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Parent versus student reporting of parental education drives contradictory gender patterns in achievement gradients

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Abstract
Research on how socioeconomic status (SES) and gender interact to affect student achievement has produced contradictory findings. Some studies suggest boys are more vulnerable to socioeconomic disadvantage; others find the opposite. This paper argues that these conflicting results stem from a methodological artifact: because boys report their parents' education less accurately than girls do, the source of parental education data in large-scale assessments fundamentally shapes estimates of the SES–gender interaction. PISA 2006 and 2009 provide data on 151,269 fifteen-year-old students from 20 countries for whom both parent-reported and student-reported parental education were available. This within-subject design allowed a direct comparison of the parental-education–gender interaction in mathematics achievement, isolating the effect of the data source. The direction of the interaction systematically reverses depending on the data source. When using reliable parent-reported data, the parental-education gradient is steeper for boys in the majority of country-waves (18 of 31), consistent with the "vulnerable boys" hypothesis. In 12 of those 18 cases, the results reverse to indicate "vulnerable girls" when using the more commonly available student-reported proxy data. A sign test confirmed that the interaction estimate was more negative with student data in 28 of 31 country-waves ($p < 0.001$). The choice of data source is not a minor technical detail but a factor that can reverse conclusions about educational equity.

Keywords Parental education, Gender differences, Measurement error, Attenuation bias, Large-scale assessments, PISA

Introduction

Understanding how socioeconomic status (SES) and gender interact to influence student achievement is a central question in educational equity research. The answer determines which students are most academically vulnerable and guides intervention design. The "vulnerable boys" hypothesis proposes that boys are more susceptible to socioeconomic disadvantage than girls (Autor et al., 2019). Several mechanisms could produce this pattern. Parents in lower-SES households may invest differently in sons and daughters when resources are scarce, and boys in disadvantaged environments exhibit higher rates of externalizing behavior that interferes with learning (Bertrand & Pan, 2013). Gender norms may also channel boys in low-SES settings toward identities that devalue academic effort.

Despite extensive research using large-scale data, the empirical picture remains contradictory. A study of large-scale assessment data from 36 countries found that SES gradients in achievement—differences in academic performance associated with socioeconomic status—were steeper for boys in most countries (Eriksson & Lindvall, 2023). This finding is in line with the hypothesis of vulnerable boys. At the same time, a comprehensive meta-analysis of international assessments concluded that SES gradients are, on average, slightly steeper for girls (Liu et al., 2022), which supports a "vulnerable girls" hypothesis instead. The use of large-scale assessment data to support two mutually exclusive hypotheses raises important questions about validity. Identifying the reasons for these divergent findings is therefore essential.

We propose that a key factor is whether studies use SES data reported by parents or by the students themselves. Large-scale assessments of adolescents often rely on students to report their parents' background. This practice, known as student proxy reporting, is used by PISA (Programme for International Student Assessment, OECD, 2024), TIMSS (Trends in International Mathematics and Science Study, von Davier et al., 2024), ICCS (International Civic and Citizenship Education Study, Schulz et al., 2024), and ICILS (International Computer and Information Literacy Study, Fraillon et al., 2025). We argue that gender differences in the reliability of student-reported data make the choice of data source a critical factor in shaping study outcomes.

Gender differences in the reliability of student reports of parental education

It is well-established that students in large-scale assessments provide less reliable information about their parents' socioeconomic status than parents themselves do (Jerrim & Micklewright, 2014). Students' reports of their *parents' educational attainment* are especially error-prone (Ensminger et al., 2000; Jerrim & Micklewright, 2014; Lien et al., 2001; Looker, 1989).

