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Are school-SES effects statistical artefacts? Evidence from longitudinal population data

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Schools' socioeconomic status (SES) has been claimed as an important influence on student performance and there are calls for a policy response. However, there is an extensive literature which for various reasons casts doubt on the veracity of school-SES effects. This paper investigates school-SES effects with population data from a longitudinal cohort of school students which includes achievement measures in Years 3, 5 and 7. Estimates for school-SES are unstable under differing model and measurement specifications. School-SES effects are trivial controlling for student- and school-level prior ability. Inconsistent with theoretical explanations, school-SES effects were stronger with weaker SES measures. Furthermore, school-SES effects differ somewhat by achievement domain. Also contrary to expectations, there were school-SES effects on Year 7 achievement in secondary school for the primary schools students attended in Year 5. In each of five domains of achievement, fixed effect models show a small negative effect for school-SES and a small positive effect for school-level prior ability. The large school-SES effects prominent in some research and policy literatures are statistical artefacts.

Keywords: *school SES*; *statistical artefacts*; *SES*; *prior ability*; *school-level prior ability*

Introduction

An important policy and research question is: Are the effects for school SES real? The OECD's PISA study routinely analyses the effects of student and school-level SES on student achievement. A 2010 OECD (2010, p. 90) report concludes that in the majority of OECD countries school-SES effects are stronger than that for student-level SES. They explain the effect in terms of peer groups, school resources and superior (or inferior) environments for teaching and learning (2010, p. 92).

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Among other policy recommendations the OECD advises countries with large school-SES effects to enact policies that target socio-economically disadvantaged schools (2010, p. 113). More strongly, Willms (2010) calls for policy responses to the effects of school-SES, such as increasing educational inclusion or allocating more school and classroom resources to low SES schools. Similarly, Perry and McConney (2010) recommend the socioeconomic desegregation of schools in order to remove the detrimental effects of school-SES.

Several studies analysing data from the OECD's PISA study using the PISA standardised measure of SES—Economic, Social and Cultural Status (ESCS)—find large effects for school-SES on student achievement.[1] Analysing Australian data from the PISA 2003, Perry and McConney (2010, pp. 1151–1152) find effects of 57 score points (around 0.6 of a standard deviation) on reading score comparing the first school-ESCS quintile to the bottom quintile, net of student-level ESCS. Similarly sized effects were found for mathematics and science. Analysing data from 57 countries from PISA 2006, Willms (2010, p. 1024) concludes that the average school-ESCS effect (at 62 score points) is much larger than the student-level effect (at 17 score points). According to the 2009 PISA study several countries exhibit very large effects of school-ESCS and much smaller effects of student-level ESCS, for example: 111 and 13 score points respectively in Belgium, 123 and 14 in the Czech Republic, 122 and 10 in Germany, 93 and 5 in the Netherlands, and 90 and 10 in Austria (for other OECD countries see Appendix Table 1). These effects compare to bivariate effects for student-level ESCS of 47, 46, 44, 37 and 48 score points respectively. These countries and others that display similar patterns (e.g. Greece, Hungary, Italy, Israel, Korea, Slovenia, the Slovak Republic and Switzerland) have tracked education systems and typically have large between-school variation in achievement (see column 3 of Appendix Table 1). Also countries with largely comprehensive education systems show weaker but still sizeable effects for school-ESCS relative to student-level ESCS: Australia (66 and 30 score points), New Zealand (61 and 36), Sweden (52 and 34), the United Kingdom (69 and 27) and the United States (63 and 27). Considering that student-level ESCS typically explains between 10% and 20% of the variation in student achievement in PISA (Appendix Table 1), these effects for school-ESCS are surprisingly large.[2] Only in Canada, Finland, Norway, Poland and Spain are the effects of school-ESCS relatively small.

School-SES can also 'explain' school sector differences. Lubienski and Lubienski (2006) found that among grade 4 and 8 students in the USA, the non-trivial positive effects of attending a Catholic or other private school compared to attending a public school on mathematics performance in the National Assessments of Educational Progress (NAEP) program of testing were reversed or were no longer statistically significant, after controlling for the school-level effects of SES type variables.[3] Analysing differences in student achievement between private (government independent), other private (government dependent) and government schools in 16 countries, Dronkers and Robert (2008, p. 293) find that 'the higher scores in pupils' mathematical tests in private independent schools can be fully explained by the social composition of these schools'. The compositional variables were school-averaged father's occupational status and parental wealth. They conclude (2008, p. 260) that the 'explanation of the gross differences in mathematical achievement is the better social composition of private schools'. Similarly, school sector (independent, Catholic and government) differences in PISA test scores in Australia are not statistically significant when controlling for school-SES allowing the authors to claim that school sector differences can be entirely attributed to SES (Thomson, De Bortoli & Buckley, 2013, pp. xvi, 34–35, 144, 183; Thomson, De Bortoli, Nicholas, Hillman & Buckley, 2010, pp. ix, 63, 188, 232). These studies explain school sector differences in student achievement by some type of contagion process involving parental SES rather than more probable sector differences in resources, ethos, discipline, teaching and delivery of the curriculum.

It is difficult to examine if school-SES effects are real in cross-national studies of achievement such as PISA. These studies, with few exceptions, are cross-sectional so cannot include controls for the intake characteristics of students such as prior achievement or prior ability. National longitudinal studies tend to be limited in the number of time points that student achievement is measured and rarely involve students changing schools. Typically studies of school-SES focus on only one or two achievement domains. In addition, most studies are based on data collected by two-stage sample strategies where data is obtained from only a proportion of students in the same year level, not all students. This introduces error. Appropriate measures of school-SES would ideally be based on all students in a large number of schools in the same year level with achievement measures at several time points.

