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Article type : Empirical Article



# Self-Concept Predicts Academic Achievement across Levels of the Achievement Distribution: Domain-Specificity for Math and Reading

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**Acknowledgements**

We thank Amy Claessens, Greg Duncan, Mimi Engel, Robert Siegler and Tyler Watt for their helpful contributions to this project. The authors are grateful to the NSF-supported Center for the Analysis of Pathways from Childhood to Adulthood (grant no. 0322356) and the Institute of Education, University College London. We are extremely grateful to all the families who took part in this study, the midwives for their help in recruiting them, and the whole ALSPAC team, which includes interviewers, computer and laboratory technicians, clerical workers, research scientists, volunteers, managers, receptionists and nurses. The UK Medical Research Council and the Wellcome Trust (Grant ref: 102215/2/13/2) and the University of Bristol provide core support for ALSPAC. This publication is the work of the authors who serve as guarantors for the contents of this paper.

Abstract

This study examines whether self-concept of ability in math and reading predicts later math and reading attainment across different levels of achievement. Data from three large-scale longitudinal data sets, the ALSPAC, NICHD-SECCYD, and PSID-CDS, were used to answer this question by employing quantile regression analyses. After controlling for demographic variables, child characteristics, and early ability, the findings indicate that self-concept of ability

in math and reading predicts later achievement in each respective domain across all quantile levels of achievement. These results were replicated across the three data sets representing different populations and provide robust evidence for the role of self-concept of ability in understanding achievement from early childhood to adolescence across the spectrum of performance (low to high).



Over the past decades, educational and developmental psychologists have tried to understand how skill development and motivation (e.g., self-concept of ability) are linked to academic achievement (Guay, Marsh, & Boivin, 2003; Marsh, Byrne, & Yeung, 1999; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005; Valentine, DuBois, & Cooper, 2004). Although there is abundant research supporting the connections between self-concept of ability and achievement (Huang, 2011; Möller, Pohlmann, Köller, & Marsh, 2009), the development of these relations from childhood to adolescence still needs to be explored. Recent research has suggested that it is important to examine age when examining the relation between self-concept of ability and achievement (Davis-Kean et al., 2008). Indeed, a recent meta-analysis between self-concept of ability and academic achievement has reported that the strength of the links between these two constructs changes with age (Huang, 2011). However, it is still unclear whether the relations vary across the achievement spectrum (i.e., low, average, or high achievers). It is possible, for example, that those who generally succeed in achievement (as indexed by grades) have higher self-concept of ability, and those who perform more poorly have weaker self-concept in the domains in which they underachieve.

Students' self-concept of ability, which refers to students' perception of their capability to successfully perform on academic tasks (Marsh & Martin, 2011), has been hypothesized as a factor explaining academic achievement. From a developmental perspective, achievement and self-concept have been described as parts of a system whereby young children successfully perform various academic skills, which in turn develops their positive regard of those skills, making them more likely to engage and become proficient with them over time (Helmke & van

Aken, 1995; Skaalvik & Valas, 2001). This positive perception of a skill could also be increased by peer comparison and positive feedback from teachers in a school context. In other words, if a student feels competent in an academic domain, this sense of ability might enhance his or her self-concept, enabling the student to persist at, and seek out, activities that further influence academic achievement, such as taking more advanced classes or researching topics of interest. In this vein, academic achievement might be promoted by students' enhanced self-perception of their capabilities in a specific domain.

Although there is evidence of the effect of prior self-concept of sports ability on subsequent sports performance in pre-adolescents (Marsh, Gerlach, Trautwein, Lüdtke, & Brettschneider, 2007), existing research showing the relation between self-concept and academic achievement has not focused on these links throughout schooling. Given that the changes in self-concept tend to become more stable and reliable with age (Davis-Kean, Jager, & Collins, 2009; Guay et al., 2003; Marsh et al., 1999), there is a need for studies that explore the relations between students' self-concept of achievement and their actual achievement over time, particularly during a period when students face many competing academic challenges. As students transition from childhood to adolescence they face important decisions regarding the classes they will take (e.g., an advanced mathematics or English course), and confidence in their academic capabilities will probably impact these decisions, which, in turn, will likely factor into subsequent academic outcomes. Thus, looking at how self-concept is linked to academic achievement from early elementary school to early and middle adolescence could help to understand the development of self-concept and achievement throughout schooling.

A recent study examined the development of the relation between self-concept and academic achievement, but only in the domain of math (Watts et al., 2015). By using a longitudinal data set (i.e., NICHD SECCYD) and controlling for a host of child and background characteristics, as well as several cognitive and emotional skills, Watts and colleagues (2015) found that students' own beliefs regarding their abilities in math mediated the relation between early and later math achievement. These results suggest that students' self-perception of their math capabilities explains a significant amount of variance in the relation between math achievement in first grade and at age 15, though the study only focused on the average relations between self-concept of ability and students' academic achievement. Petscher and Logan (2014), however, demonstrated that the associations between predictors and outcomes (e.g., academic achievement) depend on the level of the outcome itself (i.e., high, average, or low performance).

This raises the question of whether the links between self-concept of ability and academic achievement vary depending on the level of achievement of the individuals represented in the study. Thus, the current study addresses whether the relation between self-concept of ability and achievement matters across all levels of performance, or only for those who achieve at the highest levels.

Current evidence supports a domain-specific approach to understanding the connections between self-concept and academic achievement (Marsh & Craven, 2006), with cumulative research showing the links between verbal self-concept and verbal ability, and math self-concept and math ability, respectively. For example, in their study of students in grades 5 to 8, Möller and colleagues (Möller, Retelsdorf, Köller, & Marsh, 2011) found positive effects of self-concept of ability in math on math academic achievement over time, but negative or lack of effects of verbal self-concept on math academic achievement over the same period. As expected by a domain-specific framework, they also found that verbal self-concept positively predicted verbal achievement but was negatively related to math achievement. However, the time frame of this longitudinal study does not allow for an analysis of the links between self-concept of ability and achievement during an extended period of development, as demonstrated in Watts et al. (2015).

The present study takes a domain-specific approach to examining the developmental links between self-concept and academic achievement across the achievement distribution from childhood to adolescence by examining both math and reading as separate achievement constructs. We take this approach for two main reasons. First, math and reading achievement are critical academic areas in school. Thus, comparing the developmental links between self-concept and academic achievement across the achievement spectrum in math and reading allows for evaluation of these connections in two academic areas relevant to student performance over the school years. Second, there is strong evidence across grades of the domain-specificity of the links between self-concept and academic achievement (Möller et al., 2011). Therefore, evaluating the links between self-concept and academic achievement at different points of the distribution in two different domains should provide stronger evidence of these links between self-concept of ability and academic achievement across the achievement spectrum.

Specifically, this study adds to prior research by evaluating whether self-concepts of ability relate to academic achievement at adolescence across different levels of performance, after controlling for early academic achievement and other socio-demographic characteristics, as well as other cognitive and socio-emotional skills, that have been reported in prior research as being associated with academic achievement (Duncan et al., 2007). Additionally, the current study replicates the results in two ways. First, the same analyses are performed using almost identical measures across three large data sets to test the robustness of these findings across different populations. Second, whether self-concept of ability has a similar relation with achievement across various levels of the achievement spectrum is examined in two different achievement domains. Furthermore, the current study adds to developmental theory by examining the relations between self-concept and achievement throughout schooling.

**Method**

The three data sets used in this study are the Avon Longitudinal Study of Parents and Children (ALSPAC), the Study of Early Child Care and Youth Development (NICHD SECCYD), and The Panel Study of Income Dynamics-Child Development Supplement (PSID-CDS). As the goal of the study was to evaluate the links between self-concept and academic achievement across different levels of achievement, each data set includes measures of these constructs. Early and later achievement was measured by using standardized assessments in the three data sets. Early and later math achievement was measured through national Key Stage 1 and 2 math assessments for the ALSPAC, and the Applied Problems subtest of the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R) (Woodcock & Johnson, 1989, 1990) for both the NICHD SECCYD and the PSID-CDS data sets. To measure reading achievement, national Key Stage 1 and 2 reading assessments were the instruments used in the ALSPAC. The Letter-Word Identification subtest of the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R) was used to measure early reading achievement in the NICH SECCYD and the PSID-CDS data sets. The Picture Vocabulary and Passage Comprehension subtests of WJ-R were used to assess later reading achievement in the NICHD SECCYD data set, and the Letter-Word Identification and Passage Comprehension subtests of the WJ-R were used to assess later reading achievement in the PSID-CDS.