The critical insight for this study is that the measurement error is not uniform across genders. It was recently demonstrated in data from large-scale assessments that, across different societies, boys consistently report their parents' education and country of origin less accurately than girls (Eriksson et al., 2026). For parental education we replicate this finding in PISA data in the present study. This gender difference in reliability may reflect a poorer family knowledge among boys (Eriksson et al., 2026). It could also reflect boys being less conscientious in answering the survey questions, consistent with prior findings of gender differences in conscientiousness and test-taking effort (Duckworth & Seligman, 2006; Soland, 2018). Whatever the underlying reason, the gender difference in reliability has implications for statistical analysis.

Gender-specific attenuation could reverse which gender is more vulnerable

When a predictor variable contains random measurement error, regression analysis produces coefficient estimates that are attenuated, that is, biased toward zero (Fuller, 1987). The extent of attenuation depends on the reliability of the measure: noisier data produces weaker estimated relationships. Thus, if there is more noise in boys' data than in girls', estimates of the parental-education gradient will be more attenuated for boys than girls.

Gender-specific attenuation could reverse conclusions about which gender is most vulnerable. Even when the true gradient is steeper for boys, the attenuated gradient may fall below that for girls, creating the misleading appearance that girls are more vulnerable.

The present study

To investigate the presence of this statistical artifact, we focus on the parental-education gradient in mathematics achievement. The question is whether this gradient is steeper among boys or girls—and how the answer depends on the source of parental education data: parent-reported versus student-reported. We leverage data from PISA 2006 and 2009, the only iterations of PISA in which both parents and students reported parental education for the same households. This within-subject design allows us to isolate the effect of the reporting source while holding the sample and underlying construct constant.

If boys report parental education less accurately than girls, and this holds consistently across different societies, then student-reported data should consistently produce more attenuated parental-education gradients for boys than for girls. We therefore predict that (1) the support for the "vulnerable boys" hypothesis is weaker when the analysis uses student proxy reports instead of parent-reported data if parental education, and (2) this bias will be systematic across countries.

Methods

Participants

We utilized data from PISA 2006 and 2009, which collected parental education data directly from parents (via the optional parent questionnaire) in addition to standard student reports (OECD, 2009, 2012). We restricted the analysis to students with complete parent-reported and student-reported data on parental education for both parents. The final sample includes 151,269 students from 20 countries participating in PISA 2006 and/or 2009.

The proportion of excluded cases varied considerably, from under 7% to nearly 50%, with a mean of 25.2% (*SD* = 14.7%; see Table 1). Boys tended to be excluded at slightly higher rates than girls (mean difference 1.2 percentage points).

Measures

Parental education

This analysis focuses on parental education, which is the sole socioeconomic indicator available from both data sources. The PISA questionnaires ask for the level of education of each parent using national adaptations of the International Standard Classification of Education (ISCED) scale. The parent questionnaire primarily asks about higher qualifications, whereas the student questionnaire also distinguishes between lower levels of schooling (OECD, 2009, 2012). We recoded responses from both questionnaires to an identical four-point scale: bachelor's degree or higher (coded 3), shorter tertiary education (2), upper secondary or post-secondary non-tertiary education (1), and any lower level of schooling (0). We then summed the values for the mother's and father's

Table 1 Sample sizes, exclusion rates, and reporting accuracy for parental education in PISA 2006 and 2009

