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Parental Investments and Child Development: Counting Games and Early Numeracy

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Abstract

While reading to children affects the development of their own early reading skills, the set of numeracy activities studied here and undertaken by Australian parents with children before they start school had no impact on their Year 4 achievement in mathematics. It is possible that other, unmeasured parental activities affect the early numeracy skills of children, but just what these activities might be is unclear from the available literature. Activities undertaken prior to starting school other than reading to children also appear to contribute little to the early reading skills of children. Broader measures of activities, better measurement and study design are necessary to make progress in understanding how the home learning environment affects early child learning.

JEL classification: I21, J13

Keywords: Child development, numeracy, parental investments, achievement

1. Introduction and motivation

Evidence suggests that reading to children when they are young improves their own early literacy skills (Price 2012, Kalb and van Ours 2014). What effect does playing counting games with children have on their early numeracy? While associations between these activities that parents undertake with their children are readily observed, demonstrating that the child's development was affected by the activities is more difficult. Those parents most concerned to promote their child's development may naturally undertake such activities more often or more effectively than others, so estimated effects will reflect the preferences behind their observed behaviour as well as any effect it has on development. Alternatively, the children of parents concerned about child development may have better innate capacities to capitalise on the investments their parents make than other children. Within families, it is unclear whether parents are likely to invest more in their more or less gifted children (Becker and Tomes 1976, Aizer and Cunha 2010 versus Price 2012).

Kalb and van Ours (2014) estimated the relationship between Australian parents reading to their children at age 4 to 5 years and the children's later own reading. Kalb and van Ours (2014) found that their causal estimates of the impact of reading to children were no smaller, and possibly larger, than the estimates that simply measured the association between the two phenomena. Moreover, these effects were present even when objective age 4 to 5 year measures of cognitive development were included in estimation. These results are revisited here with different data and extended to assess whether there is any effect of parents engaging in counting games and other early numeracy-related activities on their child's development of numeracy-related skills.

A different strategy is adopted in this paper to the estimation of the impact of the early reading and numeracy-related activities parents engage in with children before they start school on their Year 4 reading and numeracy achievement levels. Unlike Kalb and van Ours (2014), there are no defensible instruments available here (variables that influence Year 4 achievement only via their impact on undertaking the pre-school activities). Instead, we exploit the existence in the data used here of measures of both early literacy and numeracy activities and the later outcomes. We argue that we can find groups of parents who are like-minded in their attitudes towards their child's development, and that we can estimate the effect of engaging in relevant, related activities within the groups who are similar in these attitudes, but who differ in the intensity of their engagement. We argue that people with

similar education levels who engage in a similar number of early literacy and numeracy activities reveal themselves to be similar in terms of their attitudes towards their child's development. The trick is that we use the groupings based on the alternative activities to estimate the effect of literacy-related or numeracy-related activities on outcomes. Specifically, we estimate the effect of varying levels of numeracy-related (literacy-related) activities on numeracy (literacy) achievement within groups who had common levels of participation in literacy-related (numeracy-related) activities. If parents in general view the development of literacy skills in their children as more important, the impact of our numeracy estimates will be more reliable, since families with similar engagement in activities will be more alike.

The main result in this paper is that engaging with children in the set of early numeracy-related activities captured in these data by parents does not pay off in the same way as reading to children does for a child's own reading skills. But it seems that reading to children is unique among the set of literacy-related activities studied here too – none of them, other than reading to children, appear to influence the child's reading skills much either, consistent with other results in the literature.

The remainder of the paper is organised as follows. The next section contains a review of the relevant child development literature. Section three contains descriptions of the methodology and the data used here, while section four contains the results. Concluding comments are made in section five.

2. Parental investment in children and their impact

2.1. Family background and child characteristics effects on child development

Studies consistently show that family background affects both the amount of education individuals complete and what they learn while undertaking it (Bjorklund and Salvanes 2011). Genes, resources, parental investments of time and effort in child development and the transmission of attitudes towards learning may all contribute to these family background effects.

An array of family background factors, beyond the characteristics of the children themselves, has been found to influence child development and later adult outcomes (for a review see Bjorkland and Salvanes 2011). In terms of demographic factors, these include family size (Becker and Tomes 1976), child birth order (Black, Devereux, and Salvanes

2005a, Angrist, Lavy and Schlosser 2010, Booth and Kee 2009), birth spacing (Price 2008), parental education (Black, Devereux, and Salvanes 2005b, Holmlund, Lindahl and Plug 2011) and household resources, including income (Currie 2009, Belley and Lochner 2007). Indigenous and minority group effects can be substantial (Neal 2006, Todd and Wolpin 2007).

Health factors also matter. These include factors that influence the child's later health, including mother's health, the child's own birth weight (Currie and Hyson 1999, Black, Devereux, and Salvanes 2007), the experience of childhood health conditions (Currie, 1999, Currie, Stabile, Manivong and Roos 2010), as well as the presence of other household members with a disability or long term health condition (Parish and Cloud 2006, Allin and Stabile 2012). Numerous child characteristics, such as gender and ability also influence achievement (Todd and Wolpin 2007).

When children go to school, a whole new set of factors including the school environment, peers, teachers and access to resources all matter for achievement. The focus here, however, is on what happens before children go to school.

2.2. Parental activities or investments and child development

It has been widely observed that parenting practices such as reading to children, using complex language, responsiveness, and warmth in interactions are all associated with better developmental outcomes (Bradley, 2002). Since higher SES parents use such activities more often, this partly explains links between SES and developmental outcomes (Hess *et al*. 1982). Distinguishing causation from association in understanding the role of parental practices is a major challenge for this literature. The National Early Literacy Panel (NELP) in the United States conducted a meta-analysis of research on the development of early literacy skills in children ages zero to five years (NELP 2008). The report concluded that, relying on only studies that involved randomized control trials [RCT] or quasi-experimental designs [QEDs], home and parent programs had statistically significant effects on measures of oral language (small effects) and general cognitive ability (moderate to large). Effects on other aspects of literacy, including reading, writing and spelling, for example, were not significantly different from zero. Hence, some causal effects of parental programs on early child literacy outcomes can be claimed, though there was no obvious set of common parental activities or practices across the successful parent interventions in the studies.

Many studies show that numeracy and literacy achievement at the time children commence school is strongly predictive of later performance in those domains (Claessens et al. 2009) and that the home learning environment for children is highly predictive of their performance in school, including into secondary school (Sylva *et al.*2012). Others show a strong link between activities undertaken within the household and the achievement of children at the time they commence school. Melhuish *et al*. (2008) distinguish *learning*-related activities from *social* ones, and found that only the former were related to later achievement. The literature on parental engagement in pre-school literacy-related activities and its impact on later child outcomes is much more extensive and conclusive than the literature on the effect of pre-school parental engagement in numeracy-related activities (LeFevre *et al*. 2009). Doig, McCrae and Rowe (2003) review a small number of studies in this literature, but none are based on strong experimental or quasi-experimental research designs like those reviewed in NELP (2008).

In an important contribution to the former literature, Kalb and van Ours (2014) estimated the relationship between Australian parents reading to their children at age 4 to 5 years and the children's later own reading via instrumental variables. They argued that factors that limited parents' time availability would reduce how often they read to their children, and affect their child's later own reading only through that channel. These time-limiting factors included whether the child was the oldest child in the family and the number of siblings in the family at the time the child was read to or not. These factors were supplemented with the rich set of family circumstance variables provided in the Longitudinal Study of Australian Children (LSAC). Kalb and van Ours (2014) concluded that their causal Instrumental Variable (IV) estimates of the impact of reading to children were no smaller than the estimates that ignored the endogeneity of the activity. These effects were present even when objective age 4 to 5 year measures of cognitive development were included in estimation of later reading skills. The importance of the research was that it suggested the widely-observed association between parents reading to their children and the child's own literacy skills (references) could be given a casual interpretation. The NELP (2008) report also indicated that shared-reading interventions, involving parents and others, can have a significant, substantial, and positive causal impact both on young children's oral language skills and on their understanding of print material.

LeFevre *et al*. (2009) distinguish between indirect and direct experiences as they affect the link between home experiences and numeracy development. Direct activities involve numbers and are used with the explicit purpose of developing quantitative skills. They include counting objects, practicing number names and writing numbers. Indirect activities encompass real-world tasks for which the acquisition of numeracy is likely to be incidental. They include playing card or board games that involve numbers, cooking, or carpentry where they include measurement. LeFevre *et al*. (2009) found that engagement in both indirect and direct experiences was associated with better mathematics skills, with both the reported activities and the child's assessment reported by parents.

Gustafsson, Hansen and Rosen (2013) analysed data from the Progress in International Literacy Study and the Trends in International Mathematics and Science Study (PIRLS/TIMSS) to look at similar issues to those studied here. They conduct path analyses of the roles of parental education and child gender on Year 4 achievement, taking account of the relationships between household holdings of books, parental investment activities and the early ability of children on their later achievement. They conduct these analyses in aggregate and for each country that participated in the PIRLS/TIMSS study.

The parental education path diagram for Australia from Gustafsson *et al*. (2013) is replicated in Figure 1. There is a direct parental education effect on all areas of achievement. This is about two-thirds of the total effect of parental education on reading, mathematics and scientific achievement. There are indirect effects of parental education on achievement that are mediated by books in the household, which has a similar impact on all learning domains, and via influences of "general" parental investment activities on "general" ability. The effect of unobserved, general ability on the three achievement domains is quite similar. Gustafsson *et al*. (2013) did not find any direct role for activities in Australia (or in aggregate for all countries), only an indirect effect via general ability. Where families engaged in literacy-related activities over numeracy-related ones, both general ability and relative literacy ability were increased. This fed through into increased Year 4 achievement, so it appears that literacy skills are also important for numeracy, at least in the early years of schooling. It was more common for girls than boys for families to report an emphasis on literacy over numeracy activities, which partly explained the higher level of reading achievement for girls in Year 4.

The Gustafsson *et al*. (2013) paper built on earlier work by Myrberg and Rosen (2009) and Park (2008) with a similar approach using 2001 data for PIRLS. Park (2008) found small effects of home learning activities on achievement, with bigger effects for books in the home, though the latter has a slightly negative direct impact on all achievement domains. Myrberg and Rosen (2009) also found small effects from activities and early ability on achievement.

Anders *et al*. (2012) studied the different effects of parents engaging in numeracy-related activities with their children on numeracy achievement and literacy-related activities on the development of literacy skills. They found that the quality of the home learning environment in promoting literacy skills had a strong impact in promoting both literacy and numeracy skills. In fact, this effect was larger on numeracy achievement than was the effect of the home learning environment for promoting literacy skills. In early schooling, at least, it appears that the development of numeracy skills is bound up with the development of literacy skills, or that the instruments used to measure numeracy skills also require good language skills.

