
KINDERGARTEN READINESS IMPACTS OF THE ARKANSAS BETTER CHANCE STATE PREKINDERGARTEN INITIATIVE

ABSTRACT

Enrollment in state-funded pre-K programs prior to kindergarten entry has become increasingly common. As each state develops its own model for pre-K, rigorous studies of the impacts of state-specific programs are needed. This study investigates impacts of the Arkansas Better Chance (ABC) initiative at kindergarten entry using a regression-discontinuity design. In this approach, study selection criteria are known and modeled, rather than simply comparing children who attended ABC with potentially dissimilar children who did not attend. Statistically significant impacts of ABC pre-K participation were found across three key academic domains related to children's kindergarten readiness—vocabulary, mathematics, and print awareness skills. These results suggest that the ABC pre-K program is effective and thus that it provides a potential model for expansion of large-scale public pre-K initiatives in other states.

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ENROLLMENT levels in state-funded prekindergarten (pre-K) initiatives across the United States have nearly doubled since 2001, with more than 1.3 million children enrolled by 2012 across 40 states (Barnett, Carolan, Fitzgerald, & Squires, 2012). More than one-quarter of all 4-year-olds in the United States now participate in state pre-K during the year prior to kindergarten, and state investments total \$5.1 billion annually. All state pre-K initiatives emphasize preparing children for academic success in kindergarten and later grades. Also, all state pre-K initiatives permit enrolled children to attend for at least one full school year

immediately prior to kindergarten. However, each state has developed its own model for how pre-K education should be accomplished, and some states have developed multiple models for different groups of children. While in the federally funded Head Start initiative a single set of standards applies to all programs nationwide (U.S. Department of Health and Human Services, 2006), there are substantive differences across the United States regarding availability of state pre-K initiatives, and in state pre-K program standards (Barnett et al., 2012).

State-by-state differences in the emphasis of pre-K programs make evaluation studies in individual states particularly relevant. National-scale studies (e.g., U.S. Department of Health and Human Services, 2010) are ideal for early childhood programs such as Head Start that employ a common model across the United States, but such studies would be less informative in understanding the impacts of individual state pre-K initiatives, due to differences in emphasis across the states. Although state pre-K programs have been examined in multistate studies (Mashburn et al., 2008; Wong, Cook, Barnett, & Jung, 2008) and included in analyses with other types of early childhood education programs (Early et al., 2007), there is also a need for in-depth single-state studies, because there are 40 different statewide models with different sets of policy requirements rather than a single nationwide model. Such research is especially relevant due to a growing movement in states aimed at defining school readiness and forging connections between children's early childhood education and care experiences prior to and after entry into kindergarten (e.g., Rhode Island KIDS COUNT, 2005). The current study uses a rigorous regression-discontinuity design to estimate kindergarten readiness impacts produced by the broadly available pre-K initiative in Arkansas.

Research on Short- and Long-Term Effects of Preschool Interventions

In developing and expanding state-financed pre-K initiatives, state policymakers draw from a large body of research demonstrating the benefits associated with educational approaches to preschool. A comprehensive meta-analysis of preschool studies (Camilli, Vargas, Ryan, & Barnett, 2010) shows an average effect size of 0.25 *SD* for cognitive development. Effect sizes varied considerably across the 123 studies examined in the meta-analysis, but were largest for studies with the most rigorous designs and for outcomes measured near the end of the intervention.

Three studies provide a basis for understanding the immediate and longer-term impacts of preschool because they couple rigorous designs with follow-ups to adulthood. The High/Scope Perry Preschool Study (Schweinhart et al., 2005) began with a high-risk Michigan sample in the 1960s, and research has shown both short- and long-term effects associated with preschool participation. Short-term effects of 0.75 *SD* were found for language and cognitive development. Though initial effects on IQ were not sustained, effects on achievement were 0.33 *SD* at age 19, and additional long-term effects included lower rates of special education placements, decreased levels of crime, higher graduation rates, and higher earnings. A second project, the Abecedarian study (Campbell & Ramey, 1994) in North Carolina, began during the 1970s with a high-risk sample and has included similar follow-up measures. The initial effect size of this program on children's cognitive test scores was 0.74 *SD* at age 4, with an estimated effect size of 0.37 *SD* at age 15 (Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001). Long-term effects include an estimated 0.62 *SD*

gain in years of educational attainment by age 30 (Campbell et al., 2012). A third study was conducted with participants from the publicly funded Chicago Child-Parent Centers (Reynolds, 2000) in high-poverty neighborhoods. Initial effect sizes for children's cognitive abilities were 0.45 *SD* at kindergarten entry, 0.35 *SD* in elementary school, and between 0.20 and 0.25 *SD* during high school. Longer-term findings show that by age 28, preschool participants experienced outcomes including increased high school graduation rates, higher SES, and lower arrest rates (Reynolds, Temple, Ou, Arteaga, & White, 2011). In summary, all three model preschool studies show immediate impacts on cognitive development as well as long-term educational impacts.

Examining the Impacts of State-Funded Pre-K

On average, even state-funded pre-K initiatives with the most rigorous program standards are likely to be less intensive than model initiatives such as the Perry Preschool Program and Abecedarian Project. Both programs were offered on a limited scale and included conditions such as small class sizes and optimal teacher-child ratios that could be difficult to attain in broadly available public programs (Barnett, 2011). Also, a nationwide review of current state pre-K policies (Barnett et al., 2012) shows considerable variability across states with respect to program requirements. Indeed, some have argued that public pre-K programs would have difficulty demonstrating effects comparable to those shown in model programs. For example, using a national dataset from the Early Childhood Longitudinal Study, Magnuson, Ruhm, and Waldfogel (2007) argue that public pre-K yields relatively temporary academic gains overall, with the greatest and longest-lasting effects for disadvantaged children. However, these data rely on parents' classification of the type of preschool program their children attended, which may lead to challenges in accurately estimating outcomes associated with public pre-K.

