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Outcome Evaluation of Washington State's Early Childhood Education and Assistance Program

Revised January 8, 2015 to add clarification to page 9 and the acknowledgements section.

The 2013 Washington State Legislature directed the Washington State Institute for Public Policy (WSIPP) to "conduct a comprehensive retrospective outcome evaluation and return on investment analysis" of Washington State's Early Childhood Education and Assistance program (ECEAP).[1] This report presents our results.

Nationwide, there has been considerable interest in early childhood education and whether these investments can help prepare students for success in the K–12 system and beyond.

WSIPP has previously found that early childhood education appears to be a sound investment. Beginning in the early 2000s, the Washington legislature directed WSIPP to analyze the results of credible studies from other states. Based on our most recent review, we concluded that early childhood education can be expected to improve student outcomes and generate about $4.75 of benefits for every dollar of cost.[2]

This previous bottom-line WSIPP estimate, however, is based entirely on non-Washington studies. Washington State's ECEAP program has never been evaluated rigorously. The purpose of this legislatively directed study, therefore, is to determine whether Washington's early childhood education program is achieving results comparable to those found in other states.

Summary

WSIPP conducted a retrospective evaluation of Washington State's early childhood education program, ECEAP, at the direction of the 2013 Legislature.

To analyze the impact of ECEAP, we identified a group of children who received food assistance benefits when they were three- or four-years old and subsequently attended Washington State public schools. Some of these children attended ECEAP and others did not.

We developed a statistical model to determine whether attending ECEAP had any impact on student academic outcomes.

We found that ECEAP has a positive impact on third, fourth, and fifth grade test scores. ECEAP's impact on test scores is almost twice as large as the average effect we found when we reviewed research on early childhood programs in other states.

At this time, we are unable to conduct a complete benefit-cost analysis because we cannot measure whether ECEAP affects longer-term outcomes such as high school graduation and crime.

WSIPP would be able to conduct an evaluation of these long-term outcomes after 2020 when the children in the analysis are expected to graduate from high school.

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[1] Senate Bill 5904, Chapter 16, Laws of 2013.
[2] Washington State Institute for Public Policy. (2014). *Benefit-cost results.* Retrieved from http://www.wsipp.wa.gov/BenefitCost

I. ECEAP Background

Program Description and Eligibility

ECEAP was established by the legislature in 1985. The program provides educational instruction as well as family support and health and nutrition services to eligible preschool-aged children.[3] ECEAP is a voluntary program; families choose whether to apply to the program. Since ECEAP is not currently an entitlement program, the number of slots available is determined by annual state appropriations.[4]

Children are eligible for ECEAP if their family income is at, or less than, 110% of the federal poverty level, the child has special needs, or the family has certain risk factors.[5] Eligible children must be at least three, but less than five, years old by August 31 of the school year that they enroll.

Washington State's Department of Early Learning (DEL) contracts with local organizations to provide ECEAP services. Local ECEAP contractors recruit families, determine eligibility, and assign priority levels based on risk factors. According to DEL, contractors enroll children with the highest priority levels if there are more eligible children than available slots.[6]

Changes to ECEAP

ECEAP has been modified in recent years. Prior to fall 2008, ECEAP contractors provided a minimum of 240 classroom hours per year. Beginning in the fall of 2008, the legislature increased the rate that contractors receive per slot.[7] In addition, DEL set a maximum caseload for family support specialists and required contractors to provide a minimum of 320 classroom hours per year.

Since July 2012, ECEAP sites also have the option to participate in Early Achievers—Washington's Quality Rating and Improvement System.[8] Early Achievers provides training, coaching, and incentives to early childhood programs across Washington State.

In the 2014-15 school year, 20% of ECEAP participants attended full-day or extended-day ECEAP with combined funding from ECEAP and Working Connections Child Care—a publicly funded child care subsidy program.[9]

It is important to note that, for reasons we explain below, our evaluation includes children who attended ECEAP before most of the 2008, 2012, and 2014 changes were made to the program.[10]

[3] RCW 43.215.400.

[4] ECEAP will be available to all eligible children in the 2018-19 school year. RCW 43.215.456.

[5] Risk factors include environmental factors such as family violence, chemical dependency, child protective services involvement, incarcerated parents, foster care placement, and homelessness.

[6] Nicole Rose, DEL, (personal communication, September 13, 2013). ECEAP contractors determine priority based on resources that might differ by community. It is likely that children who are offered an ECEAP slot are different from those who are not in ways that we cannot estimate.

[7] Substitute House Bill 1128, Chapter 522, Laws of 2007.

[8] Enrollment in Early Achievers is mandatory for ECEAP providers beginning in fiscal year 2015. Second Substitute House Bill 1723, Chapter 323, Laws of 2013.

[9] Nicole Rose, DEL (personal communication, December 11, 2014).

[10] The analysis of third grade test scores includes children who attended ECEAP during the 2008-09 school year when the number of hours of instruction and other quality improvements were made. We control for birth cohort in the

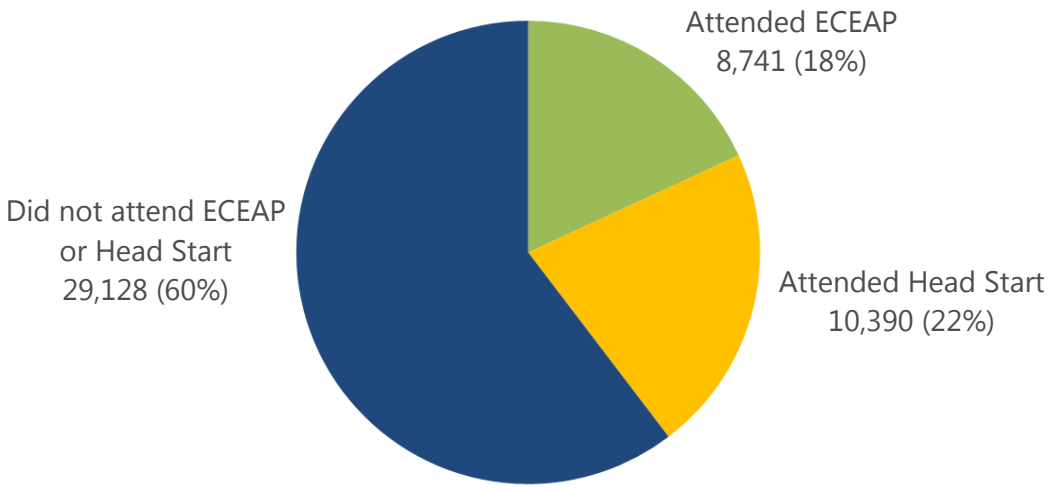
Eligible Students Served by ECEAP

During the 2013-14 school year, approximately 48,259 children in Washington State were eligible for ECEAP.[11] The 2013 Legislature funded 8,741 ECEAP slots.[12]

In addition to ECEAP, some other low-income children attend the federally-funded early childhood education program, Head Start. About 10,390 of the Head Start students in Washington in 2013-14 were income-eligible for ECEAP (Exhibit 1).[13] Over 29,000 ECEAP-eligible children in Washington State were not enrolled in either Head Start or ECEAP during the 2013-14 school year (Exhibit 1).[14]

Exhibit 1

Early Childhood Education Experience of ECEAP-Eligible Three- and Four-Year Olds in Washington State, 2013-14



Data source: Washington State Department of Early Learning & Office of Financial Management, 2013.
These estimates include children who are eligible for ECEAP based on income or because they qualify for special education.

analysis to account for and examine systematic differences based on cohort.

[11] Washington State Department of Early Learning & Office of Financial Management. (2013). *Report to the Legislature: Early Childhood Education and Assistance Program (ECEAP) Caseload Forecast.* Retrieved from http://www.del.wa.gov/publications/research/docs/2013%20pre-k_caseload_forecast.pdf

[12] Not all students who fill the allocated ECEAP slots are low-income. A maximum of 10% of children can be from families who are not income-eligible but have other risk factors.

[13] Families are eligible for Head Start if their income is at or below 130% of the federal poverty level or the child has specific risk factors. DEL and the Office of Financial Management estimate that 88% of Head Start enrollees are income-eligible for ECEAP. Washington State Department of Early Learning & Office of Financial Management, 2013.

