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Children's Reports of Parents' Education Level: Does it Matter Whom You Ask and What You Ask About?

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Education researchers who study the effect of family social background on student achievement often use students' survey reports of parental education to investigate these effects. However, past research has demonstrated that students misreport their parents' education levels. We expand upon this research in two ways. First we use cognitive theories about the response process to develop and test hypotheses about reporting inconsistencies across these variables. Second we evaluate the impact of student misreporting on estimates of the relationship between parental education levels and student math achievement. Using data from the German administration of PISA 2000 (OECD Programme for International Student Assessment) in which both students and parents were asked to report parental variables, we show that reporting inconsistencies are a function of student achievement: students with higher math scores tend to provide reports that are more consistent with their parents' reports. This interesting case of differential measurement error has consequences for comparisons of the effects of parental background on student achievement across different subgroups of the population and across countries (a common use of PISA data and other international studies similar to PISA).
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1 Introduction

The OECD Programme for International Student Assessment (PISA) was the first large-scale international educational assessment to measure family background characteristics in detail and to relate these background data to performance outcomes. The publication of the PISA 2000 results (Baumert and Schümer, 2001, Baumert et al. 2002, Baumert et al. 2003, Prenzel et al. 2004) renewed the interest of sociological researchers and educational policy makers in disparities in educational achievement (Moore, 2002; Allmendinger and Dietrich, 2004; Lara-Cinisomo et al., 2004; Duru-Bellat and Suchaut, 2005). In all participating OECD countries, positive relationships were found between the social background of the 15 year old participants and their performance on the PISA reading, mathematics, and science assessments (OECD, 2001, 2004). This relationship proved to be particularly strong in Germany (Ehmke et al., 2004; Prenzel et al., 2004; Baumert and Schümer, 2001).

Such comparisons across countries implicitly assume that social background indicators are measured equally well across countries and that no systematic measurement error distorts the comparison. However, in PISA 2000 all of the indicators of family background characteristics were reported by the students themselves, not their parents. If students with low cognitive skills misreport their social background characteristics more frequently than do those with higher skills, and those students also have lower achievement scores, then the estimated effect of social background on achievement will be biased. Similarly, comparisons of the effects of parental background across school types which themselves correlate with achievement and cognitive skills, are likely to be biased. Research on proxy-reporting in surveys gives us reason to worry about differential measurement error (Black et al., 2003; Lee et al., 2004).

The student reports of parental background in the PISA study were not subjected to preliminary validity testing at the international level. In four countries (Canada, the Czech Republic, France, and the United Kingdom), informal validation studies with very limited power were performed to determine the reliability of students' reports of their parents' social background. The international PISA consortium evidently considered the differences between student and parent responses to be negligible, noting that "useful data on parental occupation can be collected from 15-year-old students" (OECD, 2001:220). In Germany, however, results from the PISA field trial showed that not all students of this age group were well informed about their parents' jobs

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(Baumert et al., 2000). For this reason, a parent questionnaire was included in the German national extension to the PISA study, which collected reports from the parents themselves on their education and occupational status.

In this paper, we use data from the supplemental parent questionnaire administered in Germany to evaluate the quality of the student reports. We present previous findings on the quality of proxy reports of parental education, embed these findings in a theoretical framework, and discuss the extent of disagreement between parent and student responses in the PISA study. We then focus on whether, and to what extent, the use of student reports leads to different estimates of the relationship between social background and educational outcomes compared to using parents' reports in the same models.

2 Previous Research on Error in Student Reports

The question of whether student respondents can provide reliable reports of their parents' social status has been a topic of research since the 1970s (St. John, 1970; Kerckhoff et al., 1973; Mason et al., 1976; Mare and Mason, 1980; Bauer et al., 1984; Meulemann and Wieken-Mayser, 1984). A new wave of research on the topic began at the start of the 21st century (Lien et al., 2001; West et al., 2001). It is difficult to compare the findings of these studies due to the different designs, methodologies, and indicators of social background used (e.g. education, occupation, and income). Most of the authors drew positive conclusions, however, stating that student reports can, in general, be used to describe the social status of their parents (Cohen and Orum, 1972; Youngblood, 1977; Meulemann and Wieken-Mayser, 1984; West et al., 2001). Some authors drew more cautious conclusions (Kayser and Summers, 1973; Kerckhoff et al., 1973) but only a few deemed student responses to be unsuitable as proxy indicators (St. John, 1970).