For all three data sets, self-concepts of ability in math and reading were examined as predictor variables (at age 9 in the ALSPAC data set, in grade 6 in the NICHD SECCYD, and at ages 11-14 in the PSID-CDS data sets) to account for the prediction of math and reading achievement (when children were 11 years old in the ALSPAC data set, 15 years old in the NICHD SECCYD, and 16-18 years old in the PSID-CDS) across the achievement spectrum, and also to evaluate the domain-specificity of the links between self-concept and academic achievement at different levels of achievement.

Additionally, to isolate the links between self-concept of ability and academic achievement in math and reading, and control for the effect of preexisting differences (Lord, 1967), this study includes a host of relevant socio-demographic characteristics and various skills as covariates to control for other well-documented variables affecting children's academic achievement (e.g., Duncan et al., 2007; Watts et al., 2015). First, early achievement in math and reading were included as predictors, when children were 6-7 in the ALSPAC data set, and in first grade in the NICHD SECCYD and PSID-CDS data sets. In terms of the children's cognitive characteristics, working memory skills were included as covariates as children's ability to hold information in their memory and manipulate it simultaneously (Baddeley, 2003) has been reported as crucial for performance in both math (Bull, Espy, & Wiebe, 2008) and reading (Cain, Oakhill, & Bryant, 2004). Socio-emotional and behavior problems were also included in the analyses as control variables due to their links with achievement in the school years (NICHD Early Child Care Research Network & Arsenio, 2004). For all three data sets, measures of child and family characteristics were also considered as control variables. Based on existing research, these included the child's age, race/ethnicity, gender, weight at birth, number of children in the household, maternal education and maternal age at child's birth, and family income. To rigorously account for these influences on achievement, this list of covariates considers more variables than are commonly used in developmental studies. A description of these data sets is provided below, along with the samples and measures used in this study.

**Data Sets, Samples, and Measures**

**Avon Longitudinal Study of Parents and Children (ALSPAC).** ALSPAC (Golding, Pembrey, Jones, & the ALSPAC Study Team, 2001) is an ongoing population-based study in England, investigating the effects of environmental, genetic, and other influences on the health and development of children. Mothers living in an area in the southwest of the country, the former Avon Health Authority, with an expected date of delivery between April 1$^{st}$, 1991, and December 31$^{st}$, 1992, were eligible for enrollment in the study. More than 80% of the known births from the geographically-defined catchment area were included, resulting in a total cohort of 14,062 live births. The study contains a wealth of data on family background; family processes; the cognitive, social, and behavioral development of children; and key features of the school environment. In addition, school-level data and National Curriculum assessments have been merged with the study, providing records of individual achievement in math and reading.

The current study includes 13,901 children out of 14,062 children in the initial sample; 161 children who did not have any data for the variables used in this study were excluded.

***Later academic achievement measures***. Academic achievement scores in math and reading measured when children were aged 11 were used as the outcome variables. These were assessed through standard administrative achievement tests that form part of the National Curriculum, called Key Stage assessments – here Key Stage 2 (KS2) – given to all children in England over their school career to gauge individual achievement and progress. For the ALSPAC sample, the tests would have been conducted between 2002 and 2004, depending on the individual's school year. The math assessment is scored out of 100 and consists of three separate tests: a calculator paper test, a non-calculator paper test, and a mental arithmetic test. The reading test is part of the overall English assessment and is scored out of 50. The scores on both tests were used to calculate 'exact' attainment levels from 0 to 6 (following the same scale of the National Curriculum), which control for the year the pupils took their KS2 assessments and the variations in boundary cut scores each year, providing a more continuous measure of attainment in each domain than the broad National Curriculum levels (see Duckworth & Schoon, 2010; Levačić, Jenkins, Steele, Vignoles, & Allen, 2005 for further details).

***Self-concept measures***. Self-concepts of ability in math and reading were both assessed when children were aged 9 using a posting task. For the task, children were given an envelope containing two statements, one in blue writing and one in red. For example, "Some children are interested in reading" (in blue) and "Other children are not interested in reading" (in red). There were two postboxes, one blue and one red, and on each postbox there were two slots: "sort of true for me" and "really true for me." The interviewer read each statement aloud, and the child had to decide whether they were more like the children described in the blue writing or the red (and, consequently, whether to post the statement in the blue or the red box), and then whether the relevant statement was "sort of true for me" or "really true for me" (and, consequently, in which slot to post the envelope in the relevant colored box).

For the self-concept of ability in math task, eight questions were adapted from the Mathematics Scale of the Self-Description Questionnaire (Marsh, 1998). Examples of these statements are: "Some children don't enjoy doing maths work," "Some children find maths work hard," and "Some children are not interested in maths." Cronbach's alpha for the math self-concept scale at age 9 was .80 in the ALSPAC dataset.

The self-concept of reading ability posting task was adapted by Nunes and uses eight items from the scale developed by Turner and Chapman's self-perception measure (Chapman & Tunmer, 1997, 2003). The Cronbach's alpha for the self-concept of reading ability measure at age 9 was .77 in the ALSPAC dataset. Example statements from this scale include items such as: "Some children find it easy to understand the stories they read in class," "Some children feel happy when they are reading," "Some children think they read well in class," and "Some children don't like reading stories with lots of words in them." Across the four posting options in each domain, summary scores were created, ranging from 8 to 32, with a higher score indicating a more positive self-concept of ability.

***Covariates.*** Math and reading achievement, administered in Year 2 of primary school (age 6-7) using the first set of national Key Stage assessments for math and reading (Key Stage 1), were included in the analyses to take into account prior achievement. For the ALSPAC sample, the tests were carried out between 1998 and 2000, depending on the academic year of the cohort member. Included as control variables were short-term memory, assessed by the Nonword Repetition Test (Gathercole, Willis, Baddeley, & Emslie, 1994), and internalizing and externalizing problems, evaluated using the Strengths and Difficulties Questionnaire (Goodman, 1997), both measured when children were aged 8.

**The NICHD Study of Early Child Care.** Two U.S. data sets were used in this study. One comes from the NICHD Study of Early Child Care and Youth Development (SECCYD). Mothers over the age of 18 who spoke English as their first language and gave birth to healthy babies were recruited to participate in the study. Recruitment began in 1991 and lasted throughout the year. Babies born in designated 24-hour periods in 10 geographically diverse locations around the United States were eligible to be part of the recruitment sample if they met certain requirements. Participants were selected from the recruited sample based on the following conditions: mothers did not have any serious health condition, did not plan to have the child adopted, and did not plan to move in the next three years. Participants also had to reside within an hour of a study site. The study sample is diverse both economically and ethnically; however, due to the sampling and goals of the study, a nationally-representative sample was not recruited. A more detailed description of the recruitment procedures, data collection, and study procedures of the NICHD SECCYD is provided by NICHD Early Child Care Research Network (2002). The current study used all 1,364 children from the SECCYD data.

***Later academic achievement measures***. Children's math achievement at age 15, measured through the Applied Problems subtest of the WJ-R, was the math outcome of this study. The WJ-R Tests of Achievement are designed to provide a normative score that shows the child's abilities in comparison to the national average for the child's age. The Applied Problems subtest measures the child's quantitative reasoning, math knowledge, and math achievement by using either an auditory (i.e., question) or a visual (i.e., numeric, text) stimuli. It requires the child to (a) access and apply mathematical calculation knowledge to perform math calculations, (b) apply quantitative reasoning in response to problems that are presented both orally and visually, and (c) give an oral answer (Schrank, 2006). This subtest has a reported internal consistency of over .90 (Woodcock & Mather, 1989, 1990). Children's reading achievement was measured using the mean of raw scores of the Picture Vocabulary and Passage Comprehension subtests of the WJ-R. The subtest of Picture Vocabulary measures language development and lexical knowledge by asking children to identify an object in a picture and provide a verbal answer, and the Passage Comprehension subtest requires children to identify a missing keyword that fits the context of a written passage as a measure of reading comprehension (McGrew, Schrank, & Woodcock, 2007). These subtests have reported median internal consistency estimates above .90 (Woodcock & Mather, 1989, 1990).

***Self-concept measures***. The self-concept measures are taken from the How I Do in School Scale, which was administered in the lab during sixth grade. The self-concept of ability items were adapted from the Self and Task Perception Questionnaire (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002), and they ask students to indicate their beliefs regarding their abilities in math (5 items) and English or reading (5 items). Students respond to questions such as "How good at math are you?" by using a 7-point Likert scale from 1="not at all good," 4="ok," to 7="very good." The total composite score for math and English was calculated by taking the mean across the 5 items for each scale. The Cronbach's alphas were .82 for both math and reading self-concept measures in $6^{th}$ grade in the NICHD dataset.