Theoretical background and literature

The ecological fallacy and aggregated measures

The ecological fallacy has been well-known for over 60 years—that aggregated data show much higher correlations than the same variables at the individual level and, furthermore, relationships at the aggregate level cannot be used to make assertions at the micro-level (Robinson, 1950; Snijders & Bosker, 2012, p. 15). Similarly, it is well-known that the correlations between measures of socioeconomic status and student achievement aggregated at the school-level are very much stronger than that at the student level. These much larger correlations are sometimes offered as evidence that socioeconomic background is very strongly associated with student achievement and other educational outcomes. White (1982, p. 467) and Sirin's (2005) meta-analyses of mainly US data calculated mean correlations of 0.60 and 0.73, respectively, between aggregated measures of socioeconomic background and achievement. For Belgium, Opdenakker and Van Damme (2001) report a correlation of 0.82 between school mean ability and school mean father's education. A later Belgian study reported a correlation of 0.77 between school mean prior achievement and school mean sociocultural capital (Dumay & Dupriez, 2008,

p. 462). For New Zealand, Harker and Tymms (2004, p. 188) report a correlation of 0.87 for mean school prior achievement and mean school socioeconomic status. These are much stronger associations than the correlations observed at the student-level which are, depending on the context, between 0.2 and 0.4. White, Reynolds, Thomas, & Gitzlaff (1993, p. 328) conclude that aggregate measures of socioeconomic status overstate the relationship between SES and achievement by a factor of four. The reason is that aggregating individual-level data, typically by calculating the school mean, removes the individual-level variation within aggregated units. For example, the aggregation of students' scores at the school-level removes the considerable variation among students in their achievement scores within schools. Aggregation also removes the within-school variation in students' socioeconomic background.

Hauser (1970; 1974, p. 659) argues that contextual effects of SES relate to the ecological fallacy in that residual differences between groups (in this case schools) are interpreted as social processes. Such differences should disappear once relevant individual student-level predictors (correlated with the school residuals) are included. Nash (2003, p. 446) makes a similar point suggesting the contextual effects of school-SES are due to unmeasured non-cognitive or family factors that affect school performance. Gorard (2006, p. 91) points out that the school composition effect may be spurious because there is measurement error for SES at the student level, but measurement error for SES aggregated at the school-level is lower since the errors cancel out.

Proposed mechanisms for school-level effects

The mechanisms for the contextual effects of socioeconomic status are unclear (Dumay & Dupriez, 2008). Bourdieu (cited by Nash, 2003, p. 443) postulates that if the proportion of working-class students exceeds a certain threshold, school classes become more disordered, impeding learning. Alexander, Fennessey, McDill, & D'Amico (1979, p. 223) offer two mechanisms for the contextual effects of SES: a change in the academic climate of the school (academic press) or educational benefits produced by changes in peer networks. Rumberger and Palardy (2005) posit three mechanisms: alterable school characteristics (resources, structures and practices); peer effects; and through schools' responses to the student composition (for example, 'dumbing down' the curriculum to cater for low SES students, reduced teacher morale and efficacy etc.). However, for any of these mechanisms to be viable they would need to involve prior student achievement; inadequate resources or poor administration affecting overall achievement, the influence of high or low achieving peers or changing the curriculum or expectations in accordance with the students' general level of achievement. Therefore, the effects of school-SES must be indirect and involve student achievement.

Thrupp, Lauder and Robinson (2002) suggest that the effects of school-SES may not survive controls for prior achievement and advocate a full set of entry level variables. They also point out (2002, p. 486) that school-level prior achievement or ability is rarely entered as a variable in studies of school-SES. Scheerens et al. (2000, p. 136) speculate that it is the contextual effects of ability (IQ) rather than contextual effects of socioeconomic status that predominate for student achievement. The theoretical reasons for a contextual effect of ability are more direct than parallel arguments for school-SES. Students in a high-achieving school perform better, over and above that expected by their prior achievement, for a variety of reasons: the curriculum and the teaching are delivered at a higher level; the schools and teachers' expectations are higher; students' norms regarding the usefulness of academic work are more conducive to learning; and possibly there is less disruption to teaching and learning. For converse reasons, students in low-achieving schools perform lower than that expected by their prior performance.

Empirical work

The effects for school-SES tend to disappear or are much smaller when controlling for school mean prior achievement or school mean student ability (Marks, 2010; Opdenakker & Van Damme, 2001). Zimmer and Toma (2000) found strong effects for academic context in four school systems using data from a 1981 cross-national mathematics study which collected both pre- and post-test scores. However, they did not include school-SES and school-prior achievement in the same analysis. Dumay and Dupriez (2008) found school-level effects for SES and prior achievement, net of a suite of student level variables including prior achievement. However, due to the high correlation between school SES and school-level prior ability, they were unable to include both in the same analysis. In a study of 530,000 pupils in English schools, Strand (2010, p. 300) found a small negative effect for the percentage of students entitled to a free school meal[4] and a negative effect for prior school achievement on student achievement at age 11, net of the corresponding student level predictors. Snijders and Bosker (2012, pp. 83–86) in a study of reading literacy in Dutch grade-eight students found negative effects of mean school socioeconomic status on literacy score in the presence of mean school IQ and student-level measures of IQ and socioeconomic status. Employing a fixed effect model to control for unmeasured student differences, Lauen and Gaddis (2013) found no causal contextual effects at the classroom level for poverty on test scores. A recent meta-analysis of peer effects found large variations in the magnitude of the effects of school or class aggregated measures of socioeconomic background with effect sizes ranging widely from 0.03 to 0.59 (van Ewijk & Sleegers, 2010, p. 138). They account for this wide variation by differences in the reliabilities of the measures used and model specification, especially the presence or absence of prior achievement. Although they conclude there are compositional effects—they tentatively suggest an effect size of 0.31—they do not consider the role of aggregated measures of prior achievement or ability (van Ewijk & Sleegers, 2010, p. 147).