Various sociostructural factors can influence the reliability of student responses. For instance, the validity of student responses has been shown to increase with the age of the respondents (Kerckhoff et al., 1973; Mason et al., 1976; Mare and Mason, 1980). Differences have also been discerned as a function of the parents' educational level (Niemi, 1974). Furthermore, differences have been found as a function of the school type attended by respondents (Youngblood, 1977; Maaz and Watermann, 2004). In a review article, Looker (1989) concludes that students' proxy reports of parental socioeconomic status (SES) can be regarded as valid if the respondents (a) are high school seniors, (b) live with their parents, and (c) are reporting on characteristics that are salient to them.

3 A Cognitive Theory of Response Behavior

Our systematic investigation of the quality of the PISA student proxy reports is embedded in a more general theory of question response in surveys: the cognitive model of response behavior (Tourangeau et al., 2000).[1] This model takes account of the semantic and episodic memories that are involved in the *interpretation* of questions, the *retrieval* of stored information, the *judgment* of this information, and the *selection* of appropriate responses.

These four stages of the response process represent the cognitive processing of a question on the part of the respondent, the outcomes of which may differ depending on the object of assessment and the respondents' cognitive abilities. The salience and the quality of the cognitive representation of the topic in question (e.g., schooling) are decisive for the first two stages of the cognitive response process. In the case of well-formed, highly accessible cognitions, merely mentioning a few keywords in the question may suffice to activate the relevant cognitive structures (Tourangeau and Rasinski, 1988). If the cognitions are salient and readily activated, this process may even be automatic (Fazio et al., 1986). If, on the other hand, the questions are unfamiliar or relate to something about which the respondent has no well-formed cognitions, relevant information first has to be located (Dovidio and Fazio, 1992; Tourangeau and Rasinski, 1988), drawing on cues present in the question, the questionnaire, or the test situation itself (Tourangeau and Rasinski, 1988). Respondents who know little about, have little interest in, or have never thought about the stimulus presented will have to construct an answer at this stage. If the available cues relate in some way to an existing mental script, all elements associated with that script will be activated and a conclusion drawn on the basis of this information (Abelson, 1979). Information on parents' primary/secondary schooling might be better represented and more readily retrievable than information on their post-secondary education, for instance, simply because it has more in common with the students' current situation.

The judgment of the information retrieved and the mapping of this judgment onto a given set of answer categories also require mental effort on the part of the respondent (Tourangeau and Rasinski, 1988). Often, the information retrieved cannot be judged on a single dimension; rather, individual elements have to be selected and their relative importance evaluated. This process, too, is complicated and prone to error. The answer to emerge from these mental operations then has to be mapped onto the answer categories provided (Alwin and Krosnick, 1991). Respondents who were able to retrieve a relevant cognition quickly also face the challenge of identifying an appropriate response category. During this mapping stage, the response may be revised or edited, e.g., after checking it for consistency with responses to previous questions (Tourangeau and Rasinski, 1988). In the present study, students must be capable of mapping what they know about, for example, their parents' qualifications onto the categories available. If they cannot differentiate clearly between these categories (e.g., "completed an apprenticeship" vs. "completed vocational school"), minor incongruencies

[1] While this model was developed to explain adult behavior, Borgers (2003) showed that respondents older than 16 can be considered as adults regarding their cognitive growth. Thus we see this response model as a useful framework for understanding the response process of students in PISA.

may easily result, impacting on the level of agreement between parent and student responses.

The cognitive challenges outlined above are reflected in the findings of methods research on the general quality of responses provided by children and teenagers (see, e.g. Vaillancourt, 1973; Fuchs, 2002; Borgers, 2003). Results show that the quality of responses increases as a function of respondents' age and cognitive abilities, and suffers if (1) the information being assessed is irrelevant to the young respondents, (2) their knowledge on the subject is limited, or (3) they have not yet formed attitudes or cognitions about the topic under investigation.

We suspect that cognitive abilities also impact the quality of proxy reports. If this is the case, then the quality of students reports of parental background should be correlated with performance on the tests administered in the PISA study, leading to differential measurement error (Carroll et al., 2006).

Based on the cognitive model of response behavior, we expect to find support for the following hypotheses:

1. Owing to their personal experience with the general education system, parents' primary and secondary schooling is better represented in students' cognitions than parents' post-secondary schooling. Thus, questions on parents' primary or secondary education will activate familiar cues, and student reports on these variables will be more consistent with parent reports than student reports on post-secondary education will be.
2. The quality of proxy reports is positively correlated with students' test scores. The reports of students scoring lower on the test will contain more (or more serious) errors than the reports of their higher achieving peers.
3. Differential measurement error by student ability leads to bias in analyses of the effect of parental background on student achievement, particularly when comparing groups of students with different measurement error patterns.