Given substantial growth in state-funded pre-K and potentially important differences in models used across different states, more research is needed to understand the impacts associated with current policies. In comprehensive reviews of state pre-K research, Gilliam and Zigler (2000, 2004) argue that it is difficult to draw conclusions from most of the earliest studies due to methodological limitations. Also, many of these evaluations have become outdated due to subsequent policy changes. In particular, a number of states have expanded pre-K programs with the intention of enrolling all eligible children whose families wish them to attend (Barnett et al., 2012). As greater proportions of children enroll, particular care must be taken in constructing the comparison groups needed to investigate impacts of these pre-K programs. A new body of methodologically rigorous research has emerged in recent years to better estimate the effects of large-scale pre-K programs. Such studies help improve links between research and ongoing state-funded programs, and can be used to inform policy decisions. Many of these recent studies have employed quasi-experimental regression-discontinuity designs (RDD; Shadish, Cook, & Campbell, 2002) that facilitate construction of robust comparison groups.

Research from Oklahoma provides a particularly interesting examination of impacts associated with the type of large-scale public pre-K initiative that has become increasingly common. Oklahoma's state pre-K initiative is considered to be of high quality, and is broadly available, with nearly three-quarters of all 4-year-olds in the

state enrolled (Barnett et al., 2012). In an RDD study focusing on state pre-K sites in the city of Tulsa, Gormley, Phillips, and Gayer (2008) estimated pre-K impacts of 0.99 *SD* on letter-word identification, 0.74 *SD* on spelling, and 0.36 *SD* on applied mathematics at the beginning of kindergarten. Subgroup analyses showed positive impacts of state pre-K for White, Black, Hispanic, and Native American children; for children receiving free and full-price lunch; and for children in half- and full-day pre-K programs (Gormley, Gayer, Phillips, & Dawson, 2005). Researchers (Hill, Gormley, Adelstein, & Willemin, 2012) subsequently employed propensity score matching to estimate longer-term effects for two cohorts of former pre-K participants, using third-grade test scores. Results of this study revealed sustained effects several years after pre-K completion. Statistically significant findings were specific to math scores for the second cohort of children (who attended once pre-K had been more fully implemented). When again examining subgroups, persistent gains were found for boys and for students receiving free lunch. A cost-benefit analysis (Bartik, Gormley, & Adelstein, 2012) suggests that participation in Tulsa sites of Oklahoma's pre-K program may also be associated with long-term earnings benefits, with a projected economic return of \$3–\$4 for every dollar invested.

Another rigorous study (Lipsey, Farran, Bilbrey, Hofer, & Dong, 2011) is underway in Tennessee. Like Oklahoma, Tennessee has a statewide program considered to meet high quality standards, though Tennessee's program started more recently and currently enrolls 22% of 4-year-olds statewide (Barnett et al., 2012). The evaluation of the Tennessee Voluntary Pre-K Program (VPK) pairs a randomized control trial (RCT) with a substudy using RDD methodology. Initial results showed positive impacts of VPK on children's language, literacy, and early math performance using both methodological approaches. Effect sizes for the RCT substudy ranged from 0.28 to 0.42 *SD*, and effect sizes from an RDD substudy of one region of Tennessee ranged from 0.26 to 0.99 *SD*. In both substudies some of the largest effect sizes were found in the domains of letter-word identification and spelling.

The RDD approach has also been employed in an ongoing study of Boston's public school pre-K program (Weiland & Yoshikawa, 2013). Boston's initiative has a larger enrollment than some statewide pre-K models; and, as the researchers used an approach similar to state studies discussed here, the results are highly relevant. Weiland and Yoshikawa (2013) found estimated pre-K impacts of 0.45 *SD* for receptive vocabulary, 0.62 *SD* for letter-word identification, and 0.58 *SD* for applied mathematics, using types of measures common to state pre-K studies. They also found statistically significant impacts ranging from 0.18 to 0.27 *SD* for measures of emotional development and executive function less frequently incorporated into state pre-K studies. Additional analyses showed significantly greater impacts for certain subgroups. For example, Hispanic children experienced larger impacts than White children in a number of content areas.

In addition to studies conducted to examine the impacts of pre-K initiatives in individual states or cities, Wong et al. (2008) used an RDD approach to examine child outcomes associated with pre-K programs across five states—Michigan, New Jersey, Oklahoma, South Carolina, and West Virginia. This study employed a common set of measures addressing receptive vocabulary, print awareness, and applied math. Positive, statistically significant results were found in some domains for each state, but specific patterns of findings differed by state. Weighted average effect sizes across the states were 0.17 *SD* for receptive vocabulary, 0.26 *SD* for applied mathe-

matics, and 0.68 *SD* for print awareness. A similar study conducted in New Mexico, but not included in the five-state analysis, found effect sizes of 0.24 *SD* for receptive vocabulary, 0.37 *SD* for applied mathematics, and 1.30 *SD* for print awareness (Hustedt, Barnett, Jung, & Friedman, 2010).

Evidence on the Effectiveness of Pre-K Programs

While the evidence base on state pre-K is growing, less is known about specific features of pre-K programs that are associated with higher impacts. In many cases, large-scale public pre-K programs do not attempt to replicate the intensity of programs found to produce large and persistent gains in randomized trials (Yoshikawa et al., 2013). In their meta-analysis, Camilli et al. (2010) identify a key element as intentional teaching that is individualized through one-on-one and small-group interactions. The most successful model programs (such as the Perry Preschool Program) produced such teaching with highly trained and adequately paid teachers, who implemented a well-planned curriculum with strong supervision (Frede, 1998; Reynolds & Temple, 2008). Researchers differ on the relative importance of classroom structural features compared to contributions of ongoing specific professional development focused on improving classroom practices (American Educational Research Association, 2005; Pianta, Barnett, Burchinal, & Thornburg, 2009; Zigler, Gilliam, & Barnett, 2011). In general, better evidence is needed to inform costly pre-K policy decisions about length of day, staffing patterns, teacher qualifications, class size, and professional development.