Country-wave	*N*	% Excluded	Girls' *r*	Boys' *r*
Bulgaria 2006	4498	15.3	0.47	0.41
Chile 2009	5569	20.3	0.35	0.34
Colombia 2006	4478	27.3	0.63	0.67
Croatia 2006	5213	13.4	0.62	0.49
Croatia 2009	4994	15.4	0.59	0.48
Denmark 2006	4532	46.5	0.37	0.26
Denmark 2009	5924	48.4	0.30	0.26
Germany 2006	4891	33.8	0.23	0.22
Germany 2009	4979	49.3	0.10	0.11
Hong Kong 2006	4645	9.3	0.67	0.45
Hong Kong 2009	4837	34.2	0.52	0.45
Hungary 2009	4605	13.3	0.56	0.48
Iceland 2006	3789	41.6	0.63	0.47
Italy 2006	21,773	26.4	0.63	0.56
Italy 2009	30,905	19.1	0.51	0.45
Korea 2006	5176	8.6	0.72	0.68
Korea 2009	4989	8.0	0.52	0.50
Lithuania 2009	4528	12.1	0.42	0.32
Luxembourg 2006	4567	45.0	0.28	0.21
Macao 2006	4760	6.8	0.48	0.37
Macao 2009	5952	6.9	0.37	0.34
New Zealand 2006	4823	46.1	0.23	0.11
New Zealand 2009	4643	39.0	0.07	0.07
Panama 2009	3969	31.7	0.17	0.14
Poland 2006	5547	8.6	0.57	0.45
Poland 2009	4917	11.6	0.52	0.40
Portugal 2006	5109	23.2	0.60	0.56
Portugal 2009	6298	28.4	0.67	0.57
Qatar 2006	6265	45.2	0.53	0.36
Qatar 2009	9078	36.7	0.73	0.52
Turkey 2006	4842	17.2	0.67	0.62

% excluded, percentage of students excluded from analysis due to missing parent-reported or student-reported parental education data. Girls' and boys' *r*, Pearson correlations between student-reported and parent-reported parental education sum scores, computed separately by gender. Higher correlations indicate greater reporting accuracy

education to create a parental education sum score ranging from 0 to 6. While the maximum of the two parents' educational levels is more common, the sum score is a more efficient predictor (Korupp et al., 2002).

Student gender

Gender was recorded in PISA as a binary variable (st04q01: 1 = female, 2 = male). All gender-specific analyses were conducted by running separate regressions for boys and girls rather than including a single regression with a gender interaction term.

Mathematics achievement

PISA reports mathematics achievement as five plausible values, calibrated to a global mean of approximately 500 and a standard deviation of 100 (OECD, 2009, 2012). PISA tests achievement in science and reading too, but we focus on mathematics as gradients are highly similar across subjects (Eriksson et al., 2021).

Statistical analysis

To assess the assumption that proxy reports of parental education are noisier among boys than girls, we computed Pearson correlations between student-reported and parent-reported parental education separately by gender and country-wave. We also computed inaccuracy rates (the percentage of students whose coded education level for each parent did not match the parent's own report) separately by gender and education level.

The parental-education gradient was estimated by regressing mathematics achievement (plausible values) on the parental education sum score, separately for each country-wave, gender, and data source. All analyses were conducted in R (R Core Team, 2024). Regressions used PISA's final student weight (w_fstuwt). Final coefficients and standard errors were obtained by averaging across the five plausible values using Rubin's (1987) combination rules, which account for both within-imputation and between-imputation variance.

To illustrate how reporting accuracy affects the achievement–education relationship, we computed weighted mean mathematics achievement at each level of the student-reported parental education sum score (0–6), separately by gender and by whether the student's report matched the parent's report (i.e., the two sum scores were identical). Weighted linear regression lines were overlaid to assess the adequacy of a linear specification for the ordinal predictor.

The parental-education–gender interaction for each country-wave was calculated as the difference between the boys' gradient and the girls' gradient. To test whether individual interactions differed significantly from zero, we computed *z*-statistics as the ratio of the interaction to its standard error, where $SE_{\text{interaction}} = \text{sqrt}(SE^2_{\text{boys}} + SE^2_{\text{girls}})$. To test whether the direction of bias was systematic across countries, we used the sign test to examine how many country-waves showed more negative interaction estimates with student-reported versus parent-reported data.

Finally, we examine robustness with respect to exclusions. To affect our results, nonresponses must be associated with the child's math achievement in systematically different ways for boys and girls, which seems unlikely. However, if it were the case that our results are driven by exclusions, we would expect our results to be weaker in country-waves with less exclusions. We examine this in a correlational analysis.