If it is supported, this last hypothesis has important repercussions for standard analyses of the effect of social background on student test scores.

4 Data

To test these hypotheses, we use data from the German extension to the PISA study, called PISA-E, which was conducted in 2000. The sampling for PISA 2000 was done by Westat (Rust and Krawchuk, 2002); the sample for PISA-E was enlarged to permit cross-state comparisons.[2] The PISA-E had a response rate of 84.7% (Baumert et al., 2002). Students attending vocational school and schools for children with special needs were excluded from all analyses, resulting in a total respondent sample size of 28,635.

The analyses presented below make use of three measures in this dataset: the mathematics score of each student, parental primary/secondary schooling, and parental postsecondary schooling. Before presenting results of our analyses of these data, we describe the variables in detail.

Mathematics achievement. Students who participated in the PISA study were administered a standardized test comprising 117 items to assess their mathematics achievement. The items are very closely aligned to the curricula of lower secondary school, but also emphasize practical applications in everyday situations (Baumert and Schümer, 2001). Both open and closed response formats (multiple-choice) were used, and students were instructed to show their work in many of the open-ended questions. In order to cover a broad range of subject matter without exhausting the students, a multi-matrix design was used. Some anchor items were common to all booklets. Test scores were computed on the basis of Item Response Theory using the Plausible Value technique (Mislevy et al., 1992).

Parents' *primary/secondary schooling* was assessed using a structured response format with the following answer categories (note that the explanatory comments in square brackets are ours and were not included in the questionnaire) (Kunter et al., 2002):

(1) did not go to school; left school without obtaining any qualifications
(2) completed special school
(3) completed 8 grades of *Polytechnische Oberschule* [POS; comprehensive school in the former East Germany]
(4) completed *Hauptschule* [9 grades in the least academic of the three tracks in the former West Germany] or [its predecessor] *Volksschule*
(5) completed *Realschule* [10 grades of the intermediate track of the West German system], acquired the *Mittlere Reife* [qualification awarded after 10 years at *Realschule*], or completed *Polytechnische Oberschule* (POS)
(6) qualification to study at *Fachhochschule* [completed 12 grades of schooling with qualification to study at specialized colleges of higher education]
(7) qualified to study at university, acquired the *Abitur* [university entrance qualification awarded in the past after 13 years at *Gymnasium*, the academic track of the West German system, or 12 years in the academic oriented equivalent in East Germany]
(8) other school-leaving qualification.

Parents' *post-secondary degrees* were likewise assessed using a structured response format with the following answer categories (Kunter et al., 2002):

(1) did not complete vocational training
(2) completed an apprenticeship, completed *Berufsaufbauschule* [vocational extension school, provides access to advanced technical college]
(3) completed *Berufsfachschule* [specialized vocational college], *Handelsschule* [commercial college]
(4) completed *Fachschule, Technikerschule* [both technical colleges] or *Meisterschule* [master craftsmen's college], or a college for health care workers
(5) completed *Fachhochschule* [specialized college of

[2] The data can be obtained online from the *Kultusministerkonferenz* (www.kmk.org).

higher education], acquired a *Diplom (FH)* [qualification awarded upon completion of *Fachhochschule* studies], completed *Berufsakademie* [college of advanced vocational studies]

(6) completed university (acquired *Magister*, *Diplom*, or *Staatsexamen*)

(7) PhD (doctorate)

(8) other vocational/professional qualification.

Data on parental primary/secondary schooling and post-secondary schooling were collected from both the students and their parents (Kreuter et al., 2005; Maaz et al., 2006).[3] In the analyses below, we examine the consistency between the reports of the parents and their children for the two education variables. We define measurement error as those cases where parents' and children's reports differ from each other, not necessarily assuming that the parent reported data are more accurate than the student proxy-reports. With respect to predicting math achievement scores as a function of SES variables, we are mostly concerned about the differences between the estimates using one or the other measure. For explanatory convenience, we will talk about bias if the estimates differ from each other. This does not mean that the parent reports are the gold-standard, although some of our analyses provide evidence that student reports are more likely to be the erroneous ones.

PISA 2000 measured students' school achievement in many different ways. We use the math achievement scores in our analyses, because math achievement has been shown to correlate highly with general cognitive abilities (Gustafsson and Undheim, 1996). However, we do run our final model with students' reading scores as well, to ensure there is not something specific about the math scores that drives our results. The results of the analysis of reading scores are presented in the Appendix.

5 Results

Using the student scores and the student and parent reports, we can test the hypotheses we developed in section 3. In section 5.1 we test the first hypothesis about the relative accuracy of student reports of the two parent-level variables. In section 5.2 we test the hypothesis that students who have higher test scores are also better reporters. In section 5.3 we discuss the implications of our findings for the standard regression analyses of student scores on parental background variables.