[14] Ibid.

II. Evaluation Methodology

Comparison Group

The ideal way to evaluate the outcomes of ECEAP would be to conduct a randomized controlled trial. In this type of study, students who applied to ECEAP would be randomly assigned to ECEAP or a control group that does not attend ECEAP. In theory, the only difference between ECEAP participants and the control group would be their random assignment and, thus, any difference in later outcomes could be confidently attributed to ECEAP.

The legislature directed WSIPP to conduct a retrospective evaluation of ECEAP (Exhibit 2). Therefore, we could not conduct a randomized controlled trial because we relied on historical administrative data on children whose enrollment in ECEAP was not random. Since children whose families voluntarily applied for and attended ECEAP might be systematically different from other children who did not, we needed to find a comparison group of children who were similar to ECEAP participants. With a similar comparison group, we increase our confidence that any difference in outcomes is the result of ECEAP participation rather than the result of other characteristics or environments of children who attend ECEAP.

We used administrative data from the "Basic Food" program to identify a group of similar low-income children.[15] Basic Food eligibility is similar to ECEAP eligibility and detailed administrative data provides information on all individuals and households who receive Basic Food.[16]

We identified a group of children who were born between September 1999 and August 2004, received Basic Food benefits when they were three- or four-years old, and subsequently attended Washington State public schools. Some of these children attended ECEAP (the "program group") and others did not (the "comparison group").

[15] Basic Food is the US Department of Agriculture's Supplemental Nutrition Assistance Program (SNAP) in Washington State.

[16] Households are eligible for Basic Food if their gross income is not more than 130% of the federal poverty level. The Department of Social and Health Services provided WSIPP with a de-identified administrative dataset that could be matched to K–12 enrollment and assessment data. A more complete description of the datasets used in this analysis is provided in the Technical Appendix.

We examined data on children's characteristics to test whether the comparison group was similar to the program group. These characteristics included the following:

- Household income
- Neighborhood poverty rate
- Gender
- Race/ethnicity
- Primary language
- Relationship to head of household (e.g., child, grandchild, other adult)
- Homeless indicator
- Type of food benefits program.

We found few differences between the program and comparison group as presented in the Technical Appendix (Exhibit A3). In our analysis we controlled for these differences. Additionally, we undertook analytical steps to control for other differences between groups.[17]

We did not have data indicating whether children in the comparison group attended another preschool program such as Head Start. Therefore, the results of this analysis describe the effect of ECEAP compared to the average experience of other similar three- and four-year olds rather than the effect of ECEAP compared to children who received no government-funded preschool.[18]

Exhibit 2
Legislative Study Direction

The 2013 Washington State Legislature, in Senate Bill 5904, adopted the following study language for WSIPP:

(1) During the 2013-2015 biennium, the Washington state institute for public policy shall conduct a comprehensive retrospective outcome evaluation and return on investment analysis of the early childhood program established in RCW 43.215.400. To the extent possible based on data availability, the evaluation must:

a) Assess both short-term and long-term outcomes for participants in the program, including educational and social outcomes;

b) Examine the impact of variables including, but not limited to, program fiscal support, staff salaries, staff retention, education level of staff, full-day programming, half-day programming, and classroom size on short-term and long-term outcomes for program participants;

c) Report findings from a review of the research evidence on components of successful early education program strategies;

d) Examine characteristics of parents participating in the early childhood and education assistance program; and

e) Examine family support services provided through early childhood programs.

(2) The institute shall submit a report to the appropriate committees of the legislature by December 15, 2014.

This report describes results from sections 1(a), 1(b), 1(d) and 1(e) of the study assignment. A January 2014 report addressed sections 1(b) and 1(c).

[17] We use an instrumental variables approach in our statistical analysis to address unmeasured differences. We include a complete description of the analysis methodology in the Technical Appendix.

[18] In high-quality studies that WSIPP reviewed on state early childhood education programs elsewhere, there was no systematic difference in the immediate effectiveness of early childhood education when children with alternative preschool experiences such as Head Start were included in the control group. Ten out of the 11 studies investigating long-term outcomes that we reviewed use a control group that includes children with a variety of early childhood education experiences. Kay, N., & Pennucci, A. (2014). *Early childhood education for low-income students: A review of the evidence and benefit-cost analysis* (Doc. No. 14-01-2201). Olympia: Washington State Institute for Public Policy.

Exhibit 3

Individuals in ECEAP Outcome Analysis

Birth dates	ECEAP school year 3-year-old enrollees	ECEAP school year 4-year-old enrollees	School year of expected 3rd grade test scores	Year of expected high school graduation
September 1999-August 2000	2003-04	2004-05	2008-09	2018
September 2000-August 2001	2004-05	2005-06	2009-10	2019
September 2001-August 2002	2005-06	2006-07	2010-11	2020
September 2002-August 2003	2006-07	2007-08	2011-12	2021
September 2003-August 2004	2007-08	2008-09	2012-13	2022

Primary Outcomes

The primary outcomes that we examined in this study were reading and math test scores in third, fourth, and fifth grades.

Washington State administers standardized tests to students, starting in third grade.[19] We used these data to examine differences in K–12 outcomes between ECEAP participants and children in the comparison group. For example, for students who attended ECEAP as three-year-olds in 2003 or four-year-olds in 2004, we examined their third grade test scores from the 2008-09 school year (Exhibit 3).

Other Outcomes

Academic test scores are the most frequently studied outcome in the national literature on early childhood education. However, standardized test scores are not the only outcomes of interest to policymakers, parents, and educators. In particular, the legislative assignment directed WSIPP to examine both "educational and social outcomes."

Unfortunately, the data available for this study did not include measures of social and emotional learning or access to social and health services for both the program and comparison groups. Thus, we could not examine social outcomes in this evaluation. In future years, some of these outcomes may be available from the Washington Kindergarten Inventory of Developing Skills (WaKIDS). [20]

[19] Two different standardized tests were used during the analysis years. The Washington Assessment of Student Learning (WASL) was administered in 2009. The Measurements of Student Progress (MSP) was administered in 2010-2013. Test scores were converted to z-scores so that we could combine years where different tests were used in the analysis.

[20] WaKIDS became mandatory for state-funded full-day kindergarten in the 2012-13 school year (RCW 28A.150.315 and RCW 28A.655.080). This program includes an assessment of social and emotional physical and cognitive skills and could provide a source of data on the immediate effectiveness of ECEAP in the future.

We were also unable to investigate long-term outcomes such as high school graduation because the cohorts of students for whom data were available are not expected to graduate high school until at least 2018, as indicated in Exhibit 3.

Statistical Analysis

We developed a statistical model that describes the effect of attending ECEAP on third, fourth, and fifth grade math and reading standardized test scores.

The model compares individuals who attended ECEAP to similar children who did not. Our model accounts for both measured and unmeasured factors that influence a family's decision to apply for or attend ECEAP.[21]

Our research design is illustrated in Exhibit 4. Readers interested in an in-depth description of the research methods can reference the Technical Appendix.

[21] To minimize bias from unmeasured confounders, we used an instrumental variable approach. We used the distance from an ECEAP center as the instrument. We describe this method in detail in the Technical Appendix.