***Covariates***. Early achievement in math and reading when children were in first grade were both measured through subtests of the WJ-R and included as covariates in this study. Math achievement was measured by the Applied Problems subtest (raw scores), whereas reading achievement was measured by the Letter-Word Identification subtest. Also, other child characteristics before entering school and in first grade were included as control variables in the analyses. First-grade measures included child's working memory (assessed by the raw scores of the WR-J Memory for Sentences subtest), aggressive behavior, and internalizing behavioral problems. These last two behavior-related measures were assessed using the Teacher Report Form, an instrument based on the Child Behavior Checklist (Achenbach, 1991).

**Panel Study of Income Dynamics.** The Panel Study of Income Dynamics-Child Development Supplement (PSID-CDS; Hofferth, Davis-Kean, Davis, & Finkelstein, 1998, retrieved from https://psidonline.isr.umich.edu/CDS/cdsi_userGD.pdf) – Waves I (1997), II (2002), and III (2007) – was used for this study. The PSID is a nationally-representative longitudinal study of over 18,000 individuals living in American families that began in 1968, and it has collected data on families since then. The CDS is a three-wave study that began in 1997 (CDS-I) and included children aged 0-12 years in 1997, selected from the entire sample of PSID families, with a maximum of two children per family. It includes a complete battery of interviews, assessments, and observations that collect data on a broad range of developmental outcomes, including academic achievement. The CDS-I included a sample of 2,394 families and their 3,563 children; 2,907 children whose families participated in the 2001 PSID core survey were re-interviewed in the 2002 Wave II CDS (CDS-II). The CDS-III was conducted between 2007 and 2008, and only those CDS-I children whose families participated in the 2007 PSID core survey and who were aged younger than 18 in 2007 were eligible for the CDS-III (n=1,784). Of them, 1,506 children were successfully re-interviewed. This study uses all 237 CDS-I children who were PSID “gened” members (i.e., a followable descendant of an originally sampled respondent) and were in first grade in 1997, regardless of whether they participated in CDS II and CDS III. From these 237 CDS-I first graders, 193 (81.3%) were eligible for CDS-III, and 163 (84.5% of the eligible) were re-interviewed.

***Later academic achievement measures***. Children’s achievement scores in math and reading measured in the 2007 wave (CDS-III), when children were 16 to 18 years old, were used as the outcome variables. The child’s math achievement was assessed through the Applied Problems subtest of WJ-R. This subtest focuses on the ability of children to reason and successfully complete mathematical problems varying in difficulty level, and it has standardized administrative and scoring protocols. For this study, the child’s raw score on this subtest was used as the math outcome. The child’s reading achievement was measured by the mean of the raw score of the Letter-Word Identification and Passage Comprehension subtests of the WJ-R. The Letter-Word Identification subtest requires the child to detect and recognize printed letters and words, measuring early reading and decoding, and the Passage Comprehension subtest measures reading comprehension (McGrew et al., 2007). These subtests have reported median internal consistency estimates above .90 (Woodcock & Mather, 1989, 1990).

***Self-concept measures***. The children's self-concept of ability in math and reading were from CDS-II, when children were 11-14 years of age, and they were measured using the scales developed by Eccles and colleagues for both math and reading (Eccles, Wigfield, Harold, & Blumenfeld, 1993). These scales include ten items that measure self-concept in each domain (e.g., "How good at math (reading/English) are you?"; "If you were to list all the students in your class from the worst to the best in math (reading/English), where would you put yourself?"). Cronbach's alphas for the self-concept measures of math and reading in 2002 were .85 and .86, respectively, in the analytic sample used in this study.

***Covariates***. The child's math achievement measured at CDS-I was included to account for prior math ability. Early math skills were assessed using the raw score of the Applied Problems subtest of the WJ-R. Similarly, to account for verbal ability, reading skills were measured by the raw score of the Letter-Word Identification subtest of the WJ-R. Additionally, working memory skills (measured through the Digit Span Backwards subtest of the Wechsler Intelligence Scale for Children-Revised, WISC-R) and children's internalizing and externalizing problems (measured through reports from their primary caregivers, using the Behavior Problems Index), assessed in 1997, were included as control variables.

**Cross-study additional covariates.** Across each of the three data sets, an additional set of the children's characteristics and background covariates was used. Demographic characteristics and family background variables included child's birth weight (in grams), race/ethnicity, gender and age of the child, number of children in the household, natural log mean of family's income averaged across at least two periods in early childhood, and mother's education and age at birth of child. In addition, for the NICHD data set, dummy variables for the sites at which the family was recruited to participate in the study were also used.

Within each study, all continuous variables were standardized to z-scores, using weighted means and standard deviations when applicable from each imputed data set. Dummy variables used as indicators of group membership were not standardized. The mean and standard deviation for variables used in this study for all three data sets are presented in Table 1.

**Analysis Plan**

To answer the question of whether the role of self-concept of ability in math and reading predicts academic achievement through the distribution of performance across multiple data sets, the variables that provided the best replication of the data were selected. To do this, early and later math and reading achievement variables were chosen across data sets. Although there were differences in the instruments used in ALSPAC and the other two data sets, and slight differences in the subtests from the WJ-R used in the NICHD SECCYD and PSID-CDS, all were standardized instruments that assessed similar abilities to account for reading and math achievement. The measures of self-concept of ability were also comparable across data sets. Furthermore, an additional same set of child characteristics and background variables was included to rigorously account for other factors that have been described as explaining academic achievement (Duncan et al., 2007). Thus, this selection of comparable and equivalent variables across data sets allowed for addressing issues of selection bias that are common to community samples (Davis-Kean & Jager, 2011), as well as for a generalization of this study's findings across the population.

These data sets provide a rich source of longitudinal data on children's achievement, but they are vulnerable to problems with missing data bias. The rate of missing data in each data set is presented in Appendix A. This potential missing data bias was addressed by using the full target sample from the initial wave (N=13,901 for ALSPAC, 1,364 for NICHD-SECCYD, and 237 for PSID-CDS) and the same multiple imputation strategy across the data sets to handle missing data. Twenty five imputed data sets were generated for each data set, and the multiple imputation (MI) model for all data sets included all variables in our analytic model and a set of auxiliary variables (i.e., variables related to the main variables in the study, often the same measure but assessed at different waves, as well as variables that might affect drop out) that provided additional information to increase the precision of the imputations (Enders, 2010). Specific auxiliary variables used in each data set are available upon request.

Full Information Maximum Likelihood (FIML) and multiple imputations (MI) are two common procedures implemented to manage missing data. MI was used because one of the unique objectives of this study is to account (control) for multiple variables that may be related to self-concept and achievement across time. This created complex models, and the MI procedures allow for the inclusion of categorical group membership (e.g., gender and race) and a large number of auxiliary variables that are not part of the analytical model when imputing the data. Indeed, 51 auxiliary variables were used for the ALSPAC data, 39 for the NICHD-SECCYD, and 20 for the PSID-CDS. Although MI is a robust procedure for managing missing data, it assumes that these data are missing at random, which is an unverifiable assumption

(Enders, 2010). Thus, MI requires careful selection of auxiliary variables, and the specification of the MI model should correctly define the relations among variables, which must be consistent with the analytic models. Furthermore, the MI model should also include variables to adjust for sample design features to avoid misspecification of the model (Reiter, Raghunathan, & Kinney, 2006).

ICE software installed in Stata was used for MI for ALSPAC, and the Stata “mi impute” command with “chained” method was used for MI for NICHD-SECCYD and PSID-CDS. The software adopts chained equation techniques for MI. Stata “mi estimate” command was used for model estimation. Robust standard errors for linear multiple regressions and quantile regressions were obtained from model estimation to handle issues of potential heterogeneous variance and non-normal residual distributions.

## Results

### Linear Multiple Regression and Quantile Regression Analyses

As this study evaluated whether self-concepts of ability in math and reading have different effects at several levels of the achievement distribution, both linear and quantile regression methods were employed. Although linear regression analysis allows for the evaluation of the relation between self-concept and academic achievement over time, it only provides an estimate of the average relation between self-concept and math and reading achievement (Koenker, 2005; Petscher & Logan, 2014). In other words, it does not allow for the analysis of the relation between self-concept of ability in math and reading across different points of the distribution of achievement in math and reading, respectively. Quantile regression analysis, on the other hand, minimizes the disadvantages of dividing the sample into selected subgroups by analyzing the relation between constructs at different levels of the outcome (Petscher & Logan, 2014) without establishing constraints on the functional form of the relations between the variables across the outcome distribution. This methodological strategy offers a more comprehensive picture of the links between two or more variables than the one provided by the conventional least-square regression analysis that looks exclusively at the conditional means model, and it does so by making no assumptions about the distribution of errors (Koenker, 2005). Quantile regression explores how the variables and covariates may shift the central tendency of the distribution of the outcome variable by looking at different points of the outcome distribution (Petscher, Logan, & Zhou, 2013) using the full dataset for estimating the relations among variables in each quantile (Petscher & Logan, 2014). In other words, quantile regression allows for the evaluation of nonlinear relations of the predictor variables across multiple quantiles on the outcome distribution, and for the examination of whether the links between the variables may be different depending on the point of the outcome distribution (Koenker, 2005; Petscher et al., 2013; Purpura & Logan, 2015). Thus, using quantile regression allowed us to evaluate the link between self-concept of ability and academic achievement in math and reading at different levels of performance, including different points at the higher and lower ends of average achievement.

