 (0.503)	-0.089 (0.040)
<i>p</i> -value on difference	0.042	0.022	0.089	0.379
<u>E. Restricted sample (Aug. 31/Sept. 1 cutoffs only)<sup>d</sup></u>				
Universal (N=1,800)	0.267 (0.054)	0.150 (0.085)	0.561 (0.311)	-0.086 (0.072)
Targeted (N=1,850)	0.192 (0.037)	-0.038 (0.076)	-0.201 (0.397)	-0.095 (0.061)
<i>p</i> -value on difference	0.173	0.010	0.023	0.908

<sup>a</sup> Sample further limited to respondents with birthdays within 4 months of the cutoff birthdate for kindergarten entry in their wave 3 state of residence.

<sup>b</sup> Interactions between *treat* and indicators for birth 4-5 months and 6-7 months after cutoff included as controls.

<sup>c</sup> Sample expanded to include respondents residing in treatment states with middle-of-month cutoffs (targeted: AR, NC; universal: ME) not born in the cutoff birthdate month.

<sup>d</sup> Sample limited to treatment and comparison states with Aug. 31 or Sept. 1 cutoffs (Appendix Tables 1 and 2).

NOTE: The first stage and RF (ITT) columns give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). The IV (TOT) and OLS columns give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all demographic and background characteristics listed in Table 1 Panel B. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]



**Table 6. Impacts on Alternative Care Arrangements, by State Program Type: Low-Income Children**

		Alternatives:					
	Pre-K: First Stage (1)	Head Start (2)	Other center-based care (3)	Any formal (2+3) (4)	Informal non-parental care (5)	Parental care (6)	Any informal (5+6) (7)
<u>A. Ineligible Means</u>							
Universal	0.08	0.22	0.21	0.43	0.18	0.31	0.49
Targeted	0.11	0.21	0.10	0.32	0.18	0.40	0.57
<u>B. Reduced form (coef (se) on <i>elig x treat<sub>is</sub></i>)</u>							
Universal (N=1,550)	0.226 (0.062)	-0.079 (0.070)	-0.022 (0.058)	-0.102 (0.088)	-0.033 (0.047)	-0.092 (0.072)	-0.125 (0.068)
Targeted (N=1,750)	0.223 (0.051)	-0.082 (0.063)	0.016 (0.051)	-0.066 (0.069)	-0.038 (0.045)	-0.120 (0.059)	-0.158 (0.060)
<i>p</i> -value on difference	0.966	0.968	0.483	0.711	0.924	0.700	0.647
<u>C. Instrumental Variables (coef (se) on <i>prek<sub>is</sub></i>)</u>							
Universal (N=1,550)	n.a.	-0.349 (0.274)	-0.099 (0.242)	-0.448 (0.317)	-0.146 (0.203)	-0.406 (0.327)	-0.552 (0.317)
Targeted (N=1,750)	n.a.	-0.368 (0.244)	0.073 (0.227)	-0.295 (0.273)	-0.168 (0.196)	-0.537 (0.268)	-0.705 (0.273)
<i>p</i> -value on difference	n.a.	0.948	0.459	0.660	0.914	0.704	0.660

NOTE: A child is considered low income if his (preschool-age or 2005-06) family income is at or below 185% FPL, the threshold for eligibility for reduced-price lunch and the modal income-eligibility criterion for the targeted programs under study. Reduced-form coefficients in Panel A are on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The instrumental variables coefficients in Panel B are on pre-K attendance (*prek*), estimated by instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all demographic and background characteristics listed in Table 1 Panel B except the low-income indicator. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth. "n.a." means "not applicable."

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Table 7. Robustness of the Universal-Targeted Difference in Age 4 Test Estimates to Regression-Adjusting for Other Sources of State Heterogeneity in Impacts of State-Funded Pre-K**

	Full Sample			Low-Income		
	Test Scores		Characteristic:	Test Scores		Characteristic:
	RF (ITT)	IV (TOT)	RF	RF (ITT)	IV (TOT)	RF
	(1)	(2)	(3)	(4)	(5)	(6)
Baseline	0.164 (0.065)	0.942 (0.473)	n.a.	0.281 (0.120)	1.241 (0.580)	n.a.
<i>Allowing for heterogeneity by:</i>						
	<u>A. Heterogeneity by Class Size Requirements</u>					
# Class size standards	0.135 (0.071)	1.154 (0.521)	0.125 (0.067)	0.231 (0.114)	1.196 (0.590)	0.214 (0.108)
	<u>B. Heterogeneity by Individual Background Characteristics</u>					
Female	0.162 (0.065)	1.090 (0.498)	0.088 (0.063)	0.279 (0.120)	1.235 (0.576)	0.062 (0.095)
Black non-Hispanic	0.163 (0.065)	0.994 (0.485)	0.121 (0.091)	0.282 (0.121)	1.248 (0.576)	0.200 (0.114)
Hispanic	0.154 (0.066)	0.907 (0.530)	0.023 (0.086)	0.267 (0.120)	1.190 (0.600)	-0.058 (0.113)
Low birth weight	0.164 (0.065)	0.952 (0.479)	0.022 (0.083)	0.281 (0.120)	1.243 (0.578)	0.102 (0.097)
Maternal education $\leq$ HS	0.160 (0.065)	1.313 (0.662)	0.172 (0.074)	0.277 (0.121)	1.233 (0.567)	0.200 (0.103)
Both biological parents in HH	0.157 (0.065)	0.674 (0.449)	-0.143 (0.072)	0.276 (0.119)	1.228 (0.579)	-0.059 (0.096)
Non-English at home	0.165 (0.065)	1.010 (0.493)	0.119 (0.089)	0.282 (0.120)	1.255 (0.577)	0.111 (0.114)
Family income $\leq$ 185% FPL	0.168 (0.067)	1.314 (0.691)	0.116 (0.072)	n.a.	n.a.	n.a.
All characteristics	0.143 (0.066)	1.104 (0.703)	n.s.	0.256 (0.119)	1.198 (0.598)	n.s.

NOTE: A child is considered low income if his (preschool-age or 2005-06) family income is at or below 185% FPL. RF (ITT) columns give the difference in reduced-form (intent-to-treat) coefficients on *elig x treat* between universal and targeted states. IV (TOT) columns give the difference in instrumental variables (treatment-on-treated) coefficients on *prek* (instrumented with *elig x treat* using TSLS) between universal and targeted states. The RF column shows the coefficient on *elig x treat* x characteristic from the same model that produced the RF (ITT) coefficients. All regressions also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all demographic and background characteristics listed in Table 1 Panel B (except the low-income indicator in columns 4-6), with separate control coefficients for the universal and targeted estimation samples. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth. "n.a." means "not applicable." "n.s." means "not shown."

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Table 8. Impacts of Universal Public Kindergarten on Kindergarten-Age Test Scores, Overall and by Poverty Status**

	Public K: First Stage	Test Score (Average Reading and Math):		
		RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)
<u>A. Full Sample (N=2,400)</u>				
All states	0.657 (0.036)	0.376 (0.084)	0.573 (0.132)	0.250 (0.064)
<u>B. Low-Income (N=1,050)</u>				
All states	0.778 (0.050)	0.440 (0.144)	0.566 (0.182)	0.458 (0.107)
<u>C. Not Low-Income (N=1,300)</u>				
All states	0.557 (0.049)	0.332 (0.095)	0.597 (0.180)	0.110 (0.073)

NOTE: A child is considered low income if his (preschool-age or 2005-06) family income is at or below 185% FPL, the threshold for eligibility for reduced-price lunch. The first stage and RF (ITT) (reduced form (intent-to-treat)) columns in Panels A and B give coefficients on a dummy for being eligible for kindergarten in 2006-07 (*elig*). The IV (TOT) (instrumental variables (treatment on treated)) and OLS columns in Panels A and B give coefficients on public K attendance, in the first case instrumenting with *elig* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of (wave 4) residence and month x year of (wave 4) assessment, a linear term in month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, an interaction between that linear term and *elig*, and all demographic and background characteristics listed in Table 1 Panel B (except the low-income dummy in Panels B and C). Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth. Sample is limited to the subset of the original estimation sample born within 4 months after and 4 months before the minimum kindergarten entry age in their wave 4 state of residence.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates," [collection at 9 mos.] "Parent-Guardian Interviews," [collection at 48 mos.], "Direct Child Assessments," "Early Care and Education Providers," and "School Questionnaires" [collection at kindergarten entry]

**Table 9. Cost-Benefit Analysis Under Alternative Assumptions**

	Universal K (1)	Uni. Pre-K (2)	Tar. Pre-K (3)	<i>p</i> : Uni.=Tar. (4)
<u>A. Benefit-to-cost</u>				
1. Program outlays = per-pupil K-12 spending				
Cost=program outlays	1.98 (0.45) [0.03]	1.39 (0.77) [0.61]	-0.18 (1.03) [0.25]	0.16
Cost=net program outlays	2.96 (0.68) [0.00]	1.85 (1.02) [0.41]	-0.24 (1.32) [0.35]	0.15
2. Program outlays = p.p. Head Start spending				
Cost=program outlays	n.a.	2.17 (1.20) [0.33]	-0.27 (1.50) [0.40]	0.14
Cost=net program outlays	n.a.	3.52 (1.94) [0.20]	-0.40 (2.20) [0.52]	0.12
<u>B. Marginal Value of Public Funds (MVPF)</u>				
1. Program outlays = per-pupil K-12 spending	3.94 (1.63) [0.07]	1.96 (1.39) [0.49]	-0.24 (0.99) [0.21]	0.14
2. Program outlays = p.p. Head Start spending	n.a.	4.27 (4.19) [0.43]	-0.39 (1.58) [0.38]	0.25

NOTE: Calculations of benefit-cost ratios and the MVPF consider two scenarios: one where the per-pupil program outlays are equal to per-pupil K-12 spending (an upper bound for pre-K programs) and another where per-pupil program outlays are equal to per-pupil Head Start spending. For the benefit-cost ratio calculation, benefits (numerator) are calculated by multiplying the preferred IV estimates of the per-pupil attendance impact on test scores (with additional controls, low-income subsample in the case of targeted pre-K) by the predicted effect of a one-standard deviation increase in early life test scores on lifetime earnings; net costs (denominator) subtract fiscal savings from substitution from Head Start and from other private center-based care. For the MVPF, the beneficiary's marginal willingness to pay (numerator) sums predicted earnings impacts net of taxes and the transfer to parents from substitution from other private center-based care; net government costs (denominator) subtract the fiscal externalities from substitution from Head Start and predicted tax revenues from per-pupil program outlays. Throughout, I adopt Kline and Walters (2016) conservative assumption that a one standard deviation increase in test scores yields a 10% increase in earnings; that targeted pre-K attendees have lifetime earnings approximately 80% of those for the average child; and that the PDV of lifetime earnings at age 12 is on average \$522,000 (in 2010 dollars, from Chetty et al., 2011). I also assume a discount rate of 3% to calculate PDVs of lifetime earnings at age 5 (column 1) and age 4 (columns 2-3), a tax rate of 20%, and a per-pupil annual price of other, private center-based care equal to approximately \$5000 (based on Laughlin (2013) calculations from the Survey of Income and Program Participation). Per-pupil K-12 and Head Start spending is from Barnett et al. (2006) and corresponds to the 2005-06 for the relevant states. Standard errors (in parentheses) are calculated using the delta method; p-values [in brackets] test of whether the ratio is equal to one.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates," [collection at 9 mos.] "Parent-Guardian Interviews," [collection at 48 mos.] "Direct Child Assessments" and "Early Care and Education Providers" [collection at 48 mos., kindergarten entry] "School Questionnaires" [collection at kindergarten entry]

*Supplemental Online Appendix for*  
**Does Universal Preschool Hit the Target?**  
**Program Access and Preschool Impacts**

*by*

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August 7, 2020

## Appendix A: Data

### A. *Defining “Treatment” States*

My analysis focuses on state programs that served 4-year-olds nearly exclusively, according to statistics and program narratives published by the National Institute for Early Education Research (NIEER) (Barnett et al., 2006).<sup>41</sup> I define such programs as those for which the difference in NIEER-reported state pre-K enrollment rates between 4- and 3-year-olds in 2005-06 was at least 8 percentage points. This definition is necessitated by my research design and the statistical power afforded by the data. In particular, it must be the case that there is a noticeable change in the likelihood of pre-K attendance in 2005-06 for children with birthdates near school entry cutoff dates. Even if a program serves only 4-year-olds, it is hard to detect an effect on attendance if the overall 4-year-old enrollment rate in the program is low. Likewise, even if a program serves a high share of 4-year-olds, an attendance effect is difficult to detect if it also serves a high share of 3-year-olds. Twenty-three of the 38 states with state-funded programs in 2005-06 met the criterion laid forth above, Illinois being the last (Appendix Table 1).