5.1 Correspondence between Student and Parent Responses

Table 1 shows a cross-tabulation of student and parent reports of mothers' schooling, and Table 2 gives the same data for fathers. The cases in which student and parent responses correspond lie on the diagonals of these tables. The most frequently endorsed categories in each column are shown in bold.

With the exceptions of categories (3), (6) and (8), the clear majority of student responses are found on the diagonals. In the categories where the highest numbers of responses are concentrated, (4), (5) and (7), there is a very high level of correspondence between parent and student responses. For example, of the 4,827 students who stated that their mother had completed *Hauptschule*, 3,493 (72.4%) were in agreement with the parent reports, just under 4% underestimated their mother's educational level, and 22% overestimated it. Among those who overestimated, 73% selected the next category up. Category (6) was much more prone to error, with student and parent responses corresponding in only 25% of cases. However, most of the students who misjudged this qualification selected one of the adjacent categories.[4]

To test our first hypothesis, we need a summary of the consistency of each variable. The two most common measures are the percent correspondence (PC) and Cohen's κ. In terms of Tables 1 and 2 the PC is simply the fraction of all cases which lie on the diagonal. However, the percent correspondence measure does not control for the fact that student and parent responses may correspond at random. Cohen's κ corrects for chance agreement: it assesses the proportion of convergent classifications after removing the proportion that would be expected by chance (Cohen, 1969). An improvement to both methods weights discrepancies by how far they are from the correct answer: for example student responses that are more than one choice away from the correct answer count for more than those that are in an adjacent category (Hildebrand et al., 1977).

The percent correspondence and κ values for the two parent education variables are given in Table 3. The results show that, as hypothesized, the proxy reports on primary/secondary schooling are of higher quality than those on post-secondary education for both mothers and fathers, with higher percentage correspondence, κ, and weighted κ coefficients for both parents. The data in Table 3 support our first two hypotheses. Students tend to report parents' primary education more accurately than their post-secondary education.

5.2 Correlation of Error in Student Reports with Test Scores

If cognitive ability is (partly) responsible for consistent proxy reports, and students' math test scores are also related

[3] Parental occupation is also commonly used as a measure of family socio-economic status, and reports of parental occupation were collected from both students and parents. We do not use this variable in our analyses, however. Occupation data must be coded, using a standard framework such as the International Standard Classification of Occupations (ISCO-88) (International Labour Organization, 1990), before it can be analyzed. The coding step introduces another element of complexity and variance into the correspondence between student and parent reports that complicates our discussion in this paper.

[4] In further analyses we omit category 8 'other school-leaving qualification' for both parents' and students' responses; there is not enough information in this category to either find its right place in the ordinal grouping of the education variable or to convert it to years of schooling

Table 1: Student responses (rows) and parent responses (columns) of mother's primary/secondary schooling, absolute frequencies

	Parent response								
Student response	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Total
(1) no qualifications	**243**	6	168	106	49	5	20	38	635
(2) completed special school	6	**43**	6	21	3	0	1	6	86
(3) completed 8 grades of POS	8	4	204	47	120	8	13	3	407
(4) completed *Hauptschule*	100	24	133	**3493**	830	82	70	95	4827
(5) *Mittlere Reife* / 10 grades of POS	41	5	**232**	768	**7929**	**462**	260	**164**	9861
(6) qualified for *Fachhochschule*	3	0	12	54	578	357	156	27	1187
(7) *Abitur*	2	1	18	53	523	360	**3252**	75	4284
(8) other school-leaving qualification	50	2	122	179	293	98	288	160	1192
Total	453	85	895	4721	10325	1372	4060	568	22479

Table 2: Student responses (rows) and parent responses (columns) of father's primary/secondary schooling, absolute frequencies

	Parent response								
Student response	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Total
(1) no qualifications	**169**	3	135	109	52	4	21	31	524
(2) completed special school	0	23	3	12	6	0	3	2	49
(3) completed 8 grades of POS	11	3	309	91	158	8	11	14	605
(4) completed *Hauptschule*	90	**28**	175	**3121**	638	119	90	140	4401
(5) *Mittlere Reife* / 10 grades of POS	31	12	**355**	853	**5029**	351	247	**190**	7068
(6) qualified for *Fachhochschule*	1	0	24	109	384	397	207	41	1163
(7) *Abitur*	6	1	25	88	417	**463**	**3383**	132	4515
(8) other school-leaving qualification	50	3	110	203	264	89	238	179	1136
Total	358	73	1136	4586	6948	1431	4200	729	19461

to their cognitive abilities, then students whose reports correspond with those of their parents should, on average, score higher on the PISA math assessment than students whose reports differ from those of their parents.