In a study a little more like Kalb and van Ours (2014) than Gustafsson et al. (2013), Price (2012) uses within family fixed effects and birth order and spacing effects to instrument for the time mothers spend reading to their children. Using time use data, Price (2012) finds a positive effect of reading to children on the child's own reading score. In contrast, for mathematics Price found that "the impact of parents on their children's math performance results from fixed inputs (genetics, parental education, etc) rather than changes in parental time investments. This is consistent with the fact that much more parent-child time is directed towards reading than towards math." Price (2012: 11)

3. Methodology and data

3.1. Methodology

Suppose that child development is related to parental investments in the child in the following linear way:

$$(1)\ \boldsymbol{y_i} = \boldsymbol{\alpha} + \boldsymbol{X_i'\beta} + \boldsymbol{p_i\gamma} + \boldsymbol{y_i^e\,\delta} + \boldsymbol{\mu_i} + \boldsymbol{\epsilon_i}$$

where $\boldsymbol{y_i}$ is a measure of child development for individual *i*, the $\boldsymbol{X}$'s are a set of background characteristics and other explanatory variables, $\boldsymbol{p_i}$ reflects parental investments in specific

activities, $\boldsymbol{y_i^e}$ is an early measure of child *i*'s achievement in the relevant development domain and $\boldsymbol{\alpha, \beta}$, $\boldsymbol{\gamma}$ and $\boldsymbol{\delta}$ are parameters to be estimated. The residual has two components: $\boldsymbol{\mu_i}$ is a term capturing heterogeneity between families in terms of their attitudes towards child development that is common across learning domains, while $\boldsymbol{\epsilon_i}$ is a random variable, specific to the learning domain under consideration. As already noted, the problem with estimation of equation (1) is that parental investment in children, $\boldsymbol{p_i}$, is likely associated with the $\boldsymbol{\mu_i}$ heterogeneity term. That is, those with high values for the investment variable will be those particularly concerned about the development of their children. Such families may influence their children's outcomes in many other ways, including some which we will not observe properly. Hence, estimates of $\boldsymbol{\gamma}$ will reflect both any true effect of the investment on child development that exists and the bias associated with the unmeasured relationship of *p* with $\boldsymbol{\mu_i}$.

The results in Gustafsson *et al*. (2013) imply that the parental investments have no direct effect on later child development outcomes once early measures of a child's achievement are taken into account, such that $\boldsymbol{\gamma}$=0 in equations that include $\boldsymbol{y_i^e}$. However, we might find that the parameters on the parental investments are not zero if the early achievement measures are not included, since the parental investments influence $\boldsymbol{y_i^e}$.

Suppose we can identify groups, *g*, who differ in their preparedness to invest in their children such that they have common values of $\boldsymbol{\mu}$. Then we can think of the estimation problem posed by equation (1) as, conceptually, having the equivalent to a longitudinal data structure.

$$(2)\ \boldsymbol{y_{ig} = \alpha_g + X'_{ig}\beta + p_{ig}\gamma + y_i^e\,\delta + \mu_g + \epsilon_{ig}}$$

Estimation of equation (2) by OLS, ignoring the group structure, is like estimation of pooled data in a longitudinal context. In that case, we know that the OLS estimate of the parameters of equation (2) will be a weighted estimate of parameters that would be estimated from the *within* and the *between* grouped data (Cameron and Trivedi 2000). That is:

$$(3)\ \boldsymbol{\hat{\gamma}_{ols} = [M \times \hat{\gamma}_{within}] + [(1 - M) \times \hat{\gamma}_{between}]}$$

where $\boldsymbol{M}$ weights the parameters according to the contribution to the overall variance in the X's between the *within* and *between* contributions. The *within* estimates are generated from regression of the child development variable on the explanatory variables using only the variation in the parental activity or investment variables within the group. The *between*

estimates are generated by regressing the group average child development outcomes on the average parental activities for the group across all groups. If our groups are perfectly identified, then the *within* estimator will capture how child outcomes vary with parental investments among parent with the same underlying attitudes towards their child's development, but who for some reason made slightly different investments in them, in terms of the activities they undertook. If that is so, then $\widehat{\boldsymbol{\gamma}}_{\boldsymbol{within}}$, the *within* estimator will provide the best estimate of the true effect of parental activities on child development outcomes and we can estimate the "bias" in the OLS estimates using

$$(4)\ \widehat{\boldsymbol{\gamma}}_{\boldsymbol{ols}} = [\boldsymbol{M} \times \boldsymbol{\gamma}\ ] + [(\mathbf{1} - \boldsymbol{M}) \times (\boldsymbol{\gamma} + \widehat{\boldsymbol{\gamma}}_{\boldsymbol{bias}})] = \boldsymbol{\gamma}\ + [(\mathbf{1} - \boldsymbol{M}) \times \widehat{\boldsymbol{\gamma}}_{\boldsymbol{bias}}] = \widehat{\boldsymbol{\gamma}}_{\boldsymbol{within}} + [(\mathbf{1} - \boldsymbol{M}) \times \widehat{\boldsymbol{\gamma}}_{\boldsymbol{bias}}]$$

where $\widehat{\boldsymbol{\gamma}}_{\boldsymbol{bias}}$ is the "bias" associated with using the between groups estimator.

The main question for the analysis that follows is how to establish the group membership, *g*. As already noted, we argue that people with similar education levels who engage in a similar number of early literacy and numeracy activities reveal themselves to be similar in general in their attitudes towards their child's development. The approach here uses groupings based on the alternative activities to estimate the effect of literacy-related or numeracy-related activities on outcomes. We adopt a number of approaches.

First, we estimate the effect of varying levels of numeracy-related (literacy-related) activities on numeracy (literacy) achievement within family groups who had common levels of participation in literacy-related (numeracy-related) activities. Hence, we estimated equation (2) for numeracy (literacy) achievement with fixed effects specified over those households who had the same level of participation in literacy-related (numeracy-related) activities. In the first instance, we use deciles of the numeracy-related or literacy-related activities as the basis for the groups. In the second instance, we further distinguish households within these deciles by the highest level of completed education by either of the parents, using three education categories: degree or higher; other post-school qualification; school only education. These more detailed groups allow for the possibility that differing groups with the same level of engagement in activities may be more effective in undertaking them with children, in terms of their production of child achievement-related skills. The limitation of this approach is that we can only include parental engagement in the alternative set of activities for either the Year 4 reading or numeracy regression equations.

Two alternative approaches help us get around this problem. The first is to base the groups on another factor that might reflect household attitudes towards child development but not be directly related to either the literacy- or numeracy-related activities. One suitable candidate is the response given by households to the likely eventual level of education the child is expected to complete. Again, the argument is that households who share the same educational attainment ambitions for their children are likely to be very similar in terms of their preferences and attitudes towards their children's developments, so that any variation in the activities families undertake with their children might be given a causal interpretation.[1]

The second, related approach is to take the residual from an equation explaining the expected attainment of their child against broad demographic characteristics, take its rank and include that in the achievement regression equation (1). This variable is included explicitly to reflect the $\boldsymbol{\mu_i}$ component of equation (1).[2]

The equations are estimated separately for literacy and numeracy and for males and females. The set of explanatory variables include a home resources or SES index, a scale reflecting how much the respondent to the home questionnaire likes to read, whether the child is indigenous, whether the household lives in a metropolitan area, and the relative age of the child within the grade cohort of children in their state. The home resources scale combines the highest education level of the child's parents, the number of adult and children's books in the home, and the highest broad occupation (based on an SES scale) of the parents. Other than being from an indigenous background, these factors are likely to be positively correlated with the activities people engage in, the skills of children when they start school and their achievement in Year 4.

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[1] As a robustness check, we also perform Mahalanobis matching of children with high levels of numeracy or literacy activities against those with lower levels within the groups defined by parental expectations about the eventual educational attainment of the child. The results were not qualitatively different from those provided by the fixed effects regression approach.

[2] An alternative approach is to base this heterogeneity term on the parent's expectation the child will attend university (coded 1 if so, zero otherwise) compared with the average expectation of other parents with the same level of education. This difference was included as the heterogeneity term in the regression equation, indicating how unusual an expectation is for the specific education group. The results were qualitatively similar to those presented in the results section for the ranked residual approach.

3.2. PIRLS & TIMSS Data

PIRLS involves an assessment of the reading achievement of students in Year 4. TIMSS involves an assessment of the mathematical and scientific achievement of students in Years 4 and 8, though only the data for Year 4 Australian students are analysed in this paper. A stratified random sample of 280 Australian primary schools participated in the data collection for both the TIMSS and PIRLS 2011 studies. The sample was stratified by state, school sector and rurality. Some 6126 and 6146 Australian students undertook the PIRLS and TIMSS tests respectively. Two classrooms per school were sampled, along with all of the indigenous students found in Year 4 in the sampled schools. All sampled students for TIMSS at Year 4 also were asked to take the PIRLS reading tests.

These achievement tests at Year 4 provide the main set of outcome variables used in the analysis presented here. The top panel of Table 1 contains the average reading, mathematics and science scores for males and females in Year 4. In the PIRLS and TIMSS studies a number of alternative estimates of student achievement are provided, so called "plausible values". These are predictions about the students achievement given their performance in the tests, to which a random error term is added because there is some uncertainty about the students actual level of ability in the domain tested. The plausible values differ in that a different draw from the error distribution is used each time. In this paper, the "first" plausible value of each of the domains is used in all of the analysis that follows. These scales are all calculated to have a mean of 500 and standard deviation of 100 across students participating in the PIRLS and TIMSS studies from all countries. The estimates contained in Table 1 indicate that Australian Year 4 students are above average in all domains. Females had higher achievement levels in reading than boys, but there were no significant differences between males and females in mathematics and science in Australia.

In addition to the achievement tests, students completed questionnaires about their family backgrounds and attitudes towards reading, mathematics and science. Various sources of supplementary information about the child and her background were merged with her reading, mathematics and science achievement scores. Teachers were asked to complete questionnaires that asked about their backgrounds and qualifications, approaches to teaching and the school environment. Principals provided further contextual information on schools via a school survey. Adults from about half of the households of children surveyed completed questionnaires about the home learning environment and learning support provided to the child both at the time of the survey and prior to attending school, as well as the education and

occupations of the adults living with the child. In Australia, some 3210 households provided complete responses to the household questionnaire (Table 1).

Responses to the items in the household questionnaire provide the main variables capturing aspects of the home learning environment that are studied here. These items capture how often the study child was read to prior to commencing school, along with a number of activities likely to promote the development of their own reading and numerical skills. These items and the responses of parents on how often they engaged in those activities are reported in Table 2.

The responses to these questions were combined in the data released by those who collected it into two scales: one combines responses (a) to (f) into a literacy-related activities scale; the other combining responses (g) to (l) into a numeracy-related activities scale. The weights given to the responses in these scales were derived from factor analysis and reflect how often households engaged in these activities. The standardised scores were transformed in the analysis undertaken here, such that the minimum score on the standardised scales were assigned zero for the relevant concept and the maximum scores unity. The distributions of the resulting scales are shown in Figure 2. Higher values of the scale mean parents undertook more activities more often with the children. The distributions of the joint scores of the two scales are shown in Figure 3, weighted by the number of observations at the various points. These show that families that undertook more literacy-related activities tended to undertake more numeracy-related ones too, and vice versa. However, for any level of literacy or numeracy activities, there was substantial variation in the amount of the other activity undertaken.