The reliability of the school-level measures is an issue. It is well-established that, at the individual level predictor variables with more measurement error have weaker effects in the bivariate case and in the multivariate case the results are unpredictable but tend to attenuate the estimates (Berry & Feldman, 1985, pp. 28–33; Blalock, 1979, pp. 431–433). However, aggregating student-level variables with added measurement error at the school-level can have unexpected consequences. Harker and Tymms (2004, pp. 192–193) demonstrate the magnitude of school-prior achievement effects increase rather than decrease, the more *unreliable* the measure used. Their explanation is that the aggregate measure 'mops up' the unexplained variance left by the larger error component of student-level measure.

Purpose of this study

The purpose of this study is to examine the effects of school-SES on student achievement using longitudinal data with achievement test data (in numeracy and four other domains) measured at three time points, from almost all students at the same grade level, from all schools within a single jurisdiction. The achievement data are from the Australian National Assessment Program in Literacy and Numeracy (NAPLAN). With comparable measures of student achievement, SES and prior ability, and a change of school for almost all students as they move from primary to secondary school, these data enable evaluation of whether school-SES effects are sizeable and valid and therefore warrant a policy response.

This study addresses the following issues:

- The commonly employed model comprising student and school-level SES is most likely mis-specified because it does not include student and school-level measures of prior ability. What are the magnitudes of school-SES effects in the preferred model comprising student- and school-level measures of prior ability?
- There are no strong theoretical reasons for different school-SES effects with different outcome measures of student achievement. Do school-level effects vary with different outcome measures of student achievement?
- Do school-SES effects increase with larger error components in the SES measures?
- School-level effects for schools students are no longer attending would undermine the legitimacy of school-level effects. Are there school-SES and school-level prior ability effects on student achievement based on the schools the students attended two or four years earlier?
- Are there school-level SES and prior ability effects when taking into account all differences between individual students which include unmeasured differences in family background, cognitive ability and non-cognitive characteristics?

Data, measures and methods

Data

The data analysed comprise the Victorian government school sector NAPLAN data for Year 3 students in 2008, Year 5 students in 2010, and Year 7 students in 2012. Unique student identification numbers allow linkage of the three data sets creating a longitudinal cohort. Year 3 and 5 are respectively the fourth and sixth years of primary school (there is a preparatory year) and Year 7 is the first year of secondary school. Typically, several primary schools feed into a single secondary school and conversely students from a single primary school make the transition to a number of secondary schools including non-government schools.[5] In these data, students attending secondary school come from an average of 15 primary schools (the median was 11). In secondary schools with more than 20 Year 7 students, on average, 36% came from the primary feeder school supplying the most students, 16% from the second primary feeder school and 11% from the third primary feeder school. For larger secondary schools these percentages were lower and higher in non-metropolitan schools.[6]

Measures

Student achievement. Each NAPLAN scale describes the development of student achievement in Years 3, 5, 7 and 9. Student scaled scores range from 0 to 1000 (called scaled scores) in each of the five domains across the four year levels. They are standardised to have a mean of 500 and a standard deviation of 100. The scaled scores are 'conditioned' using several predictor variables to increase the precision of the estimates, minimising measurement error (ACARA, 2008, pp. 85–86). Scaled scores *within* a given domain are consistent across Year levels. For example, the same scaled score in a particular domain has the same meaning in terms of skills and understanding for Year 5 students as for Year 3 students, although their position relative to their peers and their expected performance are very different.

NAPLAN tests are equated so that one year's results can be compared with those for other years. Equating is the process by which the test items from two or more tests are placed on the same measurement scale. Equating involves selecting a sample of students that sit an additional equating test, as well as their respective grade level test, so that new items can be located on the common scale and used in subsequent years' tests (ACARA, 2010). The logic of modern test theory is that the probability of a student correctly answering a particular test item is a function of student ability and its difficulty. So if the abilities of a sample of students are known, then the difficulties of a new set of items can be calculated.

Socioeconomic background. The measure of socioeconomic background used in this study is a composite of parents' occupation and education. Information on parents' occupation and education were obtained from enrolment records. The measures of parents' occupation comprise the following categories:

- Senior management, qualified professionals
- Other business managers associate professionals
- Tradesmen/women, clerks and skilled office, sales and service staff
- Machine operators, hospitality staff, assistants, labourers and related workers
- Not in paid work in last 12 months
- Not stated or unknown (missing data)

The measures of parents' education for each parent were constructed from two variables: highest school-level attained and post-school qualification resulting in the following 'years of education' ordinal measure:

15 Bachelor degree or above

13 Advanced diploma/Diploma

12 Year 12 or equivalent

11 Year 11 or equivalent

10 Year 10 or equivalent

9 Year 9 or equivalent or below

Missing data were not included in the education measures.

Parental education and occupation were combined into a sheaf variable (Heise, 1972; Whitt, 1986). A sheaf variable is a combination of several variables that theoretically indicate the same concept.[7] One common use of sheaf variables is to summarise into a single variable, variables that relate to socioeconomic background such as mother's and father's education and occupation, and family income. The advantage of sheaf variables over standard composite variables is that the sheaf variable preserves the explanatory power of the constituent variables. The variance explained (R square) by a sheaf variable is exactly the same as in an analysis comprising the constituent variables with the same dependent variable. The first stage in constructing a sheaf variable was to obtain estimates from a regression analysis of combined NAPLAN score at the respective Year level on continuous measures of father's and mother's education and categorical measures of father's and mother's occupation group (including missing data for occupation). The sheaf variable was calculated by multiplying the estimates by the values of parental occupation and education and summing the products for each individual student. The resulting sheaf variables, one for each Year level, were then standardised to a mean of zero and a standard deviation of one.

Two additional measures of socioeconomic background were constructed that contain increasing amounts of measurement error. They were constructed by generating a random normal variate with a mean of zero and a standard deviation of one and adding the variates to the SES sheaf variable for Year 5. The resulting SES measures with additional error variance were also standardised. The first SES plus random error variable (SES_A) was correlated at 0.76 with the original Year 5 SES measure and the second (SES_B) at 0.50 (Table 1).