A first impression of the overall (in-)consistencies of parents' and students' reports is given in Table 4. Here cases are grouped by the sign of the mismatch in their reports: negative (student reports a lower educational level than the parent), zero, and positive (student reports a higher level than the parent). Table 4 gives the mean math achievement test scores for each of these three groups. On average, students whose reports corresponded with those of their parents indeed scored higher on the math assessment. This is the case for both parents and both education variables. Table 4 provides initial support for our second hypothesis.

To summarize the findings so far, we estimated three logistic regressions with the presence of reporting error as the dependent variable. The results are shown in Table 5. Each student appeared in each of the three models up to four times, once for each of their reports of primary/secondary and post-secondary education of their mothers and fathers. The models also allowed for random student effects.[5] The coefficient on the math standardized achievement score in the first column of Table 5 shows that the odds of misreporting decrease with increasing math test scores.[6] This finding indicates additional support for our hypothesis of a negative relationship between the presence of reporting errors and test scores.[7] The odds of misreporting mothers' primary/secondary education are about 30% lower than those of the fathers. These results again support our first hypothesis: the odds of misreporting are higher for both fathers' and mothers' post-secondary education compared to the reports of fathers' primary/secondary education.

To examine the robustness of this finding, we added student characteristics as well as attributes of the parent-child relationship to the model, as shown in the second and third columns of the table. In line with our discussion of cognitive ability, we note the decline in proxy-reporting error with increasing grades (most 15 year old students are in grades 8, 9 and 10). Boys show 1.3 times higher odds of misreporting than girls. This latter point is not related to our hypotheses, but is nevertheless interesting. The effects of grade and gender support the notion that measurement error is largely an issue of the student proxy reports. If the error were entirely a function of parents' misreports it is unlikely that gender of the child or grade would have an effect on misreport.

The third model includes characteristics of the parent-child relationship: whether they speak to each other regularly and whether they eat dinner together. Both of these variables have a negative and significant effect on the probability that

[5] Stata 10.1 was used to estimate this random effects model, taking the clustering of responses within students into account.

[6] The math score is standardized to ease interpretation.

[7] A regression using the reading score rather than the math score as an independent variable shows very similar results.

Table 3: Correspondence of parent and student reports, percentage correspondence and κ

	%	κ	Wgted. κ
Mother's Primary/Secondary Schooling	74.3	0.63	0.66
Father's Primary/Secondary Schooling	69.9	0.59	0.62
Mother's Post-secondary Education	50.9	0.35	0.40
Father's Post-secondary Education	55.8	0.42	0.48

Table 4: Students' mathematics test scores by difference between student and parent reports

	Diff. (student – father)			Diff. (student – mother)		
	< 0	0	> 0	< 0	0	> 0
Parent prim./second. degree						
Math test score (mean)	493.6	518.2	491.9	489.6	513.6	485.5
Math test score (SD)	100.3	92.2	95.3	100.1	92.5	94.2
Number of cases	1,255	6,873	1,706	1,326	8,604	1,617
Parent post-second. degree						
Math test score (mean)	514.0	519.8	499.1	515.5	514.8	499.7
Math test score (SD)	90.2	93.7	92.5	87.5	94.4	92.2
Number of cases	1,906	4,970	1,907	2,786	5,216	2,241

a student report will disagree with a parent report. We note also that the additional student and relationship variables in the second and third columns of Table 5 do not substantially change the coefficients on the math score, suggesting that cognitive abilities have an independent effect on measurement error.

5.3 Implications of Measurement Error in Student Reports

The results above demonstrate the mismatch between students' and parents' reports of parents' background variables. The mismatch conforms to the predictions of the cognitive model of response behavior. But what are the implications of these reporting inconsistencies for commonly used models in education research?

Educational researchers often regress student scores on parent-level achievement measures, such as parental occupation and/or education, to explore the effect of achievement in one generation on the next. When student reports are used to measure these parent-level characteristics, the independent variables in these models will differ from those that would be obtained from the parents. We also showed that the presence of the inconsistencies in these measures is correlated with the dependent variable in the model, student achievement: those with lower scores are more likely to have inconsistencies. Thus the PISA 2000 data show an interesting case of differential measurement error (Bound et al., 2001; Carroll et al., 2006). Differential measurement error is complex and in general one cannot say anything about the kind of bias that will result. However, the results above do allow us to sign the bias in the regression coefficients due to error in the student reports.