Following prior work illustrating how quantile regression could be a suitable approach for developmental research (Petscher & Logan, 2014), in this study, 10$^{th}$, 25$^{th}$, 50$^{th}$, 75$^{th}$, and 90$^{th}$ percentiles of the distribution of math and reading domains were chosen for analysis. The use of quantile regression to study this type of research question is a novel approach and, as such, there is little research to provide guidance as to how to gauge the important levels of academic achievements to study. However, quartiles are commonplace in research related to distributional differences, leading to the selection of 25$^{th}$, 50$^{th}$, and 75$^{th}$ percentiles. In addition, students in the top and bottom 10 percent of a subject or grade are often used to represent the highest- and lowest-performing students. Thus, 10$^{th}$ and 25$^{th}$ percentiles in each subject were used to represent the lower-end achievers, the 50$^{th}$ percentile (as the mean-based linear regression) for average students, and the 75$^{th}$ and 90$^{th}$ percentiles to represent the higher achievers. Both the mean-based linear regression and the 50$^{th}$ percentile (i.e., median) quantile regression allowed for the study of average achievers, but the estimates of quantile regression at the 50$^{th}$ percentile are not as sensitive to non-normal residuals and outliers as the mean-based linear regression is. The analyses were conducted separately for both math and reading.

**Self-Concept and Math Achievement**

The relation between self-concept of ability in math and reading and later math achievement was analyzed first, after controlling for a host of child and demographic variables. Table 2 presents the results of the four main predictors (early math and reading achievement and self-concept of abilities in math and reading) for both linear multiple regression analyses (top panel) and quantile multiple regression analyses (the lower five panels) for math achievement. These analyses account for the confounding variables indicated above, but the full tables with the control variables are included in Appendix B. The quantile regression tables include the estimated coefficients, which are approximate to standardized beta coefficients (i.e., effect sizes). $R^2$ for ordinary least squares (OLS) and pseudo $R^2$ for quantile regression, a measure of goodness-of-fit for quantile regression (Koenker & Machado, 1999), are also included.

The results from the multiple regression analyses indicate that across all three data sets, early math achievement relates to later math achievement when controlling for the child characteristics and background and demographic variables. The coefficients suggest that there is moderate to high significant positive prediction from early math achievement (effect sizes ranging between .22 for the PSID-CDS and .48 for the ALSPAC data sets) to later math achievement, even after controlling for reading, child characteristics, and background/demographic variables. Early reading achievement is also connected to later math achievement in the ALSPAC data set and the NICHD-SECCYD, although the coefficients are lower than those for early math achievement (.20 and .08, respectively). As expected, the findings show that self-concept of ability in math measured between 9 and 14 years of age is related to later math achievement, even after taking into account the confounders of early math and reading achievement, child characteristics, and demographic and background variables. The effect sizes for the relation between self-concept of ability in math and math achievement are .15 for ALSPAC, .19 for NICHD SECCYD, and .19 for PSID-CDS, whereas self-concept of ability in reading in middle childhood is barely related to later math achievement for all three data sets.

Quantile regression analyses were then used to test whether the pattern of the results linking self-concept of ability in math to later math achievement found in the mean-based linear regression would be replicated at the 50$^{th}$ percentile, as well as for students at other levels of the achievement distribution. This would provide evidence that this result is a phenomenon across the achievement spectrum and not merely specific to a certain group of achievers. The findings replicated across the datasets and showed strong support for self-concept of ability in math positively relating to math achievement in all quantiles of the achievement distribution.

For the low-end quantiles, the gap in math achievement at the 10$^{th}$ quantile for children who were average on self-concept of ability in math compared to children who were 1 *SD* above the mean ranged from .18 to .21 standard scores in the three datasets, after controlling for all other variables included in the model. Similarly, controlling for early achievement, reading self-concept, and several child and background characteristics, the gap in math achievement at the 25$^{th}$ quantile for children who were average on self-concept of ability in math compared to those who were 1 *SD* above the mean of self-concept ranged from .16 to .19 standard scores. Likewise, the effect sizes at the 50$^{th}$ quantile (ranging from .14 to .20) were closely aligned to those of the linear model (that ranged from .15 to .19). For the high-end quartiles of math achievement, the gap in math achievement at the 75$^{th}$ quantile for children who were average on self-concept compared to those who were 1 *SD* above the mean ranged from .14 to .21 standard scores, after controlling for the other variables. In the same vein, the gap in math performance at the 90th quantile for children who had an average score on self-concept of ability in math compared to those who were 1 *SD* above the mean ranged from .12 to .22 standard scores.

Figure 1 (in Appendix C) shows the quantile process plots for the multiple quantile regression, including the slope coefficients for self-concept of ability in math and for early math in each data set. The plots represent the partial slope coefficients for math self-concept and early math achievement when controlling for the other variables in the model. The slope coefficients for math self-concept between quantiles were then compared, to test the extent to which point estimates for slopes were statistically significant (Petscher & Logan, 2014). Consistent with the quantile process plots (Figure 1), none of the inter-quantile tests between 10th and 90th, 90th and 50th, and 50th and 10th quantiles for the coefficients of math self-concept and math achievement was significant in the PSID-CDS and NICHD SECCYD data sets. However, there were significant differences in the estimates between quantiles for the ALSPAC data set, and these appeared on the inter-quantile regression tests that were conducted as well as the quantile process plots. Specifically, when comparing the 90th and 10th quantiles, the results suggest that the estimated math self-concept of ability slope coefficients were significantly differentiated, $b$= -.06 with 95% CI [-.09, -.03], as were the differences between the 90th and 50th quantiles, $b$= -.02 with 95% CI [-.04, -.00], and the 50th and 10th quantiles, $b$= -.03 with 95% CI [-.06, -.01]. These findings suggest that the link between self-concept of math ability and math achievement is statistically differentiated depending on the math performance of the students. In other words, in the ALSPAC data set, there is a smaller association with self-concept when math achievement is at the higher end, versus a higher association that is observed between achievement and self-concept when math achievement is lower.

These results highlight the role of self-concept of ability in math in predicting math achievement across the achievement spectrum, and they suggest that self-concept of ability in math explains math achievement throughout schooling. Furthermore, the quantile regression estimates of self-concept of ability in math on later math achievement for most of the quantiles chosen in this study lie within the 95% confidence interval of the linear regression estimate across all three data sets (except for the 90th quantile for ALSPAC). This suggests that the quantile estimates align with the linear regression estimate (Koenker & Hallock, 2001), which strengthens our confidence in the robustness of the relation between self-concept of ability in math and math achievement, as a more complete picture of the links between both constructs across the math achievement spectrum emerges. The PSID, unlike the other two data sets, showed one non-significant cell, but the coefficient was like the other studies at that quantile. Due to differences in sample size in the three data sets examined, the significance levels will necessarily vary, but the effect sizes are quite similar among the data sets. Given the differences in power to detect even very small effects, the results that follow will be discussed at both the size of the coefficient as well as the significance levels (Rosenthal, Rosnow, & Rubin, 2000).

In summary, these results reveal the distinct role of self-concept of ability in math in predicting later math achievement across the full spectrum of achievement. In line with hypotheses concerning domain-specificity, self-concept of reading ability did not predict later math achievement. Again, these models fully controlled for early math and reading abilities, and variables related to children's early ability and demographic variables.

**Self-Concept and Reading Achievement**

To evaluate further the domain-specificity of the relation between self-concept of ability and academic achievement across the spectrum of achievement, the same analyses were performed between self-concepts in math and in reading and later reading achievement. As above, the first part of Table 3 presents the results for linear multiple regression analyses, whereas the results from quantile multiple regression analyses are displayed in the lower panels of Table 3. Again, the tables with the coefficients for the confound variables are included as supplemental materials (see Appendix D), along with $R^2$ for ordinary least squares (OLS) and pseudo $R^2$ for quantile regression, a measure of goodness-of-fit (Koenker & Machado, 1999).