Results

Reporting accuracy

As expected, boys' proxy reports of parental education were noisier than girls', as evidenced by a lower correlation between student-reported and parent-reported parental education among boys ($r = 0.772$, 95% CI [.769, 0.775], n = 73,706) than girls ($r = 0.822$, 95% CI [0.820, 0.824], n = 77,563). When calculated separately in each country-wave, the correlation was lower for boys than girls in 29 of 31 country-waves (Table 1).

When accuracy was assessed at each level of parental education (on the 0–6 scale), boys were less likely than girls to correctly report their parent's education at every level (Table 2). The gender gap in inaccuracy ranged from 3.8 to 6.3 percentage points, with no tendency for the gap to concentrate at particular education levels. This pattern of uniformly lower accuracy for boys is consistent with random measurement error rather than systematic bias linked to specific education levels.

Table 2 Gender differences in inaccuracy of student-reported parental education by sum score

Parental education sum score	Girls' inaccuracy (%)	Boys' inaccuracy (%)	Gap (pp)
0	16.6	21.0	4.4
1	49.0	54.5	5.5
2	53.7	58.1	4.4
3	61.1	67.3	6.3
4	48.9	52.8	3.8
5	62.3	68.2	5.8
6	16.4	20.7	4.2

Inaccuracy, percentage of students whose student-reported parental education sum score did not match the parent-reported sum score, pooled across all country-waves. The sum score ranges from 0 to 6 (sum of mother's and father's education, each coded 0–3)

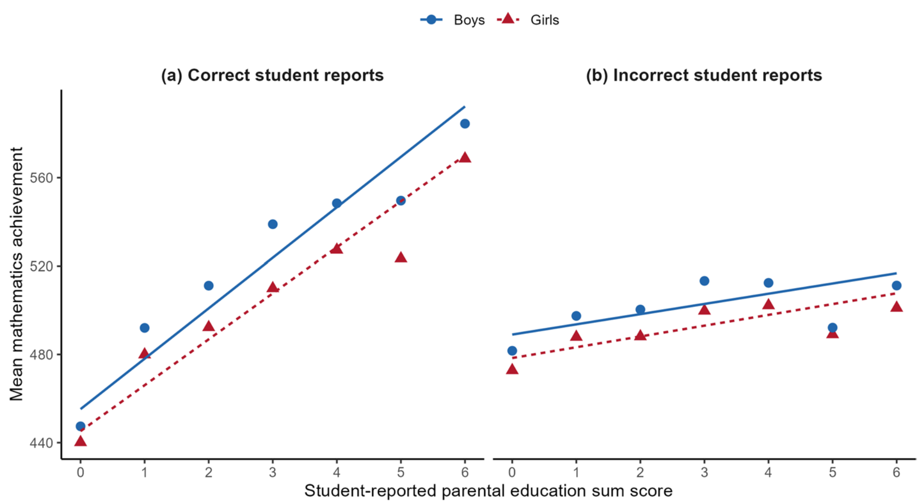

Fig. 1 Mean mathematics achievement by student-reported parental education level, separately for correct and incorrect student reports. *Note* Points show weighted mean mathematics achievement at each level of the student-reported parental education sum score (0–6). Lines show weighted linear regression fits. Panel **a** includes students whose student-reported sum score matched the parent-reported sum score; Panel **b** includes students whose reports did not match. Data are pooled across all 31 country-waves

Achievement gradients

The two panels in Fig. 1 illustrate how the parental-education gradient in math achievement is attenuated when data on parental education is noisy. Figure 1a shows the weighted mean mathematics achievement at each level of the student-reported parental education sum score among students whose report matched the parent's own report. Among these correct reporters, achievement increases approximately linearly with the education sum score (supporting the use of a linear model for the ordinal predictor). The gradient is steeper for boys than for girls (22.8 vs. 20.8 points per level), consistent with the vulnerable boys hypothesis.

