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Abstract

Using data from the Longitudinal Survey of Australian Children (LSAC), this is the first analysis for Australia to evaluate the impact of attendance at pre-school programs on matched Year 3 nation-wide NAPLAN test outcomes in the domains of Numeracy, Reading, Spelling, Writing and Grammar. We additionally disaggregate the impact of specific teacher qualifications on children's cognitive outcomes. While one year of learning in Year 3 is represented by about 50 NAPLAN points, we find average pre-school domain effects as much as 10-15 points, mainly driven by the upper quantiles of the NAPLAN distribution. To address causality issues, we use Kernel matching, whereby the ATTs and ATUs are of the magnitude 10 to 20 NAPLAN points, which are reduced only modestly to about 15 points with additional controls for observed ability. NAPLAN score impacts on Numeracy, Reading and Spelling domains are the strongest and significant with the highest increases in NAPLAN scores being attained by children whose pre-school teachers had Diploma or Degree level (high) qualifications, identifying for the first time the crucial nature of teacher qualifications in driving nationally representative long-run pre-school treatment outcomes.

JEL classification: I21, I28, J24

Keywords: ATT, causal impact, pre-school, NAPLAN, specialised qualification

1. Introduction

Recent Australian statistics on voluntary pre-school take-up rates indicate that approximately 90% of pre-school aged children attend a pre-school or kindergarten program in one form or another, before formally entering into primary school.[1] Pre-school attendance may also facilitate cognitive development important for later life for the children involved, and may also allow mothers or other carers of young children to work more flexibly to combine work and family. Not only does pre-school attendance potentially facilitate cognitive development important for later life, but also these centres allow mothers (or other carers of young children) to work more flexibly to combine work and family. (Heckman et al., 2006)

Funding of pre-school programs in Australia is mixed, with some being private and some funded by the state and Federal governments. In the 2010-11 financial year, total state and federal government expenditure on pre-school and child care services was $5.4 billion (AUD), with federal government expenditure accounting for 80% of total government expenditure. The provision of pre-school services accounted for 86% of total state and territory government expenditure across all children's services models, with Victoria and NSW spending $221 million and $168 million respectively in 2010-11. Given the substantial cost of public pre-school programs, it is of particular policy interest to examine the longer-run impacts of these programs with respect to later educational outcomes on the children attending pre-school, and to be able to determine whether these impacts can be classified as causal or simply associational.

While it is clear that the decision to enroll children in a pre-school is a non-random process, it is of great policy interest to identify any potential causal impact of this pre-schooling on children's later outcomes, however measured. As pre-school participation is voluntary, nonattendance may be a result of family circumstances that are negatively associated with development. For example, poor physical or mental health of the child's mother or main carer may prevent a child from attending pre-school. Furthermore, parents of children who are developmentally challenged at that point in development, may simply keep their children at home to allow them to "catch up", or even fear that their children may be simply overwhelmed in a more public environment such as a pre-school centre. On the other hand, centres with good reputations may be sought after by parents with challenged children, especially for the intensive treatment that they may potentially receive there. Thus non-participation might easily be associated with children's developmental issues which might persist several years into the future, confounding impact measurement. As the direction of selection is not clear *a priori*, it is all the more important to deal directly with the issue in the analysis.

[1] In some states these programs are referred to as kindergarten, in others they are called pre-school. Throughout this paper "pre-school" refers to any early childhood education program attended in the year prior to starting formal schooling.

This study uses data from the Longitudinal Study of Australian Children (LSAC), which identifies pre-school usage, and for the first time in 2012, is linked to 5 cognitive test outcomes from the National Assessment Program – Literacy and Numeracy (NAPLAN) test in the children's Year 3. Because the NAPLAN test is intended to be longitudinally and cross-sectionally comparable, approximately 50 points on the NAPLAN test represents one year of learning at Year 3 level. As there is not a purely random assignment process involved in pre-school enrolment, we use quasi-experimental methods of kernel matching to assess the extent to which the pre-schooling experience has impacted on the domain outcomes of Reading, Writing, Grammar and Punctuation, Spelling and Numeracy. We find evidence for: (a) significant average effects, (b) at various points in the distribution and (c) effects depending on the specific qualification of the pre-school teachers. Even some three years after the pre-schooling, we find lasting average domain effects in the order of 10-15 points, mainly driven by the upper end of the NAPLAN distribution. Using Kernel matching, the average treatment effects on the treated (ATTs) are of the magnitude 10 to 20 NAPLAN points, which are reduced only modestly to a maximum of about 15 points with additional explicit controls for ability. The highest increases in NAPLAN scores are attained by children whose pre-school teachers had Diploma level (high) qualifications. This is the first study of its kind for Australia and demonstrates the substantial positive impacts of pre-school on later schooling attainment and also the importance of qualified teaching personnel in the pre-school sector.

Section 2 gives a brief overview of the existing literature on evidence-based impacts of pre-school on children's later educational outcomes. Section 3 describes data from the Australian children's panel LSAC. Section 4 outlines the econometric analysis and discusses the results. Section 5 concludes.

2. Background

Many studies have shown that there are significant benefits for children who attend high quality pre-school programs, including better intellectual development and higher levels of concentration, sociability and independence. Some of the best known evidence of the benefits of high quality early education experiences on later development comes from targeted early intervention programs undertaken in the United States. These programs, which are intended for disadvantaged children, particularly those from single-parent or low-income families, include: (a) the HighScope Perry Pre-school Program, (b) the Abecedarian Project, (c) the Chicago Child Parent Centres and (d) the Head Start Program. This section will outline the previous American evidence for the effectiveness of programs targeted to the disadvantaged, the European and American more general large-scale program evidence and the Australian evidence. As there are likely to be large amounts of heterogeneity between pre-school institutions and even within the centres themselves, we address the issue of the role of pre-school teacher qualifications. Finally, crucial to this analysis is the issue of selection bias and the need for quasi-experimental methods in the absence of the non-random assignment.

2.1 The Benefits of Targeted Intervention Programs in the USA

The HighScope Perry Pre-school Program originally involved 123 children from low-income households who were assessed to be at high risk of school failure. The children were randomly assigned either to a no-program control group or to a high-quality pre-school program which involved a weekday morning pre-school routine combined with weekly home visits by program staff. The teacher-child ratio in the intervention program classrooms was one adult for every five or six children; the teachers were professionally trained and qualified in early childhood education, and the program extended over two calendar years. The classrooms were arranged to support children's self-initiated learning activities as well as small-group and large-group activities, engaging children in experiences covering the areas of personal initiative, social relations, creative representation, movement and music, logic and mathematics, and language and literacy (Schweinhart et al., 2005). Children who participated in the Perry Pre-school Program were found to be better prepared for school and significantly outperformed the no-program group on various intellectual and language tests from their pre-school years up to age 7, on school achievement tests at ages 9, 10, and 14, and on literacy tests at ages 19 and 27 (Schweinhart et al., 2005). The long-term benefits of the program include higher levels of income, reduced crime rates and higher levels of family stability. At the ages of 27 and 40, the program group were more likely to be employed, had significantly higher median annual earnings, had more stable dwelling arrangements and significantly fewer arrests, than the group who did not participate in the program (Schweinhart et al., 2005).

The Abecedarian Project is another example of an early education intervention program administered to low-income children in the United States, with long-lasting benefits. In this program, 111 infants born between 1972 and 1977 were randomly assigned to either a treatment or control group. All of the children received child care and health services at a center with enriched resources, but the treatment group also received intense intervention, consisting of a pre-school and school-age education program (Campbell and Ramey, 1994). Follow up studies have shown a statistically significant difference in the IQ of children in the treatment group at the end of pre-school and also at the ages of 8 and 12. The children who participated in the intervention program also completed more years of education, and were more likely to attend a four-year college than the children in the control group (Campbell and Ramey, 1995).

Head Start Programs are targeted to local community needs and cater for several hundred thousand children across the United States in any one year (Elliot, 2006). These programs, which have been operating since 1965, typically provide half-day, centre-based early childhood education and care for children from disadvantaged families in the two years before starting school (Deming, 2009). Program participants may also receive related health, parenting and other child and family support services. Several evaluations of Head Start programs, for example Zigler and Styfco (1993) and Barnett (1995), have found short-term improvements in cognitive development and early academic performance among children who attended Head Start. A more recent study by Deming (2009) examines the short and long-term effects of Head Start by comparing Head Start participants with their siblings who did not participate in the program. He finds that participation in Head Start generates significant short-term increases in test scores, as well as reductions in grade repetition and learning disability diagnosis, particularly for the most disadvantaged male children in the sample. In the long-term, male Head Start participants were eleven percentage points less likely to be out of the labour force and female Head Start participants were over thirteen percentage points more likely than their siblings to attend and complete at least one year of college.

The Chicago Child Parent Centres (CPC) program is a public kindergarten program aimed at children who are at risk of academic underachievement due to poverty and associated factors. This program, which has been running in Chicago Public schools since 1967, consists of a part-day pre-school program for children aged 3 and 4, and a follow on program in the early elementary school years. The pre-school program, which is run by teachers with college degrees and early childhood certification, emphasises basic skills in language and mathematics through relatively structured but diverse learning experiences that include whole-class instruction, small group activities and individualised activities (Reynolds et al., 2011). The follow-up program provides reduced class sizes and encourages parental involvement during the first three years of school. In a study of CPC participants born in 1979 and 1980, Reynolds et al. (2011) find that at age 28, the group who participated in the CPC program had significantly higher levels of educational attainment, which translated to higher economic status, including higher levels of annual income and occupational prestige; as well as a higher rate of rate of health insurance coverage, significantly lower rates of drug and alcohol abuse and lower rates of crime relative to the comparison group who did not participate in the CPC program but attended a school based kindergarten.

2.2 The Effects of Typical Large-scale Pre-school Programs

While there is clear evidence of the benefits of high quality pre-school programs that are targeted to children from disadvantaged backgrounds, much less is known about the impact of typical large-scale pre-school programs. In a review of the long-term academic impacts of both model and large-scale public pre-school programs, Barnett (1998) found that public programs often had weaker effects than the generally higher quality targeted programs. One possible explanation for this difference is that targeted intervention programs are often more intensive than universal access programs, and are usually targeted at sub-populations whose responsiveness to these programs may be higher than that of the population as a whole (Dumas and Lefranc, 2010).

Most studies of pre-school participation find a significant benefit for cognitive outcomes in the short-term. However, evidence about the long-term cognitive and social benefits of pre-school programs is mixed. Some studies, such as those of Sylva et al. (2008) and Berlinski, Galiani and Manacorda (2008) have concluded that pre-school attendance has long-term academic and social benefits for all children. Others, including Magnuson, Ruhm and Waldfogel (2007a and 2007b), have found that the academic benefits of pre-school attendance tend to fade over time, and that pre-school attendance may be associated with poorer behavioural outcomes in the long-term.

Based on evidence from the Effective Pre-school and Primary Education (EPPE) project, which involved approximately 3000 children in various types of early childhood education and care settings in the United Kingdom in 1987, Sylva et al. (2008) find that pre-school experience, compared to none, enhances all-round development in children. Attendance at a high quality pre-school (measured by the qualifications of staff, the proportion of trained teachers on staff and the quality of the interactions between staff and children) was found to be related to better reading, mathematics and behavioural outcomes, which persisted until at least age 11. In a study of the effect of pre-primary education on children's subsequent school outcomes in Uruguay, Berlinski, Galiani and Manacorda (2008) find a significant positive effect of pre-school attendance on completed years of primary and secondary education, with children who attended pre-school 27 percentage points more likely to be in school at the age of 15 compared to those who did not attend pre-school. Positive long-term effects of pre-school attendance have also been found for children in Argentina, with children who attended pre-primary education achieving higher test scores in Spanish and Mathematics and also better behavioural outcomes in terms of attention, effort, class participation, and discipline in the third grade (Berlisnki, Galliani and Gertler, 2009).

Using data from the Early Childhood Longitudinal Study - Kindergarten Class of 1998-99 (ECLS-K), a large nationally representative sample of children who entered kindergarten the United States in 1998, Magnuson, Ruhm and Waldfogel (2007a) find that attendance at a pre-school program increases reading and numeracy skills at the time of school entry, but also increases behavioural problems. Furthermore, while the advantages in terms of academic skills had largely dissipated by the first grade, the behavioural problems persisted. Similarly, Osborn and Milbank (1987) assess the effects on cognitive and behavioural development at age 5 and 10 of several different types of pre-school programs in Great Britain in the 1970's and find that that pre-school attendance generally boosts cognitive attainment at ages 5 and 10, but behavioural problems at age 10 were more common among children who had attended pre-school. Goodman and Sianesi (2005) also find positive effects from early education among a cohort of British children born in 1958. Attendance at an early education setting before entering school was found to lead to higher average test scores at age 7, which though diminished in size, remained significant up to age 16. However, parental reports of the incidence of poor social skills, particularly those related to aspects of self-control, were higher at age 7 and age 11 among children who had attended pre-school.

Several studies of universal pre-school programs have found that the benefits of pre-school attendance are most significant for children from disadvantaged backgrounds, with pre-school participation compensating to some extent for a less intellectually stimulating home environment. For example, using data from the United States ECLS-K, Magnuson, Ruhm and Waldfogel (2007a) find that the largest and most persistent academic gains from having attended pre-school were found for disadvantaged children. Also in the United States, Fitzpatrick (2008) finds that the introduction of universal pre-kindergarten in the state of Georgia led to lasting benefits on the academic achievement of children, particularly those from disadvantaged backgrounds. Based on evidence from the EPPE Project in the United Kingdom, Sylva et al. (2008) find that high quality pre-school was particularly beneficial in promoting better mathematics outcomes at age 11 for the most disadvantaged pupils and for children whose parents had not completed any post-school qualifications.

Using data from the German-Socio-Economic Panel (GSOEP), Spiess, Büchel and Wagner (2003) examine the relationship between kindergarten attendance and the 7th grade school placement of children in West Germany. The 7th grade is of particular interest, as regardless of German federal state, the children have at this point been streamed into one of the three academic levels of high school. They find that for children in immigrant households, being selected into the more academically demanding schools is significantly associated with kindergarten attendance prior to school enrollment, but this is not the case for children of German citizens. A study of a large-scale expansion of pre-school enrolment in France in the 1960's and 1970's (Dumas and Lefranc, 2010) finds a sizeable and persistent effect of pre-school attendance on subsequent schooling outcomes, particularly among children from worse off social groups.

2.3 Australian Evidence of the Effects of Pre-school Participation

Australian researchers have, at least prior to the availability of the Longitudinal Study of Australian Children (LSAC) data, not had access to rich longitudinal datasets with which to study the effects of pre-school participation on the subsequent educational outcomes of Australian children. As a result, relatively little is known about how pre-school participation affects children's outcomes later in life. Nevertheless, there is a small research literature of relevance identifying positive effects of early childhood education and care programs on short-term educational outcomes for Australian children.

Raban (2000) provides evidence of the success of the Pre-school Literacy Project (PLP), which was run in 40 pre-schools across Victoria between 1996 and 1999. This project involved encouraging pre-school teachers to introduce literacy into their programs through various means including introducing literacy materials into the “home corner”; placing a writing table in the room along with appropriate resources; introducing a post box for letter exchanges; and bringing the print around their room down to the children’s eye level. After one year of primary school, students who had attended a PLP pre-school had significantly higher scores on reading and writing tests as well as higher level oral language skills and more sophisticated phonological awareness than those students who did not attend a PLP pre-school. Furthermore, while the non-PLP students appeared to catch up with the PLP students after one year in school, during the second year in school, the PLP students maintained their advantage in reading and oral language proficiency.

Using data from the Child Care Choices Longitudinal Extension study, a study of the child care and early school experiences of children in urban and rural New South Wales from 2002 to 2008, Bowes et al. (2009) found that hours of care, multiple and changeable care arrangements and the quality of the carer-child relationship were important predictors of children’s achievement. Longer hours in early formal child care were found to be associated with poorer academic achievement, while longer hours of early informal care had a positive effect on social behaviour.

Boardman (2005) examined effect of full-day and half-day kindergarten programs on the literacy and numeracy outcomes of Tasmanian children who began their preparatory year of school in January 2004. In a comparison of Performance Indicators of Primary Schools (PIPS) test scores of 884 students across 38 schools, the results indicated that reading, numeracy and overall test scores were significantly higher among children who had attended full-day sessions of kindergarten the previous year.