Prior ability. The measure of prior ability was constructed by taking the standardised factor scores for the first factor in an unrotated factor analysis of student performance in the NAPLAN achievement tests taken two years earlier. These are estimates of *g*, the general factor for cognitive ability. The loadings of the manifest variables were between 0.70 and 0.85. For Year 3, the first factor accounted for 61% of the variance in the five student achievement domains. In Year 5, the variance accounted for was a little lower at 58%. Student-level ability correlates at about 0.85 across years.

School-level measures. Schools were identified with standard identification numbers for each NAPLAN test year. The contextual variables for SES were constructed by calculating the mean SES for each school using the available SES measure. With one exception, the school-SES was aggregated at the school attended in respective year. The correlation between the Year 3 and 5 measures school-SES was 0.80. Because students change schools between Years 5 and 7, the correlation between the Year 5 and Year 7 school-SES measures was considerably lower at 0.52. For the analyses of Year 7 numeracy presented in panel 2 of Table 5 the school-SES measure was based on SES measured in Year 5 aggregated at the school attended in Year 5. This measure correlated at 0.58 with Year 7 school-SES.

The contextual measures of ability were derived from the ability measures constructed from student achievement measured two or four years earlier. The correlation between the Year 3 and Year 5 school-level prior ability measures is 0.80. Because students change schools between Years 5 and 7, the correlation between

Table 1. Correlations and summary statistics for student and school-level variables Years 3 and 5

	1	2	3	4	5	6	7	8	9	Mean	Std
1 Numeracy Year 5	1.00									501	72
2 SES Year 5	0.35	1.00								0	1.0
3 SES Yr5 +Error A	0.26	0.76	1.00							0	1.0
4 SES Yr5 +Error B	0.17	0.50	0.94	1.00						0	1.0
5 School-level SES	0.29	0.58	0.44	0.29	1.00					−0.03	0.53
6 School-level SES A	0.27	0.55	0.46	0.33	0.95	1.00				−0.02	0.42
7 School-level SES B	0.24	0.50	0.44	0.34	0.84	0.97	1.00			−0.02	0.31
8 Ability Year 3	0.69	0.38	0.29	0.19	0.29	0.27	0.24	1.00		0	1.0
9 Year 5 School Level Ability from Year 3 Student Ability measure	0.32	0.41	0.31	0.20	0.70	0.67	0.59	0.40	1.00	−0.01	0.39

Table 2. Correlations and summary statistics for student- and school-level Variables Years 5 and 7

	1	2	3	4	5	6	Mean	SD
1 Numeracy Year 7	1.00						534	73
2 SES Year 7	0.33	1.00					0	1.0
3 School-level SES Year 7	0.25	0.53	1.00				−0.02	0.43
4 Ability Year 5	0.79	0.36	0.26	1.00			0	1.0
5 Year 7 School-level Ability from Year 5 Student ability measure	0.29	0.43	0.80	0.31	1.00		−0.10	0.33
6 Year 7 School-level Ability from Year 3 Student ability measure	0.28	0.43	0.80	0.29	0.92	1.00	−0.10	0.33

the Year 5 and Year 7 school-level prior ability measures is considerably lower at 0.45.

The school-level measures were not restandardised. The variations in school-level measures of SES and prior ability are smaller than that of respective student-level measures. Several studies cited above compare the effects of school-SES for a one standard deviation change in student SES. However, because the school-level variance is typically smaller, it is wise to also compare the standardised effects before concluding on the relative strength of the effects of student- and school-level SES.

The correlations between these student- and school-level variables are presented in Tables 1 and 2. Student-level SES is correlated at about 0.35 with numeracy achievement and the SES measures with random error components exhibit lower correlations with numeracy (0.26 and 0.17). The correlation between numeracy achievement and school-level SES is a little weaker than that with student-SES (with no added error) at about 0.3 and the school-level SES measures constructed from the random-error SES measures show slightly weaker correlations with numeracy (0.27 and 0.24). Student-level ability (or *g*) measured in Year 3 is strongly correlated with numeracy in Year 5 at about 0.7. However, the school-level ability measure shows a much weaker correlation with Year 5 numeracy (about 0.3).

Methods

Random effect models. Initially, the study analyses the effects of school-level SES and school level prior ability on Year 5 achievement in numeracy, reading, writing, spelling and grammar without controls for student-level SES and prior ability to gauge how the estimates of the school-level variables change under different model specifications. The preferred model includes student and school level measures of SES and prior ability. Schools were specified as random effects with contextual effects for SES and prior ability entered at the school level. These analyses were performed using PROC

MIXED in SAS which is appropriate for the analysis of multilevel data (Littell, Milliken, Stroup & Wolfinger, 1996; Singer, 1998). Recall that the student-level measures of SES and ability have been standardised to a mean of zero and a standard deviation of one, and the achievement measures are scaled scores (a standard deviation of 100). Generally, the use of statistical inference tests in population data is justified if the population can be considered as generated probabilistically from a super population and to test that the differences observed could be due to 'chance processes' (Blalock, 1979, pp. 241–243; Bollen, 1995; Rubin, 1985). These arguments apply to the population data analysed for this paper.

The next group of analyses assesses the extent that the effects of school-level SES and the other predictors change with increasing amounts of measurement error in the measure of student SES. This exercise was performed in response to Harker and Tymms's (2004) observation that measures of prior ability with greater error variance produce stronger school-level effects.

The next set of analyses evaluates how the school-level effects on Year 7 numeracy change with measures constructed from different Year levels:

- SES measured in Year 7 and prior ability measured in Year 5, both aggregated at the students' Year 7 schools. This is the standard procedure for the previous analyses.
- SES measured in Year 5 aggregated at the students' Year 5 schools rather than their Year 7 schools. Year 5 ability remains aggregated at students' Year 7 schools.
- SES measured in Year 7 aggregated at the students' Year 7 schools and prior ability measured in Year 3 aggregated at the students' Year 3 schools.