Figure 1b shows the same plot for students whose report did not match the parents' own report. Here the gradients are severely attenuated for both genders (4.6 for boys, 4.9 for girls) and the gender gap effectively vanishes. Because boys contribute a larger share of incorrect reports, pooling correct and incorrect reporters together (as any analysis of student-reported data necessarily does) will attenuate boys' gradient more than girls', shifting the estimated interaction toward the vulnerable girls direction.

Gradient attenuation across country-waves

Table 3 presents, for all 31 country-waves, the parental-education gradient for boys and girls and their difference (i.e., the interaction between parental education and gender) estimated either with parent-reported or student-reported data on parental education. Consistent with our argument, attenuation was stronger among boys than girls. Boys' gradient had a mean of 12.0 PISA points per unit of student-reported parental education, an attenuation of 26% compared to the mean of 16.2 points per unit of parent-reported parental education. For girls, the corresponding attenuation was only 17%, from 15.8 to 13.2 points.

Systematic reversal of the interaction between gender and parental education

Now consider the results for the interaction between gender and parental education in Table 3. Consistent with Fig. 1a, the mean interaction in parent-reported data was slightly but not significantly positive, with boys' gradients being on average 0.44 PISA points per unit of parental education steeper than girls' gradients, 95% CI [− 0.34, 1.22],

Table 3 Parental education gradients and gender interactions by country-wave and data source

Country-wave	β boys (P)	β girls (P)	β boys (S)	β girls (S)	Interaction (P)	Interaction (S)
Bulgaria 2006	28.8	27.9	15.9	17.9	0.94	− 2.01
Chile 2009	20.5	20.4	17.1	18.7	0.11	− 1.59
Colombia 2006	15.6	15.0	13.0	14.8	0.65	− 1.85
Croatia 2006	16.3	14.3	9.6	11.1	2.00	− 1.54
Croatia 2009	14.1	15.7	9.5	12.4	− 1.56	− 2.94
Denmark 2006	11.4	14.5	10.0	13.4	− 3.12	− 3.42
Denmark 2009	13.4	14.1	8.8	10.7	− 0.71	− 1.96
Germany 2006	16.2	16.9	11.9	12.8	− 0.65	− 0.97
Germany 2009	18.8	17.0	13.1	13.2	1.79	− 0.18
Hong Kong 2006	15.3	14.5	10.4	12.5	0.81	− 2.15
Hong Kong 2009	9.2	9.7	10.2	10.9	− 0.52	− 0.67
Hungary 2009	23.7	20.7	20.1	17.2	3.04*	2.92*
Iceland 2006	12.9	14.0	13.8	14.0	− 1.09	− 0.21
Italy 2006	11.9	11.7	7.3	9.8	0.26	− 2.43*
Italy 2009	14.2	10.3	7.5	6.4	3.88*	1.16
Korea 2006	13.6	13.9	10.1	11.7	− 0.26	− 1.61
Korea 2009	14.0	11.5	10.3	8.9	2.51	1.37
Lithuania 2009	24.4	24.2	16.2	19.2	0.15	− 3.08
Luxembourg 2006	15.1	16.1	12.4	12.7	− 1.03	− 0.31
Macao 2006	8.9	6.0	2.4	3.3	2.92	− 0.95
Macao 2009	3.2	5.0	4.6	5.2	− 1.81	− 0.58
New Zealand 2006	14.6	14.6	10.8	11.5	− 0.01	− 0.66
New Zealand 2009	15.5	16.3	9.2	12.4	− 0.88	− 3.23
Panama 2009	11.9	17.2	6.1	11.8	− 5.37*	− 5.75*
Poland 2006	20.9	18.9	15.8	16.8	2.05	− 1.02
Poland 2009	21.0	16.6	16.5	15.2	4.44*	1.30
Portugal 2006	15.9	15.2	12.5	12.4	0.66	0.07
Portugal 2009	16.5	18.1	14.1	16.9	− 1.62	− 2.77*
Qatar 2006	18.0	14.2	14.5	12.3	3.79*	2.24
Qatar 2009	21.6	19.5	14.3	16.6	2.10	− 2.26
Turkey 2006	25.4	25.2	24.1	25.3	0.19	− 1.23
Mean (*SD*)	16.2 (5.3)	15.8 (4.9)	12.0 (4.5)	13.2 (4.3)	0.44 (2.13)	− 1.17 (1.80)