Australian studies using the LSAC data have also shown evidence of the benefits of early childhood education and care programs for children in Australia. For example, Harrison et al., (2009) found that, children who were attending an early childhood or pre-school program at the age of 4 or 5 were more competent in their language ability than those who were not attending an early childhood program. However, vocabulary scores were negatively associated with longer weekly hours of attendance at child care or pre-school, particularly among children who were in care for more than 30 hours per week. Also using the LSAC data, Claessens (2009) examines the association between general cognitive ability and socio-emotional skills at the age of four or five and academic achievement four years later and finds that cognitive ability at the age of 4 or 5 is an important predictor of achievement in middle childhood. Quite differently, Leigh and Yamauchi (2009) use the LSAC data to examine the impact of non-parental care on children’s behavioural outcomes at the ages of 2 and 3 and find only small differences in the temperament of children who attended non-parental care and those who did not. The negative association between behaviour and non-parental care was weaker in child care centres with smaller groups of children.

2.4 Teacher Qualifications

While most of the available evidence is in favour of pre-school teachers having some type of teaching or child care qualification, the debate about the most appropriate and effective type of qualification for pre-school teachers has not yet been definitively resolved. Several studies have demonstrated that specialized training in early childhood education and care is related to the quality of pre-school teachers' interactions with children. For example, children who are educated by teachers with both a Bachelor degree and specialized training in child development and early education have been found to be more sociable, exhibit a more developed use of language, and perform at a higher level on cognitive tasks than children who are cared for by less-qualified adults (Howes, 1997; Whitebook and Ryan, 2011). Child care staff with higher levels of education have been shown to engage in warmer interactions with children; and are likely to less authoritarian and more able to demonstrate positive interaction styles (Abbott and Langston, 2005; Burchinal et al., 2005). This research, along with evidence about the long-term benefits of high quality targeted pre-school programs, has led to increased calls for pre-school teachers to have at least a Bachelor degree, preferably with a specialization in early childhood education (Barnett, 2003; Whitebook, 2003; Early et al., 2007).

However, recent studies of the relationship between pre-school teacher qualifications and children's cognitive outcomes have found contradictory results, and there is no conclusive evidence that a teacher with a Bachelor degree, or any other specific level of education, will ensure a high-quality pre-school classroom or better cognitive outcomes (Tout, Zaslow, and Berry, 2005; Early et al., 2006). In a study of 878 children attending state funded pre-kindergarten programs in the United States in 2002, Early et al. (2006) find that teachers' education level is linked to gains in children's numeracy skills, but not literacy or basic skills, across the pre-kindergarten year. They conclude that the National focus on literacy may result in pre-school teacher preparation programs at all levels concentrating on preparing teachers to work on language and pre-literacy skills, making teacher qualifications unimportant in predicting children's gains in literacy. Using seven major studies of classroom based educational programs for 4-year-olds in the United States, Early et al. (2007) find no convincing evidence of an association between pre-school teachers' education or major and children's academic gains.[2]

[2] Two of the studies indicated that quality was higher when the teacher had a Bachelor degree; one study indicated that quality was lower when the teacher had a Bachelor degree, and four studies found no association.

Early et al. (2007) conclude that policies focused solely on teachers' education will not suffice for improving classroom quality or maximising children's academic gains; but caution that these findings do not indicate that teacher's qualification levels are unimportant, and provide several explanations for the lack of association. First, many teachers completed their university training at a time when numeracy and pre-reading skills were deemphasized for young children. Second, the importance of the teacher-child relationship has possibly been underemphasized in early childhood teacher preparation programs, resulting in some degree qualified teachers with substantial content knowledge around academic instruction lacking the necessary skills for forming individual teacher-child relationships that can serve as the base for academic learning. Third, teachers may not receive sufficient on-the job support and may feel pressure to abandon what they were taught in their teacher education programs and adhere to the school's standards and teaching strategies. Finally, the lack of association between teacher qualification and children's outcomes may be a result of market forces. The higher wages and benefits provided in publicly funded programs, as compared with community-based child care, may attract and retain the best teachers without a Bachelor degree to the public system; while the lower wages provided in pre-kindergartens compared to elementary schools may lead high quality degree qualified teachers to teach older children (Early et al., 2007).

In Australia, early childhood education programs are often assumed by parents to be homogeneous in nature. However, they differ by community and state in terms of philosophical and educational approaches, the number of hours available, the location in which programs are provided, and the age at which children can enroll (Elliott, 2006). Pre-schools and kindergartens are operated by a variety of providers including schools, not-for-profit community groups and profit-making businesses; and may be stand-alone services, attached to schools or provided in child care centres. Because of these differences, pre-school children are likely to have widely varying experiences, with heterogeneous effects on learning and developmental outcomes.

In 2004, there were no nationally agreed or consistent standards for staffing across the child care and pre-school sector. The type and level of qualification of the teacher or carer was linked mainly to the age of the children, the size of the group and the type of setting, with older children typically being cared for by better qualified staff, but only in some settings and some states (Elliott, 2006). Across Federal Government approved pre-school services in 2004, the proportion of staff with relevant child care or teaching qualifications ranged from 69% in the Northern Territory to 46% in Victoria (Brennan, 2008). While long day care centres provide better support for the child care needs of working parents, there is a strong public perception that stand alone pre-schools have higher standards of educational quality than pre-school programs in long day care centres, mainly due to the fact that the legislated quality requirements for stand-alone pre-schools are higher than for long day care, with no legislative requirement to employ a teacher in long day care in most jurisdictions (Dowling and O'Malley, 2009).[3]

In recognition of the importance of early childhood education, pre-school education in Australia is currently undergoing significant restructure. In November 2008, the Council of Australian Governments (COAG) endorsed a new National Partnership Agreement on Early Childhood Education. Under this agreement, the Commonwealth, State and Territory governments have committed to ensuring that by 2013, all children in the year before formal schooling will have access to a high quality early childhood education program delivered by a degree qualified early childhood teacher for 15 hours per week, 40 weeks of the year (COAG, 2009). A new National Quality Standard for early childhood education and care providers will also be introduced. By 1 January 2014, an early childhood teacher will need to be in attendance all of the time when long day care and pre-school services are being provided to 25 children or more, and at least some of the time when services are being provided to less than 25 children. Within each long day care centre or pre-school, half of all staff will need to have (or to be actively working towards) a diploma-level early childhood education and care qualification or above, and the remaining staff will all be required to have (or be actively working towards) a Certificate III level early childhood education and care qualification, or equivalent.

To meet this commitment, the Australian Government has announced additional university places in early childhood education courses, the removal of TAFE fees for Diplomas and Advanced Diplomas of Early Childhood Education and Care, and a 50% HECS-HELP remission for early childhood education teachers who are willing to work in rural and regional areas, Indigenous communities and areas of socio-economic disadvantage (Harrington, 2008). The state governments have also introduced scholarship and incentive programs to encourage people to qualify and work in early childhood teaching. For example, the Victorian state Government provides financial support for educators currently working in a Victorian early childhood education and care service who wish to upgrade or attain an approved early childhood qualification; as well as incentives of up to $12,000 for graduate Early Childhood Teachers and $6,000 for diploma qualified educators to take up and maintain employment in hard to staff areas.[4]

[3] New South Wales is the only state that legally requires all centre-based care to employ a degree trained early childhood teacher once child numbers exceed 29. However, there is anecdotal evidence to suggest that long day care providers in New South Wales enroll 29 children or less precisely to avoid this requirement (Dowling and O'Malley, 2009).

[4] The amount of the financial incentive offered to upgrade or attain a qualification in early childhood education and care ranges from $1,000 for Certificate-Level qualifications, to $3,000 for a Diploma of Early Childhood Education and Care (previously known as Diploma of Children's Services) and $12,000 for an Early Childhood Teaching Degree. Upon completion of their qualifications, educators who received this support are required to work in a Victorian licensed or approved education and care service for 12 months (Certificate Level), 18 months (Diploma level) or 2 years (Degree level). To qualify for financial incentives, educators taking up employment in heard to staff areas are required to maintain employment in that area for a period of 12 months (Diploma-level qualification) or 2 years (Degree qualified teachers).

2.5 The Critical Issue of Selection Bias

One of the main issues faced by researchers attempting to identify the effects of non-compulsory, large-scale pre-school programs is that of selection bias. Children's pre-school experiences are not randomly determined. Parents who place a high value on their children's education may be more likely to enroll their children in a high quality pre-school program. Therefore, better educational outcomes are not likely to be due entirely to the pre-school program, but also to greater parental support. Children who attend high quality pre-school programs may also be more advantaged in terms of household income and parental education. This advantage may translate into superior levels of achievement and, if not adequately controlled for, may result in upwardly biased estimates of the effects of pre-school on later academic outcomes (Speiss et al., 2003; Berlinski et al., 2008; Magnuson et al., 2007a).

The simplest approach to addressing the selection issue is to include a rich set of control variables to account for potential confounding factors (see for example, Speiss et al., 2003 and Magnuson, Ruhm and Waldfogel, 2007b). However, despite the inclusion of such "observed" controls, there may be other "unobserved" characteristics which could result in an upward bias of the estimates of pre-school effects. Other strategies that have been used to overcome the problem of selection bias include the instrumental variables approach and propensity score matching. Examples of studies which have used an instrumental variables approach include those of Magnuson Ruhm and Waldfogel (2007a), who use state pre-school expenditure per child as their instrumental variable; Dumas and LeFanc (2010), who instrument pre-school attendance by the average age of pre-school entry by region and cohort; and Berlinski, Galliani and Manacorda (2008) who use average pre-school enrollment by locality and cohort as an instrument for treatment.[5] Studies which have used propensity score matching to test for bias in their OLS estimates of the effects of pre-school participation on subsequent educational outcomes include those of Magnuson, Ruhm and Waldfogel (2007a), Loeb et al. (2007) and Goodman and Sianesi (2005).[6]

[5] Of these three studies, only Dumas and LeFranc (2010) found that the instrumental variable estimates of the effect of pre-school participation, while positive and significantly significant, were smaller than those obtained in the OLS specification.

[6] All three studies found that the predicted outcomes resulting from propensity score matching were quite similar to their OLS results and concluded that the OLS results were not upwardly biased as a result of using an inappropriate control group.

3. Data

Data used for this analysis is drawn from Waves 1 and 3 of Longitudinal Study of Australian Children[7] (LSAC) survey, conducted in 2004 and 2008 respectively. LSAC gathers comprehensive, national Australian data on important aspects of a child's life, including their experiences within their families and communities; child care experiences and experiences in early education. The LSAC data also provide substantial information about various aspects of children's development, including physical and mental health; motor skills; social, cognitive and emotional development; and language, literacy, and numeracy. The first wave of LSAC interviews were conducted between March 2004 and January 2005. Families were subsequently interviewed every two years, and between-waves mail-out questionnaires were sent to families in 2005, 2007 and 2009. Information is collected for two cohorts of approximately 5000 children who were aged 0-1 (B Cohort) and 4-5 (K cohort) in 2004. We use the older sample of children, aged 4-5 in 2004. The age of the children at the time of interview ranges from 4 years and 3 months to 5 years and 8 months. In total, observations for 4983 children are available in wave 1. However, since the focus of this research is pre-school attendance and its effects on later cognitive outcomes, our sample is restricted to the 4157 children who had not yet begun formal schooling in 2004. See Gray and Smart (2009), Commonwealth of Australia (2012), and Hahn and Haisken-DeNew (2013) for further technical details on the LSAC data.

Cognitive outcomes are measured using National Assessment Program—Literacy and Numeracy (NAPLAN) Scores. In Wave 3 of LSAC, 81% of parents of kindergarten cohort children gave consent for their child's data to be linked with NAPLAN data for the duration of the study. Of the 4157 observations of children who were aged 4 or 5 and not yet in a pre-year 1 program in 2004, 3638 families (87.5%) were interviewed in 2008. Of the 3638 children, consent to match NAPLAN scores to the LSAC data was obtained from 2977 (81.8%) of parents, and 2696 children had valid NAPLAN information for all five domains. Of those 2696 children, 2229 were re-identified in year 3 in 2008.

3.1 NAPLAN Scores

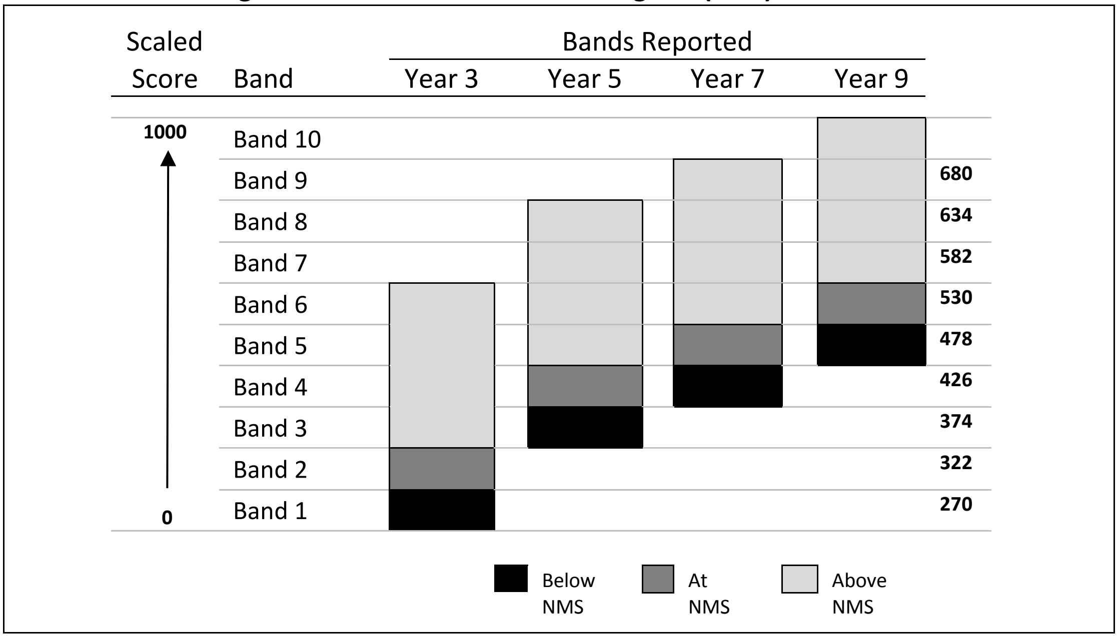
In May 2008, the National Assessment Program - Literacy and Numeracy (NAPLAN) commenced in Australian schools. Every year, students in Years 3, 5, 7 and 9 in government and non-government schools are assessed using common national tests in of Numeracy, Reading, Writing and Language Conventions (Spelling, Grammar and Punctuation). The NAPLAN tests broadly reflect aspects of literacy and numeracy common to the curriculum in each state or territory, with test formats and questions chosen so that they are familiar to teachers and students across Australia (ACARA, 2011). The tests are taken over a period of three days, with writing and language conventions tests taken on

[7] See Hahn and Haisken-DeNew (2013) for information on how to extract data from the LSAC using PanelWhiz, a user-written Stata add-on.

the same day. At the Year 3 level, the Numeracy and Reading tests are 45 minutes in duration and the writing and language conventions tests each take 40 minutes. Tests for Numeracy, Reading and Language Conventions consist of multiple-choice questions and constructed response items. The NAPLAN Writing task requires students to write a response to a stimulus or prompt.[8]

The skills assessed in the four NAPLAN tests are mapped onto national achievement scales that span Years 3, 5, 7 and 9, with scores that range from 0 to 1000 (ACARA, 2008). The results of the Language Conventions test are divided into two separate scores — one for Spelling and one for Grammar and Punctuation. The scale for each domain is divided into ten bands to cover the full range of student achievement from Year 3 through to Year 9. In 2008, each of the scales was standardized independently to have a mean of 500 and a standard deviation of 100 (VCAA, 2010). At each year level, only six of the ten bands are used for reporting student achievement. The Year 3 report shows Bands 1 to 6, the Year 5 report shows Bands 3 to 8, the Year 7 report shows Bands 4 to 9, and the Year 9 report shows Bands 5 to 10. The National Minimum Standard (NMS) is defined for each domain as the second lowest National Assessment Program (NAP) band reported for a year level, as shown in Figure 1.

