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Jeremy Smith (Head of the Department of Economics, University of Warwick) and Michael Ward (Head of the Department of Economics, Monash University)

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Gender and Disadvantage in the Evolution of Test Score Gaps

Molly Paterson*

Abstract

This paper details the evolution of numeracy test score gaps based on gender and socioeconomic status, particularly considering children's early circumstances. We use the rich dataset: The Longitudinal Study of Australian Children (LSAC) to bring together two strands of literature on gaps between students on a gender and a socioeconomic basis. We establish an interrelationship between socioeconomic gaps, based on early life household income and parental education, and the gender gap in numeracy. We find that between Grades 3 to 9, boys have an advantage in numeracy scores over girls, which widens over time. By Grade 9, poorer female students are doubly disadvantaged compared to richer female students and male students. We confirm that early life circumstances continue to impact student's achievement into adolescence, demonstrating the importance of early interventions to address gender and socioeconomic gaps.

Keywords: Australia, parental education, household income, numeracy, gender, decomposition

JEL: I24, J16, J24

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Appendix available: https://www.dropbox.com/s/z0n71s8cunz82b6/2021%20Thesis%20Edits_Appendix.docx?dl=0
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1. Introduction

Gaps in educational achievement on any basis have important and long-lasting consequences on many aspects of social and economic life as children age. Research into the importance of early interventions to address disadvantage in educational achievement demonstrate the critical nature of identifying where gaps between children occur and how they evolve (Cunha and Heckman, 2007). Two widely documented sources of achievement gaps between students over time are gender and socioeconomic status, however the interrelationship between these two less explored. This paper considers first the evolution of the gender gap in numeracy test scores and how this interacts with socioeconomic test score gaps over time, paying particular attention to the impact of early circumstances.

This paper makes three primary contributions to the literature on the evolution of both gender and socioeconomic gaps in educational achievement. The first of these being the bringing together of two strands of literature considering gender and socioeconomic status as sources of educational disadvantage separately. We instead consider the interaction between the two and how they may combine to doubly disadvantage certain students. Secondly, this paper brings to this discussion an examination of early life circumstances, namely early household income, parental education and cognitive ability before children enter school. Thirdly, this is all achieved through the use of the uniquely rich dataset, the Longitudinal Study of Australian Children (LSAC) which provides an internationally relevant picture of children's development over time. Due to the detailed nature of the data available in the LSAC, this paper is able to examine how the gender gap in numeracy scores evolves from Grade 3, when students are 8-9 years old, until Grade 9, when students are 14-15 years old. Few papers have been able to examine the evolution of such gaps over such an extended time period, seven years in this case. This is in addition to rich demographic and socioeconomic survey data.

Uniquely, the LSAC dataset also provides access to student's results from the 'Who Am I?" (WAI) and 'Peabody Picture Vocubulary Test' (PPVT) which, following from similar papers in this area, can be used as measures of early childhood cognitive ability before students enter school (Le and Nguyen, 2018). The combination of detailed data on the characteristics of the children in our sample, measures of their early cognitive ability and full sets of national test scores allow unique insight into the determinants and evolution of test score gaps.

Over the seven years this paper examines, we find that male students consistently outperform female students in numeracy at all grades, and that this gap widens between Grades 3 and 9. We also detail the socioeconomic test score gap between students who live in households at the top end of the income distribution before they enter school, and those from the bottom end of the income distribution. Beyond confirming these results across seven years of children's schooling; we also contribute by detailing the interrelationship between gender and socioeconomic gaps. The socioeconomic gap between boys appears to narrow as they progress through schooling, while the socioeconomic gap between girls appears to widen. In this regard, we find significant heterogeneity in the ways boys and girls are impacted by income and differing levels of parent's education. Based on these results, we can identify poorer female students as a key target for policy interventions and that these interventions to address both gender and socioeconomic disadvantage must take place as early as possible to ensure these gaps do not persist throughout schooling.

2. Literature Review

Test score gaps on the basis of gender have long been identified in the international literature, with male students typically excelling over female students in maths, while female students typically outperforming male students in literacy (Le and Nguyen 2018; Bedard and Cho 2010; Fryer and Levitt 2010, Husain and Millimet, 2009). This is a phenomenon seemingly not limited to any one cultural context. When looking at PISA (Program for International Student Assessment) data from across 65 countries, Bharadwaj (2016) finds substantial gaps in mathematics test scores across both developed and developing countries. Herman and Kopasz (2018) similarly use a cross-country analyses of gender test score gaps to suggest that the teaching practices and characteristics of education systems can have heterogeneous gender effects. Other studies have found that gender gaps in mathematics are not significantly related to indicators of gender equality across countries (Gevrek, 2018; Marks, 2008). So, while gender test score gaps are well established internationally, analysis of such gaps does benefit in more closely examining detailed longitudinal data from a single country. Few papers in this area, however, document the evolution of such gender test score gaps from childhood through adolescence due to data constraints (Sohn, 2012; Suryadarma, 2015). A close paper to ours is Le & Nguyen's (2018) analysis of the evolution of gender test score gaps through Grade 7, similarly using LSAC data. They find evidence of a widening of the numeracy gender gap in favour of boys, as children progress through school.