In line with the math findings, the results from the multiple regression analyses are replicated across the three data sets and show that early reading achievement positively predicts later reading achievement (beta coefficients are .36, .20, and .16 for ALSPAC, PSID-CDS, and NICHD SECCYD, respectively), after taking into account several confounding factors. As in prior research (Duncan et al., 2007), the results from the three data sets also indicate that early math achievement significantly predicts later reading achievement (effect sizes of .20, .22, and .26 for PSID-CDS, NICHD SECCYD, and ALSPAC, respectively).

The results that link self-concept of ability in reading to later reading achievement support the domain-specificity hypothesis: self-concept of ability in reading measured in middle childhood is related to later reading achievement after controlling for early math and reading, as well as for children's short-term memory, behavioral and emotional problems, and a host of demographic characteristics. This finding is replicated across the data sets, and the beta coefficients are .12 for NICHD SECCYD, .13 for ALSPAC, and .17 for PSID-CDS. Self-concept of ability in math did not predict later reading achievement in the two U.S. data sets, and it was significantly negatively related to later reading achievement in the ALSPAC data set. However, the small size of the coefficient (-.03) may be practically ignorable, and the statistically significance is probably due to the large size of the ALSPAC data set (n=13,901).

As displayed in the second part of Table 3, the results for quantile regressions show the same patterns for the relation between the two measures of self-concept and later reading achievement found in the linear regression analysis at all five quantiles of reading achievement levels studied. Again, this finding is replicated across the three data sets, highlighting the positive link between self-concept and later achievement in the arena of reading that is maintained for students who are at different levels of the distribution of achievement. For the students at the low end of the distribution of reading achievement, at the $10^{th}$ quantile, the gap in reading achievement for children who were average on self-concept of ability in reading compared to children who were 1 *SD* above the mean ranged from .11 to .23 standard scores, after controlling for early achievement, math self-concept, and several covariates. Also, the gap in reading performance at the $25^{th}$ quantile for children who were average on self-concept of ability in reading compared to those who were 1 *SD* above the mean of self-concept ranged from .11 to .21 standard scores. Similarly, the beta coefficients at the $50^{th}$ quantile (ranging from .10 to .17) were closely aligned to those of the linear model (ranging from .12 to .17).

For children at the high-end quantiles of reading achievement, similar results were found after controlling for early achievement, math self-concept, and the covariates. The gap in reading performance at the $75^{th}$ quantile for children who were average on self-concept of reading compared to those who were 1 *SD* above the mean on self-concept ranged from .09 to .14 standard scores. Similarly, the gap in reading achievement at the $90^{th}$ quantile for children who had an average score on self-concept of ability in reading compared to those who were 1 *SD* above the mean on reading self-concept ranged from .07 to .15 standard scores.

The quantile process plots for the multiple quantile regression, including the slope coefficient for self-concept of ability in reading and the slope coefficient for early reading in each data set are provided in Figure 2 in Appendix E. The plots represent the partial slope coefficients for reading self-concept and early reading when controlling for the other variables in the model. As for math achievement, the coefficients for reading self-concept between quantiles were compared to test if the differences were statistically significant (Petscher & Logan, 2014). As can be seen in the quantile process plots for self-concept and reading achievement (Figure 2), none of the inter-quantile tests between 10$^{th}$ and 90$^{th}$, 90$^{th}$ and 50$^{th}$, and 50$^{th}$ and 10$^{th}$ quantiles was statistically significant for the PSID-CDS and NICHD SECCYD data sets. However, there were significant differences in the estimates between quantiles for the ALSPAC data that were revealed on the inter-quantile regression tests that were conducted, as well as the quantile process plots. Like the results from math, when comparing between the 90$^{th}$ and 10$^{th}$ quantiles, the results indicate that the estimated reading self-concept of ability slope coefficients were significantly different, $b$= -.08 with 95% CI [-.12, -.05], as were the differences between the 90$^{th}$ and 50$^{th}$ quantiles, $b$= -.03 with 95% CI [-.05, -.01], and the 50$^{th}$ and 10$^{th}$ quantiles, $b$= -.05 with 95% CI [-.09, -.02]. These findings suggest that in the ALSPAC, there is a smaller association between reading self-concept and reading achievement when achievement is high, compared to the higher link between reading self-concept and achievement when achievement is lower.

Like the results found for math achievement, the PSID, unlike the other two data sets, showed two non-significant cells, but the effect sizes were comparable to those in the other studies at the same quantiles. As was found in the linear multiple regression analysis, there is a negligible significant negative relation between self-concept of ability in math and later reading achievement at the 10$^{th}$, 25$^{th}$, and 75$^{th}$ quantiles (ranging from -.02 to -.04) in the ALSPAC data set. Again, the small significant effect sizes of this negative relation may be practically unimportant, and the statistical significance is probably due to the large sample size.

These findings indicate that self-concept of reading ability plays a significant role in predicting later reading achievement. This relation is significant not only for the average students, but for all groups across the achievement distribution, from low to high achievers. Also, this link between self-concept of ability and reading achievement is domain-specific. Moreover, these results are replicated across three longitudinal data sets, even after controlling for child characteristics, background variables, and prior academic achievement.

## Discussion

The intent of this paper was to test whether beliefs about achievement abilities predicted later achievement (in children 11-15 years of age) in math and reading, across the different levels of the distribution of performance. There are multiple perspectives on why beliefs about achievement might be important for later achievement (Marsh, 1990), as well as takes on why they may be simply a reflection of high achievers and therefore not distinct from achievement itself (Shavelson & Bolus, 1982). This study systematically examined these ideas using multiple longitudinal data sets so that the role of self-concept in predicting later achievement across the distribution of performance could be examined while controlling for earlier achievement and other child characteristics and background variables. Additionally, the robustness of this relation was tested by looking across the quantiles of achievement ability in two distinct domains, math and reading, and by replicating the analyses in three data sets. Thus, this paper provides a comprehensive examination of the relation between self-concept of ability and later academic achievement to understand the role of achievement beliefs in motivating later achievement in students with different levels of performance in math and reading.

The results show robust, replicated evidence that children's beliefs about their math and reading abilities explain some of the variance in later math and reading achievement, respectively, after controlling for a strong set of demographic and child characteristics, as well as prior academic achievement. Perhaps even more striking is that a more positive view of math and reading ability showed higher levels of math and reading achievement, respectively, even for the lowest performing students. These results suggest that self-concept of ability does play an important role in motivating achievement over time and across achievement levels. Although there is prior research showing that self-concept of ability and academic achievement are related over time (Möller et al., 2011), and that self-concept of ability mediates academic achievement in the domain of math (Watts et al., 2015), this study adds to this research by showing that children's beliefs about their academic abilities in both math and reading play a role in promoting achievement in each respective domain from early childhood to adolescence.

Even more importantly, this study highlights the finding that this relation is not limited to students who perform at the top levels, but extends to students with different levels of achievement in math and reading. The results from the NICHD SECCYD and PSIC-CDS did not show differences in the strength of the relation between self-concept of ability and academic achievement across the quantiles. However, the same comparisons in the ALSPAC data set suggest that this link might be stronger for students at lower levels of the achievement distribution, compared to those at the top levels of achievement in math and reading. This finding, although not replicated across data sets, might indicate that students' beliefs about their academic abilities exert a stronger role for those students who are not achieving at higher levels. Contrary to the idea that higher achievers were driving the link between self-concept and academic achievement, these results suggest that students' beliefs about their academic abilities act as a booster for motivating them to achieve in academic domains across different levels of achievement, and these beliefs might be even more important for students at the lower levels of the achievement distribution. These findings, then, improve our understanding of the links between self-concept of ability and academic achievement in math and reading, but future research could account for this decreasing link.

Moreover, and in line with domain-specificity research, the current findings also revealed that self-concept of ability in math predicts later math achievement, and that self-concept of ability in reading predicts later reading achievement but not vice versa, indicating that the links between self-concepts of ability and later achievement are domain-specific across different levels of the distribution as well.

**Limitations and Future Research**

Even though this study addresses many of the problems in the literature on self-concept and achievement, there are also limitations to the research. Self-concept measures explained a rather modest amount of variance in later math and reading achievement. Even with the inclusion of a strong set of contextual and individual child variables in the model, there is much more to understand regarding later math and reading achievement before effective interventions can be designed. It will not be as simple as trying to make children feel positive about their skills. There are other factors that need to be considered when trying to untangle later achievement.

Other potential avenues not assessed in this study are the influences of teachers, parents, or peers in both the construction of beliefs about abilities as well as the role these individuals play in academic achievement over time. Indeed, children already differ in math and reading ability upon entry to school (Davis-Kean & Jager, 2014; Penno, Wilkinson, & Moore, 2002), and trying to understand what parents may be doing in the home environment to foster math and reading, as well as their perceptions about children's competence, are important aspects to study.