The data and research design also necessitate that I focus on states for which there were state-established dates by which the youngest enrollees were to have been 4-years-old; locally established cutoff dates are not available. In addition, the ECLS-B does not provide information on day of birth within a given month. To minimize misclassification in assignment of the kindergarten eligibility indicator, I therefore focus on states with cutoff birthdates at the beginning or end of the month in my main analysis. Four states (Vermont, Kentucky, Connecticut, and New Jersey) must be excluded due to local determination of their pre-K entry cutoff dates; three (Arkansas, Maine, and North Carolina) are excluded for having cutoff birthdates in the middle of the month. The latter states are included in a specification check in Table 5 (full sample) and Appendix Table 8 (low-income subsample).

Thus, sixteen states meet all of the above criteria for 2005-06.<sup>42</sup> Appendix Table 1 lists these treatment states by whether they are universal or targeted, according to the NIEER narratives, in descending order according to their enrollment rate. In addition to Georgia and Oklahoma, the six universal states under consideration include Florida, New York, West Virginia, and Wisconsin. There are ten targeted programs under consideration. Five of these (those in Colorado, Louisiana, Maryland, Tennessee and Texas) use eligibility for free- or reduced-price lunch as their income eligibility requirement, though that requirement need not apply to all enrollees. Two of these (Kansas and Michigan) use different income eligibility requirements. The remaining three states (Illinois, South Carolina, and Virginia) have no explicit income requirements, but rather risk factor requirements that arguably correlate strongly with income.<sup>43</sup>

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<sup>41</sup> I also use data from Barnett et al. (2007) on kindergarten entry cutoff birthdates for fall 2006.

<sup>42</sup> Unfortunately, Barnett et al. (2006) does not report on Washington, D.C., so I cannot include ECLS-B observations from D.C. in the analysis.

<sup>43</sup> Such risk factors include (but are not limited to) low parental education, single parenthood, English language learner (ELL) status, homelessness, placement in foster care, and developmental delays, depending on the state.

I use 17 comparison states (Appendix Table 2). All of these states had state-mandated school entry cutoff birthdates that were not in the middle of the month, as of 2005-06 and 2006-07. Eight of these states (Alabama, California, Delaware, Missouri, New Mexico, Ohio, Oregon, and Washington) had pre-K programs in 2005-06 that were too small or not different enough in terms of enrollment of 3- and 4-year-olds to be included in the treatment group.<sup>44</sup> The remaining 9 comparison states (Alaska, Hawaii, Idaho, Indiana, Mississippi, North Dakota, Rhode Island, South Dakota, and Utah) did not have pre-K programs in 2005-06.

### *Consideration 1: The Threshold Between Treatment and Comparison States*

There are two states with a difference in pre-K enrollment between 4-year-olds and 3-year-olds rates close to the 8-percentage-point threshold that distinguishes treatment and comparison states: Delaware (7.8 percentage points) and Illinois (8.6 percentage points). Though it yields a much larger gap in this enrollment difference between the comparison and treatment states (3.9 percentage points), removing Delaware and Illinois from the estimation sample barely changes the key findings of the paper, as shown in Appendix Table 11.

### *Consideration 2: Heterogeneity in the Comparison Group*

Identification comes from comparing how test scores grow with age in different pre-K environments. A challenge is that states with different pre-K environments may also differ in other ways that affect this age gradient. Other characteristics do affect this age gradient: Even within the group of 17 comparison states considered in the paper, low-income children experience weaker growth in test scores with age than children who are not low-income (Figure 5), presumably because they have more limited learning opportunities in the absence of pre-K. By extension, states with higher population shares of low-income students may also demonstrate a shallower age gradient in test scores. Indeed, any characteristic that correlates with other learning opportunities – race, ethnicity, parental education, and so on – may affect this gradient.

Ideally, then, the treatment and comparison states in this application would have similar characteristics in levels, not just in trends (Table 1 and Appendix Table 3). Appendix Tables 12a and 12b give average demographic and background characteristics for treatment states (in full and for universal and targeted states separately) and for comparison states (in full and for those without and with pre-K programs), for the full sample and the low-income subsample, respectively. While the Hispanic and non-English at home shares in the full comparison group are not statistically different from those in the treated states overall (or in universal or targeted states), these shares in comparison states without (with) pre-K are significantly lower (higher).

By the above reasoning, we might therefore expect the age gradient in test scores to be shallower – and estimates larger – for the comparison group with pre-K, where the Hispanic/non-English shares are relatively high. Appendix Tables 13a and 13b give estimated impacts from the

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<sup>44</sup> In a previous version of this paper (Cascio, 2017), the comparison group also included five states with pre-K programs (Arizona, Connecticut, Kentucky, Minnesota, and Nevada) with local rules regarding age eligibility for pre-K but statewide cutoff dates for kindergarten entry that were not in the middle of the month. Because many localities may choose a common cutoff date, like September 1, inclusion of these states in the comparison group weakens the first stage, so they were eliminated from the comparison group in the present version of the paper.

preferred specification for each respective comparison group. In the full sample (model with additional controls), the TSLS/IV estimate implies that pre-K attendance raises preschool age test scores by 0.743 standard deviations (s.e.=0.374) when the comparison group consists only of states with (small) pre-K programs (Appendix Table 13a, Panel A); when I restrict the comparison group to states without pre-K programs (Appendix Table 13b, Panel A), this estimate falls to 0.404 (0.388). However, the more robust finding of the paper is maintained in both cases: The test score effects of attending a universal pre-K program are significantly greater than those from attending a targeted pre-K program. This is the case not only in the full sample ( $p=0.069$  and  $p=0.085$  for these respective specifications), but also in the subsample of low-income children ( $p=0.034$  and  $p=0.066$ , respectively).

One reason to work with the full set of comparison states is thus that they look more similar to the treatment states in levels than do either of the two subsets of comparison states in isolation. Another reason is that the balance tests for observables look more favorable for the research design when the estimation incorporates the full set of comparison states. In particular, using the complete comparison group in the estimates for the full sample (Table 1), I fail to reject the null on the joint significance test on the DD and DDD coefficients (poverty coefficient excluded). However, I reject that null in several instances when limiting the comparison group as in Tables Appendix Tables 13a and 13b, as shown in Appendix Table 14a. A similar finding holds in the low-income subsample (c.f. Appendix Table 3 and Appendix Table R14b).

### *Consideration 3: Definition of a Universal Program*

As discussed, a “universal” state is one where eligibility for enrollment in pre-K programs, where offered, is based only on age. A “targeted” state, by contrast, is one where eligibility for pre-K enrollment is also based on family income or other risk factors. Appendix Table 1 reveals that some targeted states actually have enrollment rates for 4-year-olds that are higher than those of universal states. This could happen if some universal states do not operate pre-K programs in every community. However, it could also reflect misclassification.

Appendix Tables 15a and 15b show the main estimates of the paper but classifying states as “high” versus “not high” enrollment instead of “universal” and “targeted”; I define “high” enrollment as a 2005-06 age 4 pre-K enrollment rate of 40% and 30%, respectively. Under the 40% definition, the “high” group includes (rounding up) WV (universal) and TX (targeted), and the “not high” group includes WI and NY (both universal). Under the 30% definition, the “high” group includes TX, SC, and MD (all targeted), and the “not high” group includes NY (universal). Each of these alternative classifications of states makes the differential in effect sizes across groups smaller in magnitude and statistically insignificant. I interpret this evidence as demonstrating that the universal-targeted distinction made in the paper captures a much more meaningful differences across programs than a definition based on enrollment rates.

### *B. ECLS-B Estimation Sample*

The empirical approach taken in this paper is made possible by detailed survey data from the Birth Cohort sample of the Early Childhood Longitudinal Study (ECLS-B). The ECLS-B is a



longitudinal survey of a stratified random sample of children born in the United States in 2001.<sup>45</sup> ECLS-B respondents were assessed and their parents and caregivers interviewed at roughly 9 months of age (wave 1), 2 years of age/toddler age (wave 2), 4 years of age/preschool age (wave 3), and kindergarten age (waves 4 and 5). My estimation sample consists of all children with non-missing preschool-age cognitive assessments and demographic and background characteristics residing at preschool age in one of the 16 treatment states or 17 comparison states, 5 years old between 8 months before and 4 months after their state's kindergarten entry cutoff, and assessed during the 2005-06 school year – a total of 5,100 observations.<sup>46</sup> Reported sample sizes are rounded to the nearest 50, per IES rules to protect confidentiality of ECLS-B respondents.

Most pertinent for this study are the data from wave 3; this wave includes test scores on children who were of preschool age, but may or may not have been actually enrolled in (or age-eligible to enroll in) state-funded pre-K. More specifically, given the fall kindergarten entry cutoffs in Appendix Table 1, the 2001 birth cohort can be split into two school entry cohorts in the wave 3 data – children eligible to enter kindergarten in fall 2006 (and pre-K in fall 2005, if relevant) and children eligible to enter kindergarten in fall 2007 (and pre-K in fall 2006, if relevant). Children in the estimation sample were then tested starting in September 2005 – when any exposure to pre-K would have been limited – through June 2006 – when a child enrolled would have had a full school year of exposure.

### *C. Key Variables*

The main outcomes of interest are cognitive test scores in early math and reading. The preschool cognitive assessment was designed to test both for developmental (age-based) milestones and for knowledge and skills considered important for school readiness and early school success.<sup>47</sup> For my main estimates, I work with reading and math scale scores from this assessment that I normalized to mean zero and variance one in the subsample of comparison states. The main test score outcome is the unweighted average of these standardized scores for reading and math. For estimation of the impacts of kindergarten attendance (Table 8), I consider outcomes from the kindergarten-age (wave 4) cognitive assessment standardized in same fashion. According to the ECLS-B guidance on the scores, “the majority of items in the kindergarten 2006/2007 battery come from the ECLS-K, although several preschool items were included in order to link the data waves within the ECLS-B cohort.”