The home questionnaire also includes an assessment by the parent of the child's reading and numerical skills at the time they started school. The topics covered and responses by Australian parents are reported in Table 3. Once more, the responses to these questions were combined in the data released by those who collected it into two scales: one combines responses (a) to (f) into an early literacy skills scale; the other combining responses (g) to (l) into an early numeracy skills scale. The weights given to the responses in these scales were derived from factor analysis and reflect the child's skills, as assessed by their parent. The standardised scores were transformed in the analysis undertaken here, such that the minimum score on the standardised scales were assigned zero for the relevant concept and the maximum scores unity. The resulting scales are shown in Figure 4. Higher values of the scale suggest children had more developed literacy and mathematical skills. That many of the

prompts in Table 3 allow for one of four possible responses, rather than the three available in Table 2, means that the resulting scales are more spread out in Figure 4 than Figure 2, with more mass between 0.2 and 0.4. This is likely to mean that these early achievement scales are somewhat more "informative" in distinguishing between children than the early activities scales.

The distributions of the joint scores of the two early achievement scales are shown in Figure 5, weighted by the number of observations at the various points. These show that families that assessed their child's literacy skills more highly also tended to assess their child's numeracy skills highly too, and vice versa. However, for any level of assessed literacy or numeracy skills, there was substantial variation in the assessed skills in the other achievement domain.

Few other variables are used from the data collection in the analysis of Year 4 achievement, with the exception of a measure of the numbers of books in the household. These estimates come from the student questionnaire undertaken at the time the child undertook the survey. These data provide some benchmark against which to decide how selective the group who responded to the home questionnaire were.

Those households who provided a response to the home questionnaire, from which the activity engaged in and early skills variables were based, were not drawn randomly from the students who undertook the achievement tests: they had higher levels of achievement and were from higher SES backgrounds. This is evident from Table 4, where their average reading achievement exceeded the average of the total sample by 15 points and the proportion with 50 or more books in their household was 11 percentage points higher than the total sample. [3]

With variables being constructed from questions about similar activities and skills answered by the same people about their children, it is possible that the various constructed measures could be so highly correlated it would be very difficult to distinguish their separate effects on achievement. Correlation coefficients between these various measures are presented in Table 5. While it is true that the measures for reading and numeracy for activities, skills and actual achievement are quite highly correlated (in the range 0.6 - 0.75),

[3] In the regression analysis, we assess the sensitivity of the results we obtain to possible non-response bias by weighting respondents to reflect this likelihood of response, giving most weight to those who were most like the non-respondents.

the correlations between activities, skills and achievement are more moderate, always less than 0.3. The correlations between parental activities and Year 4 achievement appear to be smaller than those between skills at the time children start school and Year 4 achievement.

It is possible that parents may vary more in their ability to engage in numeracy-related activities than literacy-related ones with children. After all, it is clear what you do when you read to your child, but beyond counting with them, other activities to help develop their numeracy skills may be more challenging for parents. Hence, the effectiveness of time spent undertaking activities with children may be much more variable for numeracy-related activities than literacy-related activities. It is of some note that the correlation between numeracy-related activities and school start numeracy skills is lower in Table 5 than the comparable number for literacy (0.25 compared to 0.34), which are both parent reported measures. The correlations between activities and Year 4 achievement are closer, but still reflect a gap (0.15 to 0.20). This may make it harder to identify a relationship between numeracy-related activities and actual achievement than for literacy-related activities.

4. Results

4.1. Graphical presentation of the results

The key results in this paper can be summarised via a series of graphs that show the relationships between the activities parents engage in with their children prior to them commencing school, the children's achievement at the time they commence school and their measured achievement in Year 4. Essentially, these series of figures suggest that the apparent positive relationship between parental activities and Year 4 achievement becomes substantially smaller when engagement in alternative activities (that is, literacy-related activities on numeracy) and achievement at the time children enter school are taken into account. Further, estimating these effects only within groups who were alike in terms of their reported expectations about the level of education the child would eventually complete removed any positive effect of engagement in either literacy- or numeracy-related activities on related achievement. Figure 6 shows the relationships between average early literacy and numeracy achievement and the literacy- and numeracy-related activities parents engaged in with their children prior to them commencing school. The most positive relationship is between literacy-related activities and early literacy, while the relationship between numeracy-related activities and early numeracy is also positive, but more muted. There appears to be little relationship between activities undertaken and the alternative literacy

domain: higher levels of engagement in numeracy-related activities are not associated with early literacy, or vice versa.

Just how average Year 4 reading achievement moves with changes in the literacy-related activities undertaken with children prior to them starting school is shown in Figure 7. The solid line shows the relationship without taking account of numeracy-related activities and the estimated literacy achievement of children when they started school, while the dashed line does take account of those phenomena. The solid line is steeper than the dashed line, which nevertheless indicates that reading achievement is over fifty points higher among those whose parents engaged in the most literacy-related activities compared with those whose parents engaged in the least.

Figure 8 shows the comparable relationships for numeracy. The solid line shows the relationship without taking account of literacy-related activities and the estimated numeracy achievement of children when they started school, while the dashed line does take account of those phenomena. The solid line is steeper than the dashed line, which nevertheless indicates that numeracy achievement is about forty points higher among those whose parents engaged in the most numeracy-related activities compared with those whose parents engaged in the least.

The relationships between Year 4 reading and engagement in literacy- and numeracy-related activities undertaken with children prior to them starting school are shown in Figure 9, as well as the estimated literacy achievement of children when they started school. The right panel contains estimates of the relationship where this is done within groups whose parents had the same expectations about the future level of education children would complete. These estimates also took account of the social background of the children. The left hand panel did not include such fixed effects, nor did it incorporate the role of social background. The fixed effects remove any effect of the pre-school activities on reading achievement, with only the estimated literacy achievement of children when they started school being positively related to actual Year 4 achievement. The magnitude of this effect does not differ much between the two panels.

Figure 10 shows the comparable relationships for numeracy. The right panel contains estimates of the relationship where this is done within groups whose parents had the same expectations about the future level of education children would complete. These estimates also took account of the social background of the children. The left hand panel did not include such fixed effects, nor did it incorporate the role of social background. The fixed

effects remove any positive effect of the pre-school activities on mathematical achievement, with only the estimated numeracy achievement of children when they started school being positively related to actual Year 4 achievement. The magnitude of this effect is substantially smaller in the right panel than it is in the left-hand panel. In the right panel, engagement prior to school in more literacy-related activities appears to be negatively related to numeracy skills at Year 4, consistent with results reported in Gustafsson *et al.* (2013).

4.2. Regression results

Just two sets of regression results are presented and discussed in any detail. These are presented in Tables 6 and 7. The first show the results when the Year 4 achievement equation includes all background characteristics, the parent-related activities and the child's skills when commencing school, along with the heterogeneity estimated derived from the expected educational attainment equation. Results are presented separately for males and females, for Year 4 reading and numeracy achievement. The second table contains the results when no heterogeneity term is included, but fixed effects for the child's expected eventual educational attainment are included, so the effects show how achievement varies with the relevant activities and school starting achievement within expected attainment groups. The results in both tables attempt to deal with unobserved heterogeneity in household attitudes towards child development that might also influence their engagement in literacy-related activities prior to their child starting school. The two sets of results are qualitatively and quantitatively similar.

The results suggest home resources are positively associated with Year 4 achievement, while being Indigenous is negatively associated with it. The home resources variable is scaled to lie between 0 and 1, as are the literacy and numeracy skills at the commencement of school, the literacy- and numeracy-related activities, the relative age and the heterogeneity term. Hence, the parameter estimates for these variables show how moving from the bottom to the top of the distribution relates to reading and numeracy achievement. Other variables are binary indicators, and the parameters show the impact of having the particular characteristic relative to not having it. The dependent variable is scaled such that it has a mean of around 500, and a standard deviation of 100 internationally, though for Australia the standard deviations are around 80 (see the descriptive statistics in Appendix Tables A1 and A2). Hence, the value of the parameters on the home resources variable across the equations indicates that moving from the bottom to the top of the home resources

distribution is associated with an increase in achievement of considerably more than one standard deviation. Relative age also tends to be positively associated with Year 4 achievement for girls. The literacy and numeracy skills children start school with are also positively associated with Year 4 achievement, though the estimated parameters in the fixed effects specification are somewhat smaller than in the specification that includes the heterogeneity term. The magnitude of these effects vary substantially across equations, but lie somewhere such that a move from the bottom to the top of relevant distribution as having an effect of between one-quarter and three-quarters of a standard deviation in achievement. Both literacy and numeracy skills at the commencement of school are positively associated with both reading and numeracy. Interestingly, higher numeracy skills at commencement are associated with higher reading skills for girls, while higher literacy skills at commencement are associated with higher numeracy skills for boys.[4]

While the skills individuals have when they start school are positively related to achievement, the activities parents engage in with their children before they started school are not, in general. The related activities were positive and significant (at the 10 per cent level) in just one set of the estimated results for reading and numeracy achievement. Moreover, the parameters are not significant either if the skills individuals have when they started school are excluded from the Year 4 achievement equations, so any close relationship between activities and reported skills is not the reason the activity variables are not significantly different from zero.

In fact, other specifications that are less careful in dealing with unobserved heterogeneity in household attitudes towards child development typically indicated no role for engagement in literacy-related activities prior to children starting school having any impact on either reading or numeracy in Year 4. Even least squares estimates of these effects were zero. The main impact of specifying increasingly disaggregated fixed effects was to reduce the magnitude of the home resources parameter, which in the estimates in Tables 6 and 7 are about three-quarters of the magnitude of the least squares specification.[5] The parameters on other variables are not much different in the reported results to the simpler

[4] Test of significance did not indicate that the parameters on the literacy and numeracy skills when starting school were different in any of the equations, supporting the approach in Gustafsson *et al*. (2013) of there being one, general underlying ability beneath the two measures.

[5] These estimates are available on request from the author.

specifications. Matching estimates, where Mahalanobis matching on the explanatory variables within the groups used for the fixed effects analysis, also provided qualitatively similar estimates to the regression estimates presented.[6]

The specifications in Tables 6 and 7 use the scales that combine a number of activities. It is possible that the combined scale hides the effect individual elements, such as reading to children or counting games, might have on achievement. Tables 8 and 9 contain the estimated parameters when each activity was separately included in the reading and numeracy achievement equations respectively. The key result is that none of the individual numeracy-related activities are associated with Year 4 numeracy for both genders in Table 9, though playing less than often with shapes may be associated with lower numeracy for boys. The only one of the literacy-related activities associated with Year 4 reading for both genders in Table 8 is reading to children, a result consistent with literature on the importance of that variable (Kalb and van Ours 2014). The penalty associated with only sometimes reading to children as opposed to often doing it was about 20 points for both males and females.

While the parental activities do not appear to have a joint effect on Year 4 achievement, and only reading to children affects Year 4 literacy, it is clear that the activities are positively associated with the skills the children have at the time they start school. And while these skills at school start do influence Year 4 achievement, it is not the case that the parental activities affect Year 4 achievement through the intermediate skills at the time of starting school. This is apparent from other estimates where we exclude the school start skills and find that none of its effect is then picked up by the parental activities variable and others where we split the skills at the time of starting school into components that reflect the part predicted by parental activities and the part unrelated to them. We find that all of the skills at the time of starting school effect arises from the part unrelated to parental activities, which would include the child's general ability and other personality factors.