A unique aspect of this study is that it tested the relation between self-concept and achievement across levels of performance. The findings highlight that self-concept of ability in middle childhood was indeed a positive predictor of later academic achievement for students with high, average, and low performance. What is less clear from this study are the mechanisms through which self-concept of ability in math and reading predicts academic achievement in those domains across multiple points of the distribution of achievement (i.e., among high achievers, average achievers, and low achievers) over time. It might be that students who believe that they have the ability to perform well might persist or invest more effort in academic activities, which in turn might boost their academic performance within their level of achievement. In line with the work done by Dweck (2000), students who believe that their performance depends upon their effort instead of a fixed aptitude to achieve will outperform their peers with similar academic achievement. This observed relation between self-concept and academic achievement across multiple points of the distribution, and found in two different domains, needs to be further investigated to fully explain how this relation works among students who perform at high, average, and low levels when compared to their peers.

Finally, the observational data used in this study cannot establish causality between self-concept and achievement. The temporal nature of the data, however, does give some support for causal timing of the events (i.e., achievement beliefs in middle school to academic achievement in adolescence). Thus, future research should use longitudinal studies to explore the causal mechanisms related to the relation between self-concept of ability and academic achievement.

**Conclusions**

This study shows that children's perceptions of their abilities are important in promoting later achievement across different levels of the achievement distribution. The current work is a rigorous, replicated study using large longitudinal samples, and the results provide solid evidence of the role that self-concept has on the math and reading skills in adolescence. Future studies need to address other potential influences in both achievement and achievement beliefs, such as school and home. This study showed that self-concept of ability beliefs in middle childhood relate to math and reading achievement, and that this matters across the achievement spectrum. The next steps are to understand why some children are more successful in math and reading and why, even at low performance levels, self-concept of ability serves as a motivational factor for higher achievement. Since these measures focus on comparisons with other students in assessing one’s own ability, perhaps there is something to be found by examining how students make these judgments about themselves and others. Gender differences should also be explored to better understand these relations. These avenues may lead to a better understanding of what teachers and parents can do to promote achievement in school-age children.

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**Table 1: Descriptive statistics of unstandardized analysis variables by data sets**

| | UK: ALSPAC (N=13,901 each) | | | | US: NICHD SECCYD (N=1,364 each) | | | | US: PSID-CDS (N=237 each) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Variables* | **Mean** | **Std. Dev.** | **Min** | **Max** | **Mean** | **S.D.** | **Min** | **Max** | **Mean** | **S.D.** | **Min** | **Max** |
| **Later academic achievement** | | | | | | | | | | | | |
| Math | 4.51 | .92 | 0 | 6 | 41.50 | 6.00 | 18 | 59 | 42.68 | 7.38 | 26 | 58 |
| Reading | 4.64 | .89 | 0 | 6 | 34.11 | 4.06 | 15 | 45 | 39.26 | 6.53 | 14 | 47 |
| **Early academic achievement (age 5 to 8)** | | | | | | | | | | | | |
| Math | 15.78 | 4.03 | 3 | 21 | 24.92 | 4.37 | 8 | 39 | 22.56 | 5.23 | 11 | 36 |
| Reading | 15.95 | 4.50 | 3 | 21 | 26.66 | 7.32 | 5 | 47 | 23.63 | 8.97 | 5 | 49 |
| **Early child characteristics (age 5 to 8)** | | | | | | | | | | | | |
| Short-term memory | 6.88 | 2.60 | 0 | 12 | 39.37 | 4.66 | 1 | 53 | 2.93 | 1.52 | 0 | 7 |
| Conduct problems | .79 | 1.51 | 0 | 10 | 54.24 | 6.05 | 50 | 91 | 5.86 | 4.11 | 0 | 15 |
| Emotional problems | 1.41 | 1.96 | 0 | 10 | 49.36 | 9.38 | 36 | 84 | 2.65 | 2.77 | 0 | 12 |
| **Control and background variables** | | | | | | | | | | | | |
| Birth weight in grams | 3382 | 581 | 200 | 5640 | 3490 | 506 | 2000 | 5428 | 3461 | 613 | 510 | 4763 |
| Race/ethnicity (ref group white) | .05 | .22 | 0 | 1 | .24 | .42 | 0 | 1 | .36 | .48 | 0 | 1 |
| Gender (ref group female) | .52 | .50 | 0 | 1 | .52 | .50 | 0 | 1 | .54 | .50 | 0 | 1 |
| Age (in years) at early achievement | 7.42 | .31 | 6.60 | 8.50 | 7.03 | .31 | 6.29 | 8.40 | 6.97 | .48 | 6.04 | 8.18 |
| Mean # of children | 2.07 | .88 | 0 | 12 | 2.30 | .94 | 1 | 7 | 2.65 | 1.15 | 1 | 9 |
| Log mean income | 5.49 | .60 | 3.91 | 6.11 | 10.53 | .79 | 7.82 | 12.60 | 10.73 | .85 | 8.47 | 13.01 |
| Mother's education (in levels/years) | 3.06 | 1.23 | 1 | 5 | 14.23 | 2.51 | 7 | 21 | 12.85 | 3.16 | 3 | 17 |
| Mother's age at birth of child | 28.00 | 4.96 | 15 | 44 | 28.11 | 5.63 | 18 | 46 | 27.48 | 5.97 | 13 | 42 |
| **Self-concept of ability** | | | | | | | | | | | | |
| Math self-concept ability | 23.57 | 5.54 | 8 | 32 | 5.76 | 1.03 | 1.00 | 7.00 | 5.00 | .99 | 1.38 | 6.80 |
| Reading self-concept ability | 23.97 | 4.88 | 8 | 32 | 5.88 | 1.01 | 1.00 | 7.00 | 5.20 | 1.01 | 2.60 | 7.00 |

Note: Descriptive statistics were generated from 25 MI datasets and were weighted for PSID-CDS. For ALSPAC, math and reading were measured by Key Stage 2 National Assessments at age 11 (later academic achievement) and Key Stage 1 National Assessments at age 7 (early academic achievement). For NICHD SECCYD, later and early math achievement were measured by WJ-R Applied Problems raw scores at age 15 in 2006-2007 and at age 6-8 in 1998-1999. Reading achievement was measured by the mean of raw scores of Picture Vocabulary and Passage Comprehension at age 15 in 2006-2007 and by Letter-Word Identification raw scores at age 6-8 in 1998-1999. For PSID-CDS, later and early math achievement were measured by WJ-R Applied Problems raw scores at ages 15-18 in 2007 and at 1st grade in 1997 (age 5-8). Reading achievement was measured by the mean of raw scores of Letter-Word Identification and Passage Comprehension at age 15-18 in 2007 and by Letter-Word Identification raw scores at age 5-8 in 1997.