The ECLS-B also contains rich family background information on respondents.<sup>48</sup> In addition to basic demographics (age at assessment and indicators for sex (female) and ethnicity and race

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<sup>45</sup> The ECLS-B contains oversamples of some demographic groups (Chinese and other Asians, Pacific Islanders, Native Americans, and Alaskan Natives), twins, and low and very low birth weight children. I apply sampling weights to make the estimates population representative.

<sup>46</sup> Since the same comparison group is used to estimate the impact of targeted and universal programs, the number of observations may appear to be larger when summing across regression-specific sample sizes.

<sup>47</sup> The preschool-age assessment drew on the Peabody Picture Vocabulary Test (PPVT), the Preschool Comprehensive Test of Phonological and Print Processing (Pre-CTOPPP), the PreLAS® 2000, and the Test of Early Mathematics Ability-3 (TEMA-3), as well as the cognitive assessment given to the fall 1998 kindergarten cohort of the ECLS (ECLS-K).

<sup>48</sup> All time- or age-varying family background variables are measured in wave 3, or at preschool age.

(non-Hispanic black and Hispanic)), I construct indicators for low-income (family income at or below 185% of the federal poverty line (FPL)), for low birth weight (birth weight < 2,500 grams), for low maternal education (at or below a high school degree), for a language other than English being spoken in the home, and for the presence of both biological parents in the household. I use the low-income indicator to stratify the analysis and as a control in the full-sample estimates and the remaining background and demographic characteristics as controls in my preferred model. The low-income indicator is ideal for stratification, since free or reduced-price lunch eligibility (family income  $\leq$  185% FPL) is the modal income eligibility criterion for the targeted states of interest.

The ECLS-B also assessed toddler's motor and mental development using the Bayley Short Form-Research Edition (based on the Bayley Scales of Infant Development, 2<sup>nd</sup> Edition). I standardize these measures analogously to the preschool-age test scores for the specification checks in Table 4 (full sample) and Appendix Table 4 (low-income subsample). I also include these pretest scores as additional controls in a specification check in Appendix Table 5. I focus on the mental scores but impacts on and controlling for the motor scores yield similar results.

The ECLS-B also provides detailed information on the care and education of respondents at preschool age. In particular, it provides (1) Parent reports of center characteristics for the center in which a child spends the most time; and (2) Provider reports of center characteristics for the type of non-parental care in which a child spends the most time. Source (1) is available for most children, whereas source (2) is missing for a decent share of children for which it should be available.

These data constraints guide my approach to calculating the dummy for state-funded pre-K attendance. I begin with a parent report of the child attending a free program or center.<sup>49</sup> But a concern with using this measure alone is that parents might classify a state-funded pre-K in a different way. For example, the fact that some states allow/encourage subcontracting with Head Start means some children who parents report to be in Head Start are actually enrolled in a state-funded pre-K. In cases where a parent does not report that a child is attending a free program or center, I therefore recode the pre-K indicator to one if the provider reports that a program is a public-school pre-K or a preschool (or other program) sponsored by state/local government or public schools. For example, the parent of a child attending pre-K via Head Start might report that the child is in Head Start, but not another center type. The second step recodes these as state-funded pre-K when Head Start is the primary source of non-parental care. Reassuringly, the second step changes the pre-K attendance dummy much more often for low-income children. Provider reports with which to make the second correction are sometimes missing. Parents also may not accurately report on their child's enrollment.

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<sup>49</sup> Most of these are classified as pre-K or preschool by the parent; only a small share are day care or nursery school.

## Appendix B: Cost-Benefit Analysis

The cost-benefit analysis in Table 9, discussed in Section VII, relies on a number of assumptions. The table below outlines the choices of key parameter values.

Estimate/parameter	Value	Source/Justification
$\hat{\beta}_{TSLs}^U$	0.569 (0.315)	Table 2 Panel A, additional controls, column 4
$\hat{\beta}_{TSLs}^T$	-0.082 (0.450)	Table 3, Panel B, low-income column 4
$\hat{\beta}_{TSLs}^K$	0.573 (0.132)	Table 8, Panel A, column 3
$S_{U,U}^V, S_{U,U}^B$	-0.448, -0.09	Appendix Table 9, Panel C, columns 2 and 3
$S_{T,U}^V, S_{T,U}^B$	0, -0.368	Table 6, Panel C, columns 2 and 3
$S_{K,U}^V, S_{K,U}^B$	-0.378, -0.24	Appendix Table 10, Panel C, columns 2+5 and 4
$\varphi_U^U$	\$11,875 (K-12), \$7627 (Head Start)	Age 4 population-weighted averages of state figures in Barnett et al. (2006)
$\varphi_T^T$	\$10,139 (K-12), \$6974 (Head Start)	Age 4 population-weighted averages of state figures in Barnett et al. (2006)
$\varphi_K^K$	\$11,000	Approximation
$\varphi_U^V = \varphi_K^V$	\$4,966	Lower-bound estimate from Laughlin (2013)
$\varphi_U^B, \varphi_T^B, \varphi_K^B$	\$7627, \$6974, \$7,300	Age 4 population-weighted averages of state per-pupil Head Start spending in Barnett et al. (2006)
$p$	$0.1 \times e_j$ , where $e_j$ is the present discounted value of lifetime earnings at age 4 ( $j=U,T$ ) or age 5 ( $j=K$ )	Kline and Walters (2016). It is conservative to assume that a 1 standard deviation increase in test scores increases earnings by 10%.
$e_U$	\$291,287	Chetty et al. (2011). The average present discounted value of earnings at age 10 is \$522,000 (2010 dollars). Discounted back to age 4 assuming a discount rate of 3% and inflation-adjusted to 2005 dollars.
$e_T$	$0.8 \times e_U$ ,	Kline and Walters (2016). Average lifetime earnings of low-income children is lower than the national average.
$e_K$	\$380,064	Chetty et al. (2011). The average present discounted value of earnings at age 10 is \$522,000 (2010 dollars). Discounted back to age 5 assuming a discount rate of 3% and inflation-adjusted to 2005 dollars.
$\tau$	0.2	Conservative assumption suggested in personal conversation with Nathan Hendren

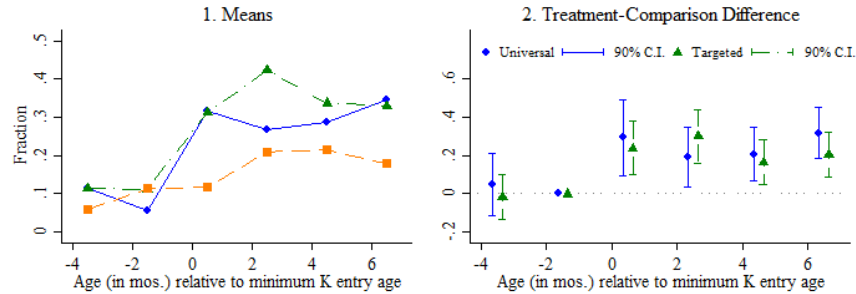
NOTE: “U” denotes universal pre-K; “T” denotes targeted pre-K, and “K” denotes universal kindergarten. All monetary values are in 2005 dollars unless otherwise noted.

## Appendix References

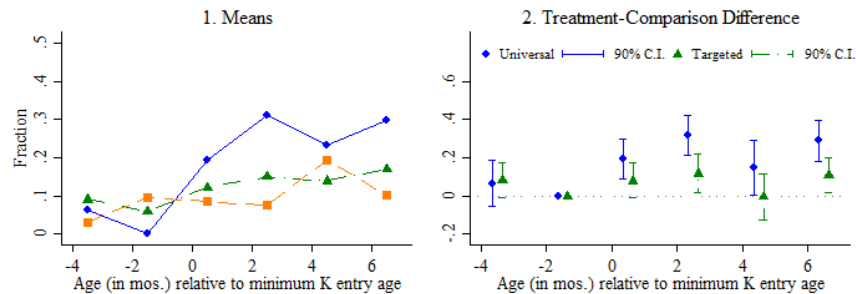
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## Appendix Figure 1. Pre-K Eligibility and Pre-K Attendance by Age, State Program Type, and Poverty Status

### A. Low-Income ( $\leq 185\%$ FPL)



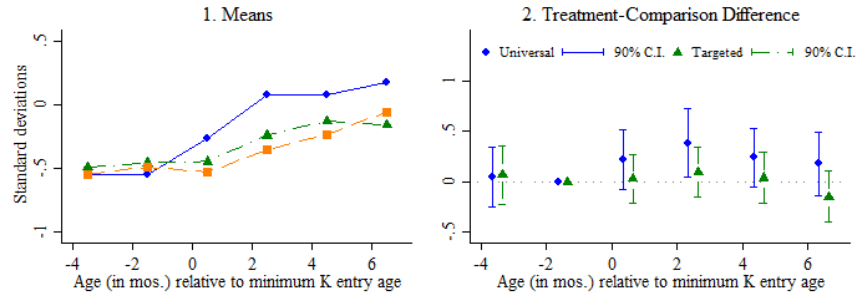
### B. Not Low-Income ( $>185\%$ FPL)



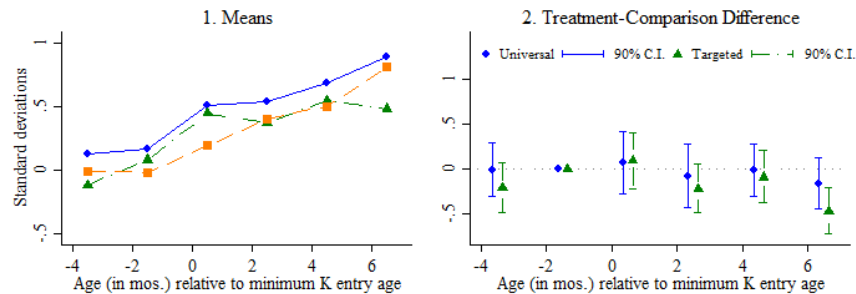
NOTE: Data are from the ECLS-B. Estimation sample is restricted to respondents with non-missing values of key variables resident in one of the analysis states at wave 3 (2005-06), born with 4 months after and 8 months before that state's cutoff birthdate for kindergarten entry, and assessed during the 2005-06 school year. The dependent variable in each panel is a dummy for pre-K attendance during wave 3, when respondents were 4 years of age. Panel A corresponds to respondents who were eligible for free- or reduced-price lunch in 2005-06; Panel B corresponds to respondents who were not. Subpanel 1 of each panel plots the average standardized test score by age relative to the minimum age for kindergarten entry (2-month bins) for treated states with universal pre-K programs, treated states with targeted pre-K programs, and comparison states; see notes to Table 1 or Appendix Tables 1 and 2. The dots in subpanel 2 of each panel represent, separately for treatment states with universal programs and treatment states with targeted programs, the coefficients on interactions between a treatment dummy and a series of dummies for age relative to the minimum age for kindergarten entry (2-month bins) from a regression that allows for direct effects of each of these (sets of) variables in addition to month x year of assessment dummies and state fixed effects. The interaction with the dummy for missing eligibility by 1 to 2 months is omitted for identification. Capped vertical lines represent 90% confidence intervals, with standard errors clustered on state by month of birth.