Fixed effect models. Fixed effect models were subsequently employed to control for the effects of unmeasured differences between students. Fixed effect models are increasingly used in educational research to control for unobserved effects (Blanden & Gregg, 2004; Jæger, 2011; Mouw, 2006). Unmeasured factors include intelligence, personality, aspirations and motivation. The measures of prior ability discussed above may not account for all differences between students in their cognitive capacities. Unmeasured variables also include unmeasured aspects of socioeconomic background, such as, family income and wealth. Two distinct fixed-effects procedures were employed, the first based on subjects-as-intercepts in multiple regression and the second on structural equation modelling.

Fixed effects from subjects-as-intercepts. Mathematically in a student-year data set:

$$Y_{it} = \alpha_i + \beta x_{it} + yz_i + e_{it}, \mathrm{i} = 1\ldots., \mathrm{n};\ \ \mathrm{t} = 1, \ldots.\mathrm{T}$$

where y_{it} refers to the score of student 'i' at time 't', x_{it} are variables that vary between individuals and time points, z_i are variables that vary between individuals but are time-invariant and α_i is the effect for student 'i'. The vector β is the set of coefficients for the x variables that vary across time points within students, i.e. school-SES and school-prior ability. The term z_i indexes measured characteristics of students that do not change with time, such as, gender and ethnicity. Since these do not vary with time, they are collinear (completely correlated) with the intercepts α_i so estimates for the vector γ cannot be obtained. School-SES is measured three times and changes and prior ability twice.

Fixed effects from structural equation modelling. The structural equation modelling approach to fixed effects is analyse the standard data of one row of data per student for two years specifying equality of the coefficients across the two years except for the intercept and include a latent variable, factor alpha (*falpha*), which is equivalent to α_i (time invariant characteristics of students) in the model above. For details, see Allison (2005, pp. 125–132). For these data the two equations are:

$$Ach_{it=1} = t_1 Intercept + \beta_1 SchSES_{it=1} + \beta_2 SchPrior\ \ Ability_{it=1} + \text{falpha} + \text{e}_{\text{it}=1}, \text{i} = 1 \ldots., \text{n};$$

$$Ach_{it=2} = t_2 Intercept + \beta_1 SchSES_{it=2} + \beta_2 SchPrior\ \ Ability_{it=2} + \text{falpha} + \text{e}_{\text{it}=2}, \text{i} = 1 \ldots., \text{n};$$

Ach denotes achievement in each of the five domains. Time 1 ($t = 1$) is Year 5 and time 2 ($t = 2$) is Year 7. School SES is measured contemporaneously and school prior ability is based on the students' ability measured two years earlier but aggregated at the school they attend presently. The intercepts have a constant value of 1. t_1 and t_2 are the actual intercepts to be estimated. The latent variable has an explicit coefficient of 1 and its variance is to be estimated. The variance of the error terms are specified as being equal. Specification of the covariances between the latent variable (falpha) and the four manifest variables is required for a fixed effects analysis.[8]

Results

The effects of the predictor variables on Year 5 achievement in each of the five domains are presented in Table 3. Model 1 in panel 1 shows a sizeable effect of school-SES on numeracy of 32 score points. Model 2 is the most commonly used model used in the literature (and the OECD) to demonstrate school-SES effects comprising both student- and school-level measures of SES. The effect of student-level SES on Year 5 numeracy is comfortably larger than that of school-SES, more if standardised coefficients are compared (0.28 and 0.10). Net of student ability (model 3), the effect of student-SES declines by more than half and the effect of school-SES becomes very much smaller (std. coeff. = 0.02). This model indicates

Table 3. Individual and school effects on achievement in Year 5 in numeracy, reading, writing, spelling and grammar

	Model 1		Model 2		Model 3		Model 4		Model 5		(Std.)
Numeracy (SD=72.0)											
Intercept	502.8	***	506.0	***	504.3	***	505.5	***	504.3	***	
SES in Year 5	.		20.2	***	7.1	***	20.2	***	7.1	***	*0.10*
School Mean SES Year 5	32.0	***	13.2	***	2.9	*	−4.7	**	4.4	**	*0.05*
Prior Ability (Year 3)	.		.		46.5	***	.		46.6	***	*0.65*
School (Year 5) Mean Ability from Year 3	.		.		.		37.7	***	−3.1		*−0.02*
N of Observations	*40143*		*30656*		*26932*		*30651*		*26932*		
N of Schools	*1289*		*1289*		*1216*		*1225*		*1216*		
Reading (SD=76.6)											
Intercept	499.6	***	502.7	***	500.7	***	501.8	***	500.8	***	
SES in Year 5	.		22.6	***	7.3	***	22.7	***	7.3	***	*0.10*
School Mean SES Year 5	36.7	***	15.5	***	3.5	**	−4.6	**	6.9	***	*0.05*
Prior Ability from Year 3	.		.		54.7	***	.		55.0	***	*0.72*
School (Year 5) Mean Ability from Year 3	.		.		.		40.9	***	−7.0	***	*−0.04*
N of Observations	*40273*		*30769*		*27034*		*30765*		*27034*		
N of Schools	*1289*		*1289*		*1216*		*1225*		*1216*		
Writing (SD=65.6)											
Intercept	491.7	***	495.1	***	493.8	***	494.9	***	493.8	***	
SES in Year 5	.		14.5	***	2.6	***	14.5	***	2.6	***	*0.04*
School Mean SES Year 5	27.0	***	12.5	***	4.0	***	−4.3	***	4.7	***	*0.04*
Prior Ability from Year 3	.		.		40.7	***	.		40.8	***	*0.62*
School (Year 5) Mean Ability from Year 3	.		.		.		34.1	***	−1.5		*−0.01*
N of Observations	*40168*		*30701*		*26988*		*30697*		*26988*		
N of Schools	*1289*		*1289*		*1216*		*1225*		*1216*		

(*Continued*)

Table 3. (*Continued*).