Evidence from Figure 10 and Tables 6 and 7 suggest that higher levels of engagement in literacy-related activities might be negatively associated with numeracy achievement in Year 4, consistent with results reported in Gustafsson *et al*. (2013).[7] It is possible this reflects

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[6] The estimated activity-related effect measures the impact on achievement of activity levels between 0.8 -1 on the relevant activity scale compared to activity levels between 0-<0.8.

[7] Tests that the parameters on the literacy-related and numeracy-related activities variables in the numeracy achievement equation were equal were rejected at the 5% level.

some substitution of effort story, or possibly something about the "types" of households that emphasise literacy-related activities over numeracy ones and their priorities between the development of literacy and numeracy skills. Households certainly do not indicate that their assessments of their children's numeracy skills at school starting age are negatively associated with literacy-related activities, so any favouring of literacy over numeracy does not appear to be conscious. To get a better understanding of the effect, we replace the literacy activities scale in a series of regression equations with the individual literacy-related activities entered separately in the numeracy regression equation to see whether this effect is related to any particular activity. The results for the individual activities are presented in Table 10. The reading to children effect apparent for both boys and girls works in the wrong direction, suggesting numeracy is low among children read to less often. Elsewhere in the table however, there are a sprinkling of significant positive effects attached to lower levels of literacy-related activities, but none have similar significant effects for both boys and girls. What does not seem random, however, is that every single coefficient, other than for reading to children, is positive. So, while no single activity explains the negative relationship between engaging in literacy-related activities and later numeracy, it seems that many of these activities may act as markers for parents who were concerned about their child's general development. It may be that it is the parents of less able children who engage in these activities, and on their own, they do not impact on development very much, so we observe this negative association. Going against this interpretation, however, is that there are already a number of other indicators among the explanatory variables of what parents think of the development of their child and a measure of how much they engage in general numeracy-related activities, which would also reflect concerns about their child's development that induced more engagement in activities, where they had concerns and acted on them.

A further possibility is that habits around activities formed early in a child's life continue through childhood. Hence, it is possible that the answers households gave about the activities they undertook prior to their child starting school are also the ones they mostly engaged in once their child was at school. In that case, continuing to focus on literacy activities after their child commenced school at the expense of numeracy ones may, conditional on the child's early skills, have a negative impact on numeracy achievement in Year 4, and no apparent impact on reading if this tendency is most pronounced in households where children are struggling most to learn to read.

As already noted, the respondents to the household questionnaire were not representative of the sample as a whole. Evidence presented in Table 4 suggested the children from responding households had above average achievement levels and were from higher SES households. It is possible to use data from the entire sample to calibrate weights that reflect how likely any particular student is to come from a respondent household. These weights can be used to give greatest weight in estimation to those respondent households that are most like the non-respondents. When applied, the weights are effective in generating re-calculated mean values for the variables in Table 4 for respondent households that match those of the non-respondents. It is also possible to re-estimate the regression equations giving greatest weight in estimation to those most like the non-respondents. The re-estimated regression parameters for the fixed effect estimates are shown in Table 11. These match those of Table 6 very closely, suggesting that trying to take account of non-response in this way does not point to substantial non-response effects for the analysis presented here.

Further, it is possible to estimate a different equation explaining Year 4 achievement using only information from the student survey and testing whether the estimated parameters are different for the household respondents compared with the non-respondents. Tests suggest that the regression parameters on the explanatory variables are generally not different between the two groups, so while the observed characteristics of the two groups are different, any differences in unobserved characteristics that influence survey response do not seem to induce any biases in identifying factors associated with Year 4 achievement.[8]

A final point of interest relates to school performance. How much variation is there in how well students in individual primary schools are able to translate their skills at the time they start school into Year 4 achievement? And does school performance vary much between reading and numeracy? These questions were addressed by estimating equations with school fixed effects. These show very substantial differences in school performance. The difference

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[8] The test was conducted using pooled data for both groups. The explanatory variables (books in the household, metropolitan/rurality, indigenous, state indicators and measures of how engaged parents are with their child's education) were interacted with a home survey response indicator. The indicator on that variable was never significant and the other interaction variables were not jointly significant in three of the equations. The p-values for the various equations were male reading 0.007, female reading 0.120, male numeracy 0.175, and female numeracy 0.329. In the equation where the variables were significant, the results pointed to a more positive reading effect for respondents who lived in remote regions or were indigenous

in average school achievement between a school at the 25th and 75th percentiles of the school performance distributions was of the order of 40 points in both reading and mathematics, which are substantial differences, while those between the 10th and 90th percentiles were just over 80 points. The school fixed effects were very similar in reading and mathematics, with the correlation coefficient 0.65. Figure 11 contains a scatter plot of the two effects for schools. It is clear that primary schools who are successful in turning their students into strong achievers in reading are also successful in mathematics (34 percent of schools had positive effects in both reading and numeracy), while poor performers in one learning domain are also likely to be poor performers in the other learning domain (37 percent of schools had negative effects in both reading and numeracy).

5. Concluding remarks

Of the activities that parents engage in with their children prior to them commencing at school, it seems that reading to children belongs in its own class as an activity that causally affects the child's development. While there are apparent positive associations with achievement, engagement in the other activities measured here appears to have little actual positive effect on reading or numeracy skills. They may act mostly as reflections of parental concern or as indicators of persistent behaviours than as factors that influence achievement on their own.

It is possible that the set of activities measured here are just the "wrong" ones, and that some other set of activities that really have the potential to affect child development remain to be uncovered. Nevertheless, just what these set of activities might be appears to be elusive from the broader literature too. The way forward in identifying them must lie in experimental studies, not with reliance on observational data collected retrospectively. Studies such as York and Loeb (2014), where parents were randomised into groups that received differing text message reminders to engage in literacy-related activities with their pre-school age children, provide a potential model of an inexpensive intervention that could be trialled with alternative numeracy and literacy-related activities to assess their impact. Instructional messages may also help in reducing possible variability in parental effectiveness in undertaking these activities too.

It is also possible that the activities studied here are not measured very well. Measures based on the number of days per week these activities were undertaken, as in Kalb and van

Ours (2014), seem much more precise than the “Often” or “Sometimes” families responded to here. Time use data as in Price (2012) is a step ahead of this again.

While some families engage in much more of these activities that seem to relate to the development of the child’s own reading or numeracy skills, it appears that this says much more about the families and their focus on the development of their child than it does about the effectiveness of these activities. Reading to children clearly helps children with their own reading skills. Beyond that, none of the other activities studied here can be conclusively said to influence the early literacy or numeracy achievement of children.

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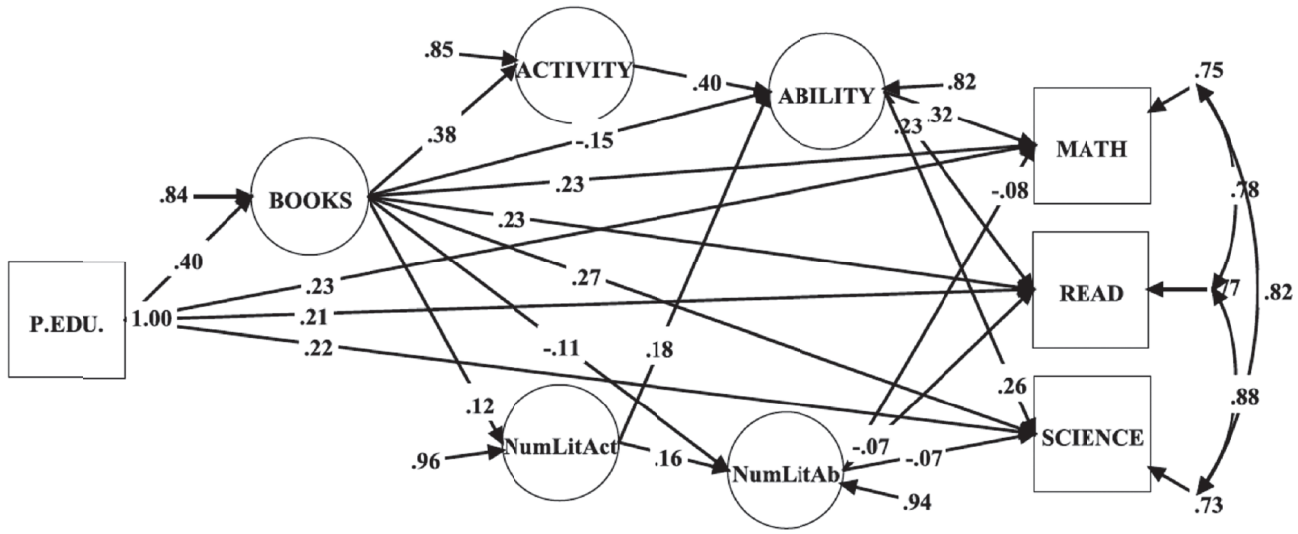
Figure 1: Parental education effects on early achievement - path diagram for Australia



Source: Gustafsson *et al*. (2013), page 249.

Figure 2: Distributions of parental engagement in child literacy and numeracy development activities

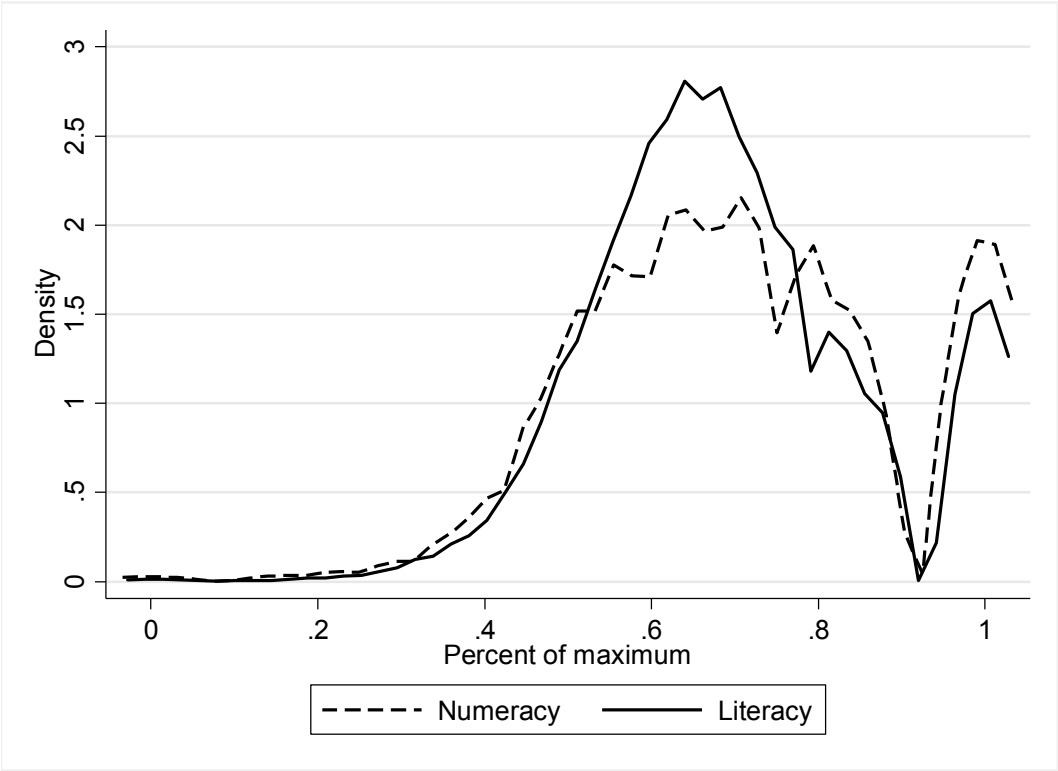


Figure 3: Joint distribution of parental engagement in child literacy and numeracy development activities