Related studies have also documented how gender test score gaps manifest across the socioeconomic distribution (Trusty et al, 2000). Cobb-Clark and Moschion (2017), find when looking at third grade scores that the early gender gap in reading manifests largely for children at the bottom of the socio-economic distribution while the early gap in numeracy appears for children at the top of the socio-economic distribution. Dahl and Lochner (2012),

in a similar vein, when looking at the effect of family income on reading and numeracy scores, find based on US data, that a $1000 increase in household income raises scores by 6% of a standard deviation. They conclude that when income increases, the gains in academic achievement are largest for those children from disadvantaged families. Looking particularly at the effect of early socioeconomic status in the evolution of test score gaps fits within a wider literature considering the impact of early life circumstances on the academic achievement of children. Pearce et al (2016) consider the impact of early life cognitive ability on socioeconomic gaps in academic achievement, similarly, using LSAC data. They conclude that socioeconomic inequalities do indeed emerge early in life, demonstrating the significant effect of early cognitive skills on academic achievement. Thus, we draw together these strands of literature regarding gender and socioeconomic gaps in our analysis.

The body of research investigating the sources of gender gaps in educational achievement points to a myriad of complex sociocultural factors. Gender differences in parental time investment (Muller, 1998), stereotyping of certain fields being the domain of certain genders (Le and Nguyen, 2018; Marx and Roman, 2002) and differential responses to education environments (Herman & Kopasz, 2018) are all potential explanations for the persistence of achievement gaps between boys and girls even as awareness of gender inequalities rises. Gevrek et al (2018) decompose the gender gap in mathematics across a selection of countries and find that this gap cannot be reasonably explained by differences in observed characteristics by gender. Fan et al (2015) found, when considering the concurrent trends of the gender test score gap and increased labour force participation of women, that boys appear adversely affect by decreases in Mother's time input. Thus, research into the causal mechanism of gender inequality in school achievement is still ongoing and beyond the purview of this paper. A lack of concrete conclusions as to the causes of these results we find

is a limitation of this paper. However, better understanding where these gaps occur, how they evolve over time and how they interrelate with other sources of inequality, as is the aim of this paper, is critically important in order to design and implement interventions.

3. Data and Methodology

3.1 Dataset

This paper uses data from The Longitudinal Study of Australian Children (LSAC), a national study which began in 2004. The LSAC began with an initial cohort of about 10,000 children forming a representative sample from across Australia. In yearly "Waves" the LSAC collects a large amount of information about study children's test scores, socioeconomic and demographic backgrounds, from parents, teachers and children themselves. The study consists of two cohorts, the birth or ''B'' cohort of 5107 children, aged 0-1 years in 2004, and the kindergarten or "K" cohort, of 4983 children, aged 4-5 years in 2004. This paper has access to LSAC survey data up to Wave 7 when B cohort is aged 12-13 and K cohort is aged 16-17. The data collected on the study children and their families is individually coded through an identifier variable so that analysis can be conducted consistently across the waves.

The measure of academic achievement used in this paper are standardised results from the National Assessment Program – Literacy and Numeracy (NAPLAN) which are obtained through data linkages with the LSAC study. The NAPLAN is a series of standardised tests designed to assess Australian student's reading, writing and numeracy abilities in grades 3, 5, 7 and 9 (ACARA, 2014). Students are generally aged 8-9 in Grade 3 and 14-15 by Grade 9. Test scores across these subjects' range between 0 and 1000 and are designed to allow comparison between students over time. All NAPLAN scores presented in this paper have

been standardised by grade with a mean 0 and standard deviation 1, as is generally done in similar papers (Le & Nguyen, 2018).

3.2 Sample

The most recently available LSAC data allows access up to Year 9 test scores for the kindergarten or 'K' cohort and up to Year 7 test scores for the birth or 'B' cohort. Given our focus on how early socioeconomic environment affects the test score gap even into adolescence, our analysis centres on the K cohort of children. This allows a unique picture of the evolution of gender test score gaps and their determinants across the school life of the sample children, using a complete set of NAPLAN test scores from Grades 3, 5, 7 and 9. The K cohort initially totals 4983 sample children but this reduces to 2948, 3796, 3535 and 3029 at Grades 3, 5, 7 and 9 respectively due to availability of linked NAPLAN data. Our sample is reduced further with the inclusion of a set of control variables, including WAI and PPVT scores and final sample sizes can be seen in Table 1 with corresponding sample statistics. Summary statistics for the entire K cohort can be found in Appendix A along with more detail on the data and sample. Our ultimate results are based on regressions conducted in each grade on the largest possible sample for the given Wave. Therefore, due to missing values in NAPLAN results, or our key variables only in certain years, some students may not be included in our regressions for certain years but reappear in others. Appendix C displays our key results for the sample of students included at the Grade 3 level, following only these students until Grade 9, allowing for attrition. Results on this sub-sample do not differ significantly from the sample where we allow students with missing values in earlier Grades to return for later Grades.

Table 1: Sample Summary Statistics by Gender

Variable	*Male*	*Female*	*Whole Sample*	*Total Observations*
Male (=1)	1	0	0.52	3087
Numeracy Test Scores				
Year 3	423.9	420.2	422.2	2265
Year 5	506.3	499.6	503.0	2891
Year 7	561.3	555.0	558.2	2717
Year 9	611.6	602.8	607.3	2385
Reading Test Scores				
Year 3	417.2	438.9	427.5	2268
Year 5	495.3	517.7	506.3	2910
Year 7	551.8	569.1	560.3	2731
Year 9	590.8	610.2	600.4	2393
Household Characteristics				
Two parents in home (=1)	0.93	0.93	0.93	3087
Indigenous (=1)	0.02	0.02	0.02	3087
Ever breastfed (=1)	0.91	0.94	0.92	3087
Main language at Home is English (=1)	0.90	0.89	0.89	3087
Lives in Major Australian City (=1)	0.54	0.56	0.55	3087
Government School (=1)	0.65	0.65	0.65	3087
Catholic School (=1)	0.22	0.21	0.22	3087
Independent School (=1)	0.12	0.13	0.13	3087
WAI Score	62.1	67.6	64.8	3087
PPVT Score	64.0	65.0	64.5	3087
Household Income Indicators				
Mother Postgraduate Qualification (=1)	0.12	0.13	0.13	3087
Mother bachelor's degree (=1)	0.16	0.17	0.17	3087
Mother other tertiary (=1)	0.37	0.35	0.36	3087
Mother Year 12 only (=1)	0.14	0.12	0.13	3087
Mother not completed Year 12 (=1)	0.21	0.23	0.22	3087