Despite this need for further evidence on specific features of pre-K programs, the overall body of rigorous research on large-scale publicly funded pre-K shows consistently positive short-term child outcomes in language, literacy, and math—skill areas that are most frequently measured in research studies. Effect sizes have often been largest for early literacy skills such as print awareness and letter-word identification; these specific content areas develop rapidly during the preschool years and therefore may be strongly influenced by participating in an early education program. There is also emerging evidence that public preschool programs produce positive outcomes across a variety of subgroups such as middle-class children and children from different racial and ethnic groups (e.g., Gormley et al., 2005) and in less frequently measured content areas such as social-emotional development (Weiland & Yoshikawa, 2013; Yoshikawa et al., 2013).

State-Funded Pre-K in Arkansas

Arkansas has a well-established pre-K program with high structural quality, and has continued to invest in the initiative's further growth. Thus, evidence on child outcomes from Arkansas will make valuable contributions to the emerging body of rigorous public pre-K research. The state first began offering state pre-K in 1991 through the Arkansas Better Chance Program (ABC), and deepened its commitment with new funding for the Arkansas Better Chance for School Success (ABCSS) initiative in 2004. After these additional funds became available, state pre-K enrollment in Arkansas increased from 3,104 children in center-based programs during 2003–2004 to 20,520 children by 2011–2012 (Barnett et al., 2012; Barnett, Hustedt, Robin, & Schulman, 2005). Currently, 37% of Arkansas 4-year-olds and 10% of Arkansas

3-year-olds participate. While the majority of ABC pre-K participants attend public schools, about one-third attend programs operated in nonpublic settings including Head Start and private child-care centers (Barnett et al., 2012; Hustedt & Barnett, 2011). Arkansas's total investment in ABC pre-K was \$111 million in 2011–2012, not including additional required matching contributions of 40% at the local level (Barnett et al., 2012).

Though widely available, Arkansas's pre-K programs are optional for children, and interested families must complete an application to enroll at a local pre-K center. Both ABC and ABCSS are targeted to children at risk, primarily based on having family incomes below 200% of the federal poverty level. Other risk factors used to determine enrollment may include experiencing foster care or family violence, having parents with low educational levels, or having family members who do not speak English. Center-based ABC pre-K classes are part of a larger ABC initiative serving children from birth to age 5, while the ABCSS initiative is intended only for pre-K children. As there are few other differences between pre-K program requirements in ABC and ABCSS (Barnett et al., 2012), we will refer to all state-funded pre-K in Arkansas as ABC pre-K. In general, ABC program standards hold local pre-K providers to high levels of structural quality, meeting 9 of 10 quality benchmarks for state pre-K programs identified by the National Institute for Early Education Research (NIEER; Barnett et al., 2012). The NIEER benchmarks encompass state policy requirements for teacher and assistant teacher training, classroom structural characteristics, comprehensive family services, and state monitoring. In Arkansas, ABC classrooms have maximum class sizes of 20 with staff-child ratios of 1:10, and a number of comprehensive child and family support services are offered, including meals as well as health screenings and referrals. The state conducts site visits and monitoring activities intended to ensure providers' implementation of state standards. The benchmark not met in Arkansas involves the criterion that all teachers hold bachelor's degrees. The ABC program designates a lead teacher for every three classrooms; this individual must have a bachelor's degree and specialized training in pre-K education. Teachers in the remaining classrooms must at minimum have associate's degrees in early childhood.

The high aggregate level of quality required in ABC pre-K is consistent with other state pre-K initiatives involved in RDD studies. As in Arkansas, state pre-K requirements in Oklahoma and Tennessee currently meet 9 of 10 NIEER quality benchmarks (Barnett et al., 2012). The Wong et al. (2008) five-state study included Oklahoma as well as four other states that meet between 6 (South Carolina) and 9 (New Jersey) benchmarks. New Mexico's pre-K initiative meets 8 benchmarks. Thus, using the NIEER framework as a comparison point, the states participating in RDD evaluation studies can be characterized as having generally high levels of quality. Of these states, Arkansas, New Jersey, Oklahoma, and Tennessee require the highest aggregate levels of quality.

Evaluations of state pre-K programs have tended to test all inputs as a set, rather than investigating outcomes associated with individual policy requirements. However, it is important to recognize that not all quality benchmarks are equivalent, and that different configurations of pre-K policies may make different contributions to child outcomes. Unlike New Jersey, Oklahoma, and Tennessee, Arkansas meets the NIEER benchmark for requiring assistant teachers to have early childhood training. While these other three states require all lead teachers to have bachelor's degrees,

Arkansas does not (Barnett et al., 2012). The importance of early childhood teachers having bachelor's degrees is a topic of some debate. In a multistate analysis, Early et al. (2007) concluded that bachelor's degrees alone do not predict pre-K classroom quality or positive child outcomes. There is increasing recognition that relationships between teacher educational requirements and child outcomes are complex and are potentially moderated by other factors (Bassok, 2013). Also, though the types of structural features emphasized in state policy provide conditions that help support positive outcomes, process quality features related to children's daily interactions are critically important (Yoshikawa et al., 2013).