To demonstrate the effects of student reporting error on bias in regression coefficients, we simplify the model to a bivariate regression of math scores on one of the various measures of parents' socio-economic status variables.[8]

$$Y = \alpha + \beta X^* + \epsilon \tag{1}$$

Here X^* is the parental SES measure (without reporting error) and Y is the student test score. β captures the relationship between the two and is estimated by:

$$\hat{\beta} = \frac{cov(X^*, Y)}{var(X^*)} \tag{2}$$

Measurement error in X^* will lead to bias in estimates of β. If the error is simply random noise and is uncorrelated with other variables in the model, estimates of β will be biased toward zero. This phenomenon, called attenuation bias, is well-known (Fuller, 1987). If, however, the measurement error is correlated with Y, the effect of the error on estimates of β is more complex.

Let η be the error in the student reports. The observed X is equal to the true value plus this error term: $X = X^* + \eta$. Then both the numerator and the denominator in the estimate of β have additional terms.

$$\begin{aligned} \hat{\beta} &= \frac{cov(X, Y)}{var(X)} \\ &= \frac{cov(X^*, Y) + cov(\eta, Y)}{var(X^*) + var(\eta) + cov(\eta, X^*)} \end{aligned}$$

We can sign the additional terms in the numerator and denominator given what we have learned from the above

[8] Many of the results published in the context of the PISA study and other international comparative assessment surveys focus on such bivariate relationships. See for example the review by Erebus International (2005).

Table 5: Logistic regression of students and question characteristics on the presence of measurement error, with random effects for students

	Odds Ratios		
Math score, standardized	0.797	0.823	0.830
	(0.012)	(0.014)	(0.014)
Father's primary education		*reference category*	
Mother's primary education	0.758	0.759	0.755
	(0.025)	(0.026)	(0.026)
Father's post. sec. education	2.014	2.019	2.039
	(0.069)	(0.069)	(0.070)
Mother's post. sec. education	2.636	2.644	2.657
	(0.088)	(0.088)	(0.089)
Grade		0.842	0.843
		(0.023)	(0.023)
Male		1.309	1.290
		(0.038)	(0.038)
Student speaks with parents			0.958
			(0.012)
Student eats meals with parents			0.950
			(0.017)
Constant	1.204	3.247	4.773
	(0.099)	(0.752)	(1.171)
Std Error (Student)	0.891	0.852	0.843
	(0.044)	(0.043)	(0.043)
rho	0.213	0.206	0.204
Wald χ^2	1942.740	2029.630	2046.950
n (students)	12,678	12,557	12,372
n (cases)	40,407	40,038	39,515

Standard errors in parentheses, all coefficient estimates significant at the 5% level

analyses. We showed above that $cov(\eta, Y)$ is negative: students with low test scores tend to make more errors in reporting their parents' education levels than those with high test scores. In the denominator, the variance of η is of course positive. The covariance of the measurement error with the true value is negative, because students make positive errors (overreport) when parental education is low, and make negative errors (underreport) when it is high. If the sum of these two extra terms in the numerator is positive, $var(\eta) + cov(\eta, X^*) > 0$, then the inclusion of the measurement error term, η, will reduce the numerator and increase the denominator, relative to the estimate of β when X is measured without error, leading to attenuation bias.

PISA-E data lets us test this finding empirically. For illustration purposes we focus on the post-secondary education indicator, which showed larger measurement error in the analyses above (see Table 3). We recode the categorical post-secondary education variable into a years of post-secondary education.[9] Expressing the categorical educational variables in years allows us to simplify the example and keep it tied to the statistical theory outlined above, which assumed a continuous X variable. We regress students' math achievement scores on father's years of post-secondary education as reported both by the parents and the students, and compare the estimated of βs. We use only fathers' post-secondary education here due to concerns with multicolinearity between mother and father education levels.

The first two columns in Table 6 (Models 1(a) and 1(b)) display the regression estimates for all students for whom students' and parents' reports are available. The math test scores of these students vary between 98 and 814 points, with a standard deviation of 92 points. According to model 1(a), without controlling for other variables, a father with a PhD contributes 138.6 ($7 * 19.8$) more points to his child's score on the PISA math assessment than a father with no post-secondary education. Model 1(b) shows the same linear regression estimates using the students' reports of fa-

[9] To do so we assigned average estimates of years needed to complete the respective post-secondary tracks while at the same time reflecting the "hierarchy" inherent in the different tracks. Not having completed any vocational training was coded with 0, vocational training with 1.5, commercial college and technical master with 2, advanced vocational studies with 3, university degree with 5 and completing a PhD with 7. These values are also used by the German Socio-Economic Panel Study to compute years of education from categorical reports of education qualifications (Krause, 2010).

thers' training. Here a father with a PhD contributes 128.8 ($7*18.4$) points more than the father without additional training. As expected from theory, the coefficient on father's post-secondary education is attenuated in model 1(b) compared to model 1(a). The differences between the two coefficients on fathers' education in the two models is statistically significant at the 5% level ($\chi^2_1 = 10.24, p < 0.01$) using seemingly unrelated regression (Srivastava and Giles, 1987). The attenuation effect on the fathers' education is significant, but modest, in this example.