## Appendix Figure 2. Pre-K Eligibility and Reading Scores by Age, State Program Type, and Poverty Status

### A. Low-Income ( $\leq 185\%$ FPL)



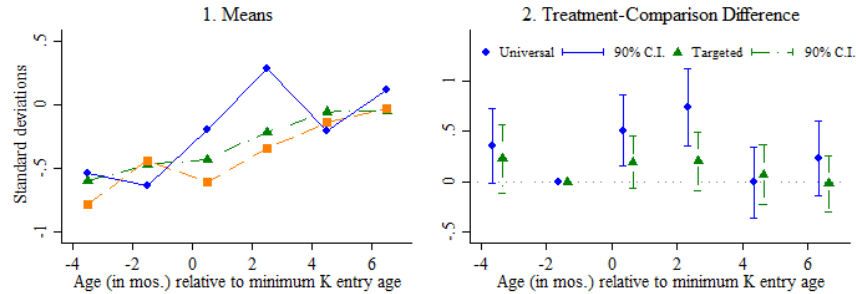
### B. Not Low-Income ( $>185\%$ FPL)



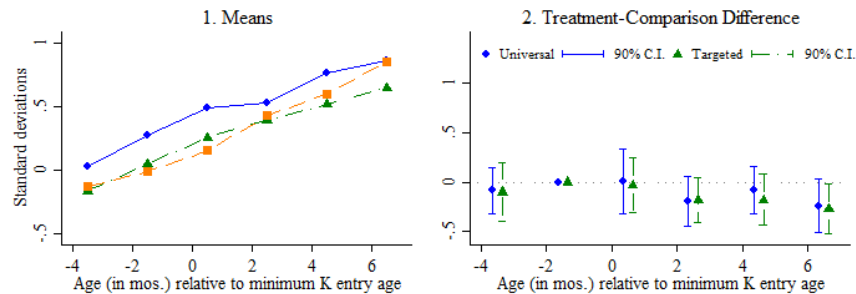
NOTE: Data are from the ECLS-B. Estimation sample is restricted to respondents with non-missing values of key variables resident in one of the analysis states at wave 3 (2005-06), born with 4 months after and 8 months before that state's cutoff birthdate for kindergarten entry, and assessed during the 2005-06 school year. The dependent variable in each panel is the standardized reading score during wave 3, when respondents were 4 years of age. Panel A corresponds to respondents who were eligible for free- or reduced-price lunch in 2005-06; Panel B corresponds to respondents who were not. Subpanel 1 of each panel plots the average standardized test score by age relative to the minimum age for kindergarten entry (2-month bins) for treated states with universal pre-K programs, treated states with targeted pre-K programs, and comparison states; see notes to Table 1 or Appendix Tables 1 and 2. The dots in subpanel 2 of each panel represent, separately for treatment states with universal programs and treatment states with targeted programs, the coefficients on interactions between a treatment dummy and a series of dummies for age relative to the minimum age for kindergarten entry (2-month bins) from a regression that allows for direct effects of each of these (sets of) variables in addition to month x year of assessment dummies and state fixed effects. The interaction with the dummy for missing eligibility by 1 to 2 months is omitted for identification. Capped vertical lines represent 90% confidence intervals, with standard errors clustered on state by month of birth.

## Appendix Figure 3. Pre-K Eligibility and Math Scores by Age, State Program Type, and Poverty Status

### A. Low-Income ( $\leq 185\%$ FPL)

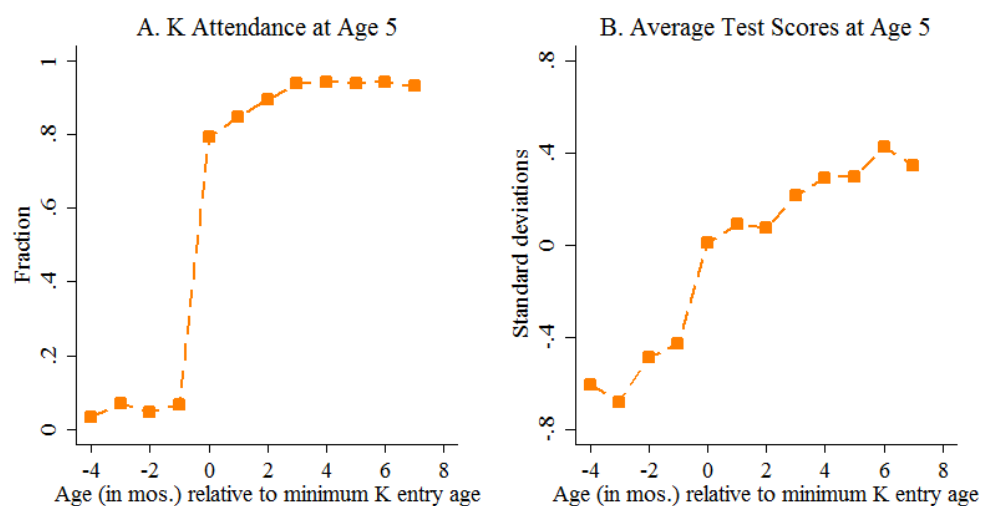


### B. Not Low-Income ( $>185\%$ FPL)



NOTE: Data are from the ECLS-B. Estimation sample is restricted to respondents with non-missing values of key variables resident in one of the analysis states at wave 3 (2005-06), born with 4 months after and 8 months before that state's cutoff birthdate for kindergarten entry, and assessed during the 2005-06 school year. The dependent variable in each panel is the standardized math score during wave 3, when respondents were 4 years of age. Panel A corresponds to respondents who were eligible for free- or reduced-price lunch in 2005-06; Panel B corresponds to respondents who were not. Subpanel 1 of each panel plots the average standardized test score by age relative to the minimum age for kindergarten entry (2-month bins) for treated states with universal pre-K programs, treated states with targeted pre-K programs, and comparison states; see notes to Table 1 or Appendix Tables 1 and 2. The dots in subpanel 2 of each panel represent, separately for treatment states with universal programs and treatment states with targeted programs, the coefficients on interactions between a treatment dummy and a series of dummies for age relative to the minimum age for kindergarten entry (2-month bins) from a regression that allows for direct effects of each of these (sets of) variables in addition to month x year of assessment dummies and state fixed effects. The interaction with the dummy for missing eligibility by 1 to 2 months is omitted for identification. Capped vertical lines represent 90% confidence intervals, with standard errors clustered on state by month of birth.

Appendix Figure 4. Kindergarten Attendance and Age 5 Test Scores  
by Age



NOTE: Data are from the ECLS-B. Estimation sample is restricted the subset of the original estimation sample born within 4 months after and 8 months before birthdate for kindergarten entry in their wave 4 state of residence. The dependent variable in each panel is measured during wave 4, when respondents were 5 years of age. Each panel plots averages by age relative to the minimum age for kindergarten entry across all analysis states (universal pre-K, targeted pre-K, comparison); see notes to Table 1 or Appendix Tables 1 and 2.



**Appendix Table 1. Characteristics of State Pre-Kindergarten Programs Under Study**

State	Birthday Cutoff  for Pre-K	% enrolled by age			Quality Checklist (out of 10)				Annual spending per child		
					Total	Teacher Train. & Creds. (4)	Staffing				
		Ratios & Class Size (2)									
				age 4			age 3	diff.	Pre-K	Head Start	K-12
A. Universal Programs											
Oklahoma	Sept. 1	70.2	0	70.2	9	3	2	4	\$6,167	\$5,809	\$7,475
Georgia	Sept. 1	51.5	0	51.5	8	2	2	4	\$3,978	\$7,149	\$10,492
Florida	Sept. 1	46.5	0	46.5	4	0	2	2	\$2,163	\$7,386	\$9,739
West Virginia	Sept. 1	39.9	4.5	35.4	7	2	2	3	\$7,758	\$6,637	\$11,262
Wisconsin	Sept. 1	32.1	0.7	31.4	5.1	2.9	0.1	2.1	\$4,590	\$6,695	\$12,789
New York	Dec. 1	28.6	0.5	28.1	5.6	1.4	2	2.2	\$3,512	\$8,794	\$15,235
pop-weighted avg.	-	41.5	0.3	41.2	5.8	1.3	1.8	2.6	\$3,569	\$7,627	\$11,875
B. Targeted Programs											
Texas	Sept. 1	44.3	4.5	39.8	4	3	0	1	\$2,653	\$7,091	\$9,076
South Carolina	Sept. 1	31	4.2	26.8	8	3	2	3	\$3,219	\$6,718	\$10,542
Maryland	Sept. 1	30.7	1	29.7	7	3	2	2	\$4,663	\$7,522	\$10,773
Illinois	Sept. 1	23	14.4	8.6	9	4	2	3	\$3,298	\$6,812	\$11,402
Louisiana	Sept. 30	21.6	0	21.6	7.8	2.05	2	3.75	\$5,012	\$6,620	\$10,241
Michigan	Dec. 1	16.2	0	16.2	6	3	2	1	\$3,934	\$6,670	\$11,437
Kansas	Aug. 31	14.5	0	14.5	3	2	0	1	\$2,554	\$6,404	\$9,676
Colorado	Oct. 1	13.5	2.2	11.3	4	1	2	1	\$3,056	\$6,941	\$9,877
Virginia	Sept. 30	11.1	0	11.1	7	2	2	3	\$5,375	\$7,216	\$11,626
Tennessee	Sept. 30	10.6	0.5	10.1	9	3	2	4	\$4,061	\$7,238	\$7,561
pop-weighted avg.	-	27.2	4.1	23.1	6.2	2.9	1.3	2.0	\$3,537	\$6,974	\$10,139

NOTE: Source is Barnett, et al. (2006), and figures correspond to the 2005-06 academic year. Monetary figures are in nominal dollars. The other components of the quality checklist come from comprehensive early learning standards, comprehensive services provided (vision, hearing, health, and one support service, at least one meal), and a site visit requirement; see notes to Figure 2 for complete description of the checklist. Head Start spending corresponds to 2004-05, and K-12 spending includes both current and capital expenditures. Spending on pre-K is a lower bound, since programs may receive funding from local or federal sources not reported.

**Appendix Table 2. Characteristics of the Comparison States**

State	Birthday Cutoff for Pre-K and K	% enrolled in state funded pre-K by age		
		age 4	age 3	diff.
<u>A. Comparison States with Pre-K Programs</u>				
Alabama	Sept. 1	1.7	0	1.7
California	Dec. 2	9.9	4.5	5.4
Delaware	Aug. 31	7.8	0	7.8
Missouri	Jul. 31	4	2.3	1.7
New Mexico	Sept. 1	6.8	0.6	6.2
Ohio	Sept. 30	4.4	1	3.4
Oregon	Sept. 1	5	2.6	2.4
Washington	Aug. 31	6	1.4	4.6
<i>pop-weighted avg.</i>	-	7.5	3.0	4.4
<u>B. Comparison States without Pre-K Programs</u>				
Alaska	Sept. 1	0	0	0
Hawaii	Dec. 31	0	0	0
Idaho	Sept. 1	0	0	0
Indiana	Aug. 1	0	0	0
Mississippi	Sept. 1	0	0	0
North Dakota	Aug. 31	0	0	0
Rhode Island	Sept. 1	0	0	0
South Dakota	Sept. 1	0	0	0
Utah	Sept. 1	0	0	0
<i>pop-weighted avg.</i>	-	0.0	0.0	0.0
<u>C. All Comparison States</u>				
<i>pop-weighted avg.</i>	-	5.9	2.4	3.5

SOURCE: Barnett, et al. (2006, 2007).