The Current Study

Emerging evidence from other ongoing studies of large-scale public programs shows consistent positive impacts of pre-K on school readiness outcomes. However, given policy differences that exist even among states receiving high aggregate ratings of quality and difficulties in disentangling contributions of individual policy elements to child outcomes, further research is needed in states across a variety of policy contexts.

Due to the scope of Arkansas's investment and widespread participation in its state pre-K system, research examining the impacts of ABC holds strong potential in informing policy decisions in states considering new or expanded investments in pre-K. A previous cost-benefit analysis (Belfield, 2006) suggests that the ABC program is a good investment, with an estimated economic return of \$1.58 per dollar invested. Prior to the present study, though, researchers had not examined school readiness outcomes attributable to Arkansas's current pre-K initiative. As a result, we designed and implemented a multiyear evaluation of ABC pre-K in collaboration with the Division of Child Care and Early Education (DCC-ECE), which administers ABC at the state level. The overall study was conducted to estimate the impacts of attending Arkansas's state pre-K program at kindergarten entry and, later, as ABC participants progressed through elementary school.

This report focuses specifically on estimating the impacts of ABC pre-K participation when children begin kindergarten. We examined the impacts of ABC pre-K across three key academic domains related to children's kindergarten readiness—language, literacy, and mathematics skills.

Method

The Research Model

In the state pre-K evaluations reviewed by Gilliam and Zigler (2000, 2004), a typical approach for estimating program effects involved assessing two groups of children within a single cohort. Using this within-cohort design, scores of children who attended pre-K were compared with scores of children who did not attend. That conventional approach can lead to selection bias, ultimately resulting in findings that underestimate the effects of pre-K participation. In pre-K initiatives, selection bias is possible when eligibility criteria or program administrators determine which children will participate, or when families can decide whether to participate. Of particular concern are unmeasured characteristics of families that may differ between

participants and nonparticipants, including parents' attitudes toward education and children's academic potential. In short, children who participate in state pre-K may differ from those who do not, because many pre-K programs select specific children, and parents select pre-K programs. As eligibility for ABC pre-K is primarily based upon families meeting income requirements, selection bias could be a major problem if program participants in Arkansas were simply compared to nonparticipants.

An alternative approach would involve random assignment of children to pre-K or a non-pre-K condition. Such approaches have been employed with preschool-age children in the Head Start Impact Study (U.S. Department of Health and Human Services, 2010) and also with infants and toddlers in Early Head Start (Love et al., 2002). Random assignment studies of early childhood programs are most feasible in situations where demand for the initiative is much greater than the number of slots available for children. Although Head Start and Early Head Start are offered nationwide, a large number of eligible families cannot participate because there are not enough slots. Thus, random assignment studies offer an ideal approach for measuring impacts of these programs. In states with smaller pre-K programs or where implementation is limited, resulting in waiting lists, random assignment is again a preferred methodological choice. However, in programs that are universally available to all interested families, including those in Florida, Oklahoma, and other states (Barnett et al., 2012), random assignment could have the effect of denying treatment to children who would otherwise attend.

While state pre-K is not universally available in Arkansas, a random assignment approach was not deemed feasible because of challenges posed by widespread ABC attendance among children targeted by the state. The ABC initiative is means-tested and available primarily to families below or near poverty level. Thus, the eligible population is not the entire population of Arkansas preschoolers, but rather a smaller subset of children that are generally well served by the ongoing ABC program.

A regression-discontinuity design was employed to produce estimates of ABC pre-K impacts that are free of selection bias. The approach in this study involves comparing two cohorts of children who enrolled in ABC pre-K. The treatment group is made up of the previous year's ABC graduates at kindergarten entry, while the control group is made up of children just entering ABC pre-K. The comparison between treatment and control groups relies on Arkansas's strict cutoff for kindergarten eligibility—September 15 at the time of this research. Use of this age cutoff can be illustrated through an extreme example. A child who turned 5 on September 16, having been ineligible for kindergarten, would have attended ABC. A child who turned 5 on September 15 the same year would have been eligible for kindergarten having already completed ABC. This approach can be applied to wider ranges around the kindergarten cutoff age, such that all children beginning ABC pre-K the same year can be included in analyses. This type of design provides an effective means of examining impacts of pre-K participation and, as discussed earlier, has been used successfully in similar studies (Gormley et al., 2005; Lipsey et al., 2011; Wong et al., 2008).

Sampling and Participants

As the initial step in sampling, we obtained a DCC-ECE master list of all ABC pre-K classrooms in Arkansas. A total of 125 ABC pre-K classrooms were randomly selected from this list. If only one classroom in a county was chosen, it was replaced

Table 1. Descriptive Statistics for Regression-Discontinuity Sample

Variable	Total			Current Pre-K			Current Kindergarten		
	<i>n</i>	% or <i>M</i>	<i>SD</i>	<i>n</i>	% or <i>M</i>	<i>SD</i>	<i>n</i>	% or <i>M</i>	<i>SD</i>
Total	901			395			506		
Gender:									
Male	468	51.9		206	52.2		262	51.8	
Female	433	48.1		189	47.8		244	48.2	
Ethnicity:									
Asian	9	1.0		3	.8		6	1.2	
African American	319	35.4		137	34.7		182	36.0	
Latino	53	5.9		23	5.8		30	5.9	
White	516	57.3		230	58.2		286	56.5	
Other	4	.4		2	.5		2	.4	
Home language:									
English	874	97.0		383	97.0		491	97.0	
Spanish	22	2.4		10	2.5		12	2.4	
English and Spanish	5	.6		2	.5		3	.6	
Score:									
Receptive vocab.	852	61.6	19.7	362	50.9	18.9	490	69.4	16.4
Math	888	13.6	4.7	385	11.2	4.0	503	15.5	4.2
Print awareness	870	65.0	29.9	371	44.7	27.2	499	80.1	21.8