Father Postgraduate Qualification (=1)	0.13	0.12	0.13	3087
Father bachelor's degree (=1)	0.14	0.16	0.15	3087
Father other tertiary (=1)	0.47	0.47	0.47	3087
Father Year 12 only (=1)	0.09	0.09	0.09	3087
Father not completed Year 12 (=1)	0.16	0.15	0.16	3087
Adjusted Weekly Average Household Income	1824.0	1814.7	1819.5	3087
Bottom Income Decile (=1)	0.08	0.07	0.08	3087
Top Income Decile (=1)	0.11	0.11	0.11	3087

Summary Statistics are for observations used in regressions on Grade 3,5,7 or 9 numeracy scores. School types and two parents in the home are calculated at Wave 3. Grade scores are calculated at their respective waves. All other variables are calculated at Wave 1.

3.3 Control Variables

Table 1 lists the key controls included in our subsequent analysis. Here we distinguish between household characteristics and household income indicators. For the purposes of this paper, when investigating interrelationships between gender and socioeconomic status in achievement gaps, parental income and parental education variables within the LSAC are used as indicators of household income. Household income and parental education variables are used at their Wave 1 levels, when K cohort students are between 4-5 years old. Our household characteristics controls, such as whether the study child every breastfed, indigenous status and school type are considered correlates of socioeconomic status, rather than causal variables for socioeconomic status. Thus, explaining their separation in subsequent analysis. Additionally, we note that as the range of ages for students sitting the NAPLAN test in any given year may vary by up to 2 years, the age of students at the time of sitting the test is included as an important control.

The LSAC also provides data on two major tests administered to study children before they enter primary school, the 'Who am I?' (WAI) Test and the 'Peabody Picture Vocabulary Test' (PPVT-III). The WAI test is designed to assess general cognitive abilities before beginning formal schooling, focusing on reading and numeracy tasks (Lemos and Doig, 1999). Meanwhile the PPVT is designed to measure a child's receptive vocabulary ability in standard English by asking the child to indicate a picture that best represents the meaning of the word spoken by an interviewer (Dunn and Dunn, 1997). The inclusion of these two cognitive tests as controls in our analysis follows from recent research, particularly Le and Nguyen (2018), highlighting the importance of early cognitive ability in explaining numeracy test score gaps up to Grade 7. For our analysis PPVT and WAI scores are standardised similarly to NAPLAN scores. The inclusion of these early ability tests is also in keeping with our investigation of early household circumstances influencing test scores into adolescence. The literature on early child development stresses the importance of early interventions and early cognitive ability for later academic and labour market outcomes (Carneiro and Heckman, 2003; O'Connor et al, 2019).

3.4 Regression Models

Tables 2 to 8 present a series of estimations of test score gaps against a succession of controls, moving from the simplest estimation to the most complete. We progressively analyse these results, including analysis of NAPLAN reading scores in early estimations as a comparison. Estimations are achieved through Ordinary Least Squares (OLS) regressions of test scores of each student in our sample against different sets of control variables, all including a gender dummy variable. A basic model, as outlined below, is used through a series of iterations to demonstrate different effects on the gender gap in test scores.

$$Score_{i,t} = \alpha + \gamma Male_i + \beta_1 X_{it} + \beta_2 H_{it} + \varepsilon_{it} \quad (1)$$

Table 7 demonstrates the full estimation above. $Male_{it}$ gives our measure of the gender gap in favour of boys, for each i student in our sample. X_{it} gives a comprehensive list of significant household characteristics variables, as outlined in Table 1. H_{it} gives a list of household income indicator variables, namely parental education and household income in Wave 1. Regressions are repeated separately for each NAPLAN grade t.

When estimating male and female test scores separately, as is first done for results in Table 8, the following base specifications are used.

$$Male\_Score_{i,t} = \alpha + \beta_1 X_{it} + \beta_2 H_{it} + \varepsilon_{it} \quad (2)$$

$$Female\_Score_{i,t} = \alpha + \beta_1 X_{it} + \beta_2 H_{it} + \varepsilon_{it} \quad (3)$$

4. Empirical Results

Tables 2 to 6 consider the gender gap in test scores alongside differing collections of controls whereby we consider the different factors affecting the magnitude of these test score gaps as they evolve over time. This leads into the core of our analysis with Tables 7 and 8. Then Tables 9 and 10 give further iterations of Table 8, *Numeracy score determinants by gender*, considering the impact of early life circumstances on academic achievement.

We begin by conducting a simple OLS analysis of the raw gender gap across standardised test scores without our set of controls. Table 2 confirms the results of recent papers in regard to the gender gap in numeracy scores in favour of boys appearing insignificant at Grade 3 (Fryer and Levitt, 2010). We can see that the advantage to boys is not significant at the Grade

3 level, but this advantage becomes highly significant and grows by 0.095 standard deviations by the time children reach Grade 9. The advantage to girls in reading, on the other hand begins in Grade 3 as highly significant and remains so, growing by 0.024 standard deviations between Grades 3 and 9. Table 3 includes a range of household characteristics controls and here we see that the significance and the magnitude of the reading gap drops away markedly. In contrast, the numeracy gap remains highly significant at the 1% level for Grades 5-9 and becomes highly significant at the Grade 3 level, once these controls are included. Thus, the bulk of our analysis considers only the gap in numeracy scores, as there appears to be factors influencing the numeracy gap in favour of boys not captured by household characteristics. As we consider standardised test scores with a mean zero and standard deviation of 1, coefficient results indicate the percentage standard deviation impact for each variable.