	Model 1		Model 2		Model 3		Model 4		Model 5		(Std.)
Spelling (SD=65.9)											
Intercept	490.1	***	493.3	***	490.6	***	493.1	***	490.6	***	
SES in Year 5	.		14.3	***	−1.6	***	14.3	***	−1.6	***	*−0.02*
School Mean SES Year 5	22.3	***	7.8	***	−2.7	**	−12.9	***	−0.6		*−0.00*
Prior Ability from Year 3	.		.		52.9	***	.		53.0	***	*0.80*
School (Year 5) Mean Ability from Year 3	.		.		.		42.2	***	−4.4	**	*−0.03*
N of Observations	*40254*		*30772*		*27044*		*30767*		*27044*		
N of Schools	*1289*		*1289*		*1216*		*1225*		*1216*		
Grammar (SD=81.2)											
Intercept	507.9	***	511.8	***	509.6	***	511.0	***	509.6	***	
SES in Year 5	.		22.5	***	5.6	***	22.5	***	5.5	***	*0.07*
School Mean SES Year 5	34.0	***	11.3	***	−0.8		−10.4	***	2.7	†	*0.02*
Prior Ability from Year 3	.		.		57.8	***	.		58.1	***	*0.72*
School (Year 5) Mean Ability from Year 3	.		.		.		44.0	***	−7.2	***	*−0.03*
N of Observations	*40254*		*30772*		*27044*		*30767*		*27044*		
N of Schools	*1289*		*1289*		*1216*		*1225*		*1216*		

Note: †0.10<P<0.05; *0.05<P<0.01; **0.01>P>0.001; ***P<0.001

that the effects of student- and school-SES on numeracy achievement in Year 5 are very much weaker when controlling for students' prior ability. Model 4 substitutes student-level ability for school prior ability (with ability measured in Year 3). The effect of school-SES becomes negative but remains small. Model 5 is the preferred model since it includes all four predictors, both student and school-level measures of SES and ability. In model 5, there is a strong effect of prior student ability (std. coeff. = 0.65) and weak effects for both student-SES (std. coeff. = 0.10) and school-SES (std. coeff. = 0.05) and a negative statistically insignificant effect of school-level ability. Collinearity, variance inflation and tolerance tests indicate that the estimates in model 5 do not suffer from high multicollinearity.[9]

The four lower panels of Table 3 present the estimates of the effects of the four predictor variables on student achievement in the other domains. As was the case for numeracy, model 2 exhibits seemingly plausible estimates for student- and school-SES. However, the initial estimates for school-SES are very much smaller controlling for prior student ability (model 3) and become negative controlling for school-level prior ability (model 4). The standardised estimates in the preferred model (model 5) for school-SES for reading and writing are of similar magnitudes to that for numeracy but smaller and not statistically significant for spelling or grammar. In all instances the standardised effects for school-prior ability are small, negative and sometimes not statistically significant. There is no readily apparent theoretical explanation for significant albeit small school-SES effects for numeracy, reading and writing but insignificant effects for spelling and writing. The most plausible explanation is that the effects of both school-SES and school prior ability are very small and subject to random variation. It is clear that prior ability is very much the dominant influence.

Table 4 reports the estimates for Year 5 numeracy obtained with increasing amounts of random error in the SES measures. As expected, the student-level SES effects are weaker than that in panel 1, Table 3: 4.1 and 2.6 compared to 7.1 score points. However, the school-SES measures constructed from the SES error measures have increasingly stronger effects in model 1 (panels 2 and 3) than the SES measure without additional error variance (panel 1, Table 3). Similarly, net of student-level SES, the SES error measures exhibit stronger school-level effects (model 2): twice as strong for SES_A and three times stronger with SES_B. In model 3, which also includes prior ability, the SES error measures at the student-level are much weaker but at the school-level appear stronger. In model 5 the school-SES measures with greater error variance appear to have stronger impacts on numeracy achievement than the SES measure without additional error variance. However, in terms of standardised effects the effects of school-level SES are not substantially larger (std. coeff. equals 0.05 for SES_A and 0.07 for SES_B). The finding that school-SES with greater amounts of measurement error has comparable (or larger effects) than the school-SES measure with minimal error is a concern. It undermines confidence that the contextual effects reported in the literature are real.

Table 5 presents the estimates from the analysis of numeracy achievement in Year 7, the first year of secondary school. The first panel shows the student- and

Table 4. Individual and school effects on numeracy achievement with random error SES measures in Year 5

	Model 1		Model 2		Model 3		Model 4		Model 5	
SES+Random Error (A)										
Intercept	502.1	***	505.7	***	504.1	***	505.4	***	504.1	***
SES_A in Year 5	.		12.7	***	4.1	***	12.7	***	4.1	***
School Mean SES_A Year 5	36.0	***	25.7	***	7.2	***	4.1	*	8.4	***
Prior Ability (Year 3)	.		.		47.5	***	.		47.5	***
School (Year 5) Mean Ability from Year 3	.		.		.		40.2	***	−2.3	
N of Observations	*40143*		*30656*		*26932*		*30651*		*26932*	
N of Schools	*1289*		*1289*		*1216*		*1225*		*1216*	
SES+Random Error (B)										
Intercept	498.0	***	501.8	***	500.4	***	501.7	***	500.4	***
SES_B in Year 5	.		8.8	***	2.6	***	8.8	***	2.6	***
School Mean SES_B Year 5	44.7	***	41.0	***	12.8	***	12.9	***	15.1	***
Prior Ability (Year 3)	.		.		56.2	***	.		56.4	***
School (Year 5) Mean Ability from Year 3	.		.		.		47.5	***	−3.8	*
N of Observations	*40143*		*30656*		*26932*		*30651*		*26932*	
N of Schools	*1289*		*1289*		*1216*		*1225*		*1216*	

Note: †0.10<P<0.05; *0.05<P<0.01; **0.01>P>0.001; ***P<0.001

school-level effects of SES measured at Year 7 and prior ability measured in Year 5. Model 2, which comprises only the SES measures, suggests that school-SES significantly affects numeracy achievement: a one unit difference is larger than that for student-level SES. However, when controlling for prior ability, the effects are much smaller and when controlling for student- and school-level prior ability the effect of school-SES moves out of statistical significance. There is a positive significant effect for school-level (prior) ability with a small standardised coefficient of 0.06. This contrasts with the insignificant effect of school-level (prior) ability for Year 5 numeracy (Model 5, Panel 1, Table 4). The dominant effect of student-level prior ability is again apparent for Year 7 numeracy as it was for Year 5.