**Appendix Table 3. Descriptive Statistics and Balance Tests on Key Variables, by Family Income and Program Type**

	Children: States:	Low-income				Not Low-Income			
		Universal		Targeted		Universal		Targeted	
		Mean	Coef. (se)	Mean	Coef. (se)	Mean	Coef. (se)	Mean	Coef. (se)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<u>A. Treatment variable</u>									
Pre-kindergarten <sup>a</sup>		0.081	0.227 (0.063)	0.113	0.226 (0.050)	0.025	0.206 (0.050)	0.074	0.041 (0.038)
<u>B. Background characteristics</u>									
Age in months <sup>a</sup>		48.551 [3.060]	-0.042 (0.074)	48.516 [3.224]	-0.107 (0.072)	48.502 [3.196]	-0.146 (0.076)	48.003 [3.359]	-0.077 (0.060)
Female		0.493	0.039 (0.082)	0.512	0.009 (0.064)	0.436	0.086 (0.057)	0.529	-0.011 (0.055)
Black non-Hispanic		0.349	0.014 (0.060)	0.345	0.031 (0.055)	0.077	0.065 (0.029)	0.082	0.042 (0.026)
Hispanic		0.206	0.000 (0.059)	0.375	-0.066 (0.050)	0.188	-0.038 (0.047)	0.156	0.037 (0.045)
Low birth weight		0.075	0.043 (0.025)	0.096	0.030 (0.028)	0.073	0.014 (0.020)	0.065	0.012 (0.019)
Maternal education ≤ HS <sup>a</sup>		0.663	0.069 (0.061)	0.695	0.035 (0.068)	0.249	0.054 (0.063)	0.281	-0.025 (0.051)
Both biological parents in HH <sup>a</sup>		0.511	-0.063 (0.057)	0.547	0.003 (0.056)	0.877	-0.113 (0.052)	0.812	0.020 (0.051)
Non-English at home <sup>a</sup>		0.199	-0.002 (0.050)	0.243	-0.005 (0.041)	0.111	0.013 (0.036)	0.091	0.014 (0.041)
<i>p</i> -value: joint test for background chars			0.61		0.44		0.04		0.41
Observations <sup>b</sup>		150	1550	200	1750	150	1850	250	2200

<sup>a</sup> Measured at preschool age, or in 2005-06 (wave 3 interview).

<sup>b</sup> rounded to the nearest 50, per IES guidelines.

NOTE: A child is considered low income if his (preschool-age or 2005-06) family income is at or below 185% FPL. Odd-numbered columns give means for respondents in treatment states ineligible for pre-K in 2005-06 [standard deviations for non-binary variables]. Even-numbered columns give DD coefficients (standard errors) on the interaction between a dummy for being eligible for pre-K in 2005-06 and a dummy for residing in a treatment state (*elig x treat*) from a separate regression that also includes dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07. Treatment states are those with state-funded pre-K programs focused much more on 4-year-olds than 3-year-olds and statewide minimum age at pre-K entry cutoffs not in the middle of the month; see Appendix Table 1. Comparison states have statewide age at kindergarten entry regulations that are not in the middle of the month; see Appendix Table 2. A child is deemed eligible for K in 2006-07 if he /she turned age 5 in time to start K in fall 2006, given his/her date of birth and the kindergarten entry age regulations in effect in 2006-07 reported by Barnett et al. (2007). Sample is limited to children who turn age 5 between 4 months after and 8 months before the cutoff date and who are assessed during the school year. Means and regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 4. Sensitivity of Estimated Effects of Pre-K to the Choice of Outcome:  
Low-Income Subsample**

	Pre-K:	Test Scores		
	First Stage	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)
<u>A. Baseline</u>				
Universal (N=1,550)	0.226	0.263	1.160	-0.037
	(0.062)	(0.107)	(0.544)	(0.055)
Targeted (N=1,750)	0.223	-0.018	-0.082	-0.015
	(0.051)	(0.102)	(0.450)	(0.051)
<i>p</i> -value on difference	0.966	0.020	0.032	0.728
<u>B. Reading score only</u>				
Universal (N=1,550)	0.226	0.272	1.201	0.028
	(0.062)	(0.109)	(0.551)	(0.056)
Targeted (N=1,750)	0.223	-0.039	-0.177	-0.007
	(0.051)	(0.102)	(0.447)	(0.058)
<i>p</i> -value on difference	0.966	0.012	0.021	0.593
<u>C. Math score only</u>				
Universal (N=1,550)	0.226	0.253	1.118	-0.102
	(0.062)	(0.130)	(0.629)	(0.068)
Targeted (N=1,750)	0.223	0.003	0.013	-0.024
	(0.051)	(0.117)	(0.515)	(0.056)
<i>p</i> -value on difference	0.966	0.080	0.096	0.286
<u>D. Mental score (age 2)<sup>a</sup></u>				
Universal (N=1,550)	0.234	-0.006	-0.025	-0.038
	(0.064)	(0.089)	(0.373)	(0.060)
Targeted (N=1,750)	0.207	0.159	0.772	-0.117
	(0.051)	(0.103)	(0.519)	(0.062)
<i>p</i> -value on difference	0.701	0.063	0.068	0.111
<u>E. = 1 if parent reports not ready for K (age 4)</u>				
Universal (N=1,550)	0.229	-0.143	-0.623	0.002
	(0.062)	(0.073)	(0.357)	(0.029)
Targeted (N=1,750)	0.223	-0.038	-0.172	-0.081
	(0.051)	(0.057)	(0.256)	(0.026)
<i>p</i> -value on difference	0.932	0.188	0.220	0.010

<sup>a</sup> Additional controls include age at assessment and dummies for month x year of assessment in wave 2 of the ECLS-B, and panel weights incorporate observation in wave 2.

NOTE: A child is considered low income if his (preschool-age or 2005-06) family income is at or below 185% FPL. The first stage and RF (ITT) columns give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The IV (TOT) and OLS columns give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all demographic and background characteristics listed in Table 1 Panel B except the low-income indicator. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Direct Child Assessments" [collection at 24 mos., 48 mos.], "Parent-Guardian Interviews" and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 5. Sensitivity of Estimated Effects of Pre-K on Test Scores to Controlling for Age 2 Scores**

	Pre-K:	Test Scores		
	First Stage	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)
<u>A. Full Sample</u>				
Universal (N=3,400)	0.210	0.128	0.609	-0.054
	(0.046)	(0.063)	(0.313)	(0.045)
Targeted (N=3,950)	0.112	-0.009	-0.084	-0.067
	(0.034)	(0.065)	(0.571)	(0.040)
<i>p</i> -value on difference	0.043	0.038	0.178	0.790
<u>B. Low-Income Subsample</u>				
Universal (N=1,550)	0.232	0.252	1.086	-0.016
	(0.063)	(0.102)	(0.505)	(0.053)
Targeted (N=1,750)	0.206	0.002	0.008	0.012
	(0.050)	(0.104)	(0.495)	(0.050)
<i>p</i> -value on difference	0.707	0.028	0.055	0.653

NOTE: A child is considered low income if his (preschool-age or 2005-06) family income is at or below 185% FPL. The first stage and RF (ITT) columns give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The IV (TOT) and OLS columns give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, all demographic and background characteristics listed in Table 1 Panel B except the low-income indicator, age 2 motor and mental scores, age at the wave 2 assessment, and dummies for month x year of wave 2 assessment. Missing values of wave 2 assessments are imputed with (weighted) sample means and indicators for imputation also included as regressors. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Direct Child Assessments" [collection at 24 mos., 48 mos.], "Parent-Guardian Interviews" and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 6. IV Estimates of the Impact of Pre-K Attendance on Parental Perceptions of Kindergarten Readiness, by Reason: Low-Income Subsample**

	Reason Not Ready for Kindergarten (=0 if deemed ready):				
	Academic (1)	Social (2)	Behavioral (3)	Physical (4)	Speech Concerns (5)
Universal (N=1,550)	-0.265 (0.170)	0.010 (0.093)	-0.003 (0.145)	0.046 (0.044)	-0.158 (0.094)
Targeted (N=1,750)	-0.044 (0.077)	0.104 (0.086)	-0.080 (0.130)	0.057 (0.047)	-0.073 (0.097)
<i>p</i> -value on difference	0.173	0.268	0.598	0.616	0.442
	Medical (6)	Limited English (7)	Young in Class (8)	Limited Preschool (9)	
Universal (N=1,550)	-0.063 (0.077)	0.016 (0.030)	-0.038 (0.031)	-0.050 (0.027)	
Targeted (N=1,750)	0.001 (0.051)	-0.011 (0.019)	0.002 (0.006)	-0.039 (0.023)	
<i>p</i> -value on difference	0.394	0.309	0.213	0.569	

NOTE: Dependent variables are coded as zero for children of parents who report no concern over their kindergarten readiness. Not every parent who reports concern over kindergarten readiness gives a reason – and parents can give multiple reasons – so the coefficients need not add up to those reported in Appendix Table 4 Panel E. Each cell entry represents an IV estimate of the impact of pre-K attendance on a dummy for a parent reporting (in wave 3) concerns that a child is not ready for kindergarten for the reason given. The instrument for pre-K attendance is the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (elig x treat). All underlying regressions include dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all demographic and background characteristics listed in Table 1 Panel B. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth. SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, “Children’s Birth Certificates” [collection at 9 mos.], “Parent-Guardian Interviews,” “Direct Child Assessments,” and “Early Care and Education Providers” [collection at 48 mos.]

**Appendix Table 7. Balance Tests on Key Variables, by Program Type:  
+/- 4 Months from Cutoff**

	Universal	Targeted	Uni - Tar
	DD Coef.	DD Coef.	DDD Coef.
	(se)	(se)	(se)
	(1)	(2)	(3)
<u>A. Treatment variable</u>			
Pre-kindergarten <sup>a</sup>	0.221 (0.055)	0.125 (0.038)	0.096 (0.056)
<u>B. Background characteristics</u>			
Age in months <sup>a</sup>	-0.156 (0.063)	-0.140 (0.054)	-0.016 (0.057)
Female	0.117 (0.053)	0.060 (0.050)	0.057 (0.057)
Black non-Hispanic	0.030 (0.041)	0.016 (0.032)	0.015 (0.042)
Hispanic	-0.021 (0.046)	-0.011 (0.037)	-0.010 (0.042)
Low birth weight	0.028 (0.016)	0.012 (0.013)	0.015 (0.016)
Maternal education $\leq$ HS <sup>a</sup>	0.012 (0.044)	-0.048 (0.050)	0.060 (0.044)
Both biological parents in HH <sup>a</sup>	-0.079 (0.047)	0.025 (0.041)	-0.105 (0.051)
Non-English at home <sup>a</sup>	-0.009 (0.034)	-0.024 (0.032)	0.016 (0.036)
Family income $\leq$ 185% FPL <sup>a</sup>	-0.075 (0.047)	-0.080 (0.048)	0.005 (0.051)
<u>C. <i>p</i>-value: joint test for background chars.</u>			
All background characteristics	0.01	0.10	0.26
Excluding poverty	0.01	0.24	0.25
Observations <sup>b</sup>	2,000	2,350	4,350

<sup>a</sup> Measured at preschool age, or in 2005-06 (wave 3 interview)

<sup>b</sup> rounded to the nearest 50, per IES guidelines.