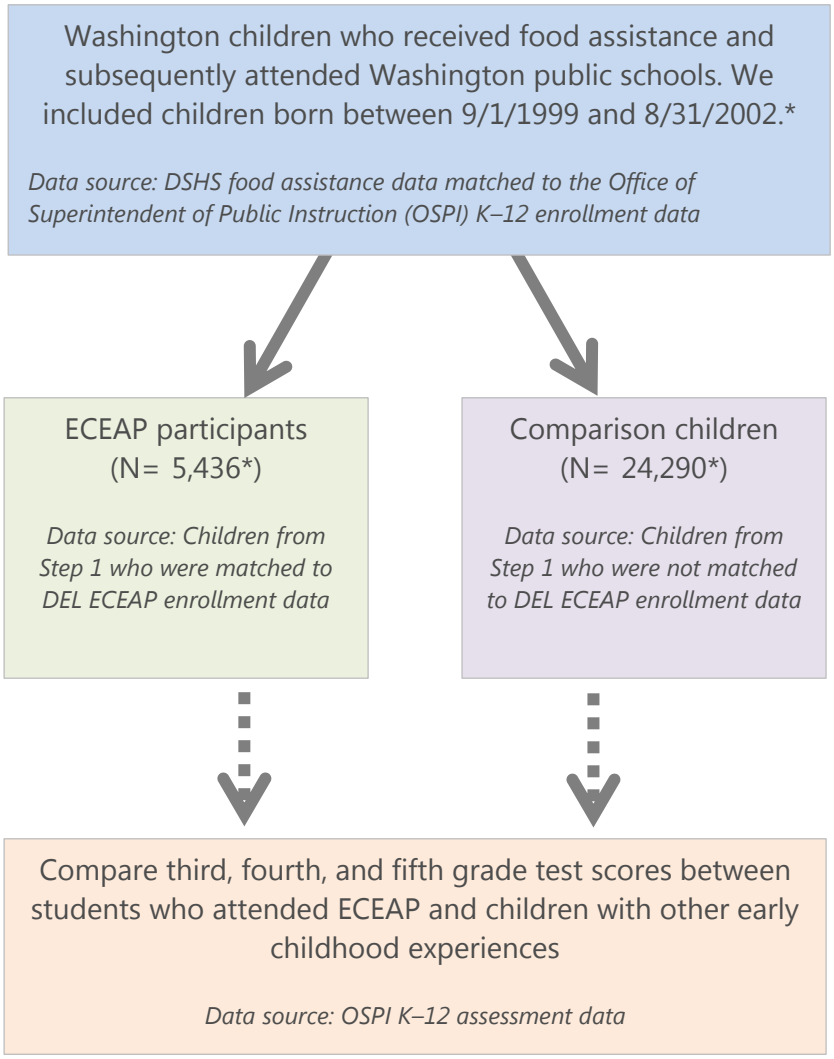
Exhibit 4

Identification of Program and Comparison Groups

Step 1: Identify a group of ECEAP income-eligible and age-eligible children who have K–12 test scores.

Step 2: Identify the students in the group who attended ECEAP and those who did not.

Step 3: Conduct a statistical analysis to compare outcomes between ECEAP participants and comparison group.



*The N's and birth cohorts shown here are children who had fifth grade test scores. The number of individuals in the third and fourth grade analyses is described in the Technical Appendix.

III. Evaluation Results

The legislative assignment directed WSIPP to conduct four distinct analyses using Washington State data:

A) An outcome evaluation;
B) A description of ECEAP households;
C) An analysis of the impact of program factors on student outcomes; and
D) A benefit cost-analysis.

We discuss each of these analyses in the sections below.

A. Outcome Evaluation

The main finding from our evaluation is that children who attended ECEAP had significantly higher math and reading test scores in third, fourth, and fifth grades compared to similar children who did not attend the program. The results for math and reading are similar. We present this finding in Exhibit 5. The result is expressed as an "effect size"—a measure that researchers use to summarize the magnitude of a program's impact on an outcome.[22]

Since an effect size is not an intuitive outcome measure, we converted the ECEAP effect sizes into test score points. We estimated that compared to other low-income students, the passing rate would be 7 percentage points higher for ECEAP participants on the fifth grade 2013 state reading test and 6 percentage points higher for ECEAP participants on the fifth grade 2013 math test.[23]

Exhibit 5

Effects of ECEAP on Academic Test Scores

Grade	Math		Reading		Average academic	
	Effect size	Standard error	Effect size	Standard error	Effect size	Standard error
Third	0.14	0.07	0.17	0.07	0.16	0.07
Fourth	0.16	0.08	0.26	0.09	0.21	0.09
Fifth	0.16	0.08	0.23	0.10	0.19	0.09

[22] WSIPP follows conventional practice and computes a standardized mean difference effect size. Lipsey, M.W., & Wilson, D. (2001). *Practical meta-analysis*. Thousand Oaks, CA: Sage Publications.

[23] For this example we used the means and standard deviations reported for economically disadvantaged students on the 2013 MSP. We assumed that children were evenly distributed in each category of proficiency and that an increase in the mean would shift the distribution but not change the shape of the distribution. Educational Testing Service. (2014). Washington Comprehensive Assessment Program, Grades 3-8, High School, Spring 2013, Technical Report. Retrieved from https://www.k12.wa.us/assessment/pubdocs/WCAP2013SpringAdministrationTechnicalReport.pdf

The test score effect sizes for ECEAP are almost twice as large as the average effect size we found when we reviewed research on early childhood programs in other states. For example, the average effect size in fifth grade is 0.19 for ECEAP and 0.10 in other states, on average.[24]

WSIPP and other researchers have found that, on average, test score gains from program participation can be expected to decline as years pass after the intervention.[25] This is sometimes referred to as "fadeout."

In this study, we did not have data available to measure test scores immediately after program participation or in kindergarten. Therefore, we do not know whether ECEAP's impact on test scores fades out over time. Our results do indicate, however, that the effect of ECEAP on test scores is similar when measured in third, fourth, and fifth grades. Thus, we did not observe fadeout during the later elementary school years.

B. Description of ECEAP Households

We examined characteristics of the heads of households of the ECEAP participants' households.[26] There were 9,681 unique heads of households for ECEAP participants that we included in our analysis of third grade test scores. Exhibit 6 presents a detailed description of the characteristics of the heads of households.

Most ECEAP participants lived in households headed by their parents. Over 30% of the heads of households do not speak English as their primary language. Approximately 38% of the heads of households did not complete high school.

[24] To estimate the fifth grade effect size for the average early childhood education program in other states we used the fadeout model described in WSIPP's January 2014 report. We applied this fadeout model to the average effects of state early childhood education programs measured immediately after the intervention, also described in this previous report. Kay, & Pennucci, (2014).

[25] Camilli, G., Vargas, S., Ryan, S., & Barnett W.S. (2010). Meta-analysis of the effects of early education interventions on cognitive and social development. *Teachers College Record, 112*(3), 579-620; Goodman, A. & Sianesi, B. (2005). Early education and children's outcomes: How long do the impacts last? *Fiscal Studies, 26*(4), 513-548. Kay, & Pennucci, (2014). Leak, J., Duncan, G., Li, W., Magnuson, K., Schindler, H., & Yoshikawa H. (2010). *Is timing everything? How early childhood education program impacts vary by starting age, program duration, and time since the end of the program.* Paper prepared for presentation at the meeting of the Association for Policy Analysis and Management, Boston, MA.

[26] There is one head of household listed for each Basic Food assistance unit. Since relationships of each member of the assistance unit are reported in relation to the head of household we could not report on the relationship of other members of the assistance unit to the ECEAP child.

Exhibit 6
Characteristics of the Heads of Household for ECEAP Participants

Characteristic	Percentage
Relationship to child	
Parent	97.1
Grandparent	2.0
Aunt or uncle	0.4
Step parent	0.2
Legal guardian	0.1
Other	0.2
Female	93.4
Age (years)	
18-19	1.8
20-24	27.1
25-29	33.0
30-39	30.8
40-49	6.0
50-59	0.8
60+	0.4
Race/ethnicity*	
White	77.4
Black	12.2
Native American/Alaska Native	6.2
Asian/Pacific Islander	5.3
Hispanic	31.2
Primary language	
English	77.2
Spanish	19.5
Enrolled student	5.8
Disabled	6.7
Years of education	
0-8	15.8
9-11	22.3
12	44.5
13-16	17.1
17+	0.3

*Categories are not mutually exclusive

C. Program Factors

The legislative assignment directed WSIPP to:

> *Examine the impact of variables including, but not limited to, program fiscal support, staff salaries, staff retention, education level of staff, full-day programming, half-day programming, and classroom size on short-term and long-term outcomes for program participants.*[27]

Unfortunately, data were not available on these program factors for the years included in our analysis. Data on teacher education and salary, the amount of family support services, and classroom size are currently being collected by DEL and might be available for future analyses. For this evaluation, however, we could not determine the impact of these factors on the effectiveness of ECEAP.

WSIPP has, however, previously examined the impact of some of these factors based on studies conducted outside of Washington. In January 2014, we conducted a literature review of program components in early childhood education programs and found a sufficient number of rigorous studies to conduct meta-analyses on classroom quality and teacher education.[28] In that earlier study we found that classroom quality and teachers having at least a bachelor's degree each had a small, positive, but not statistically significant, impact on student test scores.