Note.—Receptive vocabulary data represent PPVT raw scores. Math data represent WJ-III Applied Problems subtest raw scores. Print awareness data represent the percentage correct on the Pre-CTOPPP Print Awareness subtest.

by a different classroom randomly selected from a county where multiple classrooms had been chosen to improve efficiency of data collection. Individual children were then randomly selected from within each selected ABC pre-K classroom, with a goal of four children per class (i.e., 20% of the students in a fully enrolled classroom). This strategy ensured that the sample of current pre-K participants was drawn only from ABC classrooms. Next, kindergarten classrooms were selected within the same districts as the previously selected ABC pre-K classrooms. Liaisons at each kindergarten site were employed to gather information about children’s prior pre-K participation, primarily using existing school records. Within the selected kindergarten classrooms, students who had participated in ABC pre-K the previous year were randomly selected to participate.

Often, it was not possible to select kindergartners from the same schools as current pre-K participants since many ABC pre-K sites are located in community-based settings such as Head Start and child-care centers that do not offer kindergarten. Likewise, schools offering kindergarten do not necessarily offer ABC pre-K or may be one of several ABC providers within a given community. This approach to choosing kindergarten classrooms was used so that children who already completed ABC pre-K would be selected from classrooms likely to be kindergarten destinations for children in the selected pre-K classrooms, regardless of whether the children had attended ABC pre-K at a public or nonpublic site.

Table 1 provides descriptive statistics for the sample used in our RDD analysis. The total RDD sample includes 901 children, with 395 beginning ABC pre-K (control group) and 506 beginning kindergarten having completed ABC pre-K (treatment group). Most districts consistently followed the kindergarten entry date of September 15, which serves as the assignment rule for our RDD analyses. For 18 (2%) out of the 901 children sampled, the assignment rule was not strictly followed. These chil-

dren were thus “crossovers” in violation of the assignment rule, participating in pre-K when eligible for kindergarten or participating in kindergarten earlier or later than would be expected based on age-eligibility requirements. However, only 11 districts experienced crossover, and in these districts crossovers were limited to one or two children (and, in one case, three children).

Our RDD sample was 52% male. Children were primarily White (57%) or African American (35%), with smaller proportions who were Latino (6%), Asian (1%), or of another ethnicity (0.4%). Nearly all participants (97%) spoke English as their primary language. While the ABC initiative targets children from low-income families, we sought to gather family background information using liaisons at each site. Unfortunately, the data gathered were incomplete. Family income information was not available for inclusion in data analyses.

Measures

Child outcomes associated with ABC pre-K were assessed in key content areas related to kindergarten readiness. A standard battery was used for assessments of both pre-K and kindergarten children. All instruments were available in both English and Spanish.

Receptive vocabulary. Children’s receptive vocabulary was measured using the Peabody Picture Vocabulary Test, Third Edition (PPVT-III; Dunn & Dunn, 1997). The PPVT is predictive of general cognitive abilities and is a direct measure of vocabulary size. The rank order of item difficulties is highly correlated with the frequency with which words are used in spoken and written language. Reliability is good as judged by either split-half or test-retest reliabilities. Spanish-speaking children were also tested using the Spanish-language Test de Vocabulario en Imagenes Peabody (TVIP; Dunn, Padilla, Lugo, & Dunn, 1986). The TVIP is appropriate for measuring growth in Spanish vocabulary for bilingual students and monolingual Spanish speakers. Raw scores are reported.

Mathematical skills. Children’s early mathematical skills were measured with the Applied Problems subtest from the Woodcock-Johnson Tests of Achievement, Third Edition (WJ-III; Woodcock, McGrew, & Mather, 2001). For Spanish speakers, the comparable subtest from the Bateria Woodcock-Munoz Pruebas de Aprovechamiento—Revisado (Woodcock & Munoz, 1990) was used. Subtests of the Woodcock-Johnson Tests are reported to have good reliability. Raw scores are reported here.

Print awareness. Print awareness was measured using the Print Awareness subtest of the Preschool Comprehensive Test of Phonological and Print Processing (Pre-CTOPPP; Lonigan, Wagner, Torgeson, & Rashotte, 2002) in English and Spanish. Subsequent to initial data collection for this study, the Pre-CTOPPP was published in English as the Test of Preschool Early Literacy (TOPEL; Lonigan, Wagner, Torgeson, & Rashotte, 2007), and the Print Awareness subtest was renamed the Print Knowledge subtest. The TOPEL has been used with both middle- and low-income samples, and subtests are reported to have good to excellent reliability. Print knowledge items measure whether children recognize individual letters and letter-sound correspondences, and whether they differentiate words in print from pictures and other symbols. The percentage of items answered correctly out of the 36 total subtest items is reported.

Procedures and Data Analysis

Assessment procedures. Child assessments were conducted at children's schools each fall, as early as possible during the new school year. The child assessments were administered by assessors who reached reliability on each instrument during a 2-day training session led by researchers with extensive assessment experience. The training session also focused on sampling procedures, confidentiality, and professional etiquette for assessors. At the beginning of each assessment session, children were administered the PPVT to gather initial data about their receptive vocabulary skills in English, except in cases where children spoke only Spanish. The testing session was continued, with remaining measures administered in either English or Spanish, the best testing language as designated by the teacher. In this study, there were 17 children tested using only the TVIP. Separate analyses were conducted using TVIP scores for these children rather than PPVT scores, but the overall findings were not changed. As a result, data analyses employing the PPVT for all children are primarily emphasized here.