Β, unstandardized regression coefficient (PISA score points per unit of parental education sum score), estimated using plausible values with Rubin's combination rules and final student weights. P, parent-reported; S, student-reported. Interaction, $\beta_{boys} - \beta_{girls}$. Positive values indicate a steeper gradient for boys. *$p < 0.05$, two-tailed *z*-test

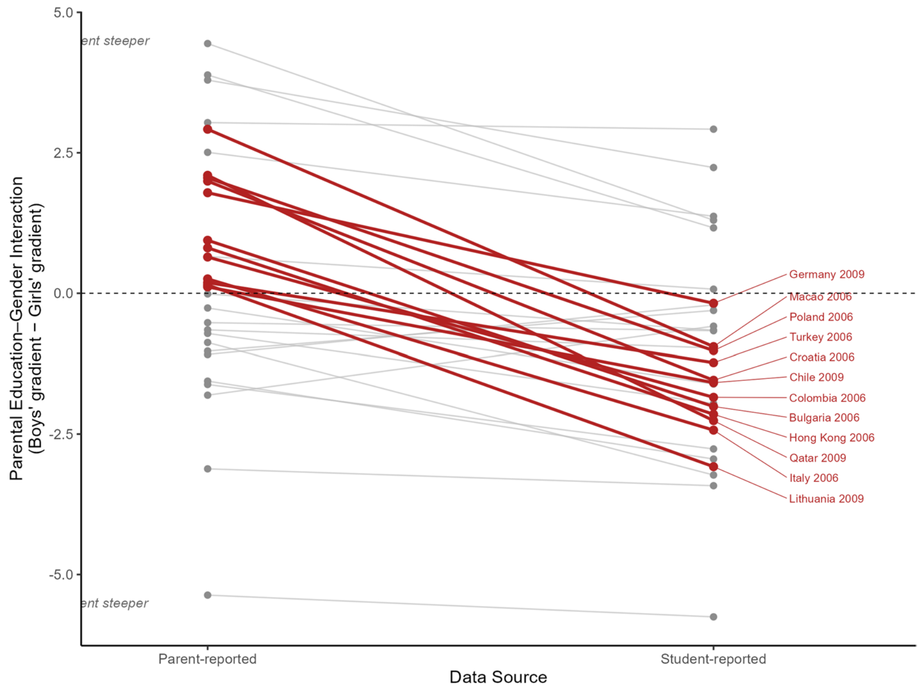

Fig. 2 Parental education–gender interaction by data source (All 31 Country-Waves). *Note* Each line connects the interaction estimate for a single country-wave using parent-reported (left) versus student-reported (right) parental education data. Positive values indicate steeper gradients for boys; negative values indicate steeper gradients for girls. Red lines mark the 12 cases that reversed from positive (supporting "vulnerable boys") to negative (suggesting "vulnerable girls") when switching data sources. Gray lines show non-reversal cases

$t(30) = 1.15$, $p = 0.26$. With parent-reported data, the interaction was positive (supporting vulnerable boys) in 18 of 31 country-waves. From the parent-reported data, a researcher would conclude that the vulnerable boys hypothesis received at least as strong support as the vulnerable girls hypothesis.

With student-reported data, this changes. Using this data, the mean interaction is significantly negative, with boys' gradients being on average 1.17 PISA points per unit of parental education less steep than girls' gradients, 95% CI [− 1.83, − 0.51], $t(30) = -3.62$, $p = 0.001$. In 12 country-waves, the interaction reversed from positive with parent data to negative with student data (Fig. 2). No reversal occurred in the opposite direction. A sign test confirmed that the shift was systematic: the interaction estimate was more negative with student-reported than parent-reported data in 28 of 31 country-waves ($p < 0.001$). Examined separately by wave, the pattern held in 14 of 16 country-waves in 2006 ($p = 0.004$) and 14 of 15 in 2009 ($p = 0.001$).