[27] Senate Bill 5904, Chapter 16, Laws of 2013.
[28] Kay & Pennucci, (2014).

D. Benefit-Cost Analysis

WSIPP has developed, and continues to refine, an economic model to estimate long-run benefits of changes in student outcomes, such as test scores. The model provides an internally consistent monetary valuation so that a variety of policy options can be compared on an apples-to-apples basis.

Previously, we conducted a benefit-cost analysis of the average impact of other states' early childhood education programs. In this prior analysis we compared the cost of the program to the benefits of increasing high school graduation rates and academic test scores and reducing crime, special education placement, and grade retention.

Our current evaluation of ECEAP only measured test scores. Thus, we could not conduct a comparable benefit-cost analysis of ECEAP.

Benefits from Test Scores. Although we could not conduct a complete benefit-cost analysis, we did compare the benefits due to higher test scores in ECEAP to the average state early childhood education program.

We estimate that the total lifetime monetary benefits that accrue from increased test scores would be about $13,030 per ECEAP participant. These monetary benefits are almost twice as high for ECEAP than for the average early childhood education program; in the average state program the benefits that accrue from increased test scores would be $6,847 per participant. Readers interested in an in-depth description of the research methods for the benefit-cost analysis can reference our Technical Manual.[29]

[29] Washington State Institute for Public Policy (2014). *Benefit-cost technical documentation.* Olympia, WA: Author. Retrieved from http://www.wsipp.wa.gov/TechnicalDocumentation/WsippBenefitCostTechnicalDocumentation.pdf

IV. Conclusion

We find that ECEAP participants have higher academic test scores in third, fourth, and fifth grades than similar children who do not attend the program. The effect of ECEAP on test scores is nearly twice the average effect of early childhood education programs in other states.

At this time, we are unable to conduct a complete benefit-cost analysis because we cannot measure whether ECEAP affects longer-term outcomes such as high school graduation and crime. A benefit-cost analysis of ECEAP using only test scores would not be comparable to the benefit-cost analyses WSIPP has conducted of early childhood education programs elsewhere.

If the legislature is interested in the longer-term outcomes from the groups we studied in this evaluation, WSIPP would be able to examine the long-term outcomes after 2020 when the children are expected to graduate from high school.

A. Analysis Methodology

This appendix provides a detailed description of the data and methodology used to conduct the outcome evaluation of ECEAP as well as a detailed description of the results. The evaluation is based on a comparison of outcomes for children who participated in ECEAP with those who did not. Children who participated in ECEAP are referred to as the "treatment group" while those who did not, are referred to as the "comparison group." Program impacts are measured as the differences in outcomes for the treatment and comparison group.

The design of the evaluation was constrained by the retrospective nature of the evaluation. As a result, the evaluation was conducted with existing data sets originally collected for the purpose of program administration. In turn, the time frame and the nature of the evaluation outcomes were limited by the available data. Most importantly, because of the retrospective nature of the evaluation, it was impossible to implement a research design based on random assignment. Because there may be both measured and unmeasured differences in the characteristics of the treatment and comparison groups, it can be difficult to attribute, with certainty, any differences in outcomes to program participation. A research design with random assignment is the best way to ensure that any differences in outcomes between the treatment and the comparison group are attributable to the program being evaluated. Fortunately, even without random assignment, statistical techniques are available to account for both measured and unmeasured differences in the characteristics of the treatment and comparison groups and provide more accurate estimates of program impacts. This evaluation uses a statistical technique known as instrumental variables to control for selection into the ECEAP program and to estimate the impact of ECEAP participation.

Evaluation Outcomes

Test scores after preschool are the most commonly measured outcome in the early childhood education literature.[30] Several studies measured other immediate outcomes such as social and emotional well-being and longer-term outcomes such as later test scores, high school graduation, and crime. Given available data, time, and resource commitments, the only outcome measures we can use are achievement test scores. We use math and reading achievement test scores in third, fourth, and fifth grades. With additional time and resources it would be possible to develop other outcome measures. For example, high school graduation rates for ECEAP participants and non-participants could be tracked over time; the first birth cohort in the current study is scheduled to graduate from high school in the 2017-18 school year. Furthermore, with additional data resources and time, it might be possible to assess the impact of ECEAP on outcomes such as child abuse and neglect and juvenile crime.

[30] Kay, N., & Pennucci, A. (2014). *Early childhood education for low-income students: A review of the evidence and benefit-cost analysis* (Doc. No. 14-01-2201). Olympia: Washington State Institute for Public Policy.

Overview of Data

Our evaluation is based on a comparison of ECEAP participants and non-participants. The comparison requires a comprehensive database identifying all children in Washington State who are eligible for ECEAP. Eligibility is determined by age and family income status. ECEAP is designed for three- and four-year-old children in low-income households in Washington State.[31] No comprehensive database of all low-income households in Washington State exists. However, very detailed data describing all households that participate in Washington State's Basic Food program is collected by Department of Social Health Services (DSHS).[32] The income thresholds to qualify for ECEAP and Basic Food are quite similar, and, therefore, we assume that all households that qualify for Basic Food would also be income-eligible for ECEAP. To qualify for ECEAP, family income must be at or below 110% of the poverty threshold.[33] For Basic Food, the income eligibility threshold is 130% of the poverty threshold for gross household income.[34]

We used the DSHS Basic Food data set to identify all children in Washington State who met the income and age eligibility requirements for ECEAP.[35] From the Basic Food database, we selected five annual birth cohorts of children born between September 1, 1999 and August 31, 2004.[36] Additionally, we limited the analysis to only include children who were members of households that received food benefits during the years when the children were age-eligible for ECEAP.[37]

[31] In lieu of low-income status, children can also qualify for ECEAP as a result of disability status. Because no comprehensive database exists on disabled children, we exclude these children from the evaluation and focus instead on children in low-income households. Among children in the birth cohorts that we examined in the analysis who attended ECEAP, 94% were income-eligible.

[32] Basic Food is Washington State's implementation of the federal Supplement Nutritional Assistance Program (SNAP). This program was formerly known as Food Stamps. Participants in Washington State's Basic Food program do not constitute the complete universe of low-income households in the state. Some income-eligible families may decide not to apply for benefits. Estimates based on national data suggest that in 2007 the SNAP take-up rate was 69% (Ganong and Liebman, 2013). Because of lack of data, this evaluation cannot account for sample selection bias attributable to eligible non-participants in the Basic Food program.

[33] In 2014, the poverty threshold for a family with one adult and two children is $19,790.

[34] Income qualification for Basic Food is based on federal SNAP rules. The income eligibility threshold is 100% of the poverty threshold for household income, net of certain expenditures such as excessive housing, utility, and medical expenses. Because detailed data describing these deductions are rarely available, researchers often approximate SNAP income eligibility by using the 130% of the poverty threshold for households. One distinction between the two programs is that Basic Food (SNAP) income eligibility is based on household income, while ECEAP income eligibility is based on family income.

[35] For this study, WSIPP received datasets from three agencies: DSHS, DEL, and OSPI. In each dataset, specific information that could be used to identify a person was removed. The Education Research & Data Center (ERDC) created cross link files containing unique research study identifiers created specifically for this project. This enabled WSIPP to merge the three data sets together for analysis.

[36] To protect the identity of specific individuals, data provided by DSHS included the month and year of birth but not the day. Since ECEAP age eligibility is determined on the last day of August, this lack of precision was unimportant.

[37] Since some ECEAP families apply in the spring before the school year, we measured receipt of food benefits as the number of months of benefits received during a 30-month window beginning March 1 prior to August 31 of the year in which a child turns three years old. We assumed that households that received food stamp benefits for at least 12 months out of the 30 month window were ECEAP income eligible. Therefore, we limited our analysis accordingly. We tested the sensitivity of our findings to alternative definitions of food benefit receipt during the 30-month window—ranging from six months to 24 months. Our findings were not sensitive to these alternatives.