Figure 1: National Assessment Program (NAP) Scale



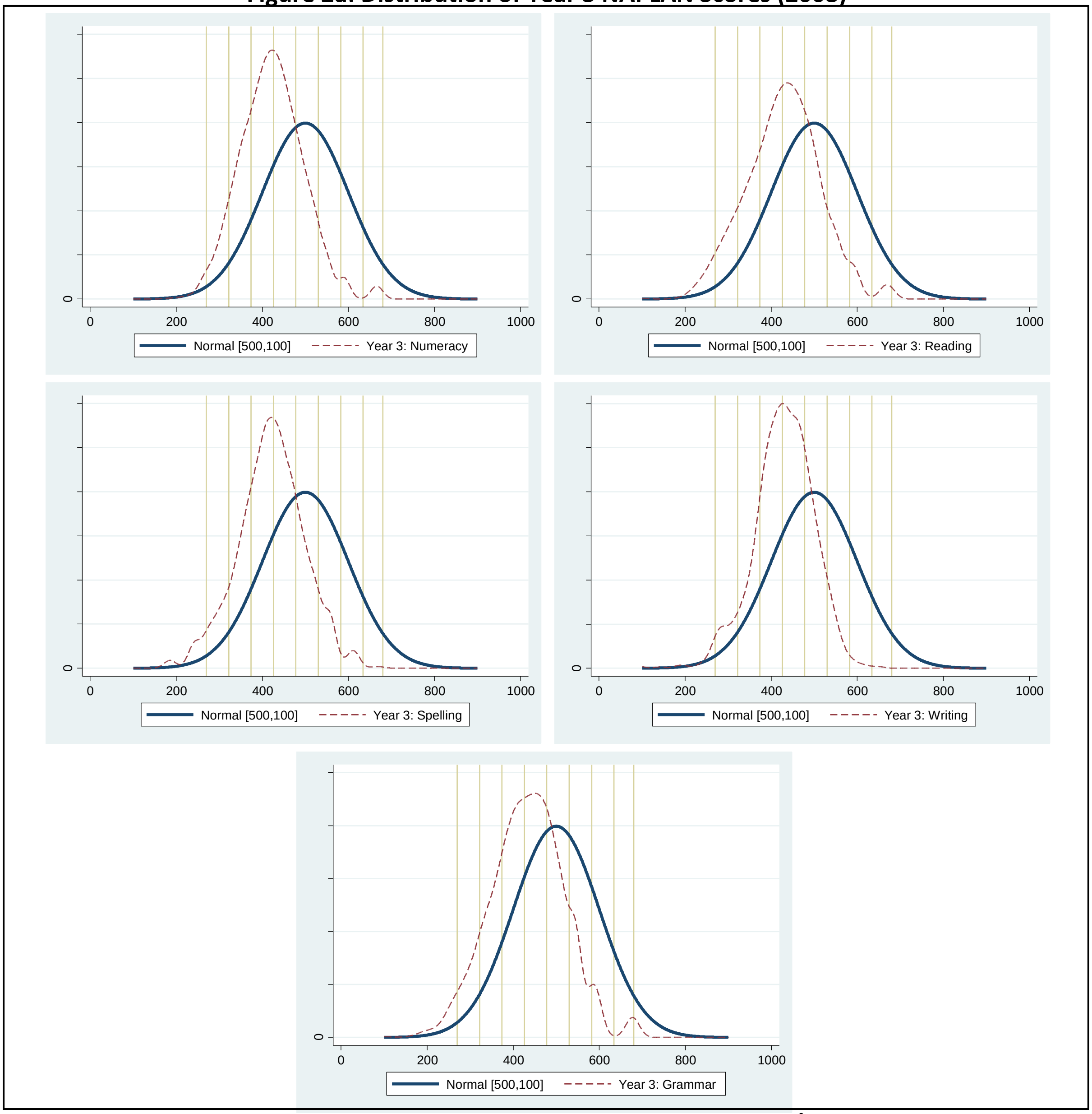
Source: VCAA (2010)

[8] Optical mark recognition is used to score multiple choice items and optical character recognition and professional officers are used to score constructed response items. Writing is marked by professional officers, with ongoing monitoring of marking consistency across all marking centres (ACARA, 2008). Between 2008 and 2010, the writing task was a narrative assessed against 10 criteria: Audience, Text Structure, Ideas, Character and Setting, Vocabulary, Cohesion, Paragraphing, Sentence Structure, Punctuation and Spelling. From 2011, the NAPLAN Writing task has required students to respond to a stimulus with a piece of persuasive writing.

For Year 3 students, a scaled score in Band 1 (lower than a NAPLAN score of 270) is considered to be below the NMS, a score in Band 2 is at the NMS and scores in Bands 3 to 6 are above the NMS. Students at the NMS have typically demonstrated the basic elements of literacy and numeracy to participate at their year level, while those who do not achieve the National Minimum Standard may need intervention and support to help them achieve the literacy and numeracy skills they require to progress satisfactorily through their schooling (ACARA, 2008).

In Figure 2, the distribution of Year 3 2008 scores are plotted against a normal distribution with a mean of 500 – which is what the standardized scores for Years 3 to 9 should look like. The vertical lines in Figure 2 represent the pre-defined cut-points for the 10 NAP Bands. Of course, the Year 3 distributions are to the left of the distribution for all year levels.

Figure 2a: Distribution of Year 3 NAPLAN Scores (2008)



Average NAPLAN scores and the proportion of scores within each NAP band are shown in Table 1, according to whether the child had attended a pre-school or kindergarten in the year prior to their first year of school.[9]

Table 1: NAPLAN Scores, by Pre-school Attendance, Mean and proportion in each NAP band

	NAPLAN Band							
	Below NMS	AT NMS	Above NMS					
	1	2	3	4	5	6	Total	Mean
Numeracy								
Pre-school	1.64	5.53	18.67	26.86	25.52	21.78	100.0	422.79
No Pre-school	*4.26	*7.52	28.97	23.24	25.66	10.36	100.0	396.35
Total	1.89	7.60	27.25	23.77	25.54	20.70	100.0	420.27
Reading								
Pre-school	3.26	9.04	13.55	19.76	28.58	25.82	100.0	427.55
No Pre-school	*5.20	13.08	22.40	20.84	21.84	16.64	100.0	398.39
Total	3.45	9.42	14.38	19.86	27.94	24.95	100.0	424.79
Spelling								
Pre-school	2.65	7.88	13.61	26.90	27.02	21.94	100.0	422.46
No Pre-school	*4.22	13.58	23.88	26.60	15.66	16.04	100.0	397.64
Total	2.80	8.42	14.58	26.87	25.94	21.38	100.0	420.10
Writing								
Pre-school	2.20	4.05	13.44	26.22	27.74	26.35	100.0	429.84
No Pre-school	*3.22	*6.82	19.00	30.55	21.71	18.72	100.0	408.28
Total	2.30	4.31	13.97	26.63	27.17	25.63	100.0	427.81
Grammar and Punctuation								
Pre-school	2.53	6.06	14.40	25.72	19.21	32.07	100.0	434.00
No Pre-school	*6.14	*7.41	22.18	25.52	17.82	20.93	100.0	404.96
Total	2.88	6.19	15.14	25.70	19.08	31.01	100.0	431.24

Note: Population weighted results. * Cell count < 20.

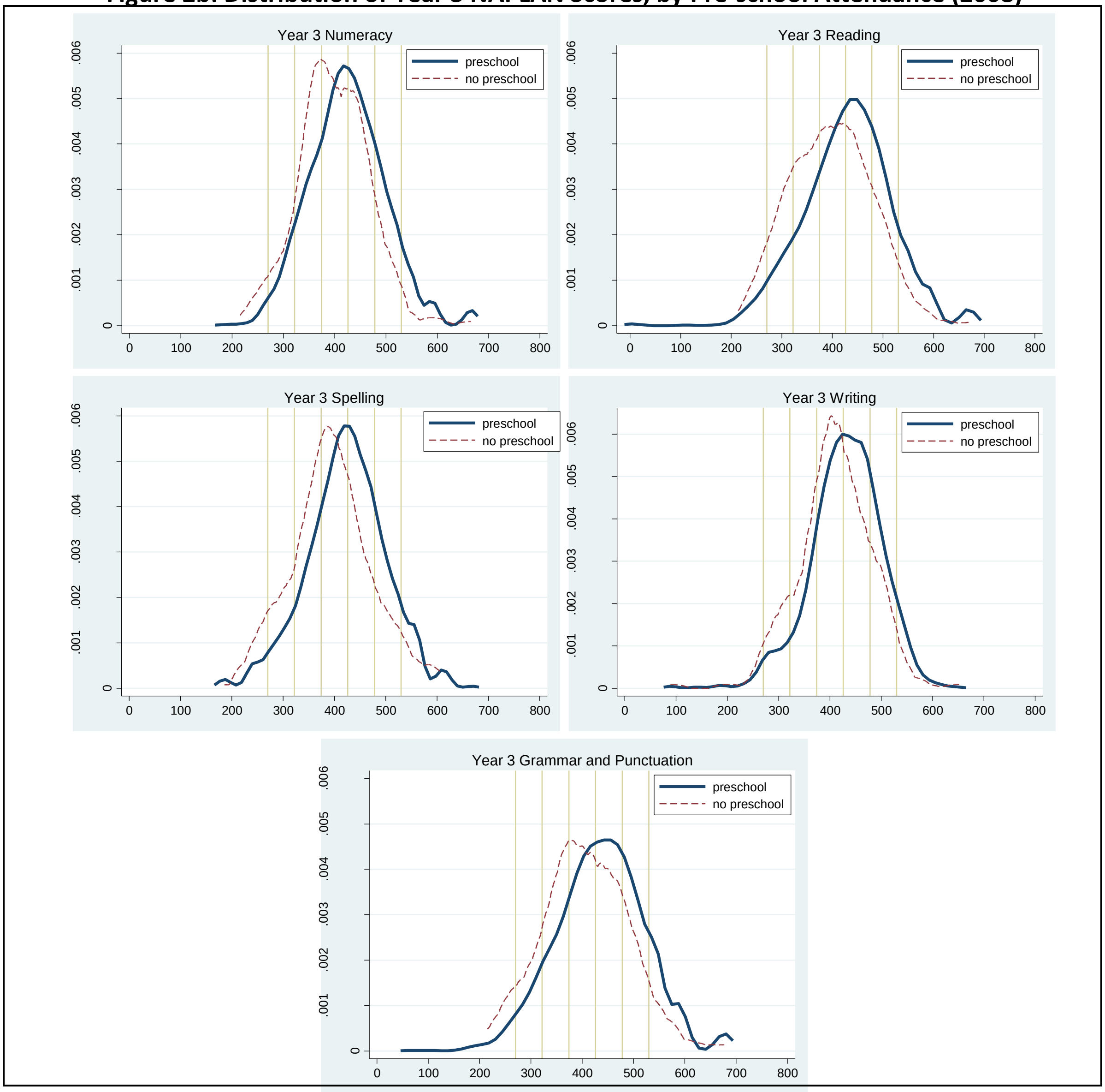
Compared to children who did not attend pre-school in 2004, average NAPLAN scores were 20 to 30 points higher among children who had attended some type of pre-school program.[10] Looking at the distribution of test scores according to NAP band, it is clear that the proportion of children with scores in Band 6 is considerably higher among children who had attended pre-school. For example, only 10% of children who did not attend pre-school had Numeracy scores in Band 6, compared to 22% of children who had participated in a pre-school program.

Kernel density plots of test scores of children who did, and did not, attend a pre-school program are shown in Figure 2b. Across all five domains, the distribution of test scores for children who did not attend pre-school sits to the left of the distribution for children who did attend a pre-school program.

[9] It should be noted that the sample used in this study is not perfectly representative of the target population. For children who completed their Year 3 NAPLAN tests in 2008, average scores for this sample were approximately 20 points higher than those reported for the Australian population by the Australian Curriculum Assessment and Reporting Authority (2008). This difference could possibly be a result of higher levels of attrition among families of children who achieved lower than average NAPLAN scores, but is more likely to be due to parents of children who received lower NAPLAN scores being more hesitant to agree to their child's NAPLAN Scores being matched with the LSAC data.

[10] For all domains, mean scores for pre-school and no-pre-school are significantly different at the 1% level in a two-tailed test.

Figure 2b: Distribution of Year 3 NAPLAN Scores, by Pre-school Attendance (2008)



The descriptive evidence above indicates that compared to children who did not attend a pre-school program, children who went to pre-school in the year prior to their first formal year of schooling had significantly higher levels of academic achievement, as measured by NAPLAN scores in year 3. However, it is important to note that the simple differences in test scores between children who attended a pre-school program and those who did not should not be regarded as causal, as they may simply reflect other characteristics, such as household income and parental education, which may be correlated with both pre-school attendance and NAPLAN test scores. Sample characteristics indicate that children who did not attend pre-school were less advantaged than those who attended a pre-school program. For example, children who did not attend any type of pre-school program more commonly lived in low income and lone parent households, and children whose parents did not complete high school were less likely to have attended pre-school. To control for these differences in characteristics, multivariate regressions are conducted.

4. Empirical Application

4.1 Descriptive Estimations

Most studies of the effects of pre-school participation report average differences between pre-school and non-pre-school participants, controlling for differences in socio-demographic characteristics. However, the estimated average pre-school effect may not be representative of the effect of pre-school participation at specific parts of the NAPLAN score distribution. For example, it would be useful to know whether the positive association between pre-school attendance and test scores is larger at the lower end of the distribution or at the higher end.

The ordinary least squares (OLS) estimates take the following form:

$$y_i = \beta_1 + \beta_2 \text{PRE}_i + \beta_3 x_i + \varepsilon_i \qquad (1)$$

where y_i is the NAPLAN score in Reading, Writing, Spelling, Grammar and punctuation or Numeracy for child i in year 3,

PRE_i is a dummy variable indicating attendance at pre-school in the year prior to formal schooling,

x_i is a vector of explanatory variables, and

ε_i is the error term.

The coefficients in (1) give the average marginal effect of the corresponding variables on test scores other things equal. For example, the regression coefficient, β_2, estimates the marginal effect of pre-school attendance on NAPLAN test scores in Year 3.

In order to identify differences in the benefits of pre-school attendance at different points on the test score distribution, the method of quantile regression (proposed by Koenker and Bassett, 1978) is used. The quantile regression technique may be viewed as a natural extension of least squares estimation of conditional mean models, to the estimation of a group of models for conditional quantile functions. The conditional quantile is specified as a linear function of covariates. For the θth quantile, a common way to write the model (Buchinsky, 1998) is

$$y_i = \beta_1 + x_i \beta_\theta + \varepsilon_{\theta i} \qquad (2)$$

where y_i is the dependent variable (NAPLAN score)

β_θ is an unknown vector of regression parameters associated with the θth quantile,

x_i is a vector of independent variables, and $\varepsilon_{\theta i}$ is the error term.

The interpretation of quantile regression estimation results is different to that of OLS as quantile coefficients provide information about effects at a certain point in the outcome distributions, not individuals. For example, a statistically significant pre-school indicator coefficient tells us that at that particular test score quantile, children who attended pre-school have a higher test score than those who did not attend pre-school, holding all else constant.

As mentioned in Section 2.5, children's pre-school experiences are not randomly determined and one of the main issues faced by researchers attempting to identify the effects of non-compulsory, large-scale pre-school programs is that of selection bias. The instrumental variable method is potentially useful for addressing this issue, provided strong and identifying instruments are available. However, in the data available for this analysis, such instruments do not exist because most measurable factors that affect the probability of attending pre-school can also arguably influence later cognitive outcomes. Therefore, to address the issue of selection bias, we rely on Kernel-based propensity score matching to estimate the Average Effect of Treatment on Treated (ATT). Thus using observed characteristics, we compare those children who had similarly high propensities to attend pre-school and did indeed attend, to those who were otherwise observationally equivalent, but did not attend pre-school. It is assumed by design that the observed characteristics used in the matching process are sufficient to identify the matching process.