Finally, we checked that the interaction shift is not larger in country-wave with more excluded data. Indeed, there was a non-significant trend in the opposite direction: higher exclusion is associated with a **less** negative shift ($r = 0.34$, $p = .065$).

Discussion

This analysis resolves an apparent contradiction in the literature on the vulnerable boys hypothesis: while one large-scale study found steeper SES gradients in achievement among boys than girls (Eriksson & Lindvall, 2023), another large-scale study found the opposite (Liu et al., 2022). The former only used parent-reported data, the other did not. The present results demonstrate that this methodological difference is important. In student-reported data on parental education, boys' reports are less accurate than girls', producing gender-specific attenuation that systematically shifts the interaction toward the "vulnerable girls" direction.

The magnitude of this bias is substantial. On average, student-reported data attenuated the parental-education gradient by 26% for boys compared to 17% for girls. This 9-percentage-point difference in attenuation was sufficient to shift the mean interaction from +0.44 (suggesting vulnerable boys) with parent data to −1.17 (supporting vulnerable girls) with student data. Though few individual country-waves reached statistical significance on their own, the systematic pattern across 28 of 31 country-waves leaves little doubt that the bias is real and directionally consistent.

This finding has implications beyond parental education. Many large-scale assessments construct composite SES indices that incorporate parental education alongside other components such as parental occupation and household possessions (e.g., PISA's ESCS index). To some extent, composite measures will therefore exhibit similar gender-specific attenuation. Researchers using composite SES indices derived from student reports should be aware that their interaction estimates may be similarly biased.

Data producers such as the OECD could expand collection of parent-reported data and develop statistical correction methods. When parent-reported SES data are unavailable, researchers may be able to access administrative records of family income or education. Alternatively, if the reliability of the measure is known or can be estimated, statistical corrections for measurement error can partially recover the attenuated coefficients (Fuller, 1987). At a minimum, researchers should conduct sensitivity analyses and report the likely direction of bias when interpreting interaction terms.

The policy stakes of this statistical artifact are concrete. Policies designed on the basis that one gender is more vulnerable to socioeconomic may be addressing the wrong disparity.

Limitations

Several limitations should be acknowledged. First, our analysis examines a single age group (fifteen-year-olds). Whether the gender gap in reporting accuracy varies across age groups is an open question. Younger children may report parental background even less accurately overall, potentially amplifying the gender difference, while older adolescents may report more accurately, reducing it. Studies using other age groups should assess reporting accuracy by gender before interpreting interactions.

Second, parents could also report inaccurately, but their errors are unlikely to contribute to the observed reversal. Parents report their own education, not a proxy for someone else's, and there is no reason to expect their accuracy to vary by their child's gender.

Finally, we only examined mathematics achievement. However, the proposed mechanism is based on the noisiness of the parental education data and is, therefore, unrelated to the achievement domain.

Conclusion

The systematic reversal documented here is a cautionary tale: in large-scale assessments, the source of data on parental education can be as consequential as the construct being measured. The parental-education–gender interaction is not merely a reflection of sociological reality but is shaped by the reliability of the proxy reporter. Any study relying solely on student proxy reports should interpret gender-specific interaction estimates with caution.

Author contributions
K.E. conceived the research, curated the data, performed the analysis, and wrote the manuscript.

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Data availability
The PISA 2006 and 2009 data are publicly available from the OECD (www.oecd.org/pisa/data/). The derived data supporting the findings of this study are presented in Tables 1–3 and Figs. 1–2.

Declarations

Ethics approval and consent to participate
Not applicable. This study involves the analysis of existing, publicly available, and anonymized data.

Competing interests
The authors declare no competing interests.

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