Exhibit A1

Birth Cohorts Included in the Analysis

Birth month and year	ECEAP participation		Achievement test scores			Projected high school graduation year
	Age three	Age four	Grade three	Grade four	Grade five	
September 1999 to August 2000	September 2003	September 2004	2008-09**	2009-10	2010-11	2017-18***
September 1999 to August 2000	September 2004	September 2005	2009-10	2010-11	2011-12	2018-19***
September 1999 to August 2000	September 2005	September 2006	2010-11	2011-12	2012-13	2019-20***
September 1999 to August 2000	September 2006	September 2007	2011-12	2012-13	2013-14***	2020-21***
September 1999 to August 2000	September 2007	September 2008*	2012-13	2013-14***	2014-15***	2011-22***

* Changes were made to ECEAP in this year.
** The WASL test was used in this year.
***Data for this outcome are not available yet.

Data from the Basic Food database was matched with the roster of ECEAP program participants provided by the Department of Early Learning (DEL). The match was performed by the Washington State Office of Financial Management's Education Resource and Data Center (ERDC).[38] The individuals in each dataset were matched by ERDC using a combination of deterministic matching, probabilistic matching, and manual checks to identify matches across administrative datasets. If a child was listed on the ECEAP roster, they were considered to be an ECEAP participant and a member of the treatment group. Conversely, a child who was not present on the ECEAP roster was considered to be a non-participant and therefore part of the comparison group. Based on this match, we created a dichotomous variable to indicate ECEAP attendance at any time during the school years when a child was eligible for ECEAP.

Each child was followed over time to determine their participation in the K–12 public school system in Washington State. This required a data match, again performed by ERDC, between the DSHS Basic Food database and the K–12 data from Office of Superintendent of Public Instruction (OSPI). We dealt with match anomalies in the same manner as described above for the problematic matches between the Basic Food and ECEAP databases. The analysis only includes children who attended public schools in Washington State during the third, fourth, and fifth grade years. Additionally, children were only included in the analysis if a reading or math achievement test score was available during one of these three grades. Separate analyses were performed for each grade level. Because of data availability, only the earliest three birth cohorts were included in the analysis for fifth grade test scores. For the earlier grade levels, additional birth cohorts were included in the analysis.

[38] In a few cases, where multiple records in the Basic Food database matched to a single record in the ECEAP database, we randomly selected one record from the Basic Food database as the definitive match for a particular ECEAP record. We followed the same procedure if the reverse were true or if multiple records in the Basic Food database matched to multiple records in the ECEAP database.

The data sources that we used are described in Exhibit A2. The DSHS Basic Food database is very detailed and includes individual level data about the ECEAP eligible child, the head of household in which the child resides, and aggregate household characteristics. The database includes basic demographic characteristics, disability status, language spoken, household income, census tract of home residence, and benefit information.[39] Data from DEL identifies ECEAP participants, while data from OSPI includes the achievement test data, free and reduced-price meal status, attendance, and provisions of disability related services. In addition to these data items, WSIPP augmented the available data with the poverty rate for census tracts.

Exhibit A2

Data Sources for the Evaluation

Data source	Variables of interest
DSHS Base Food database	• Individual level data on ECEAP-eligible children (includes age, race/ethnicity, language spoken, disability) • Individual level data on heads of households (includes age, race/ethnicity, language spoken, disability) • Household characteristics (includes benefits, income, census tract of residence)
DEL ECEAP participant database	• Year of ECEAP participation
OSPI K–12 enrollment and assessment data	• Grade level • School attended • Special education services • Free and reduced-price meal enrollment • Third, fourth, and fifth grade math and reading test scores
US Census	• Poverty rate for census tracts

Statistical Selection Bias

ECEAP participation is voluntary in the sense that some, but not all, families with eligible children will seek to enroll their children in the program. In addition, the program is a not an entitlement, which means that qualifying for the program does not guarantee participation. In short, the possibility of selection bias exists. Selection bias means that ECEAP participants and non-participants may differ systematically in characteristics which may in turn influence outcomes such as achievement test scores. Such differences in characteristics can be measured and controlled for using existing data but may also be unmeasurable in existing data. In the latter case, it will be challenging to fully statistically control for these differences and, therefore, impossible to accurately determine the impact of ECEAP participation on outcomes such as test scores.

In the case of ECEAP, there is possible selection bias on two levels. First, there is potential for selection bias resulting from each family's decision to seek to enroll their child in ECEAP. For example, some parents might place a relatively high value on education and make a greater effort to enroll their children in enriching experiences such as ECEAP. Such parents may also provide their children other enriching experiences which will contribute to improved performance on outcomes such as achievement test scores. If we do not have adequate measures of these other enrichment experiences, then we might incorrectly overstate the importance of ECEAP participation on the improved performance on test scores.

[39] The Basic Food data contains information about assistance units, a group of individuals who share a residence with common food preparation facilities. While the concept of the assistance unit is not identical to the household, this database is the best option for the ECEAP evaluation. In the remainder of the paper will use the term household to refer to the Basic Food assistance units.

Second, even if a particular child is age- and income-qualified for ECEAP, there may not be adequate capacity to accommodate that child. Thus, the potential for selection bias exists as a result of the allocation of available ECEAP slots to some but not all eligible children. If ECEAP providers allocate limited ECEAP enrollment opportunities to children with the greatest need for early childhood enrichment activities, then a statistical analysis that does not correct for selection bias would understate the importance of ECEAP participation.

Typically, researchers cannot know the magnitude or direction of possible selection bias. The only method for eliminating selection bias is a research design based on random assignment. In the absence of random assignment, some statistical techniques can simulate randomization. One such method involves the use of instrumental variables to statistically model the selection process.

For this evaluation we statistically model the probability of ECEAP enrollment as a function of an instrumental variable. The instrumental variable must be statistically correlated with ECEAP enrollment but not related to the outcome variable (in this case achievement test scores). For our analysis, the instrumental variable is distance, measured in miles, from each child's home to their nearest ECEAP provider. We expect that being located near an ECEAP provider will increase the probability that a family would seek to enroll their child in ECEAP. Further, proximity to an ECEAP provider when a child is three-or four-years-old is unlikely to be related to their performance on achievement test scores in third, fourth, or fifth grade. Thus, distance serves to simulate random assignment—households that are geographically proximate to ECEAP providers are more likely to appear in the treatment group, while those who farther from ECEAP providers are more likely to appear in the comparison group. The variable measuring distance accounts for these differences in behavior among families.

Statistical Model

Our statistical model estimates the relationship between ECEAP attendance and student outcomes. The model takes the following general form:

$$(1) \qquad Y = \beta_0 + \beta_1 * ECEAP + \beta_2 X + \varepsilon$$

where Y is the math or reading test score in either third, fourth, or fifth grades; ECEAP is a dichotomous indicator of ECEAP participation; X is a vector of covariates used as statistical controls; and ε is a random error term. This model can be estimated using ordinary least squares (OLS) regression, and the result will be unbiased estimates of the impact of ECEAP on student outcome (β_1), unless unmeasured factors influence both ECEAP attendance and test score outcomes.

We anticipated that there could be unmeasured factors that could contribute to selection bias for two reasons. First, not all families in the SNAP database with eligible children will apply to ECEAP. As a result, children whose families who seek ECEAP enrollment may differ in unmeasured ways relative to the general population of low-income families with ECEAP eligible children. These same factors may also contribute to improved test score outcomes and, if so, would bias the estimate of the effect of ECEAP on test scores upward. Second, the ECEAP enrollment process could lead to selection bias if the neediest students are directed to other programs such as Head Start or if contractors offer slots to students with the most need. In this case, there would be a concentration of disadvantaged children enrolled in ECEAP relative to the general population of low-income families with ECEAP- eligible children. Again, the result would be a biased estimate of the effect of ECEAP, however, this time the bias would be in the downward direction.

Instrumental variable estimation is a statistical strategy that reduces bias from unmeasured variables. The technique requires a variable, or instrument, that is correlated with ECEAP attendance but uncorrelated with student outcomes. For this analysis, we used the geographic distance from each ECEAP eligible child's residence

to the nearest ECEAP center as the instrument. Other researchers have successfully used distance as an instrument.[40]

We conducted a maximum likelihood estimation of a two-stage instrumental variable model.[41] In the first stage of this method, a probit function is used to estimate the probability of ECEAP attendance as a function of the instrument (distance to an ECEAP center) and other covariates. In the second stage, the fitted values from the first stage regression are used in place of the ECEAP variable in equation (1). In practice, the two equations are estimated simultaneously using maximum likelihood techniques.