Panel 2 (Table 5) presents the estimates from a different model where school-SES is measured by the SES of the school attended in Year 5, not in Year 7. Between Years 5 and 7, almost all students change schools. In the first three models, the effects of mean school-SES from the school attended in Year 5 is considerably weaker than that for school-SES for the school attended in Year 7. However, in the final two models, the effects of Year 5 school-SES were significant and in the expected positive direction unlike the effects of Year 7 school-SES. It is difficult to account for a significant, albeit small, contextual effect of the SES of the school the students are no longer attending.

Panel 3 in Table 5 demonstrates that the estimates from SES and school-SES on numeracy are largely unchanged using ability measured in Year 3 rather than

Table 5. Individual and school effects on numeracy achievement in Year 7

	Model 1	Model 2	Model 3	Model 4	Model 5	(Std.)
Intercept	533.1 ***	537.2 ***	543.4 ***	543.1 ***	544.7 ***	
SES (Year 7)	.	20.2 ***	7.0 ***	20.2 ***	7.0 ***	*0.09*
School Mean SES (Year 7)	44.1 ***	24.6 ***	10.0 ***	−5.2 *	3.0	*0.02*
Prior Ability (Year 5)	.	.	49.5 ***	.	49.4 ***	*0.66*
School (Year 7) Mean Ability in Year 5	.	.	.	53.3 ***	12.4 ***	*0.06*
N of Observations	*33701*	*25465*	*20236*	*25462*	*20236*	
N of Schools	*403*	*403*	*319*	*325*	*319*	
Intercept	530.2 ***	535.8 ***	543.3 ***	542.7 ***	544.9 ***	
SES (Year 7)	.	20.4 ***	7.0 ***	19.7 ***	6.8 ***	*0.09*
School Mean SES (Year 5)	16.6 ***	8.6 ***	5.5 ***	3.8 ***	3.4 ***	*0.03*
Prior Ability (from Year 5)	.	.	49.6 ***	.	49.3 ***	*0.66*
School (Year 7) Mean Ability in Year 5	.	.	.	45.0 ***	12.9 ***	*0.07*
N of Observations	*33617*	*25403*	*20183*	*25400*	*20183*	
N of Schools	*410*	*403*	*319*	*325*	*319*	
Intercept	533.1 ***	537.2 ***	542.6 ***	542.5 ***	543.7 ***	
SES (Year 7)	.	20.2 ***	8.5 ***	20.2 ***	8.5 ***	*0.11*
School Mean SES (Year 7)	44.1 ***	24.6 ***	9.7 ***	−2.8	3.2	*0.02*
Prior Ability (from Year 3)	.	.	46.8 ***	.	46.7 ***	*0.62*
School (Year 5) Mean Ability in Year 3	.	.	.	49.9 ***	11.6 **	*0.06*
N of Observations	*33701*	*25465*	*19311*	*25462*	*19311*	
N of Schools	*403*	*403*	*327*	*335*	*327*	

Note: †0.10<P<0.05; *0.05<P<0.01; **0.01>P>0.001; ***P<0.001

Year 5. The effect of school-SES in the final model remained small and not statistically significant. Interestingly, the effects for ability and school-level ability (with ability measured in Year 3) are only slightly less than the effects of the comparable Year 5 measures (panel 1). This is probably because student ability in Years 3 and 5 is highly correlated.

Table 6 presents the fixed effects estimates for SES, school-SES and school-level prior ability on achievement in each of the five domains. The subjects-as-intercepts method and the structural equation modelling method generate identical estimates at the second decimal place. (The standardised effects in the structural equation models are not identical for Years 5 and 7 at the third decimal place because the variances differ slightly.) There is a consistently small negative effect for school-SES when controlling for unobserved differences between students

Table 6. School SES effects on student achievement: Two fixed effects analyses on student achievement

	Numeracy	Reading	Writing	Spelling	Grammar
Regression Method					
Year 5	−41.33 ***	−48.73 ***	−27.93 ***	−51.47 ***	−40.08 ***
School SES	−2.92 **	−1.89 †	−4.93 ***	−3.74 ***	−3.08 *
School Prior Ability	6.90 ***	5.91 ***	9.06 ***	7.37 ***	5.64 ***
School SES (Std.)	*−0.02*	*−0.01*	*−0.04*	*−0.03*	*−0.02*
School Prior Ability (Std.)	*0.04*	*0.03*	*0.05*	*0.04*	*0.03*
Number of Students	*46686*	*46762*	*46733*	*46785*	*46785*
Structural Equation Method					
Intercept Year 5	497.6 ***	492.7 ***	489.0 ***	488.1 ***	502.7 ***
Intercept Year 7	538.9 ***	541.5 ***	516.9 ***	539.6 ***	542.8 ***
School SES	−2.92 ***	−1.89 ***	−4.93 ***	−3.74 ***	−3.08 ***
School Prior Ability	6.90 ***	5.91 ***	9.06 ***	7.37 ***	5.64 ***
School SES (Std.)	*−0.02*	*−0.01*	*−0.04*	*−0.03*	*−0.02*
School Prior Ability (Std.)	*0.04*	*0.03*	*0.05*	*0.04*	*0.03*
Number of Observations	*27146*	*27257*	*27257*	*27345*	*27345*

Note: †0.10<P<0.05; *0.05<P<0.01; **0.01>P>0.001; ***P<0.001

in all domains. However, the effect is very small, trivial in fact, with standardised effects −0.03 or less. For writing the effect of school-SES was not statistically significant. For school-level prior ability the effects are small and positive but also trivial.