The explanatory variables used in the econometric models can be categorised into four groups: (a) characteristics of the child (gender, age, Aboriginal or Torres Strait Islander Status, birth weight and whether the child was in poor health in 2004); (b) characteristics of the household (household size, household income, indicators of the presence of younger or older siblings, whether the child was living in a lone parent household in 2004 and whether a language other than English is spoken in the home); (c) characteristics of the mother (education level, age at the time the child was born and employment status in 2004) and (d) regional characteristics to account for differences in the provision and availability of pre-school programs in different states (state of residence, whether the family was living in a metropolitan area).[11]

4.2 Empirical Results: Average OLS and Distributional Quantile Effects

The results of the average OLS and quantile estimations of pre-school effects at various cut-points are summarised in Table 2.[12] For each NAPLAN domain, the quantiles estimated are chosen to correspond to the cut-points for NAPLAN bands. Therefore the estimated quantiles vary according to the domain being considered. For example, the estimates in column 2 represent the point at which the National Minimum Standard is attained (the cut point between Band 1 and Band 2). For the domains of Numeracy and Writing, 4% of students had scores at or below this cut point. For the other domains, 5% of students had NAPLAN scores at or below this threshold. Examining Figure 2a shows how the individual NAPLAN score distributions match up to the pre-defined Bands 1 through 10.

[11] Appendix Table A1 provides a detailed description of the explanatory variables and sample summary statistics.

[12] Detailed results are provided in Appendix Tables A2 to A6.

After controlling for a rich set of socio-demographic characteristics, a significant positive association between pre-school attendance and Year 3 NAPLAN outcomes remains across all five domains. The magnitude of the "pre-school advantage" ranges from 11 points for Writing to 19 points for Reading. That is, compared to children who did not attend pre-school, the average test scores of children who did attend pre-school were 11 points higher for Writing and 19 points higher for Reading. One way to think about the magnitude of these effects is that the cut point for the National Minimum Standard increases from 270 points (out of a hypothetical score maximum of 1000 points) in Year 3 to 374 points in Year 5. Therefore, the effect of one year of primary school at this level could be considered equivalent to 52 NAPLAN points (374-270=104, divided by 2 years (3 to 5) equals 52 points/year).

Table 2: OLS and Quantile Estimates, Effect of Pre-school Attendance on Year 3 NAPLAN Scores

Numeracy	**Average**	**Lev 1/2 (Q04)**	**Lev 2/3 (Q10)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q54)**	**Lev 5/6 (Q79)**
	13.647**	6.362	0.231	**12.042***	**10.621****	**20.852*****
	(5.591)	(19.014)	(14.407)	(6.223)	(5.320)	(7.718)
R^2 / pseudo R^2	0.137	0.086	0.069	0.083	0.074	0.075
Reading	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q14)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q49)**	**Lev 5/6 (Q75)**
	18.697***	-0.407	17.761	**27.408*****	**22.957*****	**16.845*****
	(4.536)	(12.139)	(12.037)	(8.526)	(6.571)	(4.786)
R^2 / pseudo R^2	0.146	0.102	0.092	0.090	0.077	0.060
Spelling	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q13)**	**Lev 3/4 (Q27)**	**Lev 4/5 (Q54)**	**Lev 5/6 (Q80)**
	17.316***	22.588	**19.426***	**18.525*****	**20.675*****	**24.063****
	(6.398)	(14.034)	(10.768)	(6.910)	(6.849)	(10.614)
R^2 / pseudo R^2	0.110	0.103	0.084	0.067	0.056	0.052
Writing	**Average**	**Lev 1/2 (Q04)**	**Lev 2/3 (Q08)**	**Lev 3/4 (Q22)**	**Lev 4/5 (Q48)**	**Lev 5/6 (Q75)**
	10.868**	10.406	19.773	12.867	**11.036****	10.963
	(4.272)	(13.851)	(12.610)	(9.360)	(5.175)	(10.494)
R^2 / pseudo R^2	0.110	0.103	0.084	0.067	0.056	0.052
Grammar and	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q11)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q50)**	**Lev 5/6 (Q69)**
Punctuation	**14.351****	**33.642*****	12.060	11.324	**17.411****	9.528
	(5.823)	(11.122)	(15.292)	(8.040)	(7.641)	(9.496)
R^2 / pseudo R^2	0.151	0.099	0.097	0.092	0.083	0.074

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively. Wald tests reject the null hypothesis of equality of the pre-school coefficient across the five quantiles considered.

The quantile estimates indicate that for some domains, the benefits of pre-school attendance are most significant at the top end of the test score distribution. For example, for Numeracy, the magnitude of the pre-school coefficient is largest at the cut point between Bands 5 and 6. This result suggests that for Numeracy, it is the strongest students who benefit most from attending pre-school, while students at the lower end of the distribution seem to gain no significant advantage.

For Reading, the results are quite different. While the pre-school coefficient is statistically significant at the three cut points that are above the National Minimum Standard, the magnitude of the effect is largest at the cut point between Bands 3 and 4. That is, students whose test scores are just above the National Minimum Standard gain the most from having attended pre-school, and the magnitude of the effect, while still significant, is lower at the top end of the test score distribution.

For Spelling, as was the case with Reading and Numeracy, the pre-school coefficient is significant at the three cut points which represent test scores that are above the National Minimum Standard, and significant at the 10% level for children whose test scores are at the cut point between Bands 2 and 3. So, while the benefits of having attended pre-school are largest at the top end of the distribution, children whose Spelling scores are at the lower end of the distribution also appear to gain some benefit from attending pre-school.

Compared to children who had not attended pre-school, those who went to pre-school had average test scores approximately 11 points higher for Writing and 14 points higher for Grammar and Punctuation. For these domains, it appears that children whose test scores are around the median are the ones who gain the most from attending pre-school.[13] Three years after the treatment of attending pre-school, these students appear to be doing substantially better than children who had not attended pre-school.

The results concerning other explanatory variables included in the model are also interesting in their own right. On average, boys score higher than girls in Numeracy; while girls score higher than boys in Writing, Spelling, and Grammar. Children of Aboriginal or Torres Strait Islander background have substantially lower scores for Spelling, Grammar and Numeracy. Compared to children who do not speak a language other than English at home, children who speak a second language have significantly higher Spelling scores.[14] On average, children who weighed less than 2.5kg at birth scored lower in Reading, Grammar and Numeracy than children who weighed 2.5 kg or more. The age of the child is also a significant factor, with average test scores increasing by 2 to 3 points for each additional month.

Household characteristics are also important. Compared to children who were the eldest or only child in the household, those who had an older resident sibling in the year prior to their first year of school had lower average test scores in Reading, Spelling and Grammar. This may be because children with older siblings receive less one-on-one time with their parents than first-born or only children, and there might also be differences in the type and quality of activities, including pre-school, that second and subsequent children participate in during early childhood. On the other hand, children who had younger resident siblings in the year before formal schooling had significantly higher scores for Grammar. This result could be due to a “tutoring effect”, whereby older siblings gain by teaching their younger siblings. Across all five domains, there was a small but significant effect of household income, with average test scores increasing by approximately 1 point with every $100 of weekly

[13] Although there appears to be a significant and large advantage in terms of Grammar scores for children whose test scores were below the National Minimum Standard, this result should be interpreted with caution due to the limited number of observations at the lowest part of the test score distribution.

[14] Average Reading and Writing scores were also higher. However, this difference was only significant at the 10% level.

household income. However, it should be noted that the income coefficient may reflect the association of parental employment to child outcomes, rather than the causal impact of income itself.

The level of education of the child's mother is shown to be a very important factor determining educational outcomes. Across all five domains children whose mother had a degree had significantly higher test scores. Compared to children whose mother's highest level of education was Year 11 or below, average test scores of children whose mother had a degree-level qualification were 33 points higher for Numeracy, 41 points higher for Reading, 22 points higher for Spelling, 30 points higher for Writing and 36 points higher for Grammar. There are several explanations for the mother's strong influence. First, children whose parents have a higher level of education may have a higher level of innate ability, resulting in higher test scores. Second, children whose parents have a higher level of education may provide a better home learning environment for their children. Third, children whose parents have a higher level of education may place a higher value on their children's education and therefore choose to provide better educational opportunities for their children, including higher quality pre-school.

4.2.1 Controlling for Innate Ability

It is likely that the estimated benefits from pre-school attendance implied by the previous results are partly due to the innate ability of the child. In order to account for unobserved ability, the models were re-estimated with an additional control for the child's score in the *Who Am I?* (WAI) test taken at the time of the 2004 interview.

The WAI test is a measure of cognitive development created by the Australian Council for Educational Research (ACER) in 1997 (de Lemos and Doig 1999). The test was developed based on previous research about the use of copying and writing tasks for the assessment of children's developmental level and school readiness.[15] The test is administered in the form of an eleven page booklet in which children are asked to write their name, copy shapes (a circle, cross, square, triangle and diamond) and write letters, numbers, words and sentences with simple instructions and encouragement from their interviewer.[16] Each response is assessed on a four-point scale relating to the skill required for the task. A score of 0 is assigned if no attempt was made on the item. Final test scores are transformed to a scale with a mean of 64 and standard deviation of 8 (Rothman, 2007).This test has several advantages over other measures of cognitive development in early childhood. It is

[15] Children's ability to copy regular geometrical forms has been shown to be strongly associated with cognitive development and subsequent school achievement; letter recognition has been found to be strongly related to later achievement in reading; and there is a proven link between children's early attempts at writing and their understanding of the way in which spoken sounds are represented in print (Doig, 2005).

[16] In the standard *Who Am I?* test, the final task requires children to draw a picture of themselves — a task that is commonly used as a measure of developmental level (Doig, 2005). For the LSAC testing, this task was replaced with a sentence to be copied ('John is big'), presumably because the copying task would be faster and easier to score. Responses to the new item were judged in the same manner as other items, with levels from 0 to 4 (Rothman, 2007).

easy to administer and user friendly for young children; scores are stable over time and uniform across different evaluators; and it provides a reliable measure of development which is valid across cultural groups and among children whose knowledge of English is limited (Doig, 2005).[17] When the WAI measure is included in the set of explanatory variables, the explanatory power of the model increases substantially (Table 3).[18] This is to be expected, as a substantial proportion of a child's NAPLAN results must be explained by innate ability.

Table 3: OLS and Quantile Estimates, Effect of Pre-school Attendance on Year 3 NAPLAN Scores (including *Who Am I?* test score in 2004 in the set of explanatory variables)

Numeracy	**Average**	**Lev 1/2 (Q04)**	**Lev 2/3 (Q10)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q54)**	**Lev 5/6 (Q79)**
	9.970**	7.768	8.822	7.154	7.567	**13.027****
	(4.207)	(8.018)	(9.459)	(7.548)	(6.796)	(6.285)
R^2 / pseudo R^2	0.251	0.161	0.150	0.153	0.137	0.150
Reading	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q14)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q49)**	**Lev 5/6 (Q75)**
	14.691**	5.915	10.451	12.373	**16.154***	13.563
	(6.233)	(14.192)	(9.089)	(9.156)	(8.770)	(9.811)
R^2 / pseudo R^2	0.242	0.162	0.173	0.158	0.131	0.109
Spelling	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q13)**	**Lev 3/4 (Q27)**	**Lev 4/5 (Q54)**	**Lev 5/6 (Q80)**
	13.652***	13.672	13.502	**19.566***	**21.690*****	12.005
	(5.027)	(18.268)	(8.671)	(10.169)	(5.675)	(13.037)
R^2 / pseudo R^2	0.230	0.189	0.174	0.142	0.125	0.123
Writing	**Average**	**Lev 1/2 (Q04)**	**Lev 2/3 (Q08)**	**Lev 3/4 (Q22)**	**Lev 4/5 (Q48)**	**Lev 5/6 (Q75)**
	7.785	9.508	16.498	**13.480***	**11.284***	6.342
	(5.021)	(14.425)	(14.646)	(7.891)	(6.335)	(8.184)
R^2 / pseudo R^2	0.236	0.179	0.181	0.134	0.122	0.116
Grammar and	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q11)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q50)**	**Lev 5/6 (Q69)**
Punctuation	9.958	6.690	16.467	8.020	6.594	9.410
	(6.687)	(19.920)	(12.344)	(9.864)	(6.220)	(9.461)
R^2 / pseudo R^2	0.260	0.172	0.172	0.161	0.143	0.124

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively.

When innate ability is accounted for using the *Who Am I*? score, the magnitude of the pre-school coefficient is reduced by approximately 4 points. For Numeracy, Reading and Spelling, but not for Writing or Grammar, the pre-school coefficient remains positive and statistically significant. This result implies that our previous estimates of the impact of pre-school attendance on Year 3 Writing and Grammar scores may be upwardly biased because of unobserved ability. However, it should be noted that because the WAI test was conducted at the time of the 2004 LSAC interview (between March 2004 and January 2005), the WAI test results may be influenced by pre-school participation to some degree.[19]

[17] The cross-cultural validity of the *Who Am I*? test has been, in part, confirmed by the Canadian longitudinal survey through comparisons with the Peabody Picture Vocabulary Test. *Who Am I*? shows little bias due to language factors. In studies examining the cognitive development of Chinese children in Hong Kong and Anglo-Indian children in India, *Who Am I?* was adapted to non-Roman alphabets and ideographic writing. This appears to be unique in mathematics assessment at any level (Doig, 2005).

[18] For all five domains, the coefficient on the *Who Am I?* score is positive and significant, with each WAI point associated with an increase in the NAPLAN score of approximately 4 points.

[19] For children who had not attended preschool, the average WAI score was 61.2, compared to 63.6 for children who attended preschool. The mean WAI scores are significantly different at the 1% level in a two-tailed test.

4.3 Empirical Results: Causal Impacts by Propensity Score Matching

The average treatment effect on treated (ATT) and the average effect of treatment on untreated (ATU) resulting from Kernel matching of treatment and control cases are estimated for all five NAPLAN domains.[20] The propensity score is estimated using a probit model controlling for the age and gender of the child, birth weight, birth order, health, ATSI status, whether a language other than English is spoken at home; age, health and education level of the mother; household structure (household size, lone parent household) and location (state and region of residence and the number of homes the child has lived in since birth).[21] We account directly for otherwise unobserved ability by including the child's score on the *Who Am I?* test in the set of variables used for matching. However, it should be noted that these test scores are likely to be affected by pre-school participation. The ATT estimates presented in Table 4 can be interpreted as the difference in the mean NAPLAN scores between the set of students who attended pre-school and the observationally equivalent matched set of students who did not attend pre-school. The ATU estimates can be interpreted as the average increase NAPLAN scores of children who did attend preschool, if they had indeed attended preschool.

The key assumption of propensity score matching is that both the outcome of interest and the treatment assignment do not depend on unobservable characteristics. If a treated individual and a potential control unit have the same propensity score, then the difference between the treatment and control outcome means is an unbiased estimator of the treatment effect. However, even under the best circumstances, a propensity score analysis may not necessarily address selection bias on unobservable characteristics and thus may not produce causal estimates of the effect of pre-school participation.

[20] We use Kernel matching, a non-parametric matching approach that creates matches for the treatment using (biweight) kernel weighted averages of those not in the treatment (Heckman, Ichimura, and Todd, 1998). Kernel matching compares the outcome of each treated person to a weighted average of the outcomes of all individuals in the control group, with the highest weight being placed on those with scores closest to the treated individual. One major advantage of this approach is the lower variance, which is achieved because more information is used (Heinrich, et al., 2010). The Nearest Neighbour matching method was also tested. However, Kernel matching was more effective in building balanced treatment and control groups and reducing the standardized bias.

[21] To ensure that only variables that are unaffected by participation (or the anticipation of participation) are included in the matching model., variables should either be fixed over time or measured before participation (Caliendo and Kopeinig, 2005). For this reason, we do not match on mother's employment status or household income as the mother's decision to work, and hence household income, may be affected by the child's attendance at pre-school. Indicators of household structure are included in the matching variables – it is assumed that these have not changed between the time the child began pre-school and the date of interview. Excluding these variables from the matching does not substantially change the magnitude or significance of the estimates.

Table 4: Comparison of OLS estimates and Average Treatment Effects on Treated (ATT) and Untreated (ATU)

	Without "Who Am I"			With "Who Am I"		
	OLS	**ATT**	**ATU**	**OLS**	**ATT**	**ATU**
Numeracy	**13.649****	**18.154*****	**19.304*****	**9.970****	**15.213*****	**16.635*****
	(5.591)	(5.830)	(5.429)	(4.207)	(5.342)	(4.762)
Reading	**18.697*****	**20.942*****	**24.917*****	**14.691****	**18.012*****	**21.101*****
	(4.536)	(6.474)	(5.973)	(6.233)	(7.217)	(5.561)
Spelling	**17.316*****	**20.153*****	**21.550*****	**13.652*****	**17.507*****	**17.360*****
	(6.398)	(6.682)	(6.150)	(5.027)	(6.195)	(4.330)
Writing	**10.868****	**13.132****	**15.750*****	7.785	**10.067***	**11.957*****
	(4.272)	(5.593)	(5.860)	(5.021)	(6.195)	(4.220)
Grammar and Punctuation	**14.351****	12.149	**20.218*****	9.9581	9.563	**15.464*****
	(5.823)	(7.023)	(6.164)	(6.687)	(7.193)	(5.150)
% bias after matching		2.406			2.360	
		(2.124)			(1.880)	

Note: ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively. Bootstrap standard errors (N=50) in parentheses. ATT estimates are based on Kernel matching of treatment and control cases (Normal density with a bandwidth of 0.06).