NOTE: Sample is limited to children who turn age 5 between 4 months after and 4 months before the cutoff date and who are assessed during the school year. Each column gives DD coefficients (standard errors) on the interaction between a dummy for being eligible for pre-K in 2005-06 and a dummy for residing in a treatment state (*elig*  $\times$  *treat*) from a separate regression that also includes dummies for state of residence, month  $\times$  year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07. Treatment states are those with state-funded pre-K programs focused much more on 4-year-olds than 3-year-olds and statewide minimum age at pre-K entry cutoffs not in the middle of the month; treatment states with universal programs are FL, GA, NY, OK, WI, and WV, and treatment states with targeted programs are CO, IL, KS, LA, MI, MD, SC, TN, TX, and VA. Comparison states have statewide age at kindergarten entry regulations; some comparison states have relatively small pre-K programs (AL, CA, DE, MO, NM, OH, OR, WA), while others lack pre-K programs (AK, HI, ID, IN, MS, ND, RI, SD, UT). A child is deemed eligible for K in 2006-07 if he /she turned age 5 in time to start K in fall 2006, given his/her date of birth and the kindergarten entry age regulations in effect in 2006-07 reported by Barnett et al. (2007). Means and regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state  $\times$  month of birth. SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 8. Sensitivity of Estimated Effects of Pre-K on Test Scores to Estimation Sample: Low-Income Subsample**

	Pre-K:	Test Scores		
	First Stage	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)
<u>A. Baseline</u>				
Universal (N=1,550)	0.226	0.263	1.160	-0.037
	(0.062)	(0.107)	(0.544)	(0.055)
Targeted (N=1,750)	0.223	-0.018	-0.082	-0.015
	(0.051)	(0.102)	(0.450)	(0.051)
<i>p</i> -value on difference	0.966	0.020	0.032	0.728
<u>B. Sample +/- 4 months from threshold<sup>a</sup></u>				
Universal (N=900)	0.242	0.347	1.434	-0.042
	(0.083)	(0.129)	(0.677)	(0.078)
Targeted (N=1,000)	0.241	0.049	0.202	0.026
	(0.061)	(0.112)	(0.443)	(0.075)
<i>p</i> -value on difference	0.985	0.029	0.060	0.474
<u>C. Identification +/- 4 months from threshold<sup>b</sup></u>				
Universal (N=1,550)	0.218	0.397	1.816	-0.036
	(0.083)	(0.121)	(0.826)	(0.055)
Targeted (N=1,750)	0.269	0.047	0.173	-0.014
	(0.063)	(0.114)	(0.412)	(0.052)
<i>p</i> -value on difference	0.571	0.009	0.038	0.725
<u>D. Expanded sample (+ middle of month cutoffs)<sup>c</sup></u>				
Universal (N=1,600)	0.230	0.249	1.080	-0.023
	(0.061)	(0.107)	(0.527)	(0.055)
Targeted (N=1,900)	0.211	0.008	0.036	0.015
	(0.048)	(0.095)	(0.443)	(0.049)
<i>p</i> -value on difference	0.776	0.037	0.059	0.521
<u>E. Restricted sample (Aug. 31/Sept. 1 cutoffs)<sup>d</sup></u>				
Universal (N=900)	0.296	0.178	0.602	0.008
	(0.066)	(0.125)	(0.409)	(0.101)
Targeted (N=850)	0.329	-0.037	-0.113	-0.002
	(0.048)	(0.131)	(0.388)	(0.094)
<i>p</i> -value on difference	0.645	0.103	0.081	0.936

<sup>a</sup> Sample further limited to respondents with birthdays within 4 months of the cutoff birthdate for kindergarten entry in their wave 3 state of residence.

<sup>b</sup> Interactions between *treat* and indicators for birth 4-5 months and 6-7 months after cutoff included as controls.

<sup>c</sup> Sample expanded to include respondents residing in treatment states with middle-of-month cutoffs (targeted: AR, NC; universal: ME) not born in the cutoff birthdate month.

<sup>d</sup> Sample limited to treatment and comparison states with Aug. 31 or Sept. 1 cutoffs (Appendix Tables 1 and 2).

NOTE: A child is considered low income if his (preschool-age or 2005-06) family income is at or below 185% FPL. The first stage and RF (ITT) columns give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states in the baseline sample.) The IV (TOT) and OLS columns give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all characteristics listed in Table 1 Panel B except the low-income indicator. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]



**Appendix Table 9. Impacts on Alternative Care Arrangements, by State Program Type: Full Sample**

		Alternatives:					
	Pre-K: First Stage (1)	Head Start (2)	Other center-based care (3)	Any formal (2+3) (4)	Informal non-parental care (5)	Parental care (6)	Any informal (5+6) (7)
<u>A. Ineligible Means</u>							
Universal	0.05	0.12	0.44	0.56	0.14	0.25	0.39
Targeted	0.09	0.12	0.34	0.46	0.18	0.27	0.45
<u>B. Reduced form (coef (se) on <i>elig x treat<sub>it</sub></i>)</u>							
Universal (N=3,400)	0.211 (0.047)	-0.019 (0.035)	-0.095 (0.055)	-0.114 (0.066)	-0.002 (0.029)	-0.095 (0.040)	-0.097 (0.045)
Targeted (N=3,950)	0.118 (0.034)	-0.013 (0.031)	0.001 (0.041)	-0.011 (0.046)	-0.029 (0.034)	-0.078 (0.039)	-0.107 (0.040)
<i>p</i> -value on difference	0.057	0.871	0.070	0.122	0.436	0.700	0.851
<u>C. Instrumental Variables (coef (se) on <i>prek<sub>it</sub></i>)</u>							
Universal (N=3,400)	n.a.	-0.090 (0.155)	-0.448 (0.219)	-0.539 (0.239)	-0.012 (0.136)	-0.450 (0.219)	-0.461 (0.239)
Targeted (N=3,950)	n.a.	-0.107 (0.248)	0.011 (0.343)	-0.096 (0.371)	-0.245 (0.294)	-0.659 (0.332)	-0.904 (0.371)
<i>p</i> -value on difference	n.a.	0.947	0.159	0.222	0.385	0.511	0.222

NOTE: Reduced-form coefficients in Panel A are on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The instrumental variables coefficients in Panel B are on pre-K attendance (*prek*), estimated by instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and all demographic and background characteristics listed in Table 1 Panel B. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth. "n.a." means "not applicable."

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 10. Impacts on Alternative Care Arrangements to Kindergarten: Full Sample**

	Alternatives:								
	Public K: First Stage (1)	Private K (2)	Grades 1-2 (3)	Head Start (4)	Other center- based care (5)	Any formal (4+5) (6)	Informal non- parental care (7)	Parental care (8)	Any informal (7+8) (9)
<u>A. Ineligible means</u>									
All states	0.05	0.02	0.00	0.13	0.58	0.71	0.11	0.11	0.21
<u>B. Reduced form (coef (se) on <i>elig</i>)</u>									
All states (N=2,400)	0.657 (0.036)	0.070 (0.024)	0.000 (0.000)	-0.158 (0.033)	-0.319 (0.048)	-0.477 (0.045)	-0.179 (0.037)	-0.071 (0.031)	-0.250 (0.038)
<u>C. Instrumental Variables (coef (se) on kindergarten attendance)</u>									
All states (N=2,400)	n.a.	0.107 (0.040)	0.000 (0.000)	-0.241 (0.049)	-0.485 (0.068)	-0.726 (0.060)	-0.273 (0.058)	-0.108 (0.046)	-0.381 (0.059)

NOTE: Reduced-form coefficients in Panel A are on a dummy for being eligible for kindergarten in 2006-07 (*elig*). The instrumental variables coefficients in Panel B are give coefficients on K attendance, instrumenting with *elig* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of (wave 4) residence and month x year of (wave 4) assessment, a linear term in month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, an interaction between that linear term and *elig*, and all demographic and background characteristics listed in Table 1 Panel B. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth. Sample is limited to the subset of the original estimation sample born within 4 months after and 4 months before the minimum kindergarten entry age in their wave 4 state of residence. "n.a." means "not applicable."

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates," [collection at 9 mos.] "Parent-Guardian Interviews," [collection at 48 mos.], "Direct Child Assessments," "Early Care and Education Providers," and "School Questionnaires" [collection at kindergarten entry]

**Appendix Table 11. Impacts of State-funded Pre-K on Preschool-Age Test Scores  
Dropping DE and IL from Estimation Sample**

	Pre-K:	Test Score (Average Reading and Math):			
	First Stage	Ineligible Mean	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)	(5)
<u>A. Full Sample</u>					
<u>1. Universal (N=3,400)</u>					
With additional controls	0.211 (0.047)	-0.183	0.118 (0.065)	0.562 (0.315)	-0.069 (0.048)
<u>2. Targeted (N=3,600)</u>					
With additional controls	0.121 (0.038)	0.277	-0.032 (0.064)	-0.261 (0.529)	-0.087 (0.046)
<u>3. p-value on Universal-Targeted Difference (N=7,000)</u>					
With additional controls	0.082		0.030	0.095	0.711
<u>B. By Family Income</u>					
<u>1. Universal</u>					
Low-income (N=1,550)	0.226 (0.062)	-0.572	0.257 (0.108)	1.137 (0.543)	-0.038 (0.055)
Not low-income (N=1,850)	0.189 (0.047)	0.165	0.008 (0.102)	0.041 (0.530)	-0.079 (0.077)
p-value on difference	0.552		0.128	0.201	0.64
<u>2. Targeted</u>					
Low-income (N=1,600)	0.226 (0.058)	-0.524	-0.019 (0.112)	-0.085 (0.490)	-0.032 (0.052)
Not low-income (N=2,000)	0.037 (0.039)	-0.073	-0.046 (0.087)	no f.s.	-0.140 (0.083)
p-value on difference	0.003		0.862		0.263
<u>3. p-value on Universal-Targeted Difference</u>					
Low-income	0.995		0.034	0.047	0.928
Not low-income	0.002		0.611	n.a.	0.46

NOTE: The first stage and RF (ITT) columns give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). Sample drops Delaware (comparison) and Illinois (targeted state). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The IV (TOT) and OLS columns give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and the demographic and background controls listed in Table 1 Panel B. A child is considered low income (Panel B) if his (preschool-age or 2005-06) family income is at or below 185% FPL, the threshold for eligibility for reduced-price lunch and the modal income-eligibility criterion for the targeted programs under study. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 12a. Means for Treatment Groups and Prospective Comparison Groups: Full Sample**

	Treatment Groups						Comparison Groups		
	Universal		Targeted		All		All	With Pre-K	No Pre-K
	(1)		(2)		(3)		(4)	(5)	(6)
<b>A. Treatment variable</b>									
Pre-kindergarten <sup>a</sup>	0.214	*‡	0.193	*‡	0.201	*‡	0.130	0.155	0.069
<b>B. Background characteristics</b>									
Age in months <sup>a</sup>	52.361		51.974		52.132		52.112	52.069	52.214
	[5.801]		[5.071]		[5.390]		[5.237]	[5.362]	[4.923]
Female	0.486		0.484		0.485		0.486	0.483	0.491
Black non-Hispanic	0.186	*‡	0.181	*‡‡	0.183	*‡‡	0.115	0.119	0.108
Hispanic	0.170	†	0.243	‡	0.213	†‡	0.251	0.307	0.118
Low birth weight	0.076		0.080		0.079		0.073	0.074	0.072
Maternal education ≤ HS <sup>a</sup>	0.464		0.447		0.454		0.466	0.474	0.449
Both biological parents in HH <sup>a</sup>	0.681		0.723		0.706		0.700	0.697	0.707
Non-English at home <sup>a</sup>	0.136	†‡	0.157	‡	0.148	‡	0.168	0.212	0.063
Family income ≤ 185% FPL <sup>a</sup>	0.449		0.431	*†	0.438	*†	0.485	0.494	0.464
Observations <sup>b</sup>	1,150		1,750		2,900		2,250	1,600	650

<sup>a</sup> Measured at preschool age, or in 2005-06 (wave 3 interview).