Conclusions

It has been well-established from decades of research that: bivariate relationships of variables in aggregate data are very much stronger than the relationships of the same variables at the individual level; school-level SES is highly correlated with school-level achievement; and prior ability is a strong predictor of student achievement. Furthermore, theoretical explanations for school-SES effects must involve student performance and theoretical explanations for effects of school-level prior achievement or ability are more parsimonious. Despite this there are recent studies that purport to establish the importance of school-level SES. Studies that do not include controls for prior achievement sometimes claim that the effects of school-SES are large enough to warrant a policy response.

This study, analysing data with a large number of cases with reliable measures, has established that school-SES effects are trivial and do not warrant a policy response. In the commonly used multilevel model of student achievement comprising student-SES and school-SES, sizeable (unstandardised) estimates for school-SES are produced which are at least half as large as the effect for student-SES. However, controlling for students' prior ability reduces the effects of school-SES considerably. The substitution of school-level prior ability for student prior ability often causes the estimate for school-SES to change sign or become statistically insignificant. The preferred model comprising all four predictors—student and school SES and prior ability—produces a small positive effect for school-SES on Year 5 achievement and a smaller statistically insignificant effect on Year 7 achievement. Its (unstandardised) effects on Year 5 numeracy achievement are larger with poorer measures of SES further undermining the argument that school-SES effects are real and important. Using two different types of fixed effects models, which control for unobserved differences between students that affect achievement (e.g. ability, motivation etc.), produces almost identical results: a small negative effect for school-SES and a small positive effect for school-level prior ability. The small positive effect of school-level prior ability also found in the analyses of Year 7 numeracy achievement is consistent with theoretical expectations that students benefit from being exposed to a stronger academic environment and perform lower than expected in weaker academic environments. However, these effects are relatively small compared to the very much stronger effects of students' prior ability.

These findings strongly indicate that the sizeable effects of school-level SES reported from analyses of PISA data would not survive controls for prior ability and, to a much lesser extent, school-level prior ability. The analyses presented in this paper do not support arguments that school-SES has strong effects on student achievement and that its effects warrant a policy response. This is not to say that school-level SES effects are trivial in other educational jurisdictions but studies similar to this one, controlling for student and school prior ability, would establish their magnitude and relevance to policy discussions.

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Notes

1. The ESCS measure is standardised with a mean of zero and a standard deviation of 1. The meaning of a one unit change in school ESCS differs between countries because it is dependent on the distributions of ESCS across schools within a country. Since the variance of the school-level measures is often much less than that for student-level SES, the large effects found in PISA are smaller if the effects are standardised.
2. If the effects are standardised with the appropriate standard deviations of the school SES measures, the effects are not nearly as large.

3. These were the percentage with free school lunch and family possessions index aggregated at the school level.
4. That is a positive effect for socioeconomic background since socioeconomic background is inversely correlated with receipt of a free school lunch.
5. Over the school career, an increasing proportion of Australian students attend non-government schools, from about 30% in primary school to nearly 50% in the final year of school (ABS, 2012).
6. About 95% of secondary schools had more than 20 Year 9 students.
7. For examples of recent use of sheaf variables see Evans, Kelley and Sikora (2014) and Reisel (2013).
8. If the covariances were not specified to be estimated, then the model assumes the covariances are zero, that is the underlying factor (falpha) is uncorrelated with predictor variables. This is equivalent to a random effects model.
9. The largest condition index was 3.3—well below 10, the suggested level of the condition index at which multicollinearity could be affecting the estimates. The lowest tolerance value is 0.27 (below 0.10 is problematic) and the variance inflation values are between 1.3 and 2.8 (above 10 is problematic).

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Appendix Table 1. Student and school SES effects on science achievement (PISA)

	Overall Effect of ESCS[a]	Variance Explained by ESCS[b]	Between School Variance as a Proportion of Total Variance[c]	Effect of Individual Level ESCS[d]	Effect of School-ESCS[d]
Australia	46	12.7	26.1	30	66
Austria	48	16.6	55.6	10	80
Belgium	47	19.3	52.5	13	111
Canada	32	8.6	21.7	21	32
Chile	31	18.7	55.0	8	50
Czech Republic	46	12.4	49.0	14	123
Denmark	36	14.5	15.9	28	42
Estonia	29	7.6	21.8	16	41
Finland	31	7.8	15.9	28	19
Germany	44	17.9	60.2	10	122
Greece	34	12.5	46.1	14	44
Hungary	48	26.0	66.7	7	76
Iceland	27	6.2	14.1	24	11
Ireland	39	12.6	28.7	27	53
Israel	43	12.5	48.6	18	102
Italy	32	11.8	62.1	5	67
Japan	40	8.6	48.6	5	137
Korea	32	11.0	34.2	20	62
Luxembourg	40	18.0	43.6	21	65
Mexico	25	14.5	48.1	3	30
Netherlands	37	12.8	64.6	5	93
New Zealand	52	16.6	24.2	36	61
Norway	36	8.6	10.3	28	31
Poland	39	14.8	18.8	31	29
Portugal	30	16.5	33.1	17	40
Slovak Republic[e]	41	14.6	39.6	17	72
Slovenia	39	14.3	57.2	2	77
Spain	29	13.6	21.8	21	25
Sweden	43	13.4	18.5	34	52
Switzerland	40	14.1	33.6	20	66
Turkey	29	19.0	66.8	8	60
United Kingdom	44	13.7	29.3	27	69
United States	42	16.8	36.0	23	63

Notes: [a]ESCS is the OECD's SES measure and Economic, Social, Cultural Status; [b]From (OECD, 2010, pp. 153, Table II.151.152); [c]From (OECD, 2010, pp. 185, Table II.185.181, Part 181/182,), 1 minus Proportion of Variance within Schools (last column); [d]From (OECD, 2010, pp. 186, Table II.185.181, Part 181/182) Third data column; [e]From (OECD, 2010, pp. 187 Table II.185.182 Part 182/182,) First data column