For the domains of Reading, Spelling and Numeracy, the Average Treatment Effect on Treated (ATT) is statistically significant and slightly larger in magnitude than the OLS estimates. However, for Grammar, the estimated ATT is not statistically significant. This indicates that our estimates of the effects of pre-school participation in this domain is likely to be biased, and the association between pre-school attendance and test scores for Grammar domains should not be interpreted as causal. Estimates of the Average Treatment Effect on the untreated (ATU) are slightly larger than the ATT estimates and statistically significant across all five domains. This result suggests that the children who missed out on attending preschool are actually the ones who would have gained the most from attending.

When the *Who Am I?* score is included in the set of matching variables, the ATT and ATU estimates are reduced only by 2 to 4 points, depending on the domain being considered, the ATT estimates for Numeracy, Spelling and Reading remain statistically significant at the 5% level, and the ATU estimates remain statistically significant for all five domains. This result suggests that any bias resulting from unobserved ability is not likely to have a dramatic effect on our estimates of the effects of pre-school participation.

The home learning environment is likely to have a significant impact on children's test scores. However, the home environment may potentially be affected by pre-school participation, for example, the child's preschool teacher suggests that the child may benefit from attending a particular activity. For this reason, the ATT and ATU estimates are presented separately with the addition of controls for the home learning environment (how often the child is read to; the amount of extra-curricular activities such as sport and music classes the child attends; out of home activities such as going to the movies or the library; at home activities including reading, playing games, drawing and listening to music with parents; and the number of hours per week the child spends watching television and using a computer) in Table 4a.

Table 4a: Average Treatment Effects on Treated (ATT) and Untreated (ATU) – Including Controls for the Home Learning Environment

	Without "Who Am I"			With "Who Am I"		
	OLS	ATT	ATU	OLS	ATT	ATU
Numeracy	**13.649****	**14.955*****	**16.499*****	**9.970****	**12.433***	**13.058*****
	(5.591)	(6.441)	(4.597)	(4.207)	(7.157)	(4.623)
Reading	**18.697*****	**18.773****	**21.286*****	**14.691****	**16.059***	**18.102*****
	(4.536)	(7.177)	(5.135)	(6.233)	(8.520)	(5.185)
Spelling	**17.316*****	**19.086****	**20.138*****	**13.652*****	**15.870****	**17.015*****
	(6.398)	(7.758)	(5.831)	(5.027)	(7.466)	(5.741)
Writing	**10.868****	**10.078****	**13.712****	7.785	7.663	**10.538***
	(4.272)	(6.391)	(5.641)	(5.021)	(6.702)	(4.861)
Grammar and Punctuation	**14.351****	8.954	**16.014*****	9.9581	6.386	**12.160****
	(5.823)	(7.468)	(5.535)	(6.687)	(7.401)	(5.551)
% bias after matching		2.694 (1.934)			2.666 (2.085)	

Note: ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively. Bootstrap standard errors (N=50) in parentheses. ATT estimates are based on Kernel matching of treatment and control cases (Normal density with a bandwidth of 0.06).

When controls for the home learning environment are included in the set of matching variables, the magnitude of the ATT and ATU estimates are reduced by approximately 2 to 3 points. After controlling the home learning environment and the ability of the child, the ATT estimates for Numeracy, Reading and Spelling remain statistically significant and the ATU estimates remain statistically significant for all five domains. The proportion of children in our sample who attended pre-school is very high (over 90%). In order to reduce bad matches between the treatment and control group, and focus on the effects of pre-school participation for those with a lower probability of attending pre-school and therefore most at risk of underachievement in their early school years, we estimate the average treatment effect on treated after removing the top 25% of propensity scores. When the ATT is estimated using only the lower 75% of propensity scores, thereby eliminating matches between children who did not go to pre-school and children with a very high probability of attending pre-school, the quality of the matching (measured by the percentage reduction in bias after matching) is improved only slightly. The ATT increases in magnitude and is statistically significant for all five domains (not shown in tables). This suggests that our estimates of the effects of pre-school attendance may in fact be underestimated for those most at risk of underachievement.

In summary, after controlling for a rich set of socio-demographic characteristics, we find a significant positive association between pre-school attendance in the year before starting formal schooling and Year 3 NAPLAN test scores. The magnitude of the effect varies according to the domain being considered, with the most significant effects in the domains of Reading, Spelling and Numeracy. Quantile regressions show that for Numeracy, children whose test scores are at the higher end of the distribution benefit most from attending pre-school, while for Spelling and Reading, children whose test scores are around the middle of the distribution also benefit from attending pre-school.

Estimation of the Average Treatment Effect on the Treated using propensity score matching indicates that children who attended pre-school score *causally* about 20 points higher in Reading, Spelling and Numeracy compared to children who did not attend pre-school. This effect is reduced only modestly, to around 15 points, when we explicitly control for ability.

4.4 The Role of Pre-school Teacher Qualifications

In this section we examine the impact of the qualification of the pre-school teacher on Year 3 NAPLAN outcomes. We would expect that children attending pre-school programs with teachers having higher qualifications would attain higher test scores, compared to those whose pre-school teachers had lower qualifications.

The effects of specific teacher qualifications are estimated by replacing the 'pre-school' indicator in our previous estimates with a set of five dummy variables indicating the qualification level of the pre-school teacher. The LSAC questionnaire included a separate questionnaire to be filled out by the child's main teacher. However, the response rate for the teacher questionnaire in Wave 1 was only 68.8% and for the sample used in the previous estimations of pre-school participation, information about the qualification level of the teacher is only available for 1389 observations. To address proactively the issue of missing data, multiple imputation was used to impute the qualification level of the teacher for children whose teacher information was not available.[22]

Before proceeding to the estimation of the effects of teacher qualifications, the average NAPLAN scores according to the qualification level of the teacher (for children whose teacher qualification information was available) are presented in Table 5.

Among children who had attended a pre-school program in the year prior to formal schooling, average NAPLAN scores were highest among those whose pre-school teacher had a diploma-level qualification in early childhood education or child care, and lowest for those whose teacher had only a certificate-level qualification. Compared to children whose pre-school teacher had a diploma-level qualification, average NAPLAN test scores were slightly lower for children whose pre-school teacher had a degree qualification. However, for most domains this difference is not statistically significant.[23]

[22] Multiple Imputation generally outperforms other approaches such as listwise deletion and setting missing values to the mean, each of which can lead to bias and false identification of significant differences (Croy and Novins, 2005). Imputations are based on gender, ATSI status, LOTE, child health, child age, state of residence, metropolitan area, household size, lone parent household, presence of younger and older siblings, household income, mothers education, mothers employment status in 2004, mothers age when the child was born, weekly hours of pre-school and the type of pre-school attended (day care, school or non-school). Ten imputed data sets were created and regression and ATT coefficients were combined using Rubin's Rules, which adjust standard errors to account for variation between and across imputed datasets. Rubin (1987) shows that when the rate of missing information is 30%, the efficiency of an estimate based on 10 imputations is approximately 97%.

[23] Only for Reading is the difference in test scores between children whose teacher had a diploma-level qualification and those whose teacher had a teaching degree (not specialising in early childhood education) statistically significant at the 5% level. For Numeracy, the difference in test scores between children whose pre-school teacher had a diploma-level

Table 5: Year 3 NAPLAN Scores, by Pre-school Teacher Qualification (means)

	Numeracy	Reading	Spelling	Writing	Grammar and Punctuation
No Pre-school	396.35***	398.39***	397.64***	408.28***	404.96***
Early Childhood Teaching Degree (ECD)	421.60*	428.68	420.34	430.75	430.45*
Other Teaching Degree (TCD)	412.61*	418.93**	414.33	436.42	431.51
Adv. Diploma, Diploma, Ass. Dip in child care or early childhood teaching (CC)	428.66	435.69	424.36	430.73	441.60
Certificate level qualification in child care or early childhood teaching (CERT)	409.55*	402.36**	403.04*	416.17*	405.82**
Other (OTH)	423.73*	427.72	423.23	426.99	434.74

Note: Population weighted results. The 'Other' category includes teachers with no post school qualifications (some of whom were studying for a relevant qualification) as well as individuals who had qualifications in other fields e.g. nursing. ***, ** and * indicate that the mean is different from the 'Adv. Diploma, Diploma, Ass. Dip in child care or early childhood teaching' group at the 1%, 5% and 10% levels respectively in a two-tailed t-test.

In Table 6, descriptive and non-causal OLS and quantile estimates of the effects of specific teacher qualifications are presented. The control group is children who did not attend pre-school. Therefore the estimates can be interpreted as the difference in average test scores between students who did not attend pre-school at all and students whose pre-school teacher had a specific qualification. The results indicate that compared to children who did not attend pre-school, Year 3 NAPLAN scores are significantly higher among children whose pre-school teacher had a either a degree in Early Childhood Education or a diploma-level qualification in child care or early childhood education, particularly for the domains of Numeracy, Reading and Spelling.

For Numeracy, we find that compared to children who did not attend pre-school, those who attended pre-school with a teacher with a degree in Early Childhood education scored an average of 12 points higher, and children whose pre-school teacher had a diploma level qualification had average scores 17 points higher. As was the case for the simple pre-school versus no pre-school estimates, the quantile estimates indicate that for Numeracy, the benefits of pre-school attendance with a diploma or degree qualified teacher are greatest at the higher end of the distribution. At the cut point between Bands 5 and 6, children who attended pre-school with a teacher with a degree qualification in early childhood education had average test scores 19 points higher than children who had not attended pre-school, and children whose pre-school teacher had a diploma-level qualification had test scores 25 points higher than children who had not attended pre-school.

qualification and those whose teacher had a degree level qualification is significant at the 10% significance level. For Grammar and punctuation, the difference in test scores between children whose teacher had a degree in early childhood education and children whose pre-school teacher had a diploma qualification is significant at the 10% level.

Table 6: Effect of specific pre-school teacher qualifications on Year 3 NAPLAN scores

Numeracy	**Average**	**Lev 1/2 (Q04)**	**Lev 2/3 (Q10)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q54)**	**Lev 5/6 (Q79)**
ECD	**12.065****	-7.784	-4.714	9.717	9.127	**18.900****
	(5.841)	(14.678)	(10.380)	(6.917)	(6.497)	(7.702)
TCD	**14.692***	3.311	6.685	**15.450***	6.420	19.001
	(8.710)	(22.342)	(18.591)	(9.040)	(10.276)	(11.700)
CC	**17.398*****	6.367	4.863	**13.806***	**13.776****	**25.504*****
	(6.296)	(14.576)	(10.421)	(7.969)	(6.727)	(8.129)
CERT	12.069	12.033	-1.999	14.912	12.280	7.704
	(12.504)	(26.295)	(18.453)	(20.981)	(12.469)	(18.307)
OTH	11.366	-1.587	2.476	**15.134***	6.790	**18.714***
	(7.369)	(16.521)	(15.629)	(8.906)	(8.498)	(10.883)
R^2 / pseudo R^2	0.143	0.101	0.079	0.086	0.079	0.078
Reading	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q14)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q49)**	**Lev 5/6 (Q75)**
ECD	**17.476****	-8.637	13.582	**24.586****	**20.008*****	**16.382***
	(6.859)	(12.821)	(10.598)	(10.497)	(7.745)	(8.805)
TCD	**19.459***	7.009	16.968	24.597	**20.772***	18.450
	(10.048)	(20.179)	(14.711)	(18.876)	(12.560)	(11.460)
CC	**22.678*****	7.303	16.630	**31.269*****	**27.528*****	**22.432*****
	(7.188)	(11.483)	(11.888)	(10.860)	(8.764)	(8.577)
CERT	13.967	-3.001	13.685	23.634	17.210	6.699
	(15.106)	(79.850)	(29.794)	(18.301)	(16.833)	(18.400)
OTH	**17.200***	-1.451	17.104	**24.493***	**23.228****	16.363
	(8.977)	(20.319)	(12.544)	(12.648)	(9.961)	(12.175)
R^2 / pseudo R^2	0.147	0.100	0.093	0.095	0.081	0.064
Spelling	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q13)**	**Lev 3/4 (Q27)**	**Lev 4/5 (Q54)**	**Lev 5/6 (Q80)**
ECD	**16.709*****	21.466	21.482	**16.029****	**19.467*****	**21.120****
	(6.241)	(16.544)	(13.898)	(7.060)	(7.206)	(10.518)
TCD	**18.756****	27.491	27.018	**17.554***	19.307	19.803
	(9.078)	(24.691)	(18.602)	(10.248)	(12.368)	(13.552)
CC	**19.612*****	23.446	**23.929***	**22.978*****	**20.337*****	**23.545****
	(6.746)	(16.603)	(14.473)	(7.693)	(7.666)	(11.252)
CERT	16.402	26.469	32.574	23.707	19.525	19.580
	(12.879)	(37.873)	(23.356)	(16.970)	(15.258)	(17.230)
OTH	**14.833***	24.723	**27.203***	13.183	**20.401****	16.846
	(7.971)	(20.808)	(14.928)	(9.175)	(10.077)	(13.494)
R^2 / pseudo R^2	0.113	0.098	0.086	0.070	0.057	0.061
Writing	**Average**	**Lev 1/2 (Q04)**	**Lev 2/3 (Q08)**	**Lev 3/4 (Q22)**	**Lev 4/5 (Q48)**	**Lev 5/6 (Q75)**
ECD	**11.032****	13.798	**21.951***	13.835	**11.221****	11.040
	(5.432)	(13.704)	(11.778)	(8.827)	(5.566)	(8.355)
TCD	**21.694*****	19.728	**38.100****	**20.591***	**25.214****	**18.545***
	(7.495)	(20.334)	(16.181)	(12.356)	(10.501)	(10.600)
CC	**11.170***	10.508	16.234	9.827	10.769	11.152
	(5.842)	(13.400)	(12.386)	(9.365)	(6.806)	(9.088)
CERT	8.021	7.595	10.569	7.877	6.369	7.281
	(11.656)	(36.037)	(29.960)	(22.276)	(11.649)	(15.441)
OTH	8.777	3.505	19.362	11.821	5.569	7.922
	(6.789)	(16.704)	(16.192)	(10.232)	(7.361)	(9.778)
R^2 / pseudo R^2	0.148	0.142	0.130	0.083	0.077	0.070
Grammar	**Average**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q11)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q50)**	**Lev 5/6 (Q69)**
ECD	11.047	18.046	0.969	9.988	**14.167***	6.745
	(6.845)	(12.902)	(12.764)	(9.059)	(8.297)	(9.869)
TCD	16.625	**34.587***	14.252	12.920	9.430	8.802
	(10.393)	(17.975)	(15.335)	(14.671)	(13.673)	(16.047)
CC	**18.482****	**34.210****	10.847	11.801	**20.035****	**16.209***
	(7.477)	(14.703)	(13.055)	(10.342)	(8.604)	(9.719)
CERT	4.665	13.402	2.492	4.601	11.917	3.491
	(14.797)	(31.098)	(26.554)	(18.774)	(21.889)	(22.238)
OTH	11.717	**32.700****	19.356	12.501	6.293	1.678
	(8.945)	(16.662)	(14.796)	(10.254)	(11.173)	(12.187)
R^2 / pseudo R^2	0.157	0.105	0.104	0.096	0.087	0.082

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively. Teacher Qualifications: Early Childhood Teaching Degree (ECD); Other Teaching Degree (TCD); Adv. Diploma, Diploma, Ass. Dip in child care or early childhood teaching (CC); Certificate level qualification in child care or early childhood teaching (CERT); Other (OTH).