**Table 2: Linear Multiple and Quantile Regression for Later Math Academic Achievement by Data Sets**

| | | UK: ALSPAC (N=13,901 each) | | | | | | | US: NICHD SECCYD (N=1,364 each) | | | | | | | US: PSID-CDS (N=237 each) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 95% C.I. | | | | | | | 95% C.I. | | | | | | | 95% C.I. | |
| Model | Parameter | b | | s.e. | t value | p value | LB | UB | b | | s.e. | *t* value | *p* value | LB | UB | b | | s.e. | *t* value | *p* value | LB | UB |
| Linear multiple regression | | | | | | | | | | | | | | | | | | | | | | |
| | *Early academic achievement (age 5 to 8)* | | | | | | | | | | | | | | | | | | | | | |
| | Math | .48 | *** | (.01) | 38.62 | <.001 | .45 | .50 | .41 | *** | (.03) | 11.85 | <.001 | .34 | .48 | .22 | * | (.10) | 2.26 | .026 | .03 | .41 |
| | Reading | .20 | *** | (.01) | 16.56 | <.001 | .18 | .22 | .08 | * | (.03) | 2.45 | .016 | .02 | .15 | .07 | | (.10) | 0.62 | .535 | -.15 | .28 |
| | *Self-concept of ability* | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | .15 | *** | (.01) | 13.39 | <.001 | .13 | .18 | .19 | *** | (.02) | 9.08 | <.001 | .15 | .24 | .19 | ** | (.07) | 2.90 | .005 | .06 | .33 |
| | Reading self-concept ability | .02 | | (.01) | 1.67 | .099 | .00 | .04 | .00 | | (.03) | 0.00 | .997 | -.05 | .05 | .02 | | (.06) | 0.30 | .766 | -.10 | .13 |
| | Intercept | -.06 | *** | (.01) | -4.42 | <.001 | -.09 | -.03 | -.14 | | (.07) | -1.98 | .048 | -.29 | .00 | -.14 | | (.10) | -1.42 | .159 | -.33 | .05 |
| Quantile multiple regression | | | | | | | | | | | | | | | | | | | | | | |
| QR-10 | *Early academic achievement (age 5 to 8)* | | | | | | | | | | | | | | | | | | | | | |
| | Math | .58 | *** | (.02) | 28.40 | <.001 | .54 | .62 | .39 | *** | (.04) | 9.80 | <.001 | .31 | .47 | .21 | | (.15) | 1.36 | .175 | -.09 | .51 |
| | Reading | .27 | *** | (.03) | 10.43 | <.001 | .22 | .32 | .09 | * | (.04) | 2.23 | .030 | .01 | .18 | .18 | | (.15) | 1.19 | .241 | -.12 | .48 |
| | *Self-concept of ability* | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | .18 | *** | (.02) | 11.12 | <.001 | .15 | .21 | .18 | *** | (.03) | 5.64 | <.001 | .12 | .24 | .21 | * | (.09) | 2.28 | .026 | .03 | .40 |
| | Reading self-concept ability | .02 | | (.02) | 1.20 | .235 | -.01 | .05 | -.05 | | (.03) | -1.52 | .134 | -.11 | .02 | .03 | | (.10) | 0.29 | .771 | -.17 | .23 |
| | Intercept | -.82 | *** | (.02) | -36.68 | <.001 | -.86 | -.77 | -.93 | *** | (.08) | -11.93 | <.001 | -1.09 | -.78 | -.82 | *** | (.15) | -5.61 | <.001 | -1.11 | -.53 |
| QR-25 | *Early academic achievement (age 5 to 8)* | | | | | | | | | | | | | | | | | | | | | |
| | Math | .51 | *** | (.01) | 35.12 | <.001 | .48 | .54 | .40 | *** | (.04) | 9.24 | <.001 | .31 | .48 | .30 | ** | (.10) | 3.10 | .003 | .11 | .49 |
| | Reading | .21 | *** | (.01) | 14.53 | <.001 | .18 | .23 | .09 | * | (.04) | 2.08 | .042 | .00 | .18 | .08 | | (.12) | 0.68 | .502 | -.16 | .32 |
| | *Self-concept of ability* | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | .16 | *** | (.01) | 11.91 | <.001 | .13 | .18 | .19 | *** | (.02) | 7.55 | <.001 | .14 | .24 | .17 | * | (.07) | 2.52 | .014 | .04 | .31 |
| | Reading self-concept ability | .02 | | (.01) | 1.42 | .161 | -.01 | .04 | -.02 | | (.03) | -0.67 | .501 | -.07 | .03 | .04 | | (.07) | 0.59 | .555 | -.10 | .18 |
| | Intercept | -.39 | *** | (.02) | -25.58 | <.001 | -.42 | -.36 | -.60 | *** | (.08) | -7.27 | <.001 | -.76 | -.43 | -.53 | *** | (.12) | -4.45 | <.001 | -.76 | -.29 |
| QR-50 | *Early academic achievement (age 5 to 8)* | | | | | | | | | | | | | | | | | | | | | |
| | Math | .45 | *** | (.01) | 39.32 | <.001 | .43 | .47 | .41 | *** | (.04) | 11.68 | <.001 | .34 | .48 | .22 | | (.12) | 1.93 | .058 | -.01 | .45 |
| | Reading | .18 | *** | (.01) | 15.90 | <.001 | .16 | .21 | .07 | | (.04) | 1.92 | .058 | .00 | .14 | .03 | | (.10) | 0.30 | .762 | -.18 | .24 |
| | *Self-concept of ability* | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | .14 | *** | (.01) | 14.46 | <.001 | .12 | .16 | .19 | *** | (.02) | 8.05 | <.001 | .14 | .23 | .20 | * | (.08) | 2.48 | .018 | .04 | .37 |
| | Reading self-concept ability | .02 | * | (.01) | 1.98 | .050 | .00 | .03 | .02 | | (.03) | 0.80 | .423 | -.03 | .07 | .04 | | (.07) | 0.53 | .597 | -.11 | .18 |
| | Intercept | -.01 | | (.01) | -1.17 | .244 | -.04 | .01 | -.18 | | (.09) | -1.97 | .050 | -.36 | .00 | -.21 | | (.11) | -1.88 | .063 | -.43 | .01 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QR-75 | *Early academic achievement (age 5 to 8)* | | | | | | | | | | | | | | | | | | | | | |
| | Math | .39 | *** | (.01) | 39.00 | <.001 | .38 | .41 | .40 | *** | (.04) | 9.66 | <.001 | .32 | .48 | .16 | | (.15) | 1.03 | .306 | -.15 | .46 |
| | Reading | .17 | *** | (.01) | 15.23 | <.001 | .14 | .19 | .10 | ** | (.04) | 2.61 | .010 | .02 | .18 | .05 | | (.12) | 0.44 | .660 | -.19 | .30 |
| | Self-concept of ability | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | .14 | *** | (.01) | 15.88 | <.001 | .12 | .15 | .19 | *** | (.03) | 6.39 | <.001 | .13 | .25 | .21 | * | (.09) | 2.26 | .028 | .02 | .39 |
| | Reading self-concept ability | .01 | | (.01) | 1.60 | .112 | .00 | .03 | .00 | | (.03) | 0.14 | .890 | -.06 | .07 | .00 | | (.09) | 0.03 | .977 | -.17 | .18 |
| | Intercept | .34 | *** | (.01) | 26.27 | <.001 | .31 | .36 | .23 | * | (.09) | 2.51 | .013 | .05 | .42 | .22 | | (.17) | 1.30 | .197 | -.12 | .56 |
| QR-90 | *Early academic achievement (age 5 to 8)* | | | | | | | | | | | | | | | | | | | | | |
| | Math | .35 | *** | (.01) | 29.38 | <.001 | .33 | .38 | .40 | *** | (.05) | 8.31 | <.001 | .30 | .49 | .14 | | (.19) | 0.75 | .460 | -.24 | .53 |
| | Reading | .14 | *** | (.01) | 10.87 | <.001 | .11 | .16 | .07 | | (.04) | 1.87 | .064 | .00 | .15 | .10 | | (.16) | 0.63 | .528 | -.22 | .42 |
| | *Self-concept of ability* | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | .12 | *** | (.01) | 12.84 | <.001 | .10 | .14 | .22 | *** | (.04) | 6.32 | <.001 | .15 | .29 | .16 | | (.12) | 1.35 | .184 | -.08 | .40 |
| | Reading self-concept ability | .01 | | (.01) | 1.64 | .104 | .00 | .03 | .00 | | (.04) | 0.02 | .984 | -.08 | .08 | .00 | | (.10) | -0.03 | .977 | -.20 | .20 |
| | Intercept | .63 | *** | (.02) | 40.36 | <.001 | .60 | .66 | .77 | *** | (.19) | 4.00 | <.001 | .39 | 1.14 | .64 | *** | (.18) | 3.55 | .001 | .28 | 1.00 |

* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

*Notes.* Each equation was estimated by 25 MI datasets, and quantile regressions at different quantiles (.10 [QR-10], .25 [QR-25], .50 [QR-50], .75 [QR-75], and .90 [QR-90]) were estimated simultaneously. Standard errors were obtained by robust variance estimator for linear regression and by bootstrap with 25 replications for quantile regression. All continuous variables were standardized to z-scores using the mean and standard deviation from each imputated data set. All models controlled for child's early short-term memory, conduct problems, emotional problems, birth weight, race/ethnicity, gender, age at early achievement, mean # of children, log mean income, mother's education, and mother's age at birth of child. For NICHD SECCYD, all models also controlled for study sites. For PSID-CDS, linear multiple regressions were weighted. LB is lower bound and UB is upper bound of 95% confidence interval (C.I.).