Outcome Measures

As described above, outcomes are measured using reading and math achievement tests given in third, fourth, and fifth grades in public schools in Washington State. Achievement tests are given in the spring of each school year. In the time span for this study, two different types of achievement tests were used. Prior to the 2009-10 school year, the Washington Assessment of Student Learning (WASL) test was used. Subsequently, the Measurements of Student Progress (MSP) test was employed. To make these tests comparable for analysis, we followed the common research practice of standardizing all scores so that for each test type, grade level, and year, the scores have a mean of zero and a standard deviation equal to one.[42]

Treatment Variable

As described above, the treatment variable is a binary indictor variable indicating whether a particular child attended ECEAP either as a three- or four-year-old. This variable does not account for the intensity of the ECEAP treatment—that is, a child attending ECEAP for a partial year is treated the same as a child attending ECEAP for the entire year. Similarly, this variable does not account for children who may have attended ECEAP for more than one year. Some children will start ECEAP and complete the school year while others will fail to complete the full school year. Considering all children to be ECEAP participants regardless of the intensity of their treatment is more consistent with estimating an "intent to treat" effect.

While it is possible to create two separate binary variables indicating ECEAP participation as a three-year-old and as a four-year-old, it would not be possible to implement the instrumental variable estimation technique in this case.[43]

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[40] Card, D. (1995). Using geographic variation in college proximity to estimate the return to schooling, in: N. Louis, E. Christofides, K. Grant, & R. Swidinsky, (Eds.), *Aspects of labour market behaviour: Essays in honour of John Vanderkamp* (University of Toronto Press, Toronto, Canada) pp. 201-222.

[41] We used SAS PROC QLIM to estimate the model.

[42] To calculate standardized test scores we divided the scale score by the published standard deviation for the appropriate grade level and subject. For example, for grade 3 math scores in 2013 we subtract the mean (411.2) and divided by standard deviation (36.5). Educational Testing Service. (2010). *Washington Assessment of Student Learning, Grade 3, 2009, Technical Report*. Retrieved from http://www.k12.wa.us/assessment/pubdocs/2009G3WASLTechReport.pdf; Educational Testing Service. (2011). Washington Comprehensive Assessment Program, Grades 3-8, 10, Spring 2010, Technical Report. Retrieved from http://www.k12.wa.us/assessment/pubdocs/WCAP_2010SpringAdmin_TechReport.pdf; Educational Testing Service. (2012). Washington Comprehensive Assessment Program, Grades 3-8, High School, Spring 2011, Technical Report. Retrieved from https://www.k12.wa.us/assessment/pubdocs/WCAP2011SpringAdministrationTechnicalReport.pdf; Educational Testing Service. (2013). Washington Comprehensive Assessment Program, Grades 3-8, High School, Spring 2012, Technical Report. Retrieved from https://www.k12.wa.us/assessment/pubdocs/WCAP2012SpringAdministrationTechnicalReport.pdf; Educational Testing Service. (2014). Washington Comprehensive Assessment Program, Grades 3-8, High School, Spring 2013, Technical Report. Retrieved from https://www.k12.wa.us/assessment/pubdocs/WCAP2013SpringAdministrationTechnicalReport.pdf

[43] Since the ECEAP indicators are endogenous variables, the IV approach would require two exogenous instrumental variables. Unfortunately, we have only one such variable (distance).

Covariates

In the first stage equation, we estimate the probability of ECEAP participation using distance from each child's home to the nearest ECEAP provider as an instrument variable. It is important to note that this equation is modeling the ECEAP participation decision during the years when each child is three or four years old. In addition to the instrument, the equation includes a set of covariates drawn from the DSHS Basic Food database. These covariates are temporally aligned with the ECEAP enrollment decision.[44] The equation includes characteristics of the child such as gender, race, ethnicity disability status, language spoken, and relationship to the head of household. Additional covariates include household level characteristics such as income, type of Basic Food sub-program, child care subsidy status, homelessness status, household size and age composition, and neighborhood poverty rate.[45] DSHS provided the census tract for each household home address. DEL provided an historical database of ECEAP providers and their location (street address). WSIPP used SAS to geocode or assign latitude and longitude to each ECEAP provider's address. WSIPP then calculated the distance to the geographic centroid for each census tract in Washington State. Finally, WSIPP calculated the geographic distance in miles from each ECEAP-eligible child's home census tract to their nearest provider.[46]

In the second stage equation, we model achievement test scores including the estimated probability of ECEAP participation generated from the first stage equation. In addition to the covariates included in the first stage, we include several other covariates. For each student, we include binary variables indicating whether they received free or reduced-price meal and disability status, a variable indicating percent of the school year the child attended and the total number of schools attended during the current school year. Finally, we included school-level fixed effects and birth cohort fixed effects.

Exhibit A3 presents the means and standard deviations for the covariates for ECEAP participants and non-participants. Some differences between the two groups are statistically significant but nonetheless are generally very small in magnitude. ECEAP participants are slightly more likely to be African-American or Hispanic and to speak Spanish as their primary language; Native Americans are less likely to be ECEAP participants. ECEAP households are slightly smaller in size and in particular have fewer infants and teenagers. Households where Russian is the primary language spoken at home are less likely to be ECEAP participants. ECEAP participants are less likely to be disabled. They have lower household income and subsequently are more likely to received free or reduced-price meals. However, they are less likely to receive child care subsidies.

[44] All of the covariates are drawn from the DSHS Basic Food database and correspond to September of the year in which the child attains the age of three. If the household was not present in the database in September, we measured the covariates in the month nearest to September. When two months tied for the nearest month, we chose the month following September.
[45] We used the census tract poverty rate as a proxy for the neighborhood poverty rate.
[46] The computation is based on the straight line distance between two pairs of geographic coordinates and does not account for network of roads, the type of transportation mode or evaluation changes.

Exhibit A3

Comparison of Means and Standard Deviations, ECEAP participants and Non-participants

Variable	Non-ECEAP participants		ECEAP participants		t statistic	p-value	
	Mean	SD	Mean	SD			
Distance to nearest ECEAP provider (miles)	3.74	5.60	2.25	3.14	18.89	0.00	**
Log (net income per capita)~	3.46	2.50	3.37	2.54	2.51	0.01	*
Census tract poverty rate#	0.19	0.11	0.19	0.11	1.70	0.09	
Black#	0.13	0.34	0.15	0.36	-3.94	0.00	**
Native American#	0.08	0.28	0.06	0.25	4.81	0.00	**
Asian or Pacific Islander#	0.05	0.23	0.05	0.23	0.17	0.87	
Other race#	0.33	0.47	0.36	0.48	-4.23	0.00	**
Hispanic#	0.32	0.47	0.34	0.48	-3.99	0.00	**
Female#	0.49	0.50	0.51	0.50	-2.41	0.02	*
Primary language is Russian#	0.03	0.18	0.01	0.10	9.12	0.00	**
Primary language is Spanish#	0.14	0.35	0.19	0.40	-9.41	0.00	**
Primary language is other#	0.03	0.16	0.02	0.15	1.56	0.12	
Disability status (at ECEAP enrollment)#	0.01	0.11	0.01	0.07	3.78	0.00	**
Number in household under age 2#	0.44	0.60	0.42	0.59	2.67	0.01	**
Number in household age 3 to 5#	1.24	0.48	1.25	0.48	-0.66	0.51	
Number in household age 6 to 12#	0.74	0.97	0.73	0.91	0.91	0.36	
Number in household age 13 to 17#	0.21	0.58	0.18	0.51	3.03	0.00	**
Number in household age 65 and over#	0.00	0.05	0.00	0.05	0.13	0.90	
Number in household#	4.02	1.70	3.96	1.51	2.56	0.01	*
Household head is grandparent#	0.02	0.15	0.02	0.14	1.19	0.24	
Household head is not parent or grandparent#	0.01	0.09	0.01	0.10	-0.83	0.41	
Homeless flag#	0.04	0.19	0.03	0.18	0.58	0.56	
Basic Food sub-program C#	0.34	0.47	0.35	0.48	-1.42	0.16	
Basic Food sub-program G#	0.02	0.14	0.02	0.14	0.34	0.74	
Basic Food sub-program other#	0.01	0.09	0.01	0.08	1.21	0.23	
Child care subsidy (WCCC)#	0.27	0.44	0.23	0.42	5.39	0.00	**
Disability status (at grade five) #	0.21	0.40	0.18	0.39	3.56	0.00	**
Grade five free or reduced-price meals#	0.92	0.28	0.93	0.25	-4.02	0.00	**
Percent of grade five school year in testing school#	0.96	0.13	0.96	0.12	-0.34	0.73	
Number of schools attending during grade five	1.11	0.37	1.12	0.37	-1.12	0.26	
Sample size	24,290		5,436				

Notes:

* indicates statistical significance at the 5 percent level

** indicates statistical significance at the 1 percent level

~ The net income per capita is $2,884 for the non-ECEAP participants and $2,344 for ECEAP participants.