The general upward trend in the numeracy score gap remains when including household characteristics controls between Grades 3 and 9, though there is an upswing in Grade 7.

Table 2 Test Score Gap on Gender Alone

Subject	*Grade 3*	*Grade 5*	*Grade 7*	*Grade 9*
Numeracy	0.054	0.123***	0.126***	0.149***
	(0.037)	(0.033)	(0.034)	(0.037)
Reading	-0.229***	-0.244***	-0.224***	-0.253***
	(0.037)	(0.033)	(0.034)	(0.037)
Income Indicator Controls	No	No	No	No
Characteristics Controls	No	No	No	No
Numeracy Observations	2860	3607	3333	2858
Reading Observations	2862	3629	3347	2873

Coefficient on Male dummy variable reported. Female is the base group for gender. Standard errors in parentheses. *** p <0.01, ** p <0.05, * p <0.1

Table 3 Test Score Gap with Gender and Household Characteristics Controls

Subject	*Grade 3*	*Grade 5*	*Grade 7*	*Grade 9*
Numeracy	0.308***	0.350***	0.379***	0.362***
	(0.036)	(0.032)	(0.033)	(0.037)
Reading	-0.012	-0.050	-0.034	-0.108***
	(0.036)	(0.032)	(0.033)	(0.037)
Income Indicator Controls	No	No	No	No
Characteristics Controls	Yes	Yes	Yes	Yes
Numeracy Observations	2559	3250	3013	2552
Reading Observations	2561	3270	3029	2565

Female is the base group for gender. Standard errors in parentheses. Controls included: Age at test, Government School, Catholic School and two parents at home at corresponding Wave, Indigenous, Breastfed, English as Main Language at Home, Lives in Major Australian City, WAI and PPVT at Wave 1. *** p<0.01, ** p<0.05, * p<0.1

Attention is then turned towards the impact of early household income on numeracy test scores, both across the distribution and isolating the extremes of the income distribution. Tables 4 and 5 give us results for numeracy test scores against gender and average household income, and gender and top and bottom income deciles respectively. The results here suggest that the overall impact of household income on children's test scores is significant. However, when we split our cohort into deciles based on average weekly household income in Wave 1 and consider the extremes of the distribution, the top income decile and the bottom income decile, we see that the income effect is stronger at the extremes. Students who are poorer before they enter school suffer a great disadvantage in their numeracy scores, while students who are from the richest households before they enter school accrue a significant advantage. Without yet including further controls, this impact on early childhood household income is still significant by Grade 9. Students who were poorest in Wave 1 suffer 0.128 standard

deviations drop in their numeracy scores, while students who were richest accrue a 0.545 boost in their numeracy scores.

Table 4 Numeracy Score Gap with Gender and Household Income.

Variable	*Grade 3*	*Grade 5*	*Grade 7*	*Grade 9*
Male	0.041	0.106***	0.113***	0.135***
	(0.039)	(0.034)	(0.036)	(0.038)
Household Income (100s)	0.019***	0.015***	0.017***	0.018***
	(0.002)	(0.002)	(0.002)	(0.002)
Parental Education Controls	No	No	No	No
Characteristics Controls	No	No	No	No
N	2543	3228	3009	2621

Female is the base group for gender. Standard errors in parentheses. Income variable is Wave 1 adjusted average weekly household income in 100s. *** p <0.01, ** p <0.05, * p <0.1

Table 5 Numeracy Score Gap with Gender and Income Deciles

Variable	*Grade 3*	*Grade 5*	*Grade 7*	*Grade 9*
Male	0.041	0.105***	0.110***	0.130***
	(0.034)	(0.036)	(0.036)	(0.038)
Bottom Income Decile	-0.303***	-0.222***	-0.125**	-0.128*
	(0.070)	(0.059)	(0.062)	(0.068)
Top Income Decile	0.459***	0.405***	0.499***	0.545***
	(0.063)	(0.056)	(0.058)	(0.061)
Parental Education Controls	No	No	No	No
Characteristics Controls	No	No	No	No
N	2543	3228	3009	2621

Female is the base group for gender. Standard errors in parentheses. Income variable is adjusted average weekly household income in Wave 1. *** p <0.01, ** p <0.05, * p <0.1

Table 6 gives us our results where we consider top and bottom income decile effects, now also including our set of household characteristics controls. Similarly, to Table 3, when including these demographic controls, we see gender effect becoming highly significant at all

Grade levels. The income effects at the top and bottom of the income distribution reduce in their overall magnitudes but remain highly significant.