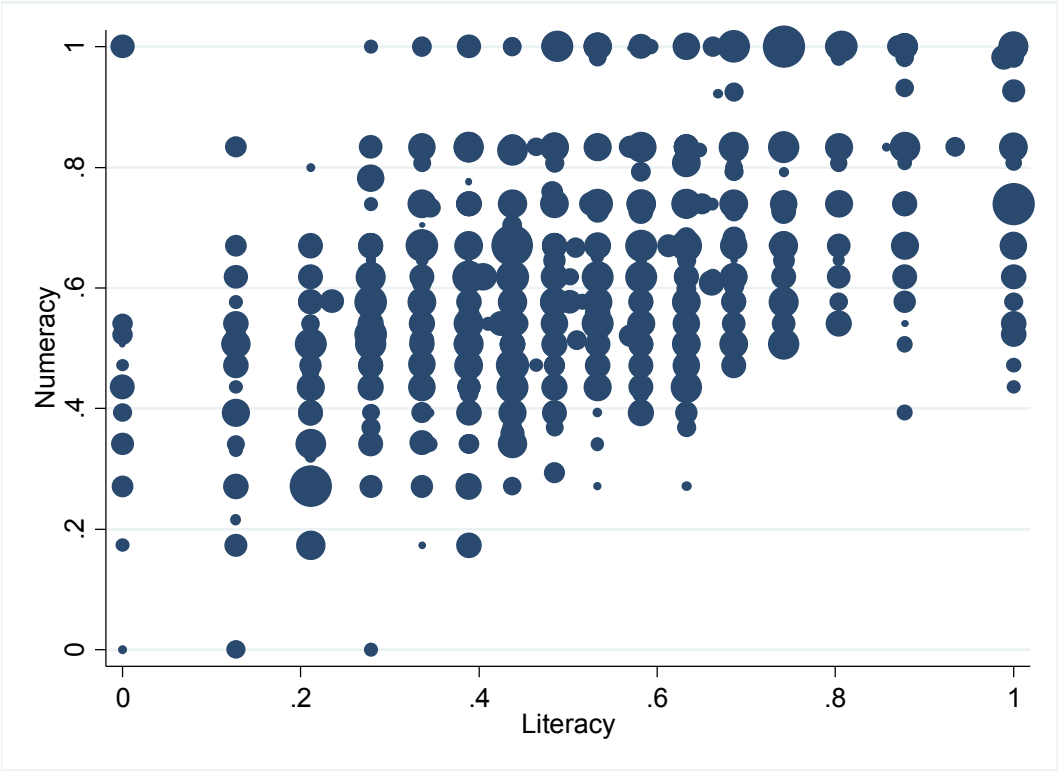


Figure 4: Distributions of child literacy and numeracy skills at the time they commenced school

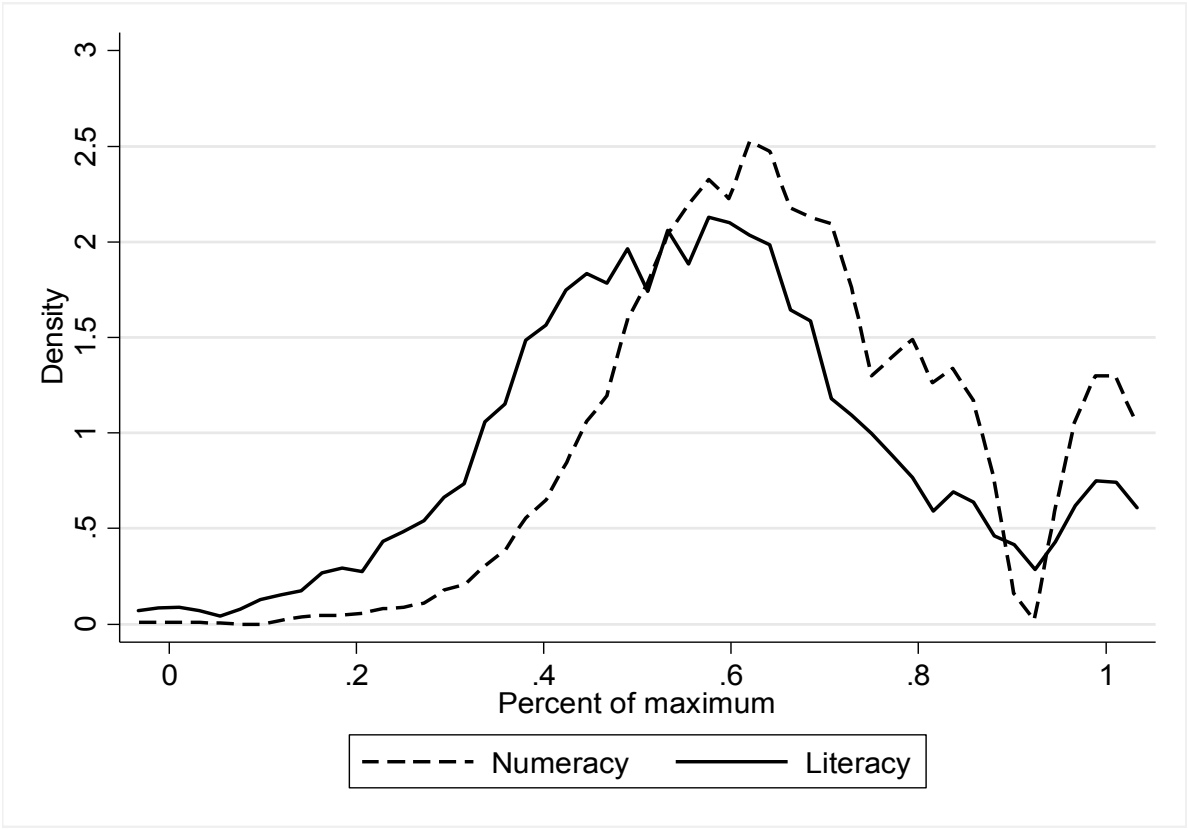


Figure 5: Joint distribution of parental assessments of child literacy and numeracy achievement

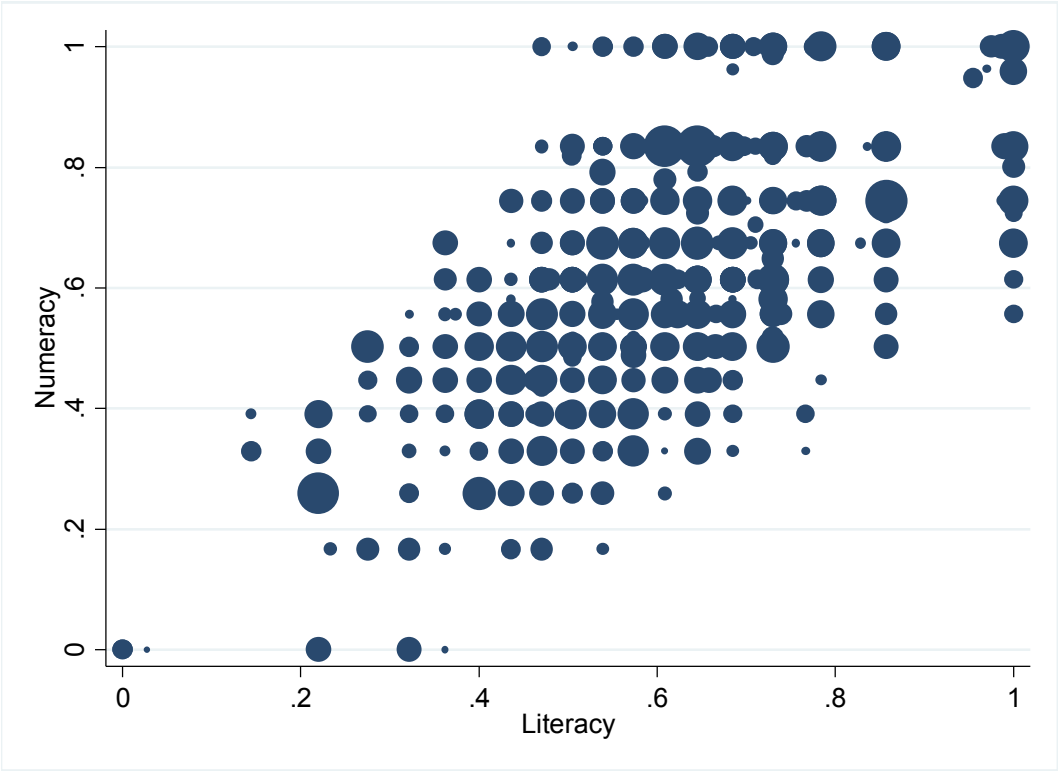


Figure 6: Effect of literacy and numeracy activities on literacy and numeracy skills at the time child started school

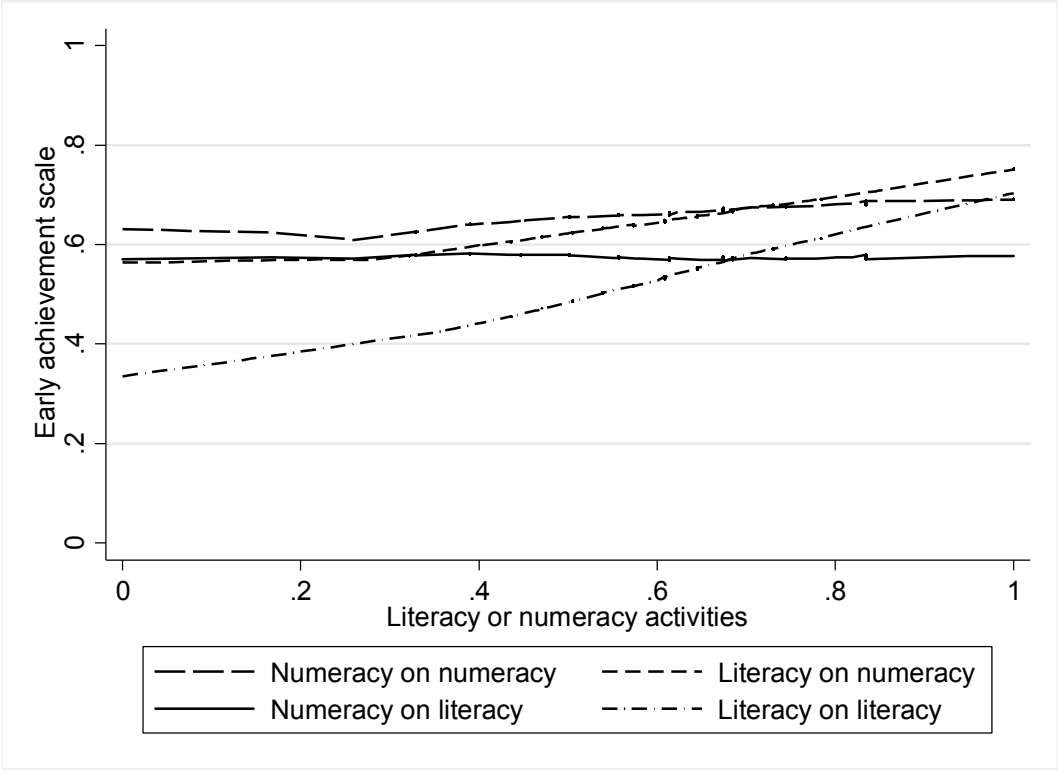


Figure 7: Effect of literacy activities on Year 4 reading, without and with controls for numeracy- related activities and literacy skills at the time child started school