<sup>b</sup> rounded to the nearest 50, per IES guidelines.

\* significantly different from the full comparison group ( $p < 0.05$ ).

† significantly different from the comparison states with pre-K ( $p < 0.05$ ).

‡ significantly different from the comparison states without pre-K ( $p < 0.05$ ).

NOTE: Columns give means for each group [standard deviations for non-binary variables]. Treatment states are those with state-funded pre-K programs focused much more on 4-year-olds than 3-year-olds and statewide minimum age at pre-K entry cutoffs not in the middle of the month; treatment states with universal programs are FL, GA, NY, OK, WI, and WV, and treatment states with targeted programs are CO, IL, KS, LA, MI, MD, SC, TN, TX, and VA. Comparison states have statewide minimum age at kindergarten entry cutoffs not in the middle of the month; some comparison states have relatively small pre-K programs (AL, CA, DE, MO, NM, OH, OR, WA), while others lack pre-K programs (AK, HI, ID, IN, MS, ND, RI, SD, UT). Sample is limited to children who turn age 5 between 4 months after and 8 months before the cutoff date and who are assessed during the 2005-06 school year. Means are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 12b. Means for Treatment Groups and Prospective Comparison Groups: Low-Income Subsample**

	Treatment Groups						Comparison Groups		
	Universal		Targeted		All		All	With Pre-K	No Pre-K
	(1)		(2)		(3)		(4)	(5)	(6)
<b>A. Treatment variable</b>									
Pre-kindergarten <sup>a</sup>	0.239	‡	0.282	*†‡	0.264	*‡	0.161	0.203	0.052
<b>B. Background characteristics</b>									
Age in months <sup>a</sup>	52.445		52.306		52.364		52.361	52.303	52.512
	[5.831]		[4.927]		[5.312]		[5.113]	[5.110]	[5.062]
Female	0.515		0.483		0.497		0.468	0.477	0.445
Black non-Hispanic	0.293	*†	0.291	*†	0.292	*†	0.184	0.172	0.215
Hispanic	0.213	*†	0.349	‡	0.292	‡	0.327	0.386	0.176
Low birth weight	0.085		0.101	†	0.094		0.081	0.077	0.093
Maternal education ≤ HS <sup>a</sup>	0.729	‡	0.745	*‡	0.738	‡	0.682	0.711	0.608
Both biological parents in HH <sup>a</sup>	0.504		0.562		0.538		0.561	0.570	0.538
Non-English at home <sup>a</sup>	0.187	†‡	0.234	‡	0.215	‡	0.247	0.307	0.093
Observations <sup>b</sup>	550		700		1,250		1,000	700	300

<sup>a</sup> Measured at preschool age, or in 2005-06 (wave 3 interview).

<sup>b</sup> rounded to the nearest 50, per IES guidelines.

\* significantly different from the full comparison group ( $p < 0.05$ ).

† significantly different from the comparison states with pre-K ( $p < 0.05$ ).

‡ significantly different from the comparison states without pre-K ( $p < 0.05$ ).

NOTE: Columns give means for each group [standard deviations for non-binary variables]. See notes to Appendix Table 12a for description of treatment and comparison states. Sample is limited to low-income children who turn age 5 between 4 months after and 8 months before the cutoff date and who are assessed during the 2005-06 school year; low-income is defined as having family income at or below 185% of the federal poverty line at preschool age (wave 3 interview). Means are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 13a. Impacts of State-funded Pre-K on Preschool-Age Test Scores**  
**Comparison Group Limited to States With Pre-K Programs**

	Pre-K:	Test Score (Average Reading and Math):			
	First Stage	Inelig. Mean	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)	(5)
<u>A. Full Sample</u>					
<u>1. Universal (N=2,750)</u>					
With additional controls	0.203 (0.051)	-0.183	0.151 (0.071)	0.743 (0.374)	-0.044 (0.052)
<u>2. Targeted (N=3,300)</u>					
With additional controls	0.111 (0.038)	- 0.235	-0.014 (0.065)	-0.125 (0.577)	-0.077 (0.045)
<u>3. p-value on Universal-Targeted Difference (N=6,050)</u>					
With additional controls	0.064		0.012	0.069	0.542
<u>B. By Family Income</u>					
<u>1. Universal</u>					
Low-income (N=1,250)	0.233 (0.070)	-0.572	0.362 (0.114)	1.551 (0.667)	-0.008 (0.057)
Not low-income (N=1,500)	0.177 (0.050)	0.165	-0.018 (0.112)	-0.104 (0.622)	-0.067 (0.085)
p-value on difference	0.411		0.033	0.114	0.536
<u>2. Targeted</u>					
Low-income (N=1,400)	0.234 (0.061)	-0.497	0.050 (0.111)	0.211 (0.472)	0.009 (0.053)
Not low-income (N=1,900)	0.030 (0.041)	-0.018	-0.078 (0.091)	no f.s.	-0.173 (0.088)
p-value on difference	0.004		0.41		0.091
<u>3. p-value on Universal-Targeted Difference</u>					
Low-income	0.991		0.011	0.034	0.784
Not low-income	0.002		0.553	n.a.	0.272

NOTE: Comparison states are limited to the subset of comparison states with pre-K programs (AL, CA, DE, MO, NM, OH, OR, WA). The first stage and RF (ITT) columns in Panels A, B.1, and B.2 give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). The IV (TOT) and OLS columns in Panels A, B.1 and B.2 give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and the demographic and background controls listed in Table 1 Panel B. A child is considered low income (Panel B) if his (preschool-age or 2005-06) family income is at or below 185% FPL, the threshold for eligibility for reduced-price lunch and the modal income-eligibility criterion for the targeted programs under study. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 13b. Impacts of State-funded Pre-K on Preschool-Age Test Scores  
Comparison Group Limited to States Without Pre-K Programs**

	Pre-K: First Stage	Test Score (Average Reading and Math):			
	(1)	Inelig. Mean (2)	RF (ITT) (3)	IV (TOT) (4)	OLS (5)
<b>A. Full Sample</b>					
<b>1. Universal (N=1,800)</b>					
With additional controls	0.217 (0.050)	-0.183	0.088 (0.087)	0.404 (0.388)	-0.081 (0.067)
<b>2. Targeted (N=2,400)</b>					
With additional controls	0.131 (0.040)	-0.235	-0.089 (0.096)	-0.685 (0.804)	-0.117 (0.054)
<b>3. <i>p</i>-value on Universal-Targeted Difference (N=4,200)</b>					
With additional controls	0.073		0.014	0.085	0.663
<b>B. By Family Income</b>					
<b>1. Universal</b>					
Low-income (N=850)	0.200 (0.062)	-0.572	0.078 (0.118)	0.390 (0.585)	-0.056 (0.093)
Not low-income (N=950)	0.206 (0.056)	0.165	0.072 (0.129)	0.351 (0.609)	-0.083 (0.095)
<i>p</i> -value on difference	0.935		0.974	0.964	0.825
<b>2. Targeted</b>					
Low-income (N=1,050)	0.192 (0.051)	-0.497	-0.131 (0.124)	-0.679 (0.658)	0.003 (0.077)
Not low-income (N=1,350)	0.049 (0.050)	-0.018	-0.041 (0.123)	no f.s.	-0.255 (0.098)
<i>p</i> -value on difference	0.042		0.594		0.05
<b>3. <i>p</i>-value on Universal-Targeted Difference</b>					
Low-income	0.917		0.048	0.066	0.615
Not low-income	0.001		0.302	n.a.	0.185

NOTE: Comparison states are limited to the subset of comparison states without pre-K programs (AK, HI, ID, IN, MS, ND, RI, SD, UT). The first stage and RF (ITT) columns in Panels A, B.1, and B.2 give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). The IV (TOT) and OLS columns in Panels A, B.1 and B.2 give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and the demographic and background controls listed in Table 1 Panel B. A child is considered low income (Panel B) if his (preschool-age or 2005-06) family income is at or below 185% FPL, the threshold for eligibility for reduced-price lunch and the modal income-eligibility criterion for the targeted programs under study. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 14a. Balance Tests on Key Variables, by Program Type and Comparison Group: Full Sample**

<i>Comparison group limited to:</i>	States without pre-K			States with pre-K		
	Universal	Targeted	Uni - Tar	Universal	Targeted	Uni - Tar
	DD Coef. (se)	DD Coef. (se)	DDD Coef. (se)	DD Coef. (se)	DD Coef. (se)	DDD Coef. (se)
	(1)	(2)	(3)	(4)	(5)	(6)
<b>A. Treatment variable</b>						
Pre-kindergarten <sup>a</sup>	0.222 (0.050)	0.129 (0.037)	0.093 (0.047)	0.202 (0.051)	0.104 (0.037)	0.098 (0.048)
<b>B. Background characteristics</b>						
Age in months <sup>a</sup>	-0.108 (0.073)	-0.120 (0.067)	0.012 (0.048)	-0.109 (0.073)	-0.094 (0.065)	-0.014 (0.051)
Female	-0.012 (0.062)	-0.078 (0.066)	0.066 (0.051)	0.131 (0.048)	0.032 (0.045)	0.100 (0.049)
Black non-Hispanic	0.051 (0.041)	0.031 (0.042)	0.020 (0.039)	0.038 (0.035)	0.021 (0.031)	0.017 (0.035)
Hispanic	-0.033 (0.045)	-0.024 (0.046)	-0.009 (0.037)	-0.033 (0.045)	-0.014 (0.037)	-0.019 (0.036)
Low birth weight	0.044 (0.021)	0.038 (0.020)	0.006 (0.014)	0.012 (0.014)	0.002 (0.012)	0.010 (0.014)
Maternal education $\leq$ HS <sup>a</sup>	-0.001 (0.056)	-0.052 (0.058)	0.050 (0.047)	0.034 (0.049)	-0.018 (0.054)	0.052 (0.043)
Both biological parents in HH <sup>a</sup>	0.016 (0.053)	0.093 (0.047)	-0.077 (0.042)	-0.086 (0.042)	0.023 (0.039)	-0.108 (0.043)
Non-English at home <sup>a</sup>	-0.006 (0.038)	-0.002 (0.036)	-0.005 (0.034)	-0.007 (0.034)	-0.006 (0.029)	-0.001 (0.030)
Family income $\leq$ 185% FPL <sup>a</sup>	-0.085 (0.061)	-0.048 (0.060)	-0.037 (0.045)	-0.098 (0.046)	-0.073 (0.047)	-0.025 (0.046)
<b>C. <i>p</i>-value: joint test for background chars.</b>						
All background characteristics	0.04	0.04	0.55	0.00	0.54	0.17
Excluding poverty	0.13	0.03	0.68	0.08	0.87	0.17
Observations <sup>b</sup>	1,800	2,400	4,200	2,750	3,300	6,050

<sup>a</sup> Measured at preschool age, or in 2005-06 (wave 3 interview).