These binary variables can be interpreted as percentages. For example, a mean of 0.12 can be interpreted as 12%.

B. Detailed Evaluation Results

Exhibit A4 displays our main results relating to the effect of ECEAP participation on math and reading test scores. Panel A displays ordinary least squares (OLS) estimates which do not take account potential selection into ECEAP and therefore may be subject to bias. Panel B presents the IV estimates, our preferred estimates, which do explicitly account for potential selection bias related to the ECEAP enrollment decision. The IV estimates are approximately twice as large the corresponding OLS estimates. Regardless of the method used, we find evidence that ECEAP participation improves math and reading achievement test scores in grades three, four, and five.

Exhibit A4

OLS and Instrumental Variable Estimates of the Effect of ECEAP on Achievement Test Scores, Grades Three, Four, and Five

	Math				Reading			
	N	Coefficient	Standard error	p-value	N	Coefficient	Standard error	p-value
A. OLS Estimates								
Grade three	51,619	0.062	0.015	0.000	51,618	0.080	0.017	0.000
Grade four	43,372	0.058	0.015	0.000	42,383	0.118	0.025	0.000
Grade five	29,726	0.048	0.018	0.007	29,764	0.093	0.027	0.001
R squared		0.213	0.227	0.233		0.227	0.209	0.219
B. IV Estimates								
Grade three	51,619	0.137	0.073	0.060	51,618	0.170	0.071	0.016
Grade four	43,372	0.160	0.076	0.035	42,383	0.257	0.094	0.006
Grade five	29,726	0.160	0.081	0.047	29,764	0.228	0.103	0.027

Note: Specification includes school level fixed effects and the full list of covariates shown in Exhibit A5. OLS coefficients are presented along with White's consistent standard errors. IV coefficients are maximum likelihood estimates based on the maximization of the joint likelihood function corresponding to the ECEAP enrollment and the achievement test score equations. If the sample is sufficiently large and if the mean and variance functions are correctly specified, the variance-covariance matrix of MLE estimates will be asymptotically normal and will yield the analogue of White's consistent standard errors for OLS. Estimates are produced by SAS v9.3 PROC QLIM (http://support.sas.com/documentation/cdl/en/etsug/66840/HTML/default/viewer.htm#etsug_qlim_details24.htm).

Our estimates are stable across the three grade levels analyzed and subject area. Further, the relative relationship between the IV and OLS coefficients is quite stable. Although the IV estimates are preferred to the OLS estimates, one consequence of the IV estimation procedure is that the standard errors are much larger than the corresponding OLS standard errors. Indeed, the 95th percent confidence intervals of the OLS and IV estimates would at least partially overlap.

As discussed in the main paper, the IV results suggest that the impact of ECEAP is approximately twice as large the average of all similar programs nationally.[47] Due to limitations in data and the design of this evaluation, we cannot determine what explains the superior performance of ECEAP relative to similar programs nationwide. For example, the observed differences could be due to variation in program quality, intensity, or research design.

[47] To estimate the fifth grade effect size for the average early childhood education program in other states we used the fadeout model described in WSIPP's January 2014 report. We applied this fadeout model to the average effects of state early childhood education programs measured immediately after the intervention, also described in this previous report. Kay, & Pennucci, (2014).

The fact that the IV estimates are larger than the OLS estimates indicates that there is negative selection into ECEAP— students who relatively disadvantaged, in ways we cannot measure given available data, are more likely to enroll in ECEAP. Although we cannot be certain about why this is occurring one possible explanation is that ECEAP providers are recruiting and otherwise prioritizing the most disadvantaged children for ECEAP participation. Another possibility is that parents of children who are more disadvantaged have a higher propensity to seek educational enrichment for their children.

Other researchers have noted the presence of a fade-out of the effect of early childhood education on test scores.[48] Because we had no data on student achievement prior to grade three, we do not know if the effects of ECEAP were subject to fade-out between the child's preschool achievement and their subsequent performance in grades three, four, or five. Our analysis does not provide any suggestion of evidence for a decrease in the impact of ECEAP on test score gains during the two-year interval between grade three and grade five. However, it is important to note that fade-out effects during such a short time interval might be small and, thus, difficult to detect.

Exhibit A5 shows the estimated coefficients on the instrumental variable, distance to nearest ECEAP provider. This equation is specified as a probit model since the dependent variable, which indicates enrollment in ECEAP, is binary. In all cases, the coefficients on distance are negative, as expected, and highly significant. This means that households farther from an ECEAP center are less likely to attend the program. To test for the endogeneity of ECEAP enrollment we use a likelihood ratio test to determine if the correlation in the error terms of the two equations is zero. In all cases, we fail to reject this hypothesis which indicates that ECEAP enrollment is indeed an endogenous variable. Again, in all cases, a Wald test indicates that distance to nearest ECEAP provider is a strong instrumental variable.

[48] Camilli, G., Vargas, S., Ryan, S., & Barnett W.S. (2010). Meta-analysis of the effects of early education interventions on cognitive and social development. *Teachers College Record, 112*(3), 579-620; Goodman, A. & Sianesi, B. (2005). Early education and children's outcomes: How long do the impacts last? *Fiscal Studies, 26*(4), 513-548. Kay, & Pennucci, (2014). Leak, J., Duncan, G., Li, W., Magnuson, K., Schindler, H., & Yoshikawa H. (2010). *Is timing everything? How early childhood education program impacts vary by starting age, program duration, and time since the end of the program.* Paper prepared for presentation at the meeting of the Association for Policy Analysis and Management, Boston, MA.

Exhibit A5

Estimated Effect of Distance on ECEAP Enrollment, Using Probit Specification

	Math				Reading			
	N	Coefficient	Standard error	p-value	N	Coefficient	Standard error	p-value
Grade three	51,619	-0.046	0.002	<.0001	51,618	-0.046	0.002	<.0001
Grade four	43,372	-0.047	0.002	<.0001	42,383	-0.047	0.002	<.0001
Grade five	29,726	-0.049	0.003	<.0001	29,764	-0.049	0.003	<.0001

Note: Specification includes school level fixed effects and the full list of covariates shown in Exhibit A5. Coefficients are maximum likelihood estimates based on the maximization of the joint likelihood function corresponding to the ECEAP enrollment and the achievement test score equations. If the sample is sufficiently large and if the mean and variance functions are correctly specified, the variance-covariance matrix of MLE estimates will be asymptotically normal and will yield the analogue of White's consistent standard errors for OLS. Estimates are produced by SAS v9.3 PROC QLIM (http://support.sas.com/documentation/cdl/en/etsug/66840/HTML/default/viewer.htm#etsug_qlim_details24.htm).

Exhibit A6 displays an example, for fifth grade math and reading test scores, of the model with the coefficients for the full set of included covariates. The model also includes fixed school effects and fixed birth cohort effects. The students in this analysis were enrolled in 1,759 schools during their fifth grade year. These schools were located 297 school districts. In the analysis, 5,436 students participated in ECEAP as either three- or four-year olds. Across the state, there were 33 ECEAP providers delivering services at 92 locations. The full set of covariates in Exhibit A6 are intended to serve as statistical control variables to insure that our estimates of the effect of ECEAP on achievement are unbiased. As discussed below, the estimated impact of ECEAP is robust regardless of the particular set of covariates included in the model.