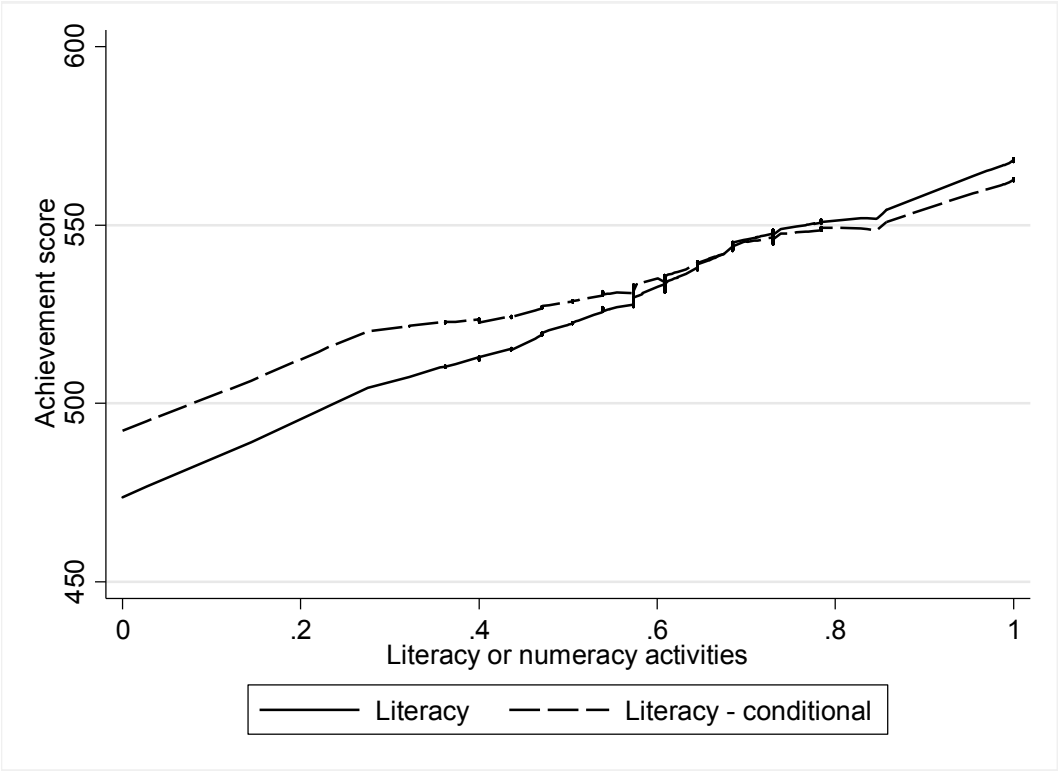


Figure 8: Effect of numeracy activities on Year 4 numeracy, without and with controls for literacy-related activities and numeracy skills at the time child started school

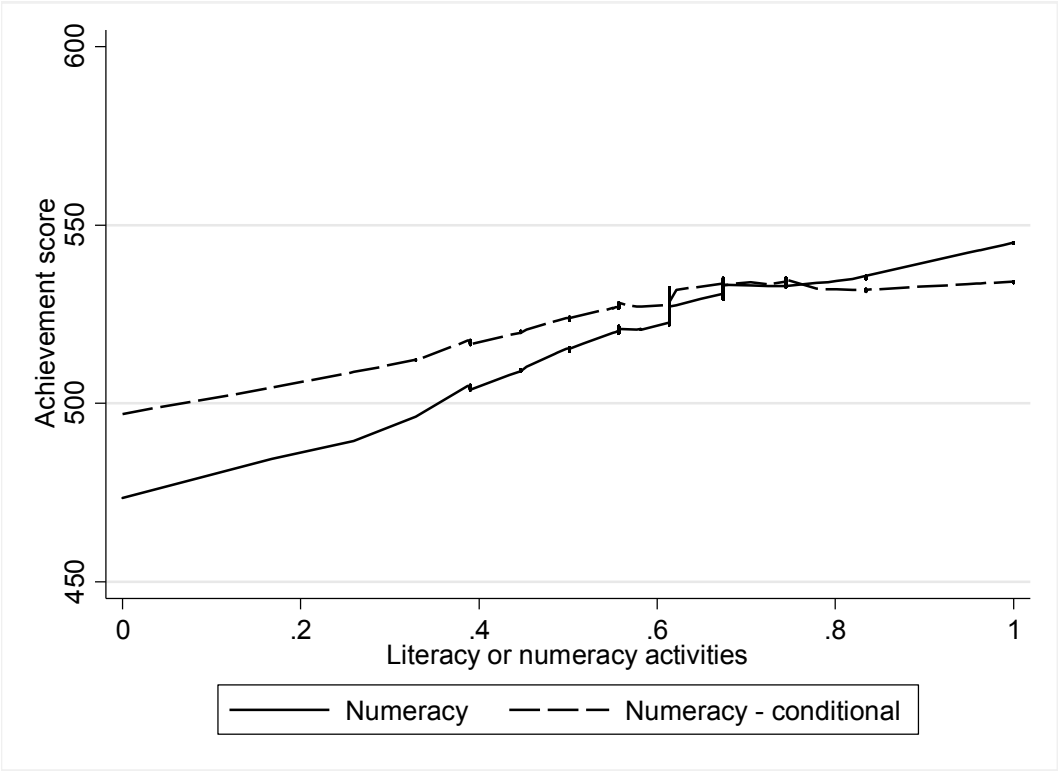


Figure 9: Effects of activities and early skills in Year 4 Reading – with controls for home study resources and with or without fixed group effects

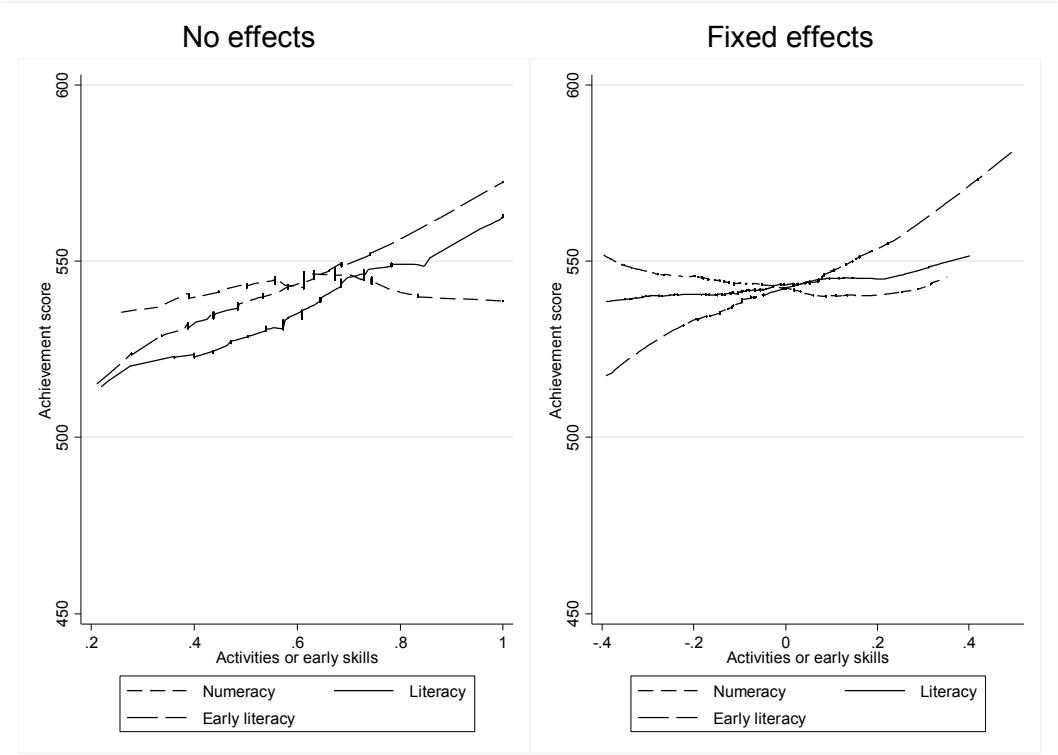


Figure 10: Effects of activities and early skills in Year 4 Numeracy – with controls for home study resources and with or without fixed group effects