For Reading, Table 6 shows that compared to children who did not attend a pre-school program, children whose teacher had a relevant degree or diploma level qualification scored 17 to 23 points higher in their Year 3 NAPLAN tests. For Reading, the benefits of having a suitably qualified pre-school teacher are more evenly distributed over the test score distribution. Children whose NAPLAN scores are just above the National Minimum Standard (that is, at the cut point between Bands 3 and 4) benefit most from having a pre-school teacher with an appropriate qualification; and while there are also significant benefits for children with test score around the median (between Bands 4 and 5) and at the higher end of the distribution, the magnitude of the effect decreases as NAPLAN scores increase.[24]

Compared to children who did not attend pre-school, those who had a pre-school teacher with a relevant degree or diploma qualification scored an average of 17 to 20 points higher in their Year 3 Spelling tests. As was the case for Reading, the benefits from having a suitably qualified teacher were significant for children whose test scores were just above the National Minimum Standard (between Bands 3 and 4), around the median (Bands 4 and 5) and also at the higher end of the distribution. However, for spelling, the magnitude of the "pre-school effect" was highest at the top end of the distribution.

The NAPLAN Writing test is quite different to the other NAPLAN tests as it requires children to compose a piece of persuasive text in response to a stimulus or prompt. The results for Writing are also different to those for the other NAPLAN domains. While children whose pre-school teacher had a degree or diploma level qualification in early childhood education or child care had average scores approximately 11 points higher than children who did not attend pre-school, children whose pre-school teacher had a degree qualification without a specialization in early childhood (presumably a primary school teaching degree) had average test scores 22 points higher. It may be the case that children whose pre-school teacher had training that focused on teaching slightly older children gained a better foundation for creative writing.

For Grammar, it appears that only children whose pre-school teacher had a diploma-level qualification scored significantly higher than children who did not attend pre-school at all. The results indicate that children at the lowest end of the distribution benefit the most from having attended pre-school. However, this result should be interpreted with caution due to the limited number of observations at the low end of the test score distribution.

[24] It is possible that children whose test scores are at or below the National Minimum Standard also benefit from having attended preschool with a suitably qualified teacher. However, because there are very few observations for children with test scores at or below the NMS, particularly among those with TCD and CERT qualifications, the estimates for the lower bands should be interpreted with caution.

It is interesting to note that the benefits of pre-school are most significant among children whose teacher specialized in child care or early childhood education, and in general, children whose pre-school teacher had a teaching degree without a specialization in early childhood education did not benefit as much. A possible explanation for this result is that, compared to primary school teachers, teachers with specialist training in early childhood education are likely to have a greater awareness of developmentally appropriate teaching practices for young children, resulting in better outcomes. It may also be the case that, as suggested by Early et al. (2007), teachers who are trained to teach older children may focus more on academic instruction and less on forming individual teacher-child relationships that provide the foundation for academic learning.

When ability is controlled for with the inclusion of the *Who Am I?* test score in the set of explanatory variables, the magnitude of the descriptive OLS estimates are reduced by approximately 4 points (see Appendix Table A7). These results indicate that even after controlling for the ability of the child, there is a significant positive association between having attended pre-school with an appropriately qualified teacher (i.e. a degree or diploma with a specialisation in early childhood education or child care) and average NAPLAN outcomes for Spelling and Reading in Year 3. For the Numeracy domain, the effect of having a degree-qualified teacher is no longer statistically significant, but the effect of having a teacher with a diploma-level qualification remains significant, with children whose test scores are at the top end of distribution gaining the most benefit. For Writing, the benefit from having a pre-school teacher with a (primary) teaching degree remains significant. However, for Grammar there appears to be almost no significant benefit from having attended pre-school.

To address again the issue of selection bias, Kernel based Propensity Score Matching is used to estimate the Average Treatment Effect on Treated (ATT), comparing each specific teacher qualification with children who did not attend pre-school at all.[25] That is, for each qualification, we calculate the ATT by restricting the subsample to that particular qualification (the treated group) and the group of children who did not attend pre-school (the control group).

Because our OLS and quantile estimates indicate that for some domains, children whose pre-school teacher had a relevant degree or diploma qualification gained the most from having attended pre-school; and among children whose pre-school teacher had a degree, those whose teacher had a degree specialising in early childhood education generally do better, we also estimate the ATT with a treatment group consisting of children whose teacher had a relevant degree or diploma qualification (ECD, TCD or CC)[26] and also with a treatment group representing teachers with a specialist

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[25] Lechner (2001) suggests in the multiple treatment case, a practical alternative to the estimation of a multinomial probit model is the estimation of a series of binomial models. He finds that there is little difference in the relative performance of the two approaches.

[26] Teacher Qualifications: Early Childhood Teaching Degree (ECD); Other Teaching Degree (TCD); Adv. Diploma, Diploma, Ass. Dip in child care or early childhood teaching (CC); Certificate level qualification in child care or early childhood teaching (CERT); Other (OTH).

qualification in early childhood education or child care (ECD or CC). The ATT for these treatment groups are first estimated using the group of children who did not attend pre-school as the control group; and then using "all others" as the control group. The results are summarised in Table 7.

Table 7: Average Treatment Effect on Treated, Specific Teacher Qualifications

	Numeracy	Reading	Spelling	Writing	Grammar	% bias after matching
ECD	**15.193****	**19.438*****	**17.525****	8.213	6.539	3.290
vs. no pre-school	(**6.414)**	(7.424)	(7.905)	(11.865)	(8.433)	(2.338)
TCD	**18.356***	**22.636***	19.239	**19.507***	15.468	5.105
vs. no pre-school	(10.157)	(12.963)	(12.996)	(10.549)	(14.750)	(3.512)
CC	**21.191*****	**23.641*****	**20.115****	9.652	14.996	2.683
vs. no pre-school	(7.270)	(8.457)	(8.512)	(7.182)	(9.573)	(1.547)
CERT	12.635	17.449	18.110	7.814	2.372	7.129
vs. no pre-school	(14.999)	(18.757)	(15.375)	(17.910)	(18.274)	(6.690)
OTH	14.587	14.860	**16.983***	10.214	12.270	3.575
vs. no pre-school	(9.982)	(10.588)	(9.597)	(9.027)	(10.571)	(2.274)
ECD/TCD/CC	**17.836*****	**20.894*****	**17.575****	8.840	10.124	2.317
vs. no pre-school	(5.684)	(6.591)	(7.242)	(5.867)	(7.766)	(1.804)
ECD/CC	**17.888*****	**21.223*****	**18.306****	9.486	10.038	2.516
vs. no pre-school	(6.358)	(7.417)	(7.526)	(6.812)	(7.802)	(1.755)
ECD/TCD/CC	**8.642****	**11.141****	**9.572***	6.139	6.740	0.829
vs. **all others**	(4.374)	(5.575)	(4.928)	(3.938)	(5.281)	(0.932)
ECD/CC	**7.460***	**9.750***	**7.536***	1.706	6.447	0.959
vs. **all others**	(3.951)	(5.680)	(4.204)	(7.304)	(4.721)	(0.817)

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively. ATT estimates are based on Kernel matching of treatment and control cases (Gaussian Kernel with a bandwidth of 0.06). Teacher Qualifications: Early Childhood Teaching Degree (ECD); Other Teaching Degree (TCD); Adv. Diploma, Diploma, Ass. Dip in child care or early childhood teaching (CC); Certificate level qualification in child care or early childhood teaching (CERT); Other (OTH).

The ATT estimates confirm our OLS results concerning the impact of specific teacher qualifications. Compared to children who did not attend pre-school, children who had a pre-school teacher with a relevant degree or diploma qualification had significantly higher average scores in their Year 3 NAPLAN tests for Numeracy, Reading and Spelling. For Writing, it was children whose pre-school teacher had a teaching degree that did not specialize in early childhood education who gained the most. However, for Grammar there was no significant effect for any specific pre-school teacher qualification.

When the group of children whose pre-school teacher had a relevant degree or diploma qualification is compared to those who did not attend pre-school at all, the ATT estimates indicate that the gain from having attended pre-school is approximately 17 points for Numeracy and Spelling and 21 points for Reading. However, for the domains for Writing and Grammar there is no significant effect. Similar results are achieved when children whose teacher had a teaching degree but did not specialize in early childhood education are excluded from the treatment group. When the ATT is estimated using "relevant degree or diploma" (ECD, TCD or CC) as the treatment group and "all others" as the control group, the estimated gains from having a pre-school teacher with a relevant qualification are 9 points for Numeracy and Spelling and 11 points for Reading.

After controlling for ability with the inclusion of the *Who Am I?* score in the set of matching variables, the magnitude of the ATT estimates is reduced by 3 to 5 points (Table 8).

Table 8: Average Treatment Effect on Treated, Specific Teacher Qualifications — including the *Who Am I?* Score in the set of matching variables

	Numeracy	Reading	Spelling	Writing	Grammar	% bias after matching
ECD	**12.453***	**17.108****	**14.976****	6.330	4.487	3.568
vs. no pre-school	(6.819)	(7.890)	(7.324)	(11.472)	(8.634)	(1.973)
TCD	15.539	19.314	16.256	16.606	11.887	4.646
vs. no pre-school	(10.070)	(13.219)	(12.407)	(10.674)	(15.786)	(3.141)
CC	**16.543****	**18.585****	**15.443***	6.372	10.589	2.470
vs. no pre-school	(7.794)	(8.238)	(8.850)	(6.386)	(9.283)	(1.524)
CERT	12.369	17.293	18.731	8.500	0.952	6.350
vs. no pre-school	(16.031)	(19.669)	(15.518)	(17.481)	(16.712)	(6.327)
OTH	14.192	13.898	**17.522***	8.778	10.772	4.574
vs. no pre-school	(9.398)	(10.973)	(10.330)	(8.789)	(10.973)	(3.167)
ECD/TCD/CC	**14.096****	**17.856****	**14.583****	7.585	7.341	2.569
vs. no pre-school	(5.869)	(7.308)	(6.920)	(6.109)	(7.867)	(1.441)
ECD/CC	**14.051****	**17.807****	**14.515****	6.899	7.130	2.546
vs. no pre-school	(6.566)	(7.871)	(6.976)	(6.743)	(8.590)	(1.564)
ECD/TCD/CC	6.888	9.150	7.458	4.511	5.026	0.785
vs. **all others**	(4.294)	(5.651)	(4.729)	(3.759)	(4.731)	(0.709)
ECD/CC	**6.351***	**8.4234***	**6.418***	0.649	7.130	0.894
vs. **all others**	(3.405)	(4.853)	(3.644)	(7.144)	(8.590)	(0.731)

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively. ATT estimates are based on Kernel matching of treatment and control cases (Gaussian Kernel with a bandwidth of 0.06). Teacher Qualifications: Early Childhood Teaching Degree (ECD); Other Teaching Degree (TCD); Adv. Diploma, Diploma, Ass. Dip in child care or early childhood teaching (CC); Certificate level qualification in child care or early childhood teaching (CERT); Other (OTH).

The estimated effects of having had a pre-school teacher with a degree in early childhood education remain significant at the 10% level for Numeracy and Reading; and the effects of having a diploma-qualified pre-school teacher remain significant for Numeracy, Reading and Spelling. However, the estimated effects of having a degree-qualified pre-school teacher who did not specialize in early childhood education are no longer statistically significant. This result supports the conclusion that there are significant benefits to be gained from pre-school teachers who are specifically trained in developmentally appropriate teaching practices for young children. Using the group of children whose pre-school teacher had a degree or diploma qualification specializing in early childhood education or child care (ECD or CC) as the treatment group and the group who did not attend pre-school at all as the control group, and controlling for ability, the estimated benefits range from 14 points for Numeracy and Spelling to 18 points for Reading.

5. Research Conclusions and Policy Implications

We find a significant positive association between pre-school attendance and Year 3 NAPLAN scores, particularly in the domains of Numeracy, Reading and Spelling. Descriptive quantile estimates show that for Numeracy, it is children whose test scores are at the higher end of the test score distribution who benefit the most from attending pre-school. However, for Reading and Spelling, children whose test scores are just above the National Minimum Standard who benefit most from having attended pre-school. We also find that the qualifications of the pre-school teacher are very important. Children whose pre-school teacher had a degree on Early Childhood Education or a Diploma in Early Childhood Education or Child Care gained the most from attending pre-school, while children whose teacher had only a certificate level qualification or no relevant qualification showed no significant benefit in terms of Year 3 NAPLAN scores.

To address directly the issue of causality not captured in our descriptive estimations, we use Kernel propensity score matching techniques to compare children who actually participated in pre-school programs to those who did not, yet based on observable characteristics, who had similar propensities to attend pre-school. Using Kernel matching, we have calculated the Average Treatment Effect on the Treated (ATT) and the Average Treatment Effect of the Untreated (ATU) for the treatment of having participated in a pre-school program on the domain-specific NAPLAN outcome. This is the first paper to calculate these estimates for Australia, which is based on a *nationally representative* panel of children (LSAC) and their NAPLAN schooling outcomes. These results are much more compelling than those of targeted, small sample, or program-specific analyses.

For the domains of Reading, Spelling, Writing and Numeracy, the causal Average Treatment Effect on Treated (ATT) is statistically significant and of the magnitude 13 to 20 NAPLAN points. However, for Grammar, the estimated ATT is not statistically significant. The Average Treatment Effect on the Untreated (ATU) provides an estimate of how much higher the NAPLAN scores of children who did not attend pre-school might have been if they had in fact attended pre-school. The ATUs are statistically significant across all five NAPLAN domains and slightly larger than the ATT estimates. This result implies that it is the children who missed out on attending pre-school who would have gained the most in terms of later cognitive outcomes.

Directly controlling for the *Who Am I?* ability score in the matching process, the previous causal ATT and ATU estimates are reduced by 2 to 4 points, depending on the domain being considered, but the ATT estimates for Numeracy, Spelling and Reading still remain statistically significant at the 5% level and ATU estimates remain significant across all five domains. This result suggests that in general, any bias resulting from *unobserved* ability is not likely to have a dramatic effect on our estimates of the effects of pre-school participation. These causal ATT estimates are substantial, given that one year of schooling at this level is represented by 52 NAPLAN points, with pre-school amounting to 30-40% of the learning impact of one additional year of schooling, *3 years after the fact*.

To assess the effect of teacher qualifications in the pre-school programs, we have estimated the ATTs for five separate levels of teacher qualification (without including controls for *Who am I?* ability scores). The strongest effects are found for teachers having Early Childhood Teaching Degree (ECD), Other Teaching Degree (TCD) and Advanced Diploma in child care or early childhood teaching (CC) in the domains for Numeracy, Reading and Spelling. For Writing and Grammar, there were less stable, yet positive effects for some of the qualifications. Those children having participated in programs in which teachers had only a Certificate level qualification in child care or early childhood teaching (CERT), or had no relevant childcare qualification, later received indistinguishably similar NAPLAN scores to those children who had not participated at all in a pre-school program.

After including *Who am I?* ability scores in the matching, the NAPLAN effects of having a teacher with a teaching degree (not specializing in early childhood education) are no longer statistically significant. This suggests that it is children who attended a pre-school program with a degree or diploma qualified teacher, specializing in early childhood education or child care, who gain the most from attending pre-school. Thus, the actual training specialisation of the teacher is also important, with immediate policy relevance.

These findings are somewhat different to those of Early et al. (2007), who find no conclusive evidence of an association between pre-school teacher qualifications, or major, and cognitive outcomes in the same (pre-school) year. Further, Early et al. (2006) find that pre-school teacher education level is linked to gains in math skills, but not literacy skills in the pre-school year.

The main difference between this study and those of Early et. al. (2006 and 2007) is that our focus is on the longer-term effects of pre-school teacher qualifications on children's cognitive outcomes (as opposed to cognitive outcomes in the pre-school year). While several studies of large-scale pre-school programs have shown that pre-school attendance has long-term academic benefits (e.g. Sylva et al., 2008; Berlinski et al., 2008; Goodman and Sianesi, 2005); and others have shown the long-term benefits of small scale, targeted pre-school programs with degree-qualified teachers specialising in early childhood education (Schweinhart et al. 2005; Campbell and Ramey, 1995; Barnett, 1995; Reynolds et al, 20011), this is the first study to provide direct comparisons of the effect of the type of qualification held by the pre-school teacher on later cognitive outcomes.

These results confirm the importance of high quality pre-school programs for later cognitive outcomes. The Council of Australian Governments (COAG) agreement ensuring that all children in Australia have access to a high quality early childhood education program delivered by a degree qualified early childhood teacher in the year before formal schooling and the introduction of the new National Quality Standard for early childhood education and care providers in Australia (in January

2014) are likely to have substantial long-term benefits, particularly for children who would not have had the opportunity to attend a pre-school with a suitably qualified teacher if these reforms had not taken place. Even 3 years after the pre-schooling has taken place, NAPLAN scores of Year 3 children are significantly higher than those who had not received the treatment.