Table 3: Linear Multiple and Quantile Regression for Later Reading Academic Achievement by Data Sets

| | | UK: ALSPAC (N=13,901 each) | | | | | | | US: NICHD SECCYD (N=1,364 each) | | | | | | | US: PSID-CDS (N=241 each) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 95% C.I. | | | | | | | 95% C.I. | | | | | | | 95% C.I. | |
| Model | Parameter | b | | s.e. | t value | p value | LB | UB | b | | s.e. | *t* value | *p* value | LB | UB | b | | s.e. | *t* value | *p* value | LB | UB |
| Linear multiple regression | | | | | | | | | | | | | | | | | | | | | | |
| | Early academic achievement (age 5 to 8) | | | | | | | | | | | | | | | | | | | | | |
| | Math | .26 | *** | (.01) | 17.96 | <.001 | .23 | .29 | .22 | *** | (.03) | 6.60 | <.001 | .15 | .28 | .20 | * | (.09) | 2.16 | .034 | .02 | .38 |
| | Reading | .36 | *** | (.01) | 24.39 | <.001 | .33 | .39 | .16 | *** | (.03) | 4.99 | <.001 | .10 | .22 | .20 | * | (.09) | 2.24 | .028 | .02 | .39 |
| | Self-concept of ability | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | -.03 | ** | (.01) | -3.17 | .003 | -.06 | -.01 | .00 | | (.02) | -0.11 | .914 | -.05 | .04 | .02 | | (.07) | 0.33 | .744 | -.11 | .16 |
| | Reading self-concept ability | .13 | *** | (.01) | 10.66 | <.001 | .10 | .15 | .12 | *** | (.03) | 4.85 | <.001 | .07 | .18 | .17 | * | (.06) | 2.60 | .011 | .04 | .30 |
| | Intercept | .07 | *** | (.01) | 5.89 | <.001 | .05 | .10 | -.05 | | (.07) | -0.67 | .505 | -.19 | .09 | .19 | * | (.09) | 2.18 | .031 | .02 | .37 |
| Quantile multiple regression | | | | | | | | | | | | | | | | | | | | | | |
| QR-10 | Early academic achievement (age 5 to 8) | | | | | | | | | | | | | | | | | | | | | |
| | Math | .31 | *** | (.02) | 13.66 | <.001 | .27 | .36 | .24 | *** | (.04) | 5.81 | <.001 | .16 | .33 | .20 | | (.16) | 1.24 | .216 | -.12 | .51 |
| | Reading | .57 | *** | (.03) | 20.19 | <.001 | .51 | .62 | .17 | *** | (.05) | 3.61 | .001 | .07 | .26 | .23 | | (.13) | 1.67 | .096 | -.04 | .49 |
| | Self-concept of ability | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | -.04 | ** | (.01) | -2.71 | .008 | -.07 | -.01 | -.03 | | (.03) | -1.05 | .299 | -.10 | .03 | .03 | | (.11) | 0.24 | .809 | -.19 | .24 |
| | Reading self-concept ability | .15 | *** | (.02) | 8.28 | <.001 | .12 | .19 | .11 | ** | (.04) | 2.75 | .009 | .03 | .19 | .23 | * | (.10) | 2.26 | .026 | .03 | .44 |
| | Intercept | -.70 | *** | (.03) | -26.82 | <.001 | -.75 | -.65 | -.89 | *** | (.12) | -7.52 | <.001 | -1.13 | -.66 | -.40 | | (.20) | -1.95 | .055 | -.81 | .01 |
| QR-25 | Early academic achievement (age 5 to 8) | | | | | | | | | | | | | | | | | | | | | |
| | Math | .24 | *** | (.01) | 16.56 | <.001 | .21 | .26 | .23 | *** | (.03) | 6.69 | <.001 | .16 | .30 | .21 | | (.11) | 1.84 | .068 | -.02 | .43 |
| | Reading | .43 | *** | (.02) | 26.23 | <.001 | .40 | .47 | .13 | *** | (.04) | 3.56 | .001 | .06 | .21 | .22 | | (.12) | 1.89 | .064 | -.01 | .45 |
| | Self-concept of ability | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | -.03 | ** | (.01) | -2.68 | .009 | -.05 | -.01 | -.02 | | (.02) | -0.89 | .377 | -.07 | .03 | .01 | | (.08) | 0.11 | .914 | -.14 | .16 |
| | Reading self-concept ability | .11 | *** | (.01) | 10.15 | <.001 | .09 | .14 | .12 | *** | (.03) | 4.54 | <.001 | .06 | .17 | .21 | ** | (.07) | 2.79 | .007 | .06 | .35 |
| | Intercept | -.23 | *** | (.02) | -14.98 | <.001 | -.26 | -.20 | -.52 | *** | (.08) | -6.37 | <.001 | -.69 | -.36 | -.10 | | (.13) | -0.79 | .431 | -.35 | .15 |
| QR-50 | Early academic achievement (age 5 to 8) | | | | | | | | | | | | | | | | | | | | | |
| | Math | .19 | *** | (.01) | 17.59 | <.001 | .17 | .21 | .19 | *** | (.04) | 4.93 | <.001 | .11 | .27 | .17 | | (.11) | 1.54 | .128 | -.05 | .39 |
| | Reading | .31 | *** | (.01) | 27.06 | <.001 | .28 | .33 | .17 | *** | (.03) | 4.91 | <.001 | .10 | .23 | .23 | * | (.10) | 2.23 | .030 | .02 | .43 |
| | Self-concept of ability | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | -.01 | | (.01) | -1.69 | .095 | -.03 | .00 | .00 | | (.03) | -0.03 | .975 | -.05 | .05 | .00 | | (.07) | 0.04 | .964 | -.14 | .15 |
| | Reading self-concept ability | .10 | *** | (.01) | 11.62 | <.001 | .08 | .12 | .12 | ** | (.03) | 3.94 | <.001 | .06 | .18 | .17 | * | (.07) | 2.45 | .017 | .03 | .31 |
| | Intercept | .17 | *** | (.01) | 14.47 | <.001 | .14 | .19 | -.08 | | (.11) | -0.75 | .452 | -.29 | .13 | .16 | | (.11) | 1.41 | .164 | -.07 | .39 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QR-75 | Early academic achievement (age 5 to 8) | | | | | | | | | | | | | | | | | | | | | |
| | Math | .15 | *** | (.01) | 15.31 | <.001 | .13 | .16 | .19 | *** | (.04) | 5.22 | <.001 | .12 | .27 | .17 | | (.10) | 1.68 | .098 | -.03 | .37 |
| | Reading | .22 | *** | (.01) | 23.31 | <.001 | .21 | .24 | .17 | *** | (.04) | 4.72 | <.001 | .10 | .25 | .15 | | (.11) | 1.36 | .183 | -.08 | .38 |
| | Self-concept of ability | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | -.02 | * | (.01) | -2.35 | .022 | -.03 | .00 | .04 | | (.03) | 1.24 | .217 | -.02 | .09 | -.01 | | (.08) | -0.08 | .936 | -.16 | .15 |
| | Reading self-concept ability | .09 | *** | (.01) | 12.95 | <.001 | .07 | .10 | .12 | *** | (.03) | 3.66 | <.001 | .05 | .18 | .14 | | (.08) | 1.63 | .113 | -.03 | .31 |
| | Intercept | .48 | *** | (.01) | 49.71 | <.001 | .46 | .50 | .43 | *** | (.08) | 5.25 | <.001 | .27 | .60 | .51 | *** | (.12) | 4.13 | <.001 | .26 | .75 |
| QR-90 | Early academic achievement (age 5 to 8) | | | | | | | | | | | | | | | | | | | | | |
| | Math | .13 | *** | (.01) | 13.30 | <.001 | .11 | .14 | .19 | *** | (.05) | 4.07 | <.001 | .10 | .28 | .16 | | (.19) | 0.86 | .394 | -.22 | .54 |
| | Reading | .16 | *** | (.01) | 17.93 | <.001 | .14 | .18 | .16 | *** | (.04) | 3.78 | <.001 | .07 | .24 | .12 | | (.14) | 0.84 | .400 | -.16 | .40 |
| | Self-concept of ability | | | | | | | | | | | | | | | | | | | | | |
| | Math self-concept ability | -.01 | | (.01) | -1.79 | .077 | -.03 | .00 | .01 | | (.04) | 0.17 | .868 | -.08 | .09 | -.03 | | (.11) | -0.30 | .765 | -.25 | .18 |
| | Reading self-concept ability | .07 | *** | (.01) | 10.72 | <.001 | .06 | .08 | .15 | *** | (.03) | 4.67 | <.001 | .08 | .21 | .09 | | (.12) | 0.79 | .430 | -.14 | .33 |
| | Intercept | .71 | *** | (.01) | 72.96 | <.001 | .69 | .73 | .81 | *** | (.08) | 9.80 | <.001 | .65 | .97 | .83 | *** | (.18) | 4.60 | <.001 | .47 | 1.19 |

* $p \le .05$. ** $p \le .01$. *** $p \le .001$.

Notes: Each equation (linear regression and each quantile regression at .10 [QR-10], .25 [QR-25], .50 [QR-50], .75 [QR-75], and .90 [QR-90]) was estimated by 25 MI datasets. Standard errors were obtained by robust variance estimator for all equations. All models included study sites for NICHD SECCYD, and 1997 child weight was used for PSID-CDS. All continuous variables were standardized to z-scores using the mean and standard deviation from each imputated data set. All models controlled for child's early short-term memory, conduct problems, emotional problems, birth weight, race/ethnicity, gender, age at early achievement, mean # of children, log mean income, mother's education, and mother's age at birth of child. For NICHD SECCYD, all models also controlled for study sites. LB is lower bound and UB is upper bound of 95% confidence interval (C.I.).