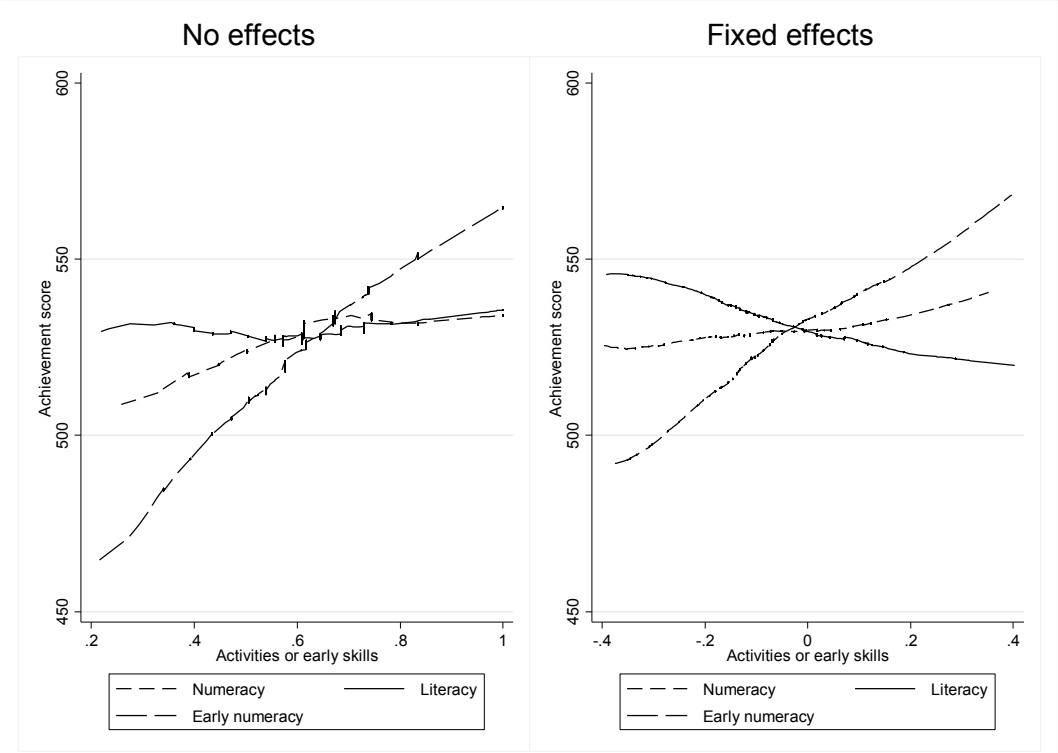


Figure 11: Relationship between schools' reading and numeracy fixed effects

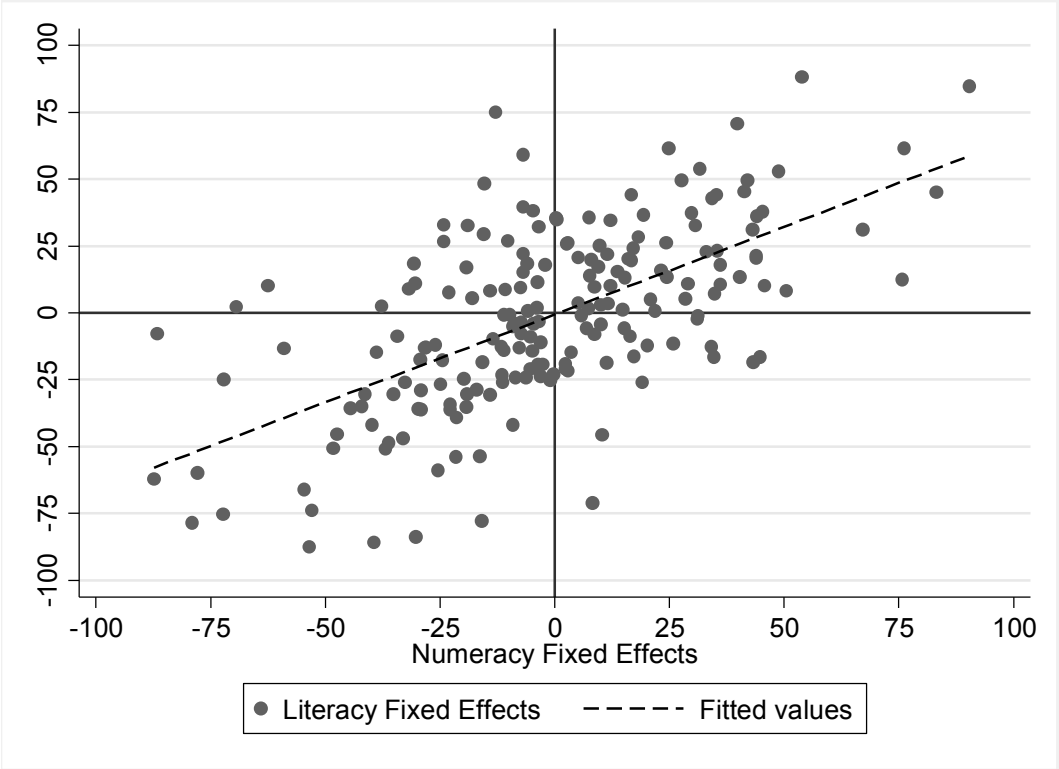


Table 1: Year 4 achievement, TIMSS and PIRLS respondent numbers and whether there was an associated home survey completed

(a) Average Achievement	Reading	Mathematics	Science
Boys	519	519	516
Girls	536	513	516
(b) Survey respondents	PIRLS & TIMSS	PIRLS only	TIMSS only
No response to home survey	2,778	116	203
Home survey respondents	3,165	67	0

Table 2: Engagement in child development activities – raw responses

Before your child began primary/elementary school, how often did you or someone else in your home do the following activities with him or her?			
	Often	Sometimes	Never or almost never
a) Read books	77.6	20.9	1.5
b) Tell stories	52.5	43.2	4.3
c) Sing songs	64.5	30.8	4.7
d) Play with alphabet toys (e.g., blocks with letters of the alphabet)	50.1	43.1	6.8
e) Talk about things you had done	72.8	25.8	1.4
f) Talk about what you had read	39.7	49.7	10.5
g) Play word games	34.5	54.6	10.8
h) Write letters or words	48.0	45.6	6.4
i) Read aloud signs and labels	54.1	38.3	7.5
j) Say counting rhymes or sing counting songs	56.7	35.6	7.8
k) Play with number toys (e.g., blocks with numbers)	43.4	47.2	9.4
l) Count different things	66.3	31.7	2.0
m) Play games involving shapes (e.g., shape sorting toys, puzzles)	60.9	35.9	3.2
n) Play with building blocks or construction toys	66.0	30.5	3.5
o) Play board games or card games	39.0	51.7	9.3

Table 3: Parental assessment of child's achievement at the time of commencing school

How well could your child do the following when he/she began primary/elementary school?				
	Very well	Moderately well	Not very well	Not at all
a) Recognize most of the letters of the alphabet	45.9	38.7	14.0	1.3
b) Read some words	21.3	38.9	32.7	7.1
c) Read sentences	10.3	21.5	37.1	31.2
d) Write letters of the alphabet	26.3	45.4	24.9	3.5
e) Write some words	16.4	35.8	35.6	12.2
	Up to 100 or higher	Up to 20	Up to 10	Not at all
a) Count by himself/herself	26.7	52.3	20.2	0.9
	More than 4 shapes	3–4 shapes	1–2 shapes	None
b) Recognize different shapes (e.g., square, triangle, circle)	58.3	33.9	6.9	0.8
	All 10 numbers	5–9 numbers	1–4 numbers	None
c) Recognize the written numbers from 1–10	74.0	13.3	9.6	3.1
d) Write the numbers from 1–10	53.1	21.0	17.9	8.0
	Yes	No		
e) Do simple addition	52.8	47.2		
f) Do simple subtraction	34.8	65.2		

Table 4: Descriptive statistics by whether a home survey was completed

	Home survey		No Home survey		Comparison	
	Mean	Std error	Mean	Std error	Diff	Std error.
Indigenous	4.8	0.7	9.0	0.8	-4.3***	0.7
Metropolitan	71.3	2.1	69.3	1.8	2.0	1.8
Books 11 - 25	12.5	0.9	17.9	0.7	-5.4***	1.1
Books 26 - 100	36.4	1.1	35.2	1.1	1.3	1.5
Books 101 - 200	23.5	1.0	19.8	1.0	3.7***	1.3
Books 200+	22.2	0.9	13.6	0.7	8.6***	1.0
Home resources	-1.7	3.5	-42.8	56.0	41.1***	54.8
Achievement						
Reading	542.5	2.4	511.7	2.7	30.8***	3.0
Mathematics	531.2	3.2	496.1	3.1	35.0***	3.4
Science	532.3	2.8	499.7	3.0	32.6***	2.9

'***', '**' and '*' mean the values for those whose family responded to the home survey are significantly different from the values of those whose family did not at the 1, 5 and 10 per cent level respectively.

Table 5: Correlations between key constructed variables

	Numeracy activities	Literacy activities	Numeracy skills	Literacy skills	Year 4 numeracy
Literacy activities	0.746				
Early numeracy skills	0.251	0.292			
Early literacy skills	0.247	0.341	0.645		
Year 4 numeracy	0.152	0.157	0.266	0.216	
Year 4 literacy	0.150	0.204	0.241	0.205	0.682

Table 6: Regression results: Year 4 reading and numeracy for boys and girls including heterogeneity term

	Reading		Numeracy	
	Girls	Boys	Girls	Boys
Home resources	154.48***	129.48***	157.59***	181.29***
	(19.11)	(19.15)	(20.92)	(22.62)
Parent likes to read	44.27***	8.95	28.40*	-8.30
	(13.00)	(16.46)	(15.06)	(15.32)
Indigenous	-38.17**	-27.56**	-43.76***	-42.76*
	(17.70)	(13.41)	(14.70)	(21.51)
Metropolitan	7.13	0.84	3.41	0.65
	(5.61)	(5.26)	(7.69)	(6.15)
Relative age	27.92***	4.39	27.67***	11.92
	(5.90)	(7.72)	(6.57)	(7.50)
Early literacy	28.17**	39.33***	27.38*	82.97***
	(12.46)	(12.04)	(14.70)	(13.46)
Literacy activities	-4.27	16.07	-46.83**	-42.70*
	(24.71)	(20.31)	(17.78)	(21.51)
Early numeracy	73.39***	75.27***	96.38***	66.68***
	(20.05)	(16.38)	(19.54)	(15.21)
Numeracy activities	12.16	-30.86	33.36*	4.02
	(15.96)	(18.84)	(17.75)	(20.33)
Heterogeneity in education aspirations	53.40***	68.19***	58.28***	61.35***
	(9.40)	(9.58)	(11.17)	(10.35)
Constant	299.56***	347.54***	285.81***	323.62***
	(15.23)	(18.28)	(16.29)	(19.29)
R^2	0.30	0.27	0.27	0.30
N	1,525	1,479	1,525	1,479

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 7: Regression results: Year 4 reading and numeracy for boys and girls with fixed effects based on child's expected educational attainment interacted with early activities in the alternative learning domain

	Reading		Numeracy	
	Girls	Boys	Girls	Boys
Regression estimates				
Home resources	146.68***	128.44***	153.04***	174.98***
	(13.40)	(14.00)	(14.01)	(14.80)
Parent likes to read	37.70***	8.91	22.89**	-13.30
	(10.36)	(10.26)	(10.83)	(10.84)
Indigenous	-21.83***	-26.21***	-35.66***	-26.15***
	(6.46)	(7.44)	(6.76)	(7.87)
Metropolitan	2.03	-2.66	0.17	-1.71
	(3.67)	(3.88)	(3.84)	(4.11)
Relative age	21.35***	5.07	22.08***	14.77**
	(5.81)	(6.10)	(6.08)	(6.44)
Early literacy	27.38**	42.33***	30.20***	71.47***
	(10.87)	(11.19)	(11.37)	(11.83)
Literacy activities	-1.93	10.96	-40.98**	-49.97***
	(16.08)	(16.58)	(16.81)	(17.53)
Early numeracy	50.83***	32.90***	62.99***	46.30***
	(12.86)	(12.24)	(13.45)	(12.94)
Numeracy activities	-1.91	-19.47	18.89	13.60
	(13.26)	(13.76)	(13.87)	(14.54)
Constant	365.99***	406.33***	352.52***	378.66***
	(12.58)	(12.95)	(13.15)	(13.69)
R^2	0.15	0.11	0.15	0.16
N	1,525	1,479	1,525	1,479
Matching estimates[(a)]				
Literacy activities	7.0	1.2		
	(13.9)	(12.3)		
Numeracy activities			6.4	12.8
			(13.7)	(12.9)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

(a) The estimated matching activity-related effect measures the impact on achievement of activity levels between 0.8 -1 on the relevant activity scale compared to lower activity levels, between 0-<0.8. Within the expected attainment categories, individuals with different activity levels were matched with those who had similar values for the other explanatory variables used in the regression equation, via Mahalanobis matching. The estimated effect is a weighted average of the estimate for each expected attainment category and is conceptually similar to the fixed effect approach.