Regression-discontinuity analyses. Regression-discontinuity analyses in this study compare two groups of children. Children in each group participated in ABC pre-K, but children in the two groups attended ABC during different (consecutive) school years. Thus, all children included in the RDD analyses would have experienced the full-day ABC pre-K program during school hours, rather than another early care and education option available to their parents during the year prior to kindergarten. The treatment group is made up of kindergartners who completed ABC pre-K the previous school year. The control group is made up of a second cohort of children currently attending ABC pre-K. At the time of their assessments, they were just starting the preschool year and just beginning to receive the ABC treatment. Our primary analyses were intent to treat (ITT) regression-discontinuity models using the full sample, in order to reflect the intention of the ABC age-eligibility policy. The ITT model estimates potential intervention effects on the basis of eligibility, rather than the true effects of participation. Only active kindergarten attendees were included. We took steps to ensure that the assignment variable was evenly distributed on either side of the cutoff. A histogram of assignment variable density around the cutoff (see Fig. 1) suggests no manipulation of child placement.

We estimated treatment effects of pre-K using the following equation:

$$Y_{ijk} = \beta_0 + \beta_1(\text{Pre-K})_{ijk} + \beta_2 X_{1ijk} + \beta_3(\text{Pre-K})_{ijk} * X_{1ijk} + \beta_4 X_{2ijk} + \beta_5 Z_k + \varepsilon_{ijk}.$$

In this equation, Y is the predicted test score on one of three assessments of kindergarten readiness, and Pre-K is a binary variable that takes on the value of 1 if the child participated in pre-K and 0 if not. X_1 is the assignment variable, the distance between the child's birth date and the kindergarten cutoff date by number of days, centered on the kindergarten cutoff date.

Pre-K * X_1 represents the interaction between ABC pre-K participation and this assignment variable. X_2 is a vector of child covariates (gender, ethnicity, and testing language), Z is a vector of district fixed effects, and ε is the error term. Robust standard errors were used to take clustering by classroom into account.

We performed a number of tests to evaluate the robustness of our models. While the structure of our sample provided estimates allowing for birthdates within a 12-month window around the kindergarten entry date (all children in the sample),

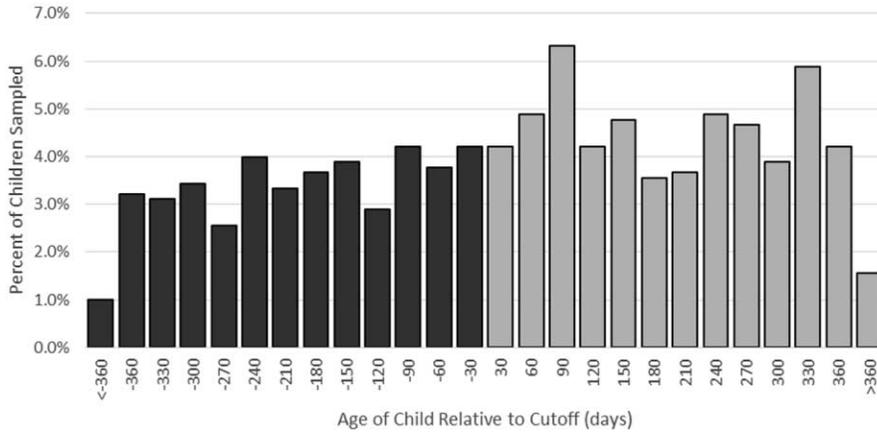


Figure 1. Density of observation around the age cutoff on the assignment variable.

alternate models using 6- and 3-month windows around the kindergarten entry date were used to provide additional estimates of the impact of ABC pre-K. As a further check on the specifications of our regression models, linear as well as higher-order polynomial and interaction forms were tested. Use of these alternative estimates of ABC pre-K impacts helps safeguard against misspecifying functional forms in the RDD analyses. Also, following Lee and Lemieux (2010) and Weiland and Yoshikawa (2013), we developed models to check for possible differences in observable characteristics between children on either side of the cutoff.

Results

In order to investigate kindergarten readiness impacts in Arkansas, we focused on estimating the language, literacy, and math outcomes associated with participating in the state-funded ABC pre-K program at age 4. We used RDD analyses, comparing children who just started ABC with those who had just completed ABC. Table 2

Table 2. Estimated ABC Pre-K Impacts from Regression-Discontinuity Analysis

	Empirically Identified Functional Form (1)	Linear, 12 Months (2)	Quadratic, 12 Months (3)	Cubic, 12 Months (4)	Truncated at 6 Months (5)	Truncated at 3 Months (6)
Receptive vocabulary	Linear	5.33* (2.17)	5.20* (2.63)	7.19* (3.22)	4.15 (3.19)	6.55 (4.91)
Math	Linear	1.31* (.54)	1.57* (.64)	1.61* (.71)	1.05 ^a (.87)	1.26 (1.06)
Print awareness	Linear	22.12*** (3.68)	25.52*** (4.33)	27.05*** (4.87)	26.73*** (5.39)	38.50*** ^b (13.21)

Note.—Robust standard errors are in parentheses. Receptive vocabulary data represent PPVT raw score point increases. Math data represent WJ-III Applied Problems subtest raw score point increases. Print awareness data represent increases in the percentage correct on the Pre-CTOPPP Print Awareness subtest.

^a A quadratic functional form was selected rather than a linear functional form.

^b A cubic functional form was selected rather than a linear functional form.

* $p < .05$.