Exhibit A6

Instrumental Variable Estimates of the Effect of ECEAP on Achievement Test Scores, Grade Five

	Math			Reading		
Variable	Coefficient	Standard error	p-value	Coefficient	Standard error	p-value
Intercept	-0.793	1.090	0.467	-0.944	1.667	0.571
ECEAP	0.160	0.081	0.047	0.228	0.103	0.027
Log (net income per capita)	-0.005	0.003	0.059	-0.008	0.004	0.054
Census tract poverty rate	-0.137	0.069	0.047	-0.144	0.105	0.173
Black	-0.215	0.022	<.0001	-0.197	0.034	<.0001
Native American	-0.121	0.026	<.0001	-0.148	0.039	0.000
Asian or Pacific Islander	0.017	0.031	0.584	-0.068	0.047	0.147
Other race	-0.071	0.019	0.000	-0.088	0.029	0.003
Hispanic	-0.072	0.021	0.001	-0.060	0.032	0.058
Female	-0.012	0.013	0.369	0.101	0.020	<.0001
Primary language is Russian	0.266	0.045	<.0001	0.038	0.068	0.582
Primary language is Spanish	-0.056	0.025	0.023	-0.166	0.037	<.0001
Primary language is other	0.052	0.045	0.244	-0.099	0.069	0.151
Disability status	-1.484	0.065	<.0001	-2.587	0.100	<.0001
Number in household under age 2	0.048	0.019	0.010	0.025	0.028	0.368
Number in household age 3 to 5	0.008	0.019	0.692	-0.039	0.030	0.192
Number in household age 6 to 12	0.008	0.016	0.611	-0.003	0.024	0.910
Number in household age 13 to 17	-0.033	0.019	0.082	-0.025	0.029	0.384
Number in household age 65 and over	0.121	0.127	0.339	0.058	0.193	0.764
Number in household	-0.002	0.013	0.903	0.001	0.020	0.970
Household head is grandparent	-0.046	0.045	0.306	-0.016	0.069	0.812
Household head is other (not parent or grandparent)	-0.112	0.068	0.099	-0.149	0.103	0.149
Homeless flag	0.014	0.035	0.693	0.042	0.054	0.438
Basic Food sub-program C	-0.095	0.014	<.0001	-0.093	0.022	<.0001
Basic Food sub-program G	0.121	0.048	0.011	0.246	0.073	0.001
Basic Food sub-program other	-0.036	0.076	0.636	-0.153	0.117	0.191
Child care subsidy (WCCC)	0.076	0.016	<.0001	0.104	0.024	<.0001
Disability status (grade five)	-1.096	0.017	<.0001	-1.571	0.025	<.0001
Grade five free or reduced-price meal	-0.125	0.025	<.0001	-0.152	0.038	<.0001
Percent of grade five school year in testing school	0.171	0.057	0.003	0.090	0.087	0.303
Number of schools attending during grade five school year	-0.049	0.020	0.013	-0.062	0.030	0.038
Birth cohort 9/1/1999 to 8/31/2000	-0.031	0.017	0.065	-0.006	0.026	0.817
Birth cohort 9/1/2000 to 8/31/2001	-0.017	0.015	0.251	0.023	0.023	0.311
School level fixed effects	YES			YES		
Sample size	29,726			29,764		

Note: Coefficients are maximum likelihood estimates based on the maximization of the joint likelihood function corresponding to the ECEAP enrollment and the achievement test score equations. If the sample is sufficiently large and if the mean and variance functions are correctly specified, the variance-covariance matrix of MLE estimates will be asymptotically normal and will yield the analogue of White's consistent standard errors for OLS. Estimates are produced by SAS v9.3 PROC QLIM (http://support.sas.com/documentation/cdl/en/etsug/66840/HTML/default/viewer.htm#etsug_qlim_details24.htm).

Sensitivity Analyses

To determine the robustness of our main results, we subjected our analysis to a variety of sensitivity tests. First, we considered alternative definitions of the threshold which determined our proxy for ECEAP income-eligibility. Our main results are based on a threshold of 12 or more months of Basic Food benefits during a 30-month window beginning six months prior to a child becoming age-eligible for ECEAP. We employed various alternative definitions of this threshold ranging from six to 24 months. In each case, our estimates of the effect of ECEAP were consistent with our main findings.

Our main results are based on model that includes a number of covariates (see Exhibit A6). To test the sensitivity of these results with respect to the particular set of covariates included in the specification, we estimated 15 alternative specifications of the model by successively removing covariates until the model included only school-level fixed effects, and race, ethnicity, and gender indicators. The estimated ECEAP coefficient was stable across each of these 15 specifications.

Finally, since the estimated IV model employs non-linear optimization the results might potentially be sensitive to the methods employed. SAS has three non-linear optimization techniques that are appropriate for medium to large size estimation problems.[49] The default method, quasi-newton, is the basis for our main results. To test sensitivity, we estimated the model again using the two alternative techniques (the "double-dogleg method" and the "conjugate gradient method"). All three methods yield virtually identical results.

C. ECEAP Matching Rate

Since we selected the intervention and comparison groups from the Basic Food dataset, not all children who were income-eligible, attended ECEAP, and were born between 9/1/1999 and 8/31/2004 were included in our analysis. We could not include ECEAP participants in the following scenarios:

1. The individual was not in the Basic Food database because their family did not apply for Basic Food.
2. The individual was not in the Basic Food database because their identifiers in each dataset did not match.
3. The individual was in the Basic Food database but did not have K–12 assessment data because he or she did not take the assessment or was not enrolled in a Washington State public school.
4. The individual was in the Basic Food database but did not have K–12 assessment data because the identifiers in each dataset did not match.

We received data for all ECEAP participants from DEL. We examined the characteristics of children who we included in the analysis and those who we could not. These data are described in Exhibit A7.

[49] For a detailed description of the methods see http://support.sas.com/documentation/cdl/en/etsug/66840/HTML/default/viewer.htm#etsug_nlomet_sect006.htm.

Exhibit A7

Characteristics of Income-Eligible Students Who Attended ECEAP and were Born Between 9/1/1999 and 8/31/2004

	Not in Basic Food database		In Basic Food database, no K–12 assessment data		In Basic Food database, has K–12 assessment data		Total	
	N	%	N	%	N	%	N	%
Total	12,940	100.0	5,022	100.0	14,594	100.0	32,556	100.0
Years attended ECEAP								
1	10,564	91.8	4,125	84.1	11,502	81.6	26,191	85.8
2	938	8.2	778	15.9	2,599	18.4	4,315	14.1
Race/ethnicity								
White	4,891	42.4	2,746	55.9	7,845	55.6	15,482	50.7
Hispanic	5,621	52.3	1,643	36.3	4,966	38.2	12,230	43.3
Black	891	7.7	623	12.7	1,758	12.5	3,272	10.7
Native American/Alaska Native	449	3.9	338	6.9	746	5.3	1,533	5.0
Asian	878	7.6	126	2.6	482	3.4	1,486	4.9
Pacific Islander	233	2.0	153	3.1	346	2.5	732	2.4
Primary language								
English	5,763	50.0	3,629	73.9	9,877	70.0	19,269	63.0
Spanish	4,806	41.7	1,062	21.6	3,433	24.3	9,301	30.4

D. Head Start Experience of a Subset of the Analysis Group

We did not have data describing the early childhood education experiences of the comparison group. However, we were able to examine the number of children who attended Head Start in a subset of the analysis group. We received data from two providers who serve Whatcom, Pierce, and King Counties (excluding Tacoma and Seattle). ERDC matched this data to our analysis dataset.

We examined the Head Start experience of all 7,137 children in our analysis dataset from Whatcom, Pierce, and King Counties (excluding Tacoma and Seattle) (Exhibit A8). We do not have data on other early childhood education experience individuals in this group may have had.

Exhibit A8

Sub-State Analysis: Head Start Experience of the Analysis Group
Whatcom, Pierce, and King Counties (excluding Tacoma and Seattle)

	Attended Head Start		
Attended ECEAP	**Yes**	**No**	**Total**
Yes	86 (1%)	1,332 (19%)	1,418 (20%)
No	1,355 (19%)	4,364 (61%)	5,719 (80%)
Total	1,441 (20%)	5,696 (80%)	7,317 (100%)

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