Table 6 Numeracy Score Gap with Gender, Income Deciles and Characteristics Controls

Variable	*Grade 3*	*Grade 5*	*Grade 7*	*Grade 9*
Male	0.307***	0.344***	0.371***	0.365***
	(0.039)	(0.034)	(0.035)	(0.038)
Bottom Income Decile	-0.178***	-0.186***	-0.091	-0.167**
	(0.067)	(0.057)	(0.060)	(0.067)
Top Income Decile	0.286***	0.234***	0.261***	0.301***
	(0.060)	(0.054)	(0.055)	(0.059)
Parental Education Controls	No	No	No	No
Characteristics Controls	Yes	Yes	Yes	Yes
N	2286	2921	2729	2348

Female is the base group for gender. Standard errors in parentheses. Income variable is adjusted average weekly household income in Wave 1. Controls included: Age at test, Government School, Catholic School and two parents at home at corresponding Wave; Indigenous, Breastfed, English as Main Language at Home, Lives in Major Australian City, WAI and PPVT at Wave 1. *** p <0.01, ** p <0.05, * p <0.1

Table 7 gives us our results for the gender gap in numeracy, now with our full set of controls, including household characteristics controls, top and bottom income deciles and Mother and Father's education in Wave 1. Again, the gender gap in favour of boys is significant and growing by 0.05 standard deviations between Grades 3 and 9. Additionally our income decile variables demonstrate a significant impact of early household income on student's achievement. These results also highlight the significant role of parent's education in explaining children's numeracy scores. However, controlling even for higher parent's education, the gender effect on numeracy scores remains at a high level. Importantly these effects still manifest while controlling for early cognitive ability, a result in line with previous studies in this area (Le and Nguyen, 2018; Pearce et al, 2016). While the effects of both Mother's and Father's education groups are significant and growing across Grades 3 to 9,

Fathers who possess particularly a postgraduate degree or a bachelor's degree, affect student's scores at a larger magnitude than Mothers with similar levels of education. Having established a significant and growing gender gap favouring boys in numeracy scores across Grades 3 to 9, we consider the same analysis but now separating boys and girls scores. Results for numeracy score determinants by gender are displayed in Table 8. This enable us to better investigate the differing impacts of early socioeconomic variables on male and female students.

Table 7 Numeracy Score Gap with Gender, Income Deciles and All Controls

Variable	*Grade 3*	*Grade 5*	*Grade 7*	*Grade 9*
Male	0.296***	0.324***	0.343***	0.343***
	(0.038)	(0.034)	(0.035)	(0.037)
Bottom Income Decile	-0.160**	-0.172***	-0.042	-0.142**
	(0.066)	(0.057)	(0.059)	(0.066)
Top Income Decile	0.160***	0.096*	0.103*	0.110*
	(0.061)	(0.055)	(0.056)	(0.060)
Mother Postgraduate Degree	0.149**	0.128**	0.273***	0.240***
	(0.068)	(0.061)	(0.062)	(0.067)
Mother bachelor's degree	0.254***	0.314***	0.388***	0.368***
	(0.063)	(0.057)	(0.058)	(0.062)
Mother other tertiary	0.025	0.085**	0.109**	0.133***
	(0.049)	(0.043)	(0.045)	(0.049)
Mother Year 12 only	0.180***	0.155***	0.228***	0.166***
	(0.064)	(0.055)	(0.057)	(0.062)
Father Postgraduate Degree	0.282***	0.340***	0.408***	0.471***
	(0.072)	(0.065)	(0.067)	(0.071)
Father bachelor's degree	0.400***	0.376***	0.422***	0.532***
	(0.068)	(0.062)	(0.063)	(0.069)
Father other tertiary	0.056	0.073	0.084*	0.110**
	(0.052)	(0.046)	(0.048)	(0.052)
Father Year 12 only	0.231***	0.204***	0.261***	0.226***
	(0.074)	(0.065)	(0.067)	(0.074)
Characteristics Controls	Yes	Yes	Yes	Yes
N	2265	2890	2699	2327
R^2	0.278	0.261	0.302	0.296

Female is the base group for Gender. Highest education level below Year 12 is the base for Mother and Father's Wave 1 Education. Income variable is adjusted average weekly household income in Wave 1. Standard errors in parentheses. Controls included: Age at test, Government School, Catholic School and two parents at home at corresponding Wave, Indigenous, Breastfed, English as Main Language at Home, Lives in Major Australian City, WAI and PPVT at Wave 1. .*** p <0.01, ** p <0.05, * p <0.1

Table 8 Numeracy Score Determinants by Gender

Variable	*Grade 3*		*Grade 5*		*Grade 7*		*Grade 9*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Bottom Income Decile	-0.146 (0.100)	-0.207** (0.086)	-0.188** (0.083)	-0.169** (0.080)	0.024 (0.086)	-0.141* (0.082)	0.023 (0.097)	-0.343*** (0.090)
Top Income Decile	0.256*** (0.087)	0.049 (0.083)	0.145* (0.080)	0.032 (0.076)	0.227*** (0.080)	-0.033 (0.078)	0.211** (0.087)	0.009 (0.082)
Mother Postgraduate Degree	0.062 (0.103)	0.267*** (0.090)	0.075 (0.091)	0.211*** (0.081)	0.114 (0.092)	0.461*** (0.085)	0.085 (0.100)	0.425*** (0.089)
Mother bachelor's degree	0.237** (0.096)	0.291*** (0.082)	0.336*** (0.086)	0.316*** (0.076)	0.330*** (0.086)	0.467*** (0.079)	0.291*** (0.093)	0.466*** (0.083)
Mother other tertiary	-0.010 (0.073)	0.075 (0.064)	0.048 (0.065)	0.141** (0.058)	0.032 (0.066)	0.199*** (0.061)	0.053 (0.073)	0.230*** (0.065)
Mother Year 12 only	0.184** (0.093)	0.174** (0.086)	0.185** (0.081)	0.134* (0.076)	0.204** (0.082)	0.255*** (0.079)	0.139 (0.091)	0.192** (0.084)
Father Postgraduate Degree	0.403*** (0.102)	0.167* (0.099)	0.434*** (0.093)	0.238*** (0.090)	0.485*** (0.094)	0.304*** (0.095)	0.595*** (0.101)	0.321*** (0.101)