*** $p < .001$.

Table 3. Estimated Effect Sizes for ABC Using Different Intervals Around the Kindergarten Eligibility Age

	Effect Size, 12 Months	Effect Size, 6 Months	Effect Size, 3 Months
Unadjusted models:			
Receptive Vocabulary—PPVT	.28*	.22	.33
Math	.33*	.26 ^a	.31
Print awareness	.82***	.95***	1.35** ^b
Adjusted model including TVIP scores:			
Receptive vocabulary—PPVT/TVIP	.28*	.23	.33
Multiple imputation models:			
Receptive vocabulary—PPVT	.30**	.25	.36
Math	.32*	.25 ^a	.31
Print awareness	.80***	.92***	1.18* ^b

Note.—Effect sizes are calculated using sample standard deviations. Receptive vocabulary data represent PPVT or PPVT and TVIP raw score point increases as indicated. Math data represent WJ-III Applied Problems subtest raw score point increases. Print awareness data represent increases in the percentage correct on the Pre-CTOPPP Print Awareness subtest.

^a A quadratic functional form was selected rather than a linear functional form.

^b A cubic functional form was selected rather than a linear functional form.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

presents the estimated ITT impacts of ABC participation on entering kindergartners’ receptive vocabulary, math, and print awareness skills from a sample of 901 children across Arkansas. In columns 2 through 4, estimates allowing linear, quadratic, and cubic functional forms as well as their respective interaction terms are shown, based on 12-month windows around the kindergarten entry date. In all cases, linear estimates were selected as the preferred functional form. Results from RDD analyses using 12-month samples show that ABC pre-K has positive and statistically significant impacts on children’s early language, literacy, and math development (see col. 2). The largest effect sizes were found for print awareness. The estimated effect sizes were 0.28 *SD* for receptive vocabulary ($p < .05$), 0.33 *SD* for applied math ($p < .05$), and 0.82 *SD* for print awareness ($p < .001$).

Additional analyses used the RDD approach to test the impacts of ABC pre-K participation using narrower 6- and 3-month windows around the kindergarten entry cutoff. Linear models and models with polynomial functional forms were tested, as well as respective interactions with the assignment variable. Table 2 also presents our preferred functional forms for bandwidths of 6 months and 3 months (see cols. 5 and 6). For the 6-month bandwidth, a quadratic model was chosen for math, while for the 3-month bandwidth a cubic model was chosen for print awareness. Linear models were preferred for all other analyses. These estimated results are generally similar to results using 12-month windows; however, the estimates for receptive vocabulary and math are not statistically significant in 3- or 6-month models.

Table 3 presents estimated effect sizes using 12-, 6-, and 3-month windows around the kindergarten entry cutoff. Three different RDD models are represented here. In comparison to the primary unadjusted model described above, which incorporated only English-language PPVT scores for receptive vocabulary, adjusted models incorporating Spanish-language TVIP receptive vocabulary scores produced extremely similar results. We also used multiple imputation methods to take missing data into

Table 4. Predicted Differences in Child Characteristics on Either Side of the Kindergarten Cutoff

	12 Months	6 Months
Regression models:		
Female	.018 (.06)	.010 (.10)
African American	.087 (.05)	.069 (.08)
Latino	-.065* (.03)	-.033 (.04)
White	-.027 (.06)	-.041 (.08)
Other race	-.018 (.02)	-.021 (.03)
English only home language	-.008 (.02)	.004 (.03)
Spanish home language	.008 (.02)	-.004 (.03)
Logistic models:		
Female	-.072 (.26)	.042 (.43)
African American	.732 (.40)	.531 (.55)
Latino	-1.731* (.77)	-1.247 (1.28)
White	-.204 (.37)	-.302 (.49)
Other race	-.837 (.89)	-.847 (1.63)

* $p < .05$.

account. Data were missing for 5.4% of children's PPVT scores, 1.4% of WJ-III math scores, and 3.6% of Pre-CTOPPP print awareness scores. Again, the estimated effect sizes were similar to those found for the unadjusted model.

We conducted additional analyses to examine possible differences in observable characteristics between children on either side of the kindergarten entry cutoff, using 12- and 6-month windows. New regression models were developed to include child characteristics as outcome, treatment variable, assignment variable, and interaction between the two variables as predictors. District fixed effects were also included. Results are shown in Table 4. No significant differences were found except in 12-month estimates for children who were Latino. In general, this set of findings suggests that there were few differences in observable child characteristics on either side of the kindergarten entry cutoff.

Finally, we conducted subgroup analyses to test for possible differences in ABC impacts on the basis of children's race or ethnicity, and on the basis of child sex. Interaction effects were tested to see if some subgroups of children benefited more from their ABC pre-K participation than others. Child outcomes in language, literacy, and early mathematics did not differ on the basis of children's race or ethnicity, or on the basis of children's sex, as no statistically significant effects were found.

Discussion

The objective of this study was to estimate impacts of the Arkansas Better Chance Program at kindergarten entry, using a regression-discontinuity approach. Results from our analyses show that the ABC pre-K program produces gains in all three key content areas that were measured—vocabulary, mathematics, and print awareness. These types of skills are among those linked with success in kindergarten and in later grades (Fantuzzo et al., 2005; Kurdek & Sinclair, 2001; Schweinhart et al., 2005; Snow, Burns, & Griffin, 1998). As the ABC initiative currently enrolls more than one-third of Arkansas's 4-year-olds (Barnett et al., 2012), many of the state's children enter kindergarten having just completed ABC pre-K, particularly children from low-income and high-risk families who are the primary target of this program. Our

findings of positive academic impacts associated with ABC have important implications in Arkansas and as a potential model for other states seeking to offer large-scale public pre-K initiatives.