<sup>b</sup> rounded to the nearest 50, per IES guidelines.

NOTE: Each entry in columns 1, 2, 4, and 5 gives a DD coefficient (standard error) on the interaction between a dummy for being eligible for pre-K in 2005-06 and a dummy for residing in a treatment state (*elig x treat*) from a separate regression that also includes dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07. Columns 3 and 6 give the difference in these DD coefficients between states with universal programs and states with targeted programs. A child is deemed eligible for K in 2006-07 if he /she turned age 5 in time to start K in fall 2006, given his/her date of birth and the kindergarten entry age regulations in effect in 2006-07 reported by Barnett et al. (2007). Sample is limited to children who turn age 5 between 4 months after and 8 months before the cutoff date and who are assessed during the 2005-06 school year. Columns 1-3 limit the comparison states to those without pre-K programs, whereas columns 4-6 limit the comparison states to those with pre-K programs. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]



**Appendix Table 14b. Balance Tests on Key Variables, by Program Type and Comparison Group: Low-Income Subsample**

<i>Comparison group limited to:</i>	States without pre-K			States with pre-K		
	Universal	Targeted	Uni - Tar	Universal	Targeted	Uni - Tar
	DD Coef. (se)	DD Coef. (se)	DDD Coef. (se)	DD Coef. (se)	DD Coef. (se)	DDD Coef. (se)
	(1)	(2)	(3)	(4)	(5)	(6)
<b>A. Treatment variable</b>						
Pre-kindergarten <sup>a</sup>	0.200 (0.061)	0.213 (0.045)	-0.013 (0.069)	0.237 (0.069)	0.230 (0.060)	0.006 (0.071)
<b>B. Background characteristics</b>						
Age in months <sup>a</sup>	-0.098 (0.088)	-0.228 (0.083)	0.130 (0.073)	-0.017 (0.096)	-0.048 (0.089)	0.031 (0.074)
Female	-0.125 (0.093)	-0.121 (0.083)	-0.004 (0.090)	0.130 (0.084)	0.087 (0.069)	0.043 (0.088)
Black non-Hispanic	0.021 (0.078)	0.018 (0.075)	0.004 (0.069)	0.010 (0.067)	0.028 (0.059)	-0.019 (0.062)
Hispanic	-0.040 (0.070)	-0.107 (0.073)	0.066 (0.066)	0.020 (0.067)	-0.040 (0.053)	0.059 (0.060)
Low birth weight	0.068 (0.047)	0.049 (0.053)	0.019 (0.030)	0.034 (0.026)	0.019 (0.028)	0.015 (0.026)
Maternal education $\leq$ HS <sup>a</sup>	-0.057 (0.072)	-0.110 (0.072)	0.053 (0.069)	0.128 (0.067)	0.097 (0.075)	0.030 (0.070)
Both biological parents in HH <sup>a</sup>	0.063 (0.069)	0.108 (0.068)	-0.045 (0.066)	-0.122 (0.063)	-0.054 (0.061)	-0.068 (0.066)
Non-English at home <sup>a</sup>	-0.036 (0.053)	-0.022 (0.048)	-0.014 (0.063)	0.019 (0.055)	0.010 (0.045)	0.009 (0.056)
<b>C. <i>p</i>-value: joint test for background chars.</b>						
All background characteristics	0.40	0.01	0.63	0.08	0.62	0.91
Observations <sup>b</sup>	850	1,050	1,900	1,250	1,400	2,650

<sup>a</sup> Measured at preschool age, or in 2005-06 (wave 3 interview).

<sup>b</sup> rounded to the nearest 50, per IES guidelines.

NOTE: Each entry in columns 1, 2, 4, and 5 gives a DD coefficient (standard error) on the interaction between a dummy for being eligible for pre-K in 2005-06 and a dummy for residing in a treatment state (*elig x treat*) from a separate regression that also includes dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07. Columns 3 and 6 give the difference in these DD coefficients between states with universal programs and states with targeted programs. A child is deemed eligible for K in 2006-07 if he /she turned age 5 in time to start K in fall 2006, given his/her date of birth and the kindergarten entry age regulations in effect in 2006-07 reported by Barnett et al. (2007). Sample is limited to low-income children who turn age 5 between 4 months after and 8 months before the cutoff date and who are assessed during the 2005-06 school year; low-income is defined as having family income at or below 185% of the federal poverty line at preschool age (wave 3 interview). Columns 1-3 limit the comparison states to those without pre-K programs, whereas columns 4-6 limit the comparison states to those with pre-K programs. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 15a. Impacts of State-funded Pre-K on Preschool-Age Test Scores**  
**High Enrollment v. Low Enrollment instead of Universal v. Targeted**  
**High Enrollment if NIEER Age 4 Pre-K Enrollment Rate  $\geq 40\%$**

	Pre-K:	Test Score (Average Reading and Math):			
	First Stage	Inelig. Mean	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)	(5)
<u>A. Full Sample</u>					
<u>1. High Enrollment (N=3,500)</u>					
With additional controls	0.212 (0.040)	-0.197	0.053 (0.064)	0.250 (0.295)	-0.061 (0.045)
<u>2. Low Enrollment (N=3,850)</u>					
With additional controls	0.103 (0.034)	-0.232	-0.008 (0.064)	-0.077 (0.621)	-0.103 (0.043)
<u>3. p-value on High-Low Difference (N=7,350)</u>					
With additional controls	0.011		0.369	0.555	0.377
<u>B. By Family Income</u>					
<u>1. High Enrollment</u>					
Low-income (N=1,650)	0.275 (0.055)	-0.538	0.118 (0.109)	0.429 (0.392)	0.005 (0.056)
Not low-income (N=1,900)	0.154 (0.045)	0.11	0.003 (0.089)	0.019 (0.566)	-0.126 (0.072)
p-value on difference	0.052		0.448	0.579	0.122
<u>2. Low Enrollment</u>					
Low-income (N=1,650)	0.166 (0.050)	-0.517	0.096 (0.107)	0.581 (0.657)	-0.054 (0.051)
Not low-income (N=2,150)	0.047 (0.038)	-0.004	-0.091 (0.084)	no f.s.	-0.136 (0.084)
p-value on difference	0.043		0.199		0.433
<u>3. p-value on High-Low Difference</u>					
Low-income	0.082		0.861	0.809	0.339
Not low-income	0.016		0.299	n.a.	0.908

NOTE: Treated states are now divided into two groups based on NIEER-reported pre-K enrollment of 4-year-olds in 2005-06; a state is classified as "high enrollment" if this enrollment rate was at least 40%. (See Appendix Table 1 for enrollment rates.) The first stage and RF (ITT) columns in Panels A, B.1, and B.2 give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The IV (TOT) and OLS columns in Panels A, B.1 and B.2 give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and the demographic and background controls listed in Table 1 Panel B. A child is considered low income (Panel B) if his (preschool-age or 2005-06) family income is at or below 185% FPL, the threshold for eligibility for reduced-price lunch and the modal income-eligibility criterion for the targeted programs under study. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]

**Appendix Table 15b. Impacts of State-funded Pre-K on Preschool-Age Test Scores  
High Enrollment v. Low Enrollment instead of Universal v. Targeted  
High Enrollment if NIEER Age 4 Pre-K Enrollment Rate  $\geq 30\%$**

	Pre-K:	Test Score (Average Reading and Math):			
	First Stage	Inelig. Mean	RF (ITT)	IV (TOT)	OLS
	(1)	(2)	(3)	(4)	(5)
<u>A. Full Sample</u>					
<u>1. High Enrollment (N=3,850)</u>					
With additional controls	0.204 (0.037)	-0.231	0.046 (0.061)	0.224 (0.292)	-0.066 (0.043)
<u>2. Low Enrollment (N=3,500)</u>					
With additional controls	0.084 (0.035)	-0.179	-0.006 (0.067)	-0.075 (0.791)	-0.104 (0.046)
<u>3. p-value on High-Low Difference (N=7,350)</u>					
With additional controls	0.003		0.445	0.674	0.428
<u>B. By Family Income</u>					
<u>1. High Enrollment</u>					
Low-income (N=1,800)	0.273 (0.049)	-0.54	0.114 (0.101)	0.420 (0.368)	-0.028 (0.054)
Not low-income (N=2,050)	0.141 (0.041)	0.068	-0.008 (0.083)	-0.057 (0.581)	-0.105 (0.070)
p-value on difference	0.022		0.381	0.512	0.359
<u>2. Low Enrollment</u>					
Low-income (N=1,500)	0.134 (0.050)	-0.501	0.095 (0.120)	0.705 (0.940)	-0.032 (0.053)
Not low-income (N=2,000)	0.043 (0.040)	0.034	-0.098 (0.089)	no f.s.	-0.162 (0.088)
p-value on difference	0.136		0.244		0.234
<u>3. p-value on High-Low Difference</u>					
Low-income	0.021		0.879	0.744	0.941
Not low-income	0.023		0.321	n.a.	0.502

NOTE: Treated states are now divided into two groups based on NIEER-reported pre-K enrollment of 4-year-olds in 2005-06; a state is classified as "high enrollment" if this enrollment rate was at least 30%. (See Appendix Table 1 for enrollment rates.) The first stage and RF (ITT) columns in Panels A, B.1, and B.2 give coefficients on the interaction between a dummy for being eligible for kindergarten in 2006-07 (same as a dummy for being eligible for pre-K in 2005-06 in a treatment state) and a dummy for being in a treated state (*elig x treat*). (See Table 1 or Appendix A for a definition of treatment and comparison states.) The IV (TOT) and OLS columns in Panels A, B.1 and B.2 give coefficients on pre-K attendance (*prek*), in the first case instrumenting with *elig x treat* using TSLS. All coefficients are from separate regressions that also include as controls dummies for state of residence, month x year of assessment, and month age five relative to the state kindergarten entry cutoff birthdate in 2006-07, and the demographic and background controls listed in Table 1 Panel B. A child is considered low income (Panel B) if his (preschool-age or 2005-06) family income is at or below 185% FPL, the threshold for eligibility for reduced-price lunch and the modal income-eligibility criterion for the targeted programs under study. Regressions are weighted by longitudinal sampling weights, and standard errors (in parentheses) are clustered on state x month of birth.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) of children born in calendar year 2001, "Children's Birth Certificates" [collection at 9 mos.], "Parent-Guardian Interviews," "Direct Child Assessments," and "Early Care and Education Providers" [collection at 48 mos.]