In terms of later (NAPLAN) outcomes, pre-school teachers/carers should have at least a diploma level qualification for maximal program impact. Some children - possibly those who would gain the most from attending a high quality pre-school program - might still miss out because of “loopholes” in the new National Quality Framework that will be introduced in January 2014. For example, child care and pre-school centres in Australia will be able to overcome the requirement for an early childhood teacher to be present at all times if: (a) there are fewer than 25 children attending the facility; or (b) if a high proportion of staff are not actually qualified but “actively working towards” a relevant qualification, likely leading to the quality of the program being lower. These conditions exist due to an acute current undersupply of qualified staff. Thus this will likely require targeted government policy to encourage people (a) to obtain higher level qualifications, i.e. continue with incentives to study child care and early childhood education, and (b) for child care workers to work in rural and remote areas. With a sufficient number of qualified staff, quality standards could be improved even further to ensure that children who are most at risk of underachievement are not disadvantaged**.**

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APPENDIX

Table A1: Data Description and Summary Statistics (N=2009)

Description	Mean	Std. Dev.
Attended Pre-school in 2004	0.907	0.291
Male: Male = 1 Female = 0	0.522	0.500
ATSI: Aboriginal or Torres Strait Islander (1/0)	0.024	0.154
LOTE: Speaks a language other than English at home (1/0)	0.097	0.297
Low birth weight (< 2.5 kg)	0.057	0.231
Parent reported child health 2004 (fair or poor = 1, else 0)	0.026	0.158
Age of child in January 2004 (months)	49.819	3.088
Lone parent household in 2004	0.116	0.320
Household size 2004	4.424	1.106
Younger resident siblings 2004	0.478	0.500
Older resident siblings 2004	0.566	0.496
Mothers education level (Control = year 11 or below)		
Year 12	0.146	0.353
Non-degree post school qualification	0.352	0.478
Degree qualification	0.311	0.463
Mother employed in 2004	0.444	0.497
Mother's age at the time child was born	30.941	5.111
State of residence in 2004 (Control = NSW)		
Vic (Victoria)	0.276	0.447
Qld (Queensland)	0.114	0.317
Other	0.231	0.422
Living in a metropolitan area in 2004	0.634	0.482
Weekly household income 2004 ($)	1351.656	648.438
Who Am I (WAI) Test Score 2004	63.402	7.406

Table A2: OLS and Quantile Estimates: Effect of Pre-school Participation on Year 3 NAPLAN Scores - Numeracy

	OLS	Lev 1/2 (Q04)	Lev 2/3 (Q10)	Lev 3/4 (Q28)	Lev 4/5 (Q54)	Lev 5/6 (Q79)
Pre-school	13.6486**	6.3623	0.2313	12.0417*	10.6213**	20.8521***
	(5.5914)	(19.0140)	(14.4066)	(6.2225)	(5.3202)	(7.7177)
Male	8.8567***	-4.5889	-0.4894	6.3133	7.8446*	16.7297***
	(2.8932)	(5.7304)	(4.4232)	(4.2344)	(4.2501)	(4.6645)
ATSI	-28.3847***	-23.2920	-33.6590**	-44.8188***	-37.9233***	-23.6436**
	(8.8555)	(14.8243)	(15.6543)	(8.5850)	(9.4787)	(11.1130)
LOTE	7.0828	19.7937**	7.3665	3.1991	-0.4642	14.5160
	(5.0607)	(9.4024)	(7.5973)	(6.9266)	(7.6974)	(10.1979)
Low Birth Weight	-20.4372***	-20.5021**	-27.2792*	-23.0197**	-10.7599	-24.2635**
	(6.3703)	(8.2446)	(14.8005)	(9.1510)	(7.9136)	(9.5146)
Poor Health	-5.2502	-38.8401	0.3690	0.3766	-17.0924	-0.9582
	(9.6027)	(42.1716)	(32.4414)	(10.5076)	(10.7674)	(22.3702)
Child Age	2.6049***	2.6246**	2.4150***	2.3551***	2.5718***	2.3287***
	(0.5236)	(1.2408)	(0.9041)	(0.5098)	(0.6151)	(0.7594)
Metropolitan	4.1714	0.7226	6.2213	4.5274	2.0600	3.1967
	(3.3156)	(7.9646)	(6.8671)	(4.8446)	(4.0343)	(3.5311)
Lone parent HH	-4.8492	4.8563	-11.0864	-3.6618	4.4657	-0.5094
	(5.4124)	(11.5046)	(11.1911)	(8.6790)	(5.3127)	(7.9550)
HH Size	-3.4955	-2.5404	-3.4342	-2.3182	-5.5429***	-6.6440**
	(2.1616)	(4.0111)	(3.3128)	(2.2618)	(1.9107)	(2.8733)
Younger Siblings	6.0321	13.5531	10.4710*	9.5809	14.3581**	3.9922
	(3.9255)	(8.6890)	(6.1997)	(6.4785)	(5.7825)	(5.4621)
Older Siblings	-4.2737	8.1668	3.3860	-5.1542	-1.0348	-4.4797
	(4.8971)	(10.7682)	(8.4991)	(6.2211)	(6.8048)	(7.1287)
Mother Employed	1.5877	-12.5122	-1.7284	6.6371	0.2034	-2.6188
	(3.2586)	(9.2535)	(6.2120)	(5.3853)	(4.5540)	(3.7570)
Mother Age	0.4940	0.2593	0.3125	0.8400	0.6968	0.6771
	(0.3526)	(0.8122)	(0.7235)	(0.5525)	(0.4382)	(0.4919)
Household Income	0.0137***	0.0151**	0.0092*	0.0149***	0.0185***	0.0125***
	(0.0026)	(0.0068)	(0.0053)	(0.0040)	(0.0041)	(0.0026)
Vic	2.1803	-2.5649	-4.3223	0.2773	3.8140	6.1786
	(4.0392)	(8.9227)	(7.2276)	(6.5345)	(6.0146)	(6.2987)
Qld	-7.8285	-26.6606*	-16.9703	-14.2247	-1.0192	-2.1932
	(6.3256)	(13.7420)	(10.9499)	(12.6176)	(9.9874)	(8.6100)
Other States	-15.0013***	-5.8990	-24.6932***	-15.5982***	-10.9852***	-13.1003**
	(4.0066)	(7.7363)	(6.4806)	(4.3827)	(3.9773)	(5.2755)
MQual – Year 12	13.3268**	5.8148	6.1170	11.5987	11.9405	20.3347**
	(6.2147)	(12.4938)	(11.7581)	(7.8966)	(8.5555)	(8.0161)
MQual –non Degree	7.0120	0.3041	6.8250	5.9702	6.5081	8.7010
	(4.2920)	(9.5963)	(8.5586)	(6.7953)	(6.2163)	(7.7133)
MQual - Degree	32.8688***	35.8358***	35.8944***	30.0434***	29.4761***	36.3178***
	(4.7372)	(11.5892)	(8.2855)	(8.1245)	(6.8750)	(6.4634)
Constant	245.4187***	141.8095**	199.1044***	203.9873***	245.6282***	309.3208***
	(28.7163)	(67.7475)	(52.5671)	(30.2093)	(34.4114)	(37.6876)
Observations	2004	2004	2004	2004	2004	2004
R^2	0.137	--	--	--	--	--
Pseudo R^2	--	0.086	0.069	0.083	0.074	0.075

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively.

Table A3: OLS and Quantile Estimates: Effect of Pre-school Participation on Year 3 NAPLAN Scores - Reading

	OLS	Lev 1/2 (Q05)	Lev 2/3 (Q14)	Lev 3/4 (Q28)	Lev 4/5 (Q49)	Lev 5/6 (Q79)
Pre-school	18.6968***	-0.4074	17.7614	27.4076***	22.9571***	16.8449***
	(4.5358)	(12.1392)	(12.0372)	(8.5255)	(6.5710)	(4.7855)
Male	-22.1149***	-27.1904***	-23.8317***	-23.8036***	-19.0461***	-11.5300**
	(3.6810)	(5.9636)	(5.6150)	(5.8169)	(4.4396)	(5.7603)
ATSI	-20.4227	6.1672	-16.1849	-31.9636*	-27.8427	-19.1157
	(14.2121)	(26.5019)	(15.1900)	(16.7043)	(18.2137)	(17.0230)
LOTE	9.4993*	29.9240***	23.8068***	10.3099*	2.8449	6.5084
	(5.7307)	(10.1208)	(6.6279)	(5.8152)	(8.9504)	(11.9111)
Low Birth Weight	-20.9592***	-24.4471*	-17.4363	-16.8424***	-27.2927***	-19.0010
	(7.2824)	(14.5013)	(15.4049)	(6.3978)	(7.7830)	(14.2705)
Poor Health	-17.6872	-77.4485	15.4227	6.1192	-10.3348	-15.2832
	(13.3026)	(67.0245)	(34.3276)	(22.3960)	(11.5094)	(13.8157)
Child Age	2.8208***	1.9191	2.3106**	2.7975***	2.5568***	2.1664***
	(0.6722)	(1.2996)	(0.9277)	(0.8095)	(0.7066)	(0.7190)
Metropolitan	6.3021	3.1368	6.2689	5.9473	9.7140**	7.1723
	(3.9981)	(9.2555)	(6.7439)	(5.7746)	(4.9017)	(5.5049)
Lone parent HH	-11.5765	-20.4313	-9.0042	-2.8847	-1.8455	-14.8116*
	(7.9026)	(13.9259)	(13.0510)	(13.8200)	(8.9722)	(7.6024)
HH Size	-4.5988*	-7.0041*	-4.0971	-4.6602	-2.2196	-5.6027
	(2.7023)	(4.1195)	(5.2465)	(3.7195)	(3.0543)	(3.9761)
Younger Siblings	8.6075	4.2784	7.5748	10.0379	4.9721	14.0871**
	(5.3536)	(9.6541)	(8.1344)	(7.3340)	(5.7367)	(6.2177)
Older Siblings	-13.9150**	3.7124	-15.1404	-12.7340	-13.8131**	-9.0786
	(5.6791)	(9.7140)	(11.6938)	(8.5336)	(6.0275)	(7.8352)
Mother Employed	0.1955	-8.3454	-1.8179	1.5552	6.1296	1.1311
	(3.2955)	(10.2319)	(6.2169)	(5.9797)	(4.8563)	(4.4463)
Mother Age	1.0132***	0.0497	0.8102	1.5405**	0.7624*	0.7085
	(0.3798)	(0.9683)	(1.0670)	(0.5975)	(0.4261)	(0.4459)
Household Income	0.0116***	0.0158*	0.0232***	0.0122***	0.0122***	0.0077*
	(0.0029)	(0.0081)	(0.0052)	(0.0046)	(0.0037)	(0.0044)
Vic	1.7311	-5.7287	0.2530	0.8558	3.1544	0.4475
	(4.2914)	(10.2896)	(8.1128)	(6.9494)	(5.8751)	(3.6826)
Qld	-4.7472	-22.2300**	-2.5708	-4.7246	-1.7187	-4.3615
	(6.2833)	(10.6651)	(12.1709)	(9.7829)	(8.5479)	(8.3482)
Other States	-11.6178**	-26.7537***	-17.3374	-14.4765*	-12.0186**	-2.3922
	(5.0336)	(10.1760)	(11.4003)	(8.5194)	(5.8794)	(8.3640)
MQual – Year 12	21.6772***	26.7302*	22.7694*	21.0400**	15.6458***	16.8888*
	(7.3489)	(15.4928)	(12.4574)	(10.1922)	(5.7658)	(9.0333)
MQual –non Degree	11.5751**	13.2447	12.8080	7.4720	7.5099	7.9462
	(5.3550)	(12.7803)	(12.9797)	(9.6498)	(6.1726)	(6.9971)
MQual - Degree	41.4180***	54.6009***	42.5651***	38.4483***	31.2971***	31.7491***
	(5.6704)	(12.2864)	(10.2742)	(10.0201)	(7.1094)	(7.2387)
Constant	240.2302***	204.9653**	171.2698***	173.8578***	244.5711***	337.1866***
	(34.1965)	(82.0771)	(60.3059)	(37.2479)	(32.6991)	(35.6415)
Observations	2008	2008	2008	2008	2008	2008
R^2	0.146	--	--	--	--	--
Pseudo R^2	--	0.102	0.092	0.090	0.077	0.060

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively.

Table A4: OLS and Quantile Estimates: Effect of Pre-school Participation on Year 3 NAPLAN Scores - Spelling

	OLS	Lev 1/2 (Q05)	Lev 2/3 (Q13)	Lev 3/4 (Q27)	Lev 4/5 (Q54)	Lev 5/6 (Q80)
Pre-school	17.3164***	22.5880	19.4255*	18.5254***	20.6746***	24.0632**
	(6.3975)	(14.0342)	(10.7682)	(6.9098)	(6.8485)	(10.6135)
Male	-15.7370***	-24.1005***	-24.9432***	-16.6605***	-13.8545***	-9.5784**
	(2.9851)	(7.4785)	(7.3824)	(4.5602)	(4.3391)	(4.5987)
ATSI	-24.3388**	-9.9366	-23.4339	-38.9643**	-35.7257**	-17.1556
	(10.8379)	(14.7443)	(18.2234)	(17.2799)	(14.7115)	(20.3343)
LOTE	26.7858***	21.8618**	24.0047***	18.9806**	23.6292***	38.4559***
	(5.9737)	(10.6685)	(7.8193)	(7.7975)	(6.6641)	(13.3670)
Low Birth Weight	-5.7200	-30.0321	-13.8853	-1.1720	-2.9871	-17.3366
	(7.4927)	(19.3373)	(16.3691)	(8.8634)	(7.3969)	(12.4560)
Poor Health	2.4838	-41.7853	19.9558	1.8158	0.9397	11.0809
	(12.9907)	(45.4412)	(37.8416)	(13.5491)	(10.4376)	(15.0933)
Child Age	1.7659***	0.6618	1.3791	1.9136**	1.7455**	1.5824
	(0.6468)	(1.6860)	(0.9418)	(0.8351)	(0.8281)	(1.1563)
Metropolitan	8.1729**	-4.3272	-1.7948	7.4328*	11.2738***	10.7160**
	(3.3516)	(8.7934)	(6.0992)	(4.3419)	(3.4691)	(5.4053)
Lone parent HH	-8.3832	-13.0445	-15.5385	-10.8409*	-13.6567*	-2.2121
	(5.6462)	(19.8962)	(12.5088)	(6.4948)	(7.4627)	(12.3278)
HH Size	-1.0574	-3.1184	-2.8007	-1.9460	-2.0090	1.3751
	(2.2580)	(5.6142)	(4.2556)	(2.8241)	(3.4492)	(4.4314)
Younger Siblings	4.5572	1.9763	6.0266	8.8908*	11.3996**	-2.2560
	(4.8304)	(7.5856)	(5.3132)	(4.6231)	(5.6487)	(9.3378)
Older Siblings	-9.8757**	-3.9673	-14.3518**	-3.4582	-0.1954	-15.8196*
	(4.2689)	(16.6315)	(7.2883)	(4.8433)	(6.6955)	(8.1965)
Mother Employed	3.1634	-1.1386	-5.6136	1.3842	6.6697*	1.4701
	(3.6911)	(8.7724)	(5.6533)	(5.3224)	(3.6049)	(5.9661)
Mother Age	0.4984	0.6079	0.8990*	0.0077	0.3132	0.8468
	(0.4376)	(0.7866)	(0.5317)	(0.5058)	(0.4876)	(0.5584)
Household Income	0.0090***	0.0123*	0.0165***	0.0114***	0.0054*	0.0076
	(0.0030)	(0.0067)	(0.0046)	(0.0033)	(0.0031)	(0.0054)
Vic	-8.9208***	-16.5733	-9.4985	-9.7074**	-5.4648	-4.6417
	(3.4496)	(10.4986)	(6.2418)	(4.1858)	(4.1234)	(4.9154)
Qld	-23.1367***	-39.9446***	-30.1353**	-23.3308***	-15.3707**	-23.6641***
	(6.0172)	(13.7881)	(13.8604)	(7.7413)	(7.0043)	(7.4401)
Other States	-15.6959***	-35.7879***	-26.6167***	-20.9842***	-14.2275***	-6.2455
	(4.3978)	(10.5136)	(7.9102)	(5.3559)	(4.3935)	(6.2622)
MQual – Year 12	12.2227**	30.9188**	16.8448*	14.6392**	10.7009	4.5785
	(5.6186)	(14.6941)	(9.2732)	(6.5460)	(6.5933)	(8.1149)
MQual –non Degree	4.7390	17.2152	8.0001	8.5188	0.3109	3.5648
	(4.8776)	(13.4445)	(7.1945)	(5.4202)	(3.9371)	(5.6671)
MQual - Degree	22.1294***	56.6149***	29.5963***	25.4164***	14.0080***	18.6161***
	(4.6873)	(14.5778)	(8.2631)	(7.2539)	(5.0163)	(4.6875)
Constant	296.9208***	231.0967**	237.8690***	259.0581***	307.1458***	341.5719***
	(36.0027)	(105.4656)	(54.4361)	(43.1025)	(30.8427)	(50.1802)
Observations	2009	2009	2009	2009	2009	2009
R^2	0.110	--	--	--	--	--
Pseudo R^2	--	0.103	0.084	0.067	0.056	0.052

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively.