Kindergarten entry estimates of state pre-K impacts from Arkansas are generally consistent with impacts shown in other studies employing an RDD approach (Gormley et al., 2005; Hustedt et al., 2010; Lipsey et al., 2011; Weiland & Yoshikawa, 2013; Wong et al., 2008). Using regression-discontinuity analyses, we found effect sizes of 0.28 *SD* for receptive vocabulary, 0.33 *SD* for applied mathematics, and 0.82 *SD* for print awareness. Impacts from the Arkansas state pre-K program are similar in magnitude to those found in previous studies where the same domains were measured, particularly research conducted in Tennessee and New Mexico (Hustedt et al., 2010; Lipsey et al., 2011). The estimates are somewhat higher than overall estimates in the five-state investigation by Wong et al. (2008), though in that study there was variability across states in pre-K impact estimates. Pre-K initiatives examined in each of these RDD studies have many features associated with high quality, though specific features differ from state to state (Barnett et al., 2012). Unlike state initiatives that are the focus of in-depth studies in Oklahoma and Tennessee, Arkansas's pre-K program does not require all teachers to have bachelor's degrees, though in practice most pre-K teachers serving children in the current study did have bachelor's degrees.

By using the RDD approach rather than a more traditional within-cohort control group approach, selection criteria for the current study are known and modeled, and there are less likely to be unmeasured factors such as parental motivation that contribute to decisions about pre-K participation. In a New Jersey study that similarly used an RDD approach at kindergarten entry as well as a follow-up longitudinal design to estimate pre-K impacts into elementary school, the researchers found that RDD impact estimates were of greater magnitude than estimates from a within-cohort approach (Frede & Barnett, 2011; Frede, Jung, Barnett, & Figueras, 2009). These findings are consistent with results from a meta-analysis of preschool studies showing that higher-quality research designs yielded larger estimates of preschool impacts (Camilli et al., 2010). Also, the similarity of our Arkansas RDD findings with results from other studies employing similar methodologies increases our confidence that these RDD findings provide relatively unbiased estimates of ABC pre-K impacts at kindergarten entry.

Although use of the RDD methodology appears to reduce selection bias in estimating kindergarten readiness impacts of ABC, this approach may unintentionally introduce bias due to attrition. In short, by relying on identification of children currently attending pre-K or kindergarten classrooms having already completed pre-K, samples in RDD research may fail to include comparison group children who began pre-K but terminated enrollment before the assessment point as well as treatment group children who completed pre-K but could not be located for a kindergarten-year assessment. Until recently, these potential attrition issues had not been addressed in RDD studies of public pre-K. However, Weiland and Yoshikawa (2013) used administrative data to make statistical adjustments for the absence of such children in their Boston sample. When estimating impacts of pre-K, their models generated similar effect sizes regardless of whether corrections were made for attrition. Although attrition had little influence on the results in Boston, this issue merits further study. In general, when seeking unbiased estimates, randomized con-

trolled trials are viewed as a methodologically stronger approach (Bloom, 2005) than RDD techniques. While randomized trials are desirable from a methodological standpoint, we selected an RDD approach because it offered greater ease of implementation for a statewide study. Arkansas has a fairly high rate of participation in ABC pre-K by 4-year-olds from the targeted low-income families. As a result, there were logistical challenges in identifying and focusing on areas of the state with large enough populations of unserved ABC-eligible children to support an RCT. A recent review of the evidence base on preschool (Yoshikawa et al., 2013) identifies RDD approaches as a preferred alternative to researchers seeking rigorous designs when RCT designs are not feasible.

Another limitation involved in using our results to understand Arkansas children's kindergarten readiness is that school readiness is best viewed as a multidimensional concept, recognizing that physical development, social and emotional development, language and literacy development, approaches to learning, and cognitive development each make contributions toward preparing young children for school success (Rhode Island KIDS COUNT, 2005). The data gathered in Arkansas and most other state pre-K studies offer a fairly narrow frame of reference, speaking primarily to two academic domains—cognitive development, and language and literacy development. This measurement decision can be attributed to the ready availability and ease of administration of assessment tools measuring language and math skills. However, data on additional developmental domains would be useful in providing a more complete understanding of kindergarten readiness among children participating in pre-K.

Future studies would also benefit from a more nuanced understanding of the conditions under which state pre-K programs are most effective. Although there is growing evidence documenting the impacts of high-quality state pre-K programs, which features of those high-quality programs are most closely linked with positive child outcomes? Also, to what degree do pre-K participants from a variety of backgrounds, including those with diversity of family incomes, benefit? Policymakers have debated whether pre-K initiatives should be targeted to children meeting specific criteria (such as Arkansas's income requirements) or universally available to families wishing to participate (Barnett, 2010). Data from additional states such as Oklahoma, where pre-K is available to all 4-year-olds, may be particularly valuable. Subgroup analyses show that Oklahoma children receiving both full-price and free lunch derive benefits from pre-K participation (Gormley et al., 2005). Finally, just as studies of model programs (e.g., Campbell et al., 2012; Schweinhart et al., 2005) have examined long-term outcomes, it will be important to examine longer-term outcomes associated with the current generation of state pre-K programs. For this reason, a complementary longitudinal study of ABC pre-K was continued into elementary school. Also, research in New Jersey and Oklahoma (Frede et al., 2009; Hill et al., 2012) has shown some continued positive impacts of pre-K participation as children progress through elementary school.

The current data provide evidence suggesting that the ABC pre-K initiative is effective in producing academic benefits at kindergarten entry. Results from rigorous studies such as this one can help inform decisions about state pre-K models and further growth of state-funded pre-K in the United States. In his 2013 and 2014 State of the Union addresses, President Obama recognized the importance of state pre-K programs and proposed new government investments in these initiatives. Under this

proposal, the federal government would partner with states to offer high-quality pre-K programs to all 4-year-olds in the United States with family incomes at or below 200% of poverty (White House, 2013). If implemented, the proposal would be expected to result in major expansion or revision of existing state pre-K initiatives, as well as creation of new initiatives in states not currently offering them. Thus, evidence regarding kindergarten readiness impacts of well-developed, high-quality pre-K programs in states such as Arkansas is particularly relevant.

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