Father bachelor's degree	0.395*** (0.103)	0.393*** (0.088)	0.417*** (0.093)	0.327*** (0.083)	0.412*** (0.092)	0.394*** (0.087)	0.581*** (0.101)	0.444*** (0.093)
Father other tertiary	0.091 (0.076)	0.043 (0.070)	0.114* (0.067)	0.043 (0.064)	0.098 (0.068)	0.065 (0.067)	0.164** (0.075)	0.060 (0.072)
Father Year 12 only	0.317*** (0.107)	0.171* (0.100)	0.275*** (0.095)	0.142 (0.090)	0.300*** (0.097)	0.214** (0.092)	0.385*** (0.107)	0.075 (0.103)
Characteristics Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1183	1082	1459	1431	1363	1336	1160	1167
R^2	0.278	0.314	0.249	0.278	0.313	0.311	0.292	0.322

Standard errors in parentheses. Highest education level below Year 12 is base for Mother and Father's Wave 1 Education. Income variable is adjusted average weekly household income in Wave 1. Controls included: Age at test, Government School, Catholic School and two parents at home at corresponding Wave, Indigenous, Breastfed, English as Main Language at Home, Lives in Major Australian City, WAI and PPVT at Wave 1. *** p <0.01, ** p <0.05, * p <0.1

Table 8 demonstrates the gender heterogeneity in effects of different socioeconomic variables on the numeracy test scores between Grades 3 to 9. Namely parent's highest level of education and whether the child has grown up in a household at the top income decile or the bottom income decile. Girls from a top income decile in Wave 1, are consistently outperformed by boys from the same socioeconomic background. By Grade 9 girls receive almost no benefit from growing up in a richer household while boys receive a 0.21 standard deviation boost in their numeracy scores. Girls from the bottom income decile are also outperformed by boys from the same socioeconomic background at all but the Grade 5 level. By Grade 9 the previously negative effect of growing up in a poorer household has almost disappeared for boys, while for girls there is a 0.34 standard deviations disadvantage still present. It appears that boys, on average, retain a gender advantage, even in comparison to girls from similarly disadvantaged backgrounds. While girls appear to not gain access to the full academic advantage that accrues to the highest income group. What is unclear here is the direction of causality; whether the socioeconomic effect is worsening the gender test score gap or whether the gender effect is worsening the socioeconomic test score gap.

The differing effect for higher Mother's and Father's education on sons and daughter also follows a rather consistent pattern. A child's Mother having a postgraduate degree is consistently insignificant in boy's numeracy scores whilst highly significant for girls. A child's Father having a postgraduate degree, by contrast, is significant for both boys and girls between Grades 3 and 9 but has a markedly stronger effect on boy's scores than girls. Overall female student's scores seem to respond more positively with higher levels of Mother's education. Conversely male students seem more strongly affected than female students by higher levels of Father's education. Both the income and parental education variables displayed here are from Wave 1 of the LSACs survey data. This demonstrates that the early

socioeconomic circumstances of our sample children are still impacting their grades almost 10 years later, at the Grade 9 level. When looking at the effects of our controls, indigenous status has a broadly negative relationship with numeracy scores, though Indigenous girls seem to suffer a greater disadvantage than Indigenous boys in this area (full coefficient results can be found in Appendix B: Table B2). Similarly, students from non-English speaking backgrounds (NESB) appear to perform better than students from English speaking backgrounds (ESB), though again ESB girls are more disadvantaged in this area than ESB boys. This particular result is consistent with similar studies looking at the impact of immigrant background on educational attainment (Cobb-Clark and Nguyen, 2012).

4.1 Early Circumstances Results

To further test the significance of student's early socioeconomic circumstances on their later academic achievement we repeat our analysis in Table 8, but also control for different indicators of early circumstances. Table 10 controls for Grade 3 scores in our regressions on Grade 5, 7 and 9 scores to consider how much of the effects of our socioeconomic variables are captured in the difference in Grade 3 scores. Table 9, similarly, considers the remaining effects of contemporaneous income on numeracy scores, after controlling for Wave 1 income. This should give us a picture of the impact of a student's socioeconomic status at the time of sitting the test.

Both the sets of results in Tables 9 and 10 are consistent with the overall conclusion of the related literature in this area; that children's early circumstances have a significant and ongoing effect on academic achievement. Unsurprisingly, in Table 10, higher Grade 3 scores have a large and significant effect on later numeracy scores achieved but it also appears that much of the income effects displayed in Table 8 are captured in Grade 3 results. The

exception to this being the Wave 1 bottom income decile effect in Grade 9. Similarly, in Table 9, we consider the separate effect of contemporaneous income on numeracy achievement in that same year, by also controlling for Wave 1 household income. We find that contemporaneous income does not follow the consistent pattern of effect that Wave 1 income deciles had. Overall, contemporaneous income is less significant than early income in numeracy scores by gender. Table D2 in Appendix D gives the same regression against contemporaneous income without controlling for Wave 1 income however results are very similar.

Table 9 Numeracy Score Determinants by Gender with Contemporaneous and Wave 1 Income

Variable	*Grade 3*		*Grade 5*		*Grade 7*		*Grade 9*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Bottom Income Decile (Contemporaneous)	-0.020 (0.137)	0.109 (0.120)	-0.193* (0.099)	0.121 (0.104)	0.053 (0.102)	0.114 (0.106)	-0.198* (0.115)	-0.221** (0.104)
Top Income Decile (Contemporaneous)	0.129 (0.103)	0.049 (0.086)	0.232** (0.092)	0.088 (0.081)	-0.022 (0.086)	0.147* (0.083)	0.076 (0.095)	0.093 (0.091)
Wave 1 Household Income (100s)	0.010*** (0.003)	0.002 (0.003)	0.002 (0.003)	0.000 (0.002)	0.009*** (0.003)	-0.001 (0.002)	0.004 (0.003)	0.001 (0.003)
Parental Education Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Characteristics Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1147	1050	1403	1354	1281	1251	1078	1072
R^2	0.286	0.315	0.245	0.282	0.318	0.303	0.287	0.327