Models 2(a) and 2(b) in Table 6 add controls for student characteristics. While introducing these variables leads to a reduced correlation between fathers' background and student scores in both models, we do still see an attenuation effect between the two models. The difference between the two coefficients is again significantly different at the 5% level ($\chi^2_1 = 12.67, p < 0.01$). These results support our theoretical model: using the students' reports of fathers' education leads to attenuation in the estimated relationship between father's education and student achievement. (Similar models in the Appendix show that these results also hold when reading scores are the dependent variable.)

The German secondary school system is more strongly tracked than in many other countries: in most federal states, students are placed in different school types after grade 4 (10 to 11 years old), based by and large on academic ability. Estimation of differential effects across school types are of common interest to researchers there. However, the effects of differential measurement are likely to bias these results in particular. Students in the less academic tracks of the German education system both have lower cognitive skills and lower math test scores. To illustrate how differential measurement error in student reports can bias these common group comparisons, we add an interaction term to the multivariate models shown in Table 6. We interact father's post-secondary education with student school type, focusing on the least academic track (*Hauptschule*) and the most academic track (*Gymnasium*) of the German school system. These models ask whether the effect of parents' education on math achievement is different across school types. In light of our research questions in this paper, we are most interested in how measurement error in student reports biases the answer to such a question.

Table 7 shows the full multivariate model, including the interaction. In the first column, the model uses parent reports of fathers' education, and interact this variable with student school type. The model in the second column uses student reports of fathers' education. The coefficients on most of the variables are not changed substantially. However, the coefficient on the interaction term is quite different between the first and second columns.

Using parent reports to fit this model, we find a strong interaction between fathers' post-secondary education and student school type. For students in *Hauptschule*, each additional year of education for their fathers leads to 12.1 (3.700 + 8.435) additional points on the PISA mathematics assessment. For students in *Gymnasium*, each additional year leads to only a 3.7 point gain. This difference in the influence of parental education on student test scores is statistically significant ($p < 0.01$).

Fitting the same model with student reports of fathers' post-secondary education leads to different substantive conclusions, as shown in the second column of Table 7. For students in *Hauptschule*, each additional year of education for their fathers leads to 6.2 (4.064 + 2.100) additional points on the PISA mathematics assessment. For students in *Gymnasium*, each additional year leads to 4.1 points. The difference between the effects for the two sets of students (the coefficient on the interaction term) is here lower in magnitude and not statistically significant ($p = 0.34$).

Researchers interested in estimating the differential effects of parental background on the performance of students from different populations, such as those enrolled in *Hauptschule* and those in *Gymnasium*, may draw inappropriate conclusions when they rely on student reports of parental background, when the quality of those reports varies with performance itself. This conclusion has implications beyond these two school types, and beyond Germany.

6 Discussion and Summary

In line with the hypotheses derived from the cognitive theory of response behavior, students' reports of their parents' primary/secondary education are more consistent than their reports of parents' post-secondary education. Asking students to report on variables related to the education of their parents invariably involves a mental processing on the part of the respondents, as well as a certain capacity to think in abstract terms. How well students perform these tasks is correlated with their score on the PISA mathematical achievement assessment. Our hypotheses formulated on the basis of the theory of response behavior were largely confirmed.

We then turned to the effects that the errors in student report of parental variables have for common regression models of the effects of parental education on student achievement. The negative correlation between the presence of measurement error in student reports and student test scores leads to systematic attenuation bias in estimates of coefficients in common regression models. Although the bias was not pronounced when estimated with PISA-E data, it was certainly discernable.

We showed that error in student reports varied across groups of students, and demonstrated that this differential measurement error can lead to inappropriate conclusions in inter-group comparisons.

This reasoning can be extrapolated to comparisons of other subgroups. When examining the effect of parental background on learning for immigrant and non-immigrant students, or for students from different countries, we should first ask whether the level of the measurement error in the proxy reports is likely to differ across the subgroups. Likewise, in school systems where the qualifications attained are relatively closely tied to the type of school attended, students' reports of their parents' educations will be less prone to error, simply because it is easier to infer the qualification

Table 6: Bivariate and multivariate regressions of math scores on father's post-secondary training, measured in years. Models using parent reports are indicated with (a), models using student reports are indicated with (b).