Table 8: Regression results: Year 4 reading for boys and girls - effect of individual literacy-related activities on reading achievement

	Girls		Boys	
	Sometimes	Never or almost never	Sometimes	Never or almost never
a) Read books	-24.87***	6.51	-20.51***	-24.14
	(4.74)	(15.75)	(4.83)	(15.70)
b) Tell stories	1.15	-2.72	-11.18***	16.07
	(3.71)	(8.58)	(3.83)	(9.81)
c) Sing songs	4.25	-7.44	2.04	11.05
	(4.04)	(9.16)	(3.97)	(8.78)
d) Play with alphabet toys	6.13	1.35	4.20	8.65
	(4.06)	(8.13)	(4.17)	(8.01)
e) Talk about things you had done	-4.19	-0.94	-2.39	18.46
	(4.09)	(13.72)	(4.24)	(16.84)
f) Talk about what you had read	2.51	-6.69	-4.65	-3.26
	(3.84)	(6.61)	(4.01)	(6.79)
g) Play word games	5.21	16.36**	2.50	4.45
	(4.15)	(7.32)	(4.29)	(7.11)
h) Write letters or words	3.28	19.29**	0.07	-0.60
	(3.86)	‘(8.16)	(4.11)	(7.68)
i) Read aloud signs and labels	-0.29	7.79	-3.98	-2.31
	(3.95)	(7.33)	(4.01)	(8.12)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$. The specification includes the same set of controls as was reported in Table 7, except that the Literacy activities scale was replaced by two indicators capturing responses to the individual literacy-related activities. These indicators identify whether the activity was “sometimes” or “never or almost never” engaged in, relative to “often”. This exercise was conducted separately for each activity, so nine regression equations were estimated for each gender. Only the parameters on the relevant activity indicators are reported.

Table 9: Regression results: Year 4 numeracy for boys and girls - effect of individual numeracy-related activities on achievement

	Girls		Boys	
	Sometimes	Never or almost never	Sometimes	Never or almost never
j) Say counting rhymes or	-3.41	-5.95	-2.70	-2.95
sing counting songs	(4.23)	(8.17)	(4.31)	(7.48)
k) Play with number toys	0.18	-7.99	4.27	15.31**
(e.g., blocks with numbers)	(4.19)	(7.59)	(4.35)	(7.79)
l) Count different things	-4.94	3.83	-2.21	11.15
	(4.26)	(14.48)	(4.65)	(14.16)
m) Play games involving	-5.04	7.75	-7.22*	-20.55*
shapes (e.g., shape sorting toys, puzzles)	(4.08)	(11.35)	(4.33)	(12.12)
n) Play with building	-0.41	0.13	0.01	2.70
blocks or construction toys	(3.94)	(9.17)	(4.79)	(14.60)
o) Play board games or	-4.69	-1.00	-1.66	-8.53
card games	(3.98)	(7.09)	(4.20)	(7.37)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$. The specification includes the same set of controls as was reported in Table 7, except that the Numeracy activities scale was replaced by two indicators capturing responses to the individual numeracy-related activities. These indicators identify whether the activity was "sometimes" or "never or almost never" engaged in, relative to "often". This exercise was conducted separately for each activity, so six regression equations were estimated for each gender. Only the parameters on the relevant activity indicators are reported.

Table 10: Regression results: Year 4 numeracy for boys and girls - effect of individual literacy-related activities on numeracy

	Girls		Boys	
	Sometimes	Never or almost never	Sometimes	Never or almost never
a) Read books	-18.01***	18.02	-10.77**	0.57
	(4.99)	(16.60)	(5.13)	(16.68)
b) Tell stories	8.31**	25.46***	2.97	26.04**
	(3.88)	(8.97)	(4.07)	(10.40)
c) Sing songs	6.06	-8.32	9.58**	27.10***
	(4.24)	(9.61)	(4.20)	(9.28)
d) Play with alphabet toys	6.83	1.33	13.44***	16.94**
	(4.26)	(8.52)	(4.40)	(8.45)
e) Talk about things you had	4.88	13.07	4.64	34.65*
done	(4.28)	(14.37)	(4.50)	(17.89)
f) Talk about what you had	8.88**	11.29	9.36**	18.01**
read	(4.02)	(6.93)	(4.25)	(7.20)
g) Play word games	7.27*	15.53**	2.35	6.46
	(4.35)	(7.66)	(4.55)	(7.54)
h) Write letters or words	3.40	10.54	1.07	0.00
	(4.05)	(8.56)	(4.36)	(8.15)
i) Read aloud signs and	0.34	2.81	2.29	7.86
labels	(4.14)	(7.68)	(4.26)	(8.63)

* $p<0.1$; ** $p<0.05$; *** $p<0.01$. The specification includes the same set of controls as was reported in Table 7, except that the Literacy activities scale was replaced by two indicators capturing responses to the individual literacy-related activities. These indicators identify whether the activity was "sometimes" or "never or almost never" engaged in, relative to "often". This exercise was conducted separately for each activity, so nine regression equations were estimated for each gender. Only the parameters on the relevant activity indicators are reported.

Table 11: Regression results: Year 4 reading and numeracy for boys and girls with fixed effects based on child's expected educational attainment, survey non-response weights

	Reading		Numeracy	
	Girls	Boys	Girls	Boys
Home resources	142.57***	128.56***	151.07***	172.10***
	(13.62)	(14.37)	(14.20)	(14.90)
Parent likes to read	37.30***	7.67	19.89*	-12.12
	(10.43)	(10.23)	(10.87)	(10.61)
Indigenous	-21.67***	-27.96***	-30.85***	-23.88***
	(6.27)	(7.22)	(6.54)	(7.48)
Metropolitan	1.83	-2.40	0.79	-2.02
	(3.65)	(3.85)	(3.80)	(4.00)
Relative age	22.68***	6.41	21.23***	15.50**
	(5.85)	(6.15)	(6.10)	(6.38)
Early literacy	29.82***	43.83***	32.52***	70.86***
	(10.95)	(11.38)	(11.42)	(11.80)
Literacy activities	0.13	14.86	-38.03**	-46.46***
	(16.08)	(16.77)	(16.76)	(17.39)
Early numeracy	50.64***	36.06***	64.31***	47.76***
	(12.91)	(12.41)	(13.46)	(12.87)
Numeracy activities	-1.95	-19.10	17.26	13.73
	(13.17)	(13.80)	(13.73)	(14.31)
Constant	362.07***	394.89***	348.58***	370.97***
	(12.58)	(12.93)	(13.12)	(13.41)
R^2	0.15	0.11	0.14	0.16
N	1,525	1,479	1,525	1,479

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Appendix A: Data description and summary statistics

Table A1 - Variables used in the analysis of Year 4 achievement for home survey respondents

Variable name	Description	Mean	Std Dev
Year 4 reading	1st Plausible value in Reading - PIRLS variable: *asrrea01*	543.8	76.9
Year 4 mathematics	1st Plausible value in Mathematics - TIMSS variable: *asmmat01*	532.0	81.8
Gender	Male=1, Female =0, TIMSS variable: *itsex*	0.49	0.50
Home resources[(a)] or SES	Home Resources for Learning (HRL) scale - PIRLS variable: *asbghrl* (combines books, highest parental education and occupation)	0.68	0.14
Parent likes to read[(a)]	Parents Like Reading (PLR) scale - PIRLS variable: *asbhplr*	0.69	0.18
Indigenous Australian	TIMSS variable: *indigenous*	0.06	0.25
Metropolitan	Metropolitan region, TIMSS variable: *geoloc*=1	0.72	0.45
Relative age[(a)]	Age in days within grade level across State sample, calculated from birth date	0.51	0.28
Literacy skills at time child started school[(a)]	Could Do Early Literacy Tasks When Began Primary School (ELT) scale - PIRLS variable: *asbhelt*	0.57	0.21
Early literacy activities[(a)]	Early Literacy Activities Before Beginning Primary School (ELA) scale - PIRLS variable: *asbhela*	0.70	0.17
Numeracy skills at time child started school[(a)]	Could Do Early Numeracy Tasks When Began Primary School (ENT) scale PIRLS variable: *asbhent*	0.67	0.18
Early numeracy activities[(a)]	Early Numeracy Activities Before Beginning Primary School (ENA) - PIRLS variable: *asbhena*	0.72	0.19

(a) Variable re-scaled as (individual value- variable minimum)/(variable maximum – variable minimum) to place all values between 0 and 1.

Table A2 - Variables used in the analysis of home survey response and Year 4 achievement for entire sample

Variable name	Description	Mean	Std Dev
Reading literacy	1st Plausible value in Reading - TIMSS variable: *asrrea01*	530.9	78.7
Mathematical literacy	1st Plausible value in Mathematics - TIMSS variable: *asmmat01*	517.3	85.8
Scientific literacy	1st Plausible value in Science - TIMSS variable: *asssci01*	519.7	79.3
Completed home survey	Completed home survey or not	0.54	0.50
Few books in home (0-10)	Books in home - TIMSS variable: *asbg04*=1	0.06	0.24
One shelf of books in home (11-25)	Books in home - TIMSS variable: *asbg04*=2	0.15	0.36
One bookcase in home (26-100)	Books in home - TIMSS variable: *asbg04*=3	0.37	0.48
Two bookcases in home (101-200)	Books in home - TIMSS variable: *asbg04*=4	0.22	0.42
Three of more bookcases in home (200+)	Books in home - TIMSS variable: *asbg04*=5	0.19	0.39
Home possessions scale	Derived as the total of variables *asbg05a-asbg05h.* Each is an indicator of whether there was a particular item (computer, desk, child's own room etc.) in the house	6.93	1.21
ACT	TIMSS variable: *state*=1	0.02	0.13
NSW	TIMSS variable: *state*=2	0.34	0.47
VIC	TIMSS variable: *state*=3	0.23	0.42
QLD	TIMSS variable: *state*=4	0.22	0.41
SA	TIMSS variable: *state*=5	0.07	0.26

Table A2 - Variables used in the analysis of home survey response and Year 4 achievement for entire sample (continued)

Variable name	Description	Mean	Std Dev
WA	TIMSS variable: *state*=6	0.10	0.29
TAS	TIMSS variable: *state*=7	0.02	0.15
NT	TIMSS variable: *state*=8	0.01	0.09
Metropolitan	TIMSS variable: *geoloc*=1	0.73	0.45
Provincial	TIMSS variable: *geoloc*=2	0.26	0.44
Remote	TIMSS variable: *geoloc*=3	0.01	0.11
Indigenous	TIMSS variable: *indig*=1	0.07	0.25
Parents irregular in asking about school	Parents do not ask what child learns at school every day - TIMSS variable: *asbg07a*	0.43	0.49
Limited discussion with parents about schoolwork	Child does not talk about schoolwork with parents every day - TIMSS variable: *asbg07b*	0.63	0.48