Table A5: OLS and Quantile Estimates: Effect of Pre-school Participation on Year 3 NAPLAN Scores - Writing

	OLS	**Lev 1/2 (Q04)**	**Lev 2/3 (Q08)**	**Lev 3/4 (Q22)**	**Lev 4/5 (Q48)**	**Lev 5/6 (Q75)**
Pre-school	10.8684**	10.4058	19.7729	12.8665	11.0353**	10.9633
	(4.2722)	(13.8513)	(12.6104)	(9.3602)	(5.1751)	(10.4936)
Male	-25.8512***	-42.5377***	-43.4982***	-33.2402***	-21.5482***	-21.3776***
	(2.9953)	(10.1334)	(8.9258)	(3.9491)	(3.5052)	(4.0992)
ATSI	-12.3980	-18.4568	-38.2757*	-31.5232*	-6.8321	0.8455
	(9.4197)	(16.9240)	(21.9847)	(17.4077)	(13.1081)	(13.3772)
LOTE	9.1061*	18.1901*	9.3908	13.0716*	8.2517	9.4318
	(4.9308)	(9.9120)	(9.8120)	(7.4608)	(6.9357)	(8.2442)
Low Birth Weight	-5.0405	-31.9237**	-28.6808	0.6540	5.7402	-8.0435
	(5.7675)	(13.5553)	(18.0400)	(11.7678)	(8.1546)	(5.3168)
Poor Health	1.2656	36.7408	16.1354	4.4149	2.0307	1.8805
	(10.1315)	(76.3715)	(15.0578)	(13.4216)	(8.6407)	(9.4436)
Child Age	2.3833***	0.8925	1.6987	2.3346***	2.1954***	2.1764***
	(0.5853)	(1.4582)	(1.3785)	(0.7614)	(0.7060)	(0.7139)
Metropolitan	8.0885***	9.6342	14.3453**	9.0824**	8.0763**	5.0839
	(2.9266)	(7.8542)	(5.9142)	(4.5411)	(3.2650)	(4.5335)
Lone parent HH	-8.9628*	-0.7076	-4.9089	-11.5633	-8.9087	-15.5861**
	(4.9819)	(13.1194)	(11.9580)	(7.2445)	(7.3961)	(6.1266)
HH Size	-3.6957*	-3.4495	-6.1581	-0.0116	-1.9303	-4.9192**
	(1.9695)	(4.0482)	(4.1937)	(3.1369)	(1.7934)	(2.1832)
Younger Siblings	4.8925	-7.6166	0.0154	-2.4521	7.9426*	7.1165*
	(3.9698)	(9.1329)	(9.9322)	(4.8118)	(4.5620)	(3.6764)
Older Siblings	-5.2170	-6.8617	-2.4276	-10.2247**	-4.7815	-8.7355**
	(4.5503)	(9.5996)	(8.7091)	(4.6971)	(5.1295)	(3.8041)
Mother Employed	0.5279	-3.7532	-8.3070	-2.0462	0.0462	0.8642
	(3.0937)	(8.0549)	(8.5040)	(2.6895)	(3.6324)	(3.6935)
Mother Age	0.5443*	0.2302	0.2738	0.4646	0.6590*	1.0127***
	(0.2932)	(0.8267)	(0.7092)	(0.4219)	(0.3889)	(0.3877)
Household Income	0.0077***	0.0177*	0.0147**	0.0069**	0.0032	0.0064*
	(0.0026)	(0.0097)	(0.0071)	(0.0033)	(0.0029)	(0.0035)
Vic	-8.4076**	-15.8809	-19.0231**	-17.6882***	-7.5047*	-4.0837
	(3.2809)	(11.4433)	(8.8852)	(3.4784)	(4.2946)	(4.6750)
Qld	-11.9321*	-29.6326*	-26.8584*	-8.5726	-9.9551	-9.0075
	(6.4559)	(16.2042)	(15.4240)	(8.6141)	(8.2617)	(8.6271)
Other States	-21.3176***	-30.0110***	-30.4559***	-28.6495***	-24.9315***	-15.4253**
	(3.4658)	(11.4837)	(9.6968)	(4.5202)	(5.8370)	(6.7677)
MQual – Year 12	8.6374	0.0163	8.9792	9.3036*	5.2934	4.5187
	(5.6702)	(13.3577)	(11.4555)	(5.1798)	(6.4309)	(7.2347)
MQual –non Degree	10.7451***	3.2942	12.5052	8.7896*	9.9579*	6.5831
	(4.0944)	(9.3660)	(9.4867)	(5.2563)	(5.9420)	(5.9944)
MQual - Degree	29.8876***	36.2465***	40.8664***	28.8379***	30.8323***	22.2662***
	(3.7840)	(8.1699)	(7.3579)	(4.0520)	(6.6219)	(5.0456)
Constant	293.7488***	272.0017***	251.4479***	253.9443***	293.1116***	342.2246***
	(29.0304)	(71.4484)	(65.0396)	(37.8150)	(31.1706)	(32.8772)
Observations	2005	2005	2005	2005	2005	2005
R^2	0.144	--	--	--	--	--
Pseudo R^2	--	0.132	0.122	0.080	0.075	0.067

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively.

Table A6: OLS and Quantile Estimates: Effect of Pre-school Participation on Year 3 NAPLAN Scores - Grammar

	OLS	Lev 1/2 (Q05)	Lev 2/3 (Q11)	Lev 3/4 (Q28)	Lev 4/5 (Q50)	Lev 5/6 (Q69)
Pre-school	14.3510**	33.6420***	12.0596	11.3236	17.4114**	9.5281
	(5.8234)	(11.1217)	(15.2920)	(8.0400)	(7.6405)	(9.4960)
Male	-23.3770***	-27.9629***	-24.4614***	-22.4009***	-28.0045***	-20.9510***
	(3.6741)	(7.2739)	(7.0908)	(5.8753)	(5.1630)	(6.4589)
ATSI	-44.6289***	-36.6466**	-47.1203***	-53.3928***	-58.5457***	-53.1436***
	(12.0791)	(14.5042)	(16.8373)	(16.7786)	(14.2745)	(12.4277)
LOTE	8.1516	17.2281	22.3007	6.2482	3.6073	5.1906
	(6.0853)	(10.8641)	(15.1246)	(8.5722)	(8.0867)	(7.1220)
Low Birth Weight	-16.7634**	-7.2582	-9.0836	-9.8889	-10.2432	-8.8012
	(7.8602)	(16.7274)	(11.3507)	(8.7588)	(10.4877)	(13.5203)
Poor Health	8.7075	45.9097***	29.4067**	13.8249	7.9554	6.9705
	(11.8849)	(12.0886)	(11.6099)	(13.2124)	(12.0817)	(17.3882)
Child Age	2.9738***	1.8195	2.4465**	2.9889***	3.0403***	2.7936***
	(0.5879)	(1.2103)	(1.1387)	(0.7011)	(0.8878)	(0.8663)
Metropolitan	7.0770*	7.9013	6.3994	5.1646	8.6933*	7.3402
	(4.0495)	(8.1917)	(4.6850)	(5.1887)	(4.6963)	(4.6523)
Lone parent HH	-3.3951	-2.0449	-17.1397	-7.4870	-0.3663	-3.8416
	(7.7869)	(11.4206)	(14.8781)	(14.2345)	(10.4804)	(9.3756)
HH Size	-2.5968	1.8430	-2.3867	-4.8870	-5.9048*	-2.9303
	(2.4431)	(4.1589)	(3.8249)	(3.0641)	(3.1695)	(4.8853)
Younger Siblings	10.7862**	7.3333	11.5225	13.6150**	13.4257***	9.0571
	(4.8593)	(12.3796)	(10.2732)	(5.3578)	(4.8588)	(6.2736)
Older Siblings	-11.8166**	-15.2990	-13.6753	-9.8781	-6.9705	-13.7897*
	(4.6565)	(10.3160)	(10.0923)	(6.4358)	(5.9805)	(7.1307)
Mother Employed	1.8246	3.0832	6.0180	0.4297	0.0438	1.7020
	(3.5328)	(9.7840)	(6.3141)	(6.2138)	(5.2201)	(6.0003)
Mother Age	0.9241**	0.4715	0.4554	1.2152**	1.1002***	1.1688***
	(0.3649)	(0.8387)	(0.6053)	(0.5435)	(0.3855)	(0.4502)
hhinc04	0.0135***	0.0132	0.0149**	0.0173***	0.0117***	0.0098**
	(0.0035)	(0.0085)	(0.0070)	(0.0050)	(0.0042)	(0.0047)
Vic	2.6396	1.8783	7.6944	3.1970	-4.0922	-3.0987
	(3.8246)	(10.5950)	(8.6307)	(5.9451)	(5.2772)	(5.0660)
Qld	-15.8445***	-16.2180	-25.3408**	-19.2800**	-6.6424	-13.2725*
	(5.8112)	(13.9585)	(10.7564)	(8.2735)	(6.4646)	(6.9592)
Other States	-20.0503***	-22.4030**	-21.0982***	-21.0866***	-20.5026***	-19.7504***
		(10.3674)	(7.0915)	(5.8009)	(5.4489)	(6.3636)
MQual – Year 12	13.7405**	-0.2585	11.9269	5.7611	17.4117**	17.3733*
	(6.0076)	(13.0613)	(12.9250)	(7.6061)	(7.8605)	(9.2624)
MQual –non Degree	11.0202***	-5.7042	8.2989	7.8384	10.8458*	11.2034*
	(3.9595)	(12.8941)	(8.7507)	(7.8050)	(6.3292)	(5.9509)
MQual - Degree	36.1964***	31.1204**	30.1159***	33.4708***	33.5955***	35.8448***
	(4.5013)	(12.0958)	(9.2320)	(6.5422)	(5.5122)	(7.5440)
Constant	236.3522***	156.9901**	181.8838***	189.4196***	241.9613***	289.7694***
	(33.3673)	(66.0748)	(66.9489)	(48.2082)	(50.5343)	(52.2777)
Observations	2008	2008	2008	2008	2008	2008
R^2	0.151	--	--	--	--	--
Pseudo R^2	--	0.099	0.097	0.092	0.083	0.074

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively.

Table A7: OLS and Quantile Estimates - with *Who Am I?*

Numeracy	OLS	Lev 1/2 (Q04)	Lev 2/3 (Q10)	Lev 3/4 (Q28)	Lev 4/5 (Q54)	Lev 5/6 (Q79)
ECD	8.639	4.755	6.190	7.229	6.191	11.992
	(5.495)	(12.482)	(10.887)	(8.011)	(6.145)	(8.3675)
TCD	10.344	10.567	7.462	8.128	3.753	14.611
	(7.935)	(17.299)	(15.998)	(10.969)	(8.614)	(11.173)
CC	**12.786****	13.533	7.259	8.040	10.945	**17.913****
	(5.968)	(13.508)	(12.703)	(9.230)	(7.291)	(8.694)
CERT	12.239	11.816	8.260	14.380	11.356	7.750
	(11.743)	(23.047)	(20.867)	(14.5051)	(12.359)	(19.194)
OTH	7.039	10.590	6.102	8.1253	4.966	9.909
	(6.876)	(15.860)	(12.216)	(9.9496)	(8.546)	(10.781)
Reading	**OLS**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q14)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q49)**	**Lev 5/6 (Q75)**
ECD	**13.817****	3.625	14.053	13.987	14.545	11.182
	(6.504)	(16.114)	(9.803)	(9.158)	(10.033)	(9.295)
TCD	14.836	2.944	5.927	15.023	16.342	8.748
	(9.370)	(20.125)	(16.216)	(14.437)	(11.235)	(11.631)
CC	**17.789*****	7.628	13.640	**18.101***	**21.384****	15.431
	(6.870)	(16.675)	(10.321)	(9.676)	(9.992)	(9.730)
CERT	14.104	16.193	13.588	15.047	12.534	12.610
	(14.285)	(81.769)	(18.497)	(17.460)	(17.676)	(19.727)
OTH	12.689	18.835	7.661	9.764	15.928	12.133
	(8.315)	(17.667)	(13.522)	(10.924)	(12.725)	(11.234)
Spelling	**OLS**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q13)**	**Lev 3/4 (Q27)**	**Lev 4/5 (Q54)**	**Lev 5/6 (Q80)**
ECD	**13.122****	9.802	14.680	**18.868****	**21.461*****	11.521
	(5.798)	(15.999)	(10.225)	(7.805)	(7.533)	(10.268)
TCD	**14.118***	8.445	12.279	17.753	**19.895***	13.314
	(8.433)	(18.526)	(13.261)	(11.993)	(11.998)	(13.121)
CC	**15.021****	13.010	15.862	**20.193****	**23.099*****	13.364
	(6.293)	(16.678)	(10.107)	(8.168)	(7.753)	(10.812)
CERT	16.426	26.503	20.308	31.764	18.330	14.231
	(11.507)	(32.270)	(17.579)	(20.347)	(13.303)	(20.130)
OTH	10.420	16.086	**20.124***	**16.997***	**19.532****	4.450
	(7.453)	(19.247)	(11.555)	(9.529)	(8.640)	(12.474)
Writing	**OLS**	**Lev 1/2 (Q04)**	**Lev 2/3 (Q08)**	**Lev 3/4 (Q22)**	**Lev 4/5 (Q48)**	**Lev 5/6 (Q75)**
ECD	8.085	10.632	16.587	14.537	**11.270****	4.731
	(5.163)	(15.743)	(11.847)	(9.749)	(5.691)	(9.308)
TCD	**18.083****	26.254	**28.240***	**25.831***	**24.459*****	14.788
	(7.131)	(20.352)	(16.996)	(15.094)	(8.169)	(11.770)
CC	7.068	3.151	8.101	7.520	8.993	7.490
	(5.594)	(16.958)	(12.165)	(11.136)	(6.407)	(9.261)
CERT	7.957	0.140	11.273	10.881	13.229	1.213
	(10.686)	(44.532)	(26.178)	(18.825)	(13.031)	(14.904)
OTH	5.139	8.209	15.527	15.011	6.093	1.309
	(6.404)	(19.410)	(14.353)	(11.755)	(7.544)	(11.341)
Grammar	**OLS**	**Lev 1/2 (Q05)**	**Lev 2/3 (Q11)**	**Lev 3/4 (Q28)**	**Lev 4/5 (Q50)**	**Lev 5/6 (Q69)**
ECD	6.763	8.811	8.605	6.831	6.049	5.552
	(6.468)	(15.819)	(13.527)	(9.354)	(6.795)	(9.491)
TCD	11.501	13.703	15.457	1.752	4.387	10.178
	(9.734)	(23.778)	(16.867)	(12.229)	(11.395)	(15.983)
CC	**13.086***	18.493	15.493	9.139	11.724	15.240
	(7.113)	(20.151)	(13.666)	(10.287)	(8.109)	(10.197)
CERT	4.186	3.323	14.847	2.580	5.870	10.345
	(13.819)	(39.213)	(28.044)	(20.386)	(20.781)	(18.033)
OTH	6.657	13.158	21.790	8.040	-0.381	2.262
	(8.405)	(21.461)	(15.625)	(9.885)	(9.763)	(12.450)

Bootstrap Standard Errors (N = 20) in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels respectively.