Standard errors in parentheses. Household income is adjusted average weekly household income in Wave 1. Bottom and Top Income Deciles refer to contemporaneous income for the corresponding grades. Controls included: Age at test, Government School, Catholic School and two parents at home at corresponding Wave; Parent's education groups, Indigenous, Breastfed, English as Main Language at Home, Lives in Major Australian City, WAI and PPVT at Wave 1.*** p <0.01, ** p <0.05, * p <0.1

Table 10 Numeracy Score Determinants by Gender; Controlling for Grade 3 Scores

Variable	*Grade 3*		*Grade 5*		*Grade 7*		*Grade 9*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Bottom Income Decile	-0.146 (0.100)	-0.207** (0.086)	-0.051 (0.080)	-0.112 (0.074)	0.110 (0.082)	-0.088 (0.073)	0.173* (0.094)	-0.299*** (0.084)
Top Income Decile	0.256*** (0.087)	0.049 (0.083)	-0.032 (0.070)	0.002 (0.071)	0.118* (0.070)	-0.034 (0.068)	0.181** (0.076)	0.012 (0.076)
Grade 3 Numeracy Score	-	-	0.650*** (0.023)	0.642*** (0.026)	0.622*** (0.024)	0.685*** (0.026)	0.552*** (0.025)	0.605*** (0.027)
Mother has Postgraduate Degree	0.062 (0.103)	0.267*** (0.090)	-0.020 (0.081)	0.061 (0.078)	0.063 (0.083)	0.256*** (0.076)	0.095 (0.090)	0.257*** (0.082)
Mother has bachelor's degree	0.237** (0.096)	0.291*** (0.082)	0.113 (0.077)	0.066 (0.071)	0.176** (0.078)	0.188*** (0.070)	0.190** (0.084)	0.252*** (0.076)
Mother has other tertiary qualification	-0.010 (0.073)	0.075 (0.064)	-0.012 (0.059)	0.084 (0.055)	0.075 (0.061)	0.137** (0.055)	0.113* (0.067)	0.160*** (0.061)
Mother has completed Year 12 only	0.184** (0.093)	0.174** (0.086)	0.062 (0.073)	0.038 (0.074)	0.107 (0.076)	0.073 (0.072)	0.072 (0.084)	0.118 (0.081)
Father has Postgraduate Degree	0.403*** (0.102)	0.167* (0.099)	0.189** (0.082)	0.070 (0.085)	0.432*** (0.084)	0.123 (0.085)	0.478*** (0.089)	0.149 (0.092)

Father has bachelor's degree	0.395*** (0.103)	0.393*** (0.088)	0.129 (0.083)	0.141* (0.076)	0.293*** (0.083)	0.128* (0.076)	0.390*** (0.089)	0.204** (0.083)
Father has other tertiary qualification	0.091 (0.076)	0.043 (0.070)	0.117* (0.060)	0.016 (0.060)	0.142** (0.062)	0.040 (0.060)	0.215*** (0.066)	0.047 (0.067)
Father has completed Year 12 only	0.317*** (0.107)	0.171* (0.100)	0.050 (0.084)	0.011 (0.087)	0.218** (0.087)	0.120 (0.084)	0.280*** (0.095)	0.025 (0.095)
Characteristics Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1183	1082	1089	1016	1016	947	864	831
R^2	0.278	0.314	0.545	0.555	0.591	0.615	0.553	0.564

Standard errors in parentheses. Highest education level below Year 12 is base for Mother and Father's Wave 1 Education. Income variable is adjusted average weekly household income in Wave 1. Controls included: Grade 3 numeracy score, Age at test, Government School, Catholic School and two parents at home at corresponding Wave, Indigenous, Breastfed, English as Main Language at Home, Lives in Major Australian City, WAI and PPVT at Wave 1.*** p <0.01, ** p <0.05, * p <0.1

These results suggest that were interventions to be made to address both gender and socioeconomic gaps in academic achievement, early interventions are likely to have the greatest impact.

5 Discussion and Model Students

To better illustrate the gaps between students on a gender basis and a socioeconomic basis, we include the predicted results for a set of six imagined, average students. For the sake of brevity, we consider the gaps between these students at the Grade 3 and Grade 9 levels.

The six model students are a male and female student at the Bottom income decile, Top income decile and average level of household income in Wave 1. All other controls being held constant students thus differ only by gender, income level and parent's education level in Wave 1. The share of each combination of Mother and Father's education is calculated at each income group and thus each student's score is adjusted as per the average coefficient of parent's education level for their income group and gender. For instance, approximately 13.73% of students in the bottom income decile in Wave 1 have at least one parent with a postgraduate degree, this is compared to 48.74% of students in the Top income decile. 22.42% of students overall have at least one parent with a postgraduate degree and these differing shares of education by income group are thus reflected in the average scores for each student. The scores as reported in Table 11 are thus the average standardised numeracy scores adjusted for gender, income groups and average parental education within those income groups.

The six average student's scores at the Grade 3 and Grade 9 level demonstrate both the gender gap at each different level of income and the socioeconomic gap by gender. This gives

a comprehensive picture of the interplay between gender and socioeconomic status, as measured by income level and parental education. We can see at the Grade 3 level the gender gap between the model male and female students is greatest at the top income decile, at 0.548 standard deviations in favour of the male student. The socioeconomic gap however is highest between male students at the bottom income decile and top income decile, at 0.623 standard deviations in favour of the student from the richer household. Overall, at the Grade 3 level, there is a clear gender gap across income groups and a clear socioeconomic gap across genders.

Table 11: Average Model Students at Grade 3 and Grade 9

		Bottom Income Decile	*Average Household Income*	*Top Income Decile*	*Socio-economic Gap*	*Top – Average Gap*	*Average – Bottom Gap*
Year 3	Male	(1) -1.657	(3) -1.444	(5) -1.034	0.623	0.410	0.212
	Female	(2) -2.055	(4) -1.784	(6) -1.582	0.472	0.201	0.271
	Gender Gap	0.398	0.339	0.548			
Year 9	Male	(1) -0.929	(3) -0.855	(5) -0.431	0.498	0.424	0.074
	Female	(2) -3.155	(4) -2.717	(6) -2.486	0.669	0.231	0.438
	Gender Gap	2.226	1.862	2.055			

Note: Gender Gap is calculated as male score minus female score at each income group. Socioeconomic Gap is calculated as score from top income decile minus score from bottom income decile, for each gender. Top – Average Gap is calculated as the top income decile score minus the average by gender, Average – Bottom Gap is calculated as the Average household income score minus the bottom. Negative values largely reflect the negative constant term.

Considering these same students at the Grade 9 level, the gender gaps across all three income groups have increased substantially. This is in keeping with our previous results demonstrating the consistent increase in the gender gap between Grades 3 and 9. By Grade 9, however, the gender gap is now greatest at the bottom income decile, rather than the top. The socioeconomic gap is now also shifted to be larger between girls at the top and bottom of the

income distribution, than for boys. Thus overall, across our average students, inequality between male students appears to be decreasing over time, while inequality between female students appears to be increasing over time. Initially the inequality between boys in Grade 3 appears to be concentrated at the top end of the income distribution, with the Top – Average Gap being almost double in magnitude to the gap between the average and the bottom. Alternatively, for girls the gaps between the top and the average and the average and the bottom are relatively similar. By Grade 9, the bulk of inequality between male students is concentrated at the top end of the income distribution, with a minimal gap of 0.074 standard deviations between our boy in the bottom income decile and the boy with average household income. The inequality between girls, by Grade 9, appears to concentrate at the top end of the income distribution. The gender gap also is increasing substantially between Grades 3 and 9 but growing at a faster rate at the bottom of the socioeconomic distribution. The gender and socioeconomic gaps, in this way, appear to compound, so that by the time our average students reach Grade 9, poorer female students experience a double disadvantage of sorts, when compared to male students at the bottom of the socioeconomic distribution or richer female students.

Ultimately our results are consistent with conclusions drawn from the literature investigating early interventions to address childhood disadvantage (Cunha and Heckman, 2007). Visualising the gaps between our model students enables us to identify both the optimal timing of intervention and the optimal student to intervene with, should policy makers wish to design interventions to address both gender and socioeconomic test score gaps between students. It appears early interventions are likely to have the greatest impact, as by Grade 3 inequalities have already manifested between students. Similarly, it appears poorer female students suffer a double disadvantage by the time they reach the Grade 9 level.

5.1 Robustness

To supplement our analysis, we also conduct a series of robustness checks that can be found in the Appendix. Appendix A provides further details on our sample including Table A1 which gives summary statistics for the full K cohort of students. Appendix B gives the full results for our key regressions Tables 7 and 8, including coefficient results for all included controls. Appendix C repeats the analysis for Tables 7 and 8 using only the Grade 3 sample of students, not including those students missing from our Grade 3 sample but present for later Grades. Results based on this sub-sample are not significantly different and follows generally the same pattern of effects as our primary sample. Appendix D includes robustness checks for our results for the impact of early socioeconomic status, including considering controlling for Grade 3 scores in later test results and controlling for contemporaneous income without Wave 1 income. Appendix E includes further iterations of our model students, demonstrating the breadth of possible sources of inquiry. Table E1 gives results for our 6 model students, calculated instead using the most frequent value for parental education at each income group rather than the average. Table E2 considers variation in a range of our control variables, giving an initial picture of how other factors may contribute to socioeconomic gaps besides purely income and parental education. Similarly, Table E3 calculates another 6 model student's results, this time students from non-English speaking backgrounds (NESB). Tables E2 and E3 are an initial investigation into the effects of other factors on socioeconomic and gender gaps and further investigating this would be a fruitful area of future research.

6 Conclusion

Ultimately there are significant gender and socioeconomic effects manifesting across children's academic achievement which contribute to academic inequalities and may

potentially influence the trajectory of student's lives after schooling. This paper contributes to the literature on the determinants of numeracy test score gaps by including a detailed examination of the interplay between socioeconomic disadvantage and gender in influencing academic achievement. This draws together two strands of literature in this area and demonstrates that socioeconomic and gender disadvantage compound to doubly disadvantage poorer female students in their numeracy results. By measuring gender gaps in numeracy across a seven-year period between Grades 3 and 9, we are able to illustrate the evolution of gender heterogeneous effects over time, where previous papers in this area have been constrained to a shorter timespan in their analyses. We detail the differing impacts of Mother's and Father's education on student's achievement, with higher Father's education more strongly influencing students results overall, but girls being more impacted by higher Mother's education than boys. We briefly consider the different gender impacts for indigenous and non-English speaking background (NESB) students, but this is a clear area for further research. By focusing our analysis on early household income and parental education, before children enter school, we further demonstrate the importance of early life circumstances on the evolution of socioeconomic and gender gaps throughout schooling. This has important policy implications when designing interventions to address educational inequalities. Our analysis highlights both who and when to target when designing such interventions; namely poorer female students as early as is possible.

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