	Bivariate		Multivariate	
	1(a)	1(b)	2(a)	2(b)
Father's post-secondary, in years (parental report)	19.797 (0.636)		16.507 (0.589)	
Father's post-secondary, in years (student report)		18.338 (0.652)		15.011 (0.604)
Grade			59.458 (1.496)	60.219 (1.509)
Male			22.360 (1.735)	21.335 (1.753)
Constant	468.075 (1.751)	471.849 (1.776)	-100.058 (14.051)	-101.667 (14.178)
R^2	0.100	0.083	0.243	0.230
n	8783	8783	8704	8704

Standard errors in parentheses, all coefficient estimates significant at the 5% level

Table 7: Multivariate regression of math scores on father's post-secondary training, student school type, and their interaction. Models using parent reports are indicated with (a), models using student reports are indicated with (b).

	(a)	(b)
Father's post-secondary, in years (parental report)	3.700 (0.682)	
Father's post-secondary, in years (student report)		4.064 (0.695)
School type dummy (*Hauptschule*=1)	-164.808 (4.773)	-155.558 (4.796)
Interaction of school type with father's post-secondary (parent)	8.435 (2.285)	
Interaction of school type with father's post-secondary (student)		2.100 (2.192)
Grade	38.093 (1.899)	38.027 (1.905)
Male	31.771 (2.117)	31.309 (2.125)
Constant	171.878 (18.002)	172.502 (18.047)
R^2	0.578	0.577
n	3978	3978

Standard errors in parentheses, all coefficient estimates, except the interaction term in right column (b), significant at the 5% level

attained from the type of school attended.[10] When school types are less closely tied to qualifications – a development seen in Germany in recent decades, for example Baumert et al. (2003) – it is likely to be more difficult for students to state their parents' level of primary/secondary schooling correctly, meaning in Germany we would expect to see more measurement error in student reports. Inter-group and cross-cultural comparisons are not as straightforward as is usually assumed.

Our results suggest that whenever possible, parent reports should be used in these analyses instead of student reports. We do recognize, however, that collecting data

[10] For a discussion of the importance of national parameters for socioprofessional coding see publications from the European Foundation for the Improvement of Living and Working Conditions (1998). Issues with measuring education as a sociological background variable in international comparison are reviewed in Hoffmeyer-Zlotnik (2003).

from parents in large scale international assessments is prohibitively costly. We suggest collecting parent responses from a subsample of the cases in each of the participating countries to allow for estimates of error in the student reports. These estimates could then support adjustments in the student reports. This technique would be particularly important if one assumes different measurement error patterns across countries (or other subgroups) that will be compared and ranked with respect to the effect of parental background on achievement. A similar recommendation is made by Medina et al. (2009).

Finally it is important to point out that the measurement inconsistencies discovered here are item and person specific. In this way, our findings are in line with current trends in survey methodology to renew the focus on total survey error estimates as item specific rather than a measure that can be applied to a survey as a whole. Recent research by Groves and Peytcheva (2008) makes this point in the context of nonresponse. Future research on proxy-reporting can benefit from this perspective as well.

7 Appendix

Table 6 compared estimates of the effect of father's schooling on students' math scores. We argue above that math scores are the appropriate measure to use in such an analysis as they are known to be highly correlated with cognitive abilities, which likely drives the quality of student reports of parental background. Students with low math scores tend to make more reporting errors, leading to attenuation bias in estimates of the relationship between parental background and student scores.

Table 8 shows that a similar relationship holds when reading rather than math scores are the dependent variable. In this table we again see an attenuation in the relationship between fathers' years of education and student achievement, here measured by reading scores. Within both the bivariate models and the multivariate models, the differences in the coefficients on parent and student reports of fathers' education are statistically significant at the 5% level (bivariate: $\chi^2_1 = 16.09, p < .01$; multivariate: $\chi^2_1 = 12.49, p < .01$).

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Table 8: Bivariate and multivariate regressions of reading scores on father's post-secondary education. Models using parent reports are indicated with (a), models using student reports are indicated with (b).

	Bivariate		Multivariate	
	1(a)	1(b)	2(a)	2(b)
Years of education of father, parent reported	11.228 (0.221)		9.930 (0.206)	
Years of education of father, student reported		10.660 (0.228)		9.476 (0.213)
Grade			51.020 (1.043)	51.365 (1.052)
Male			-23.895 (1.209)	-25.394 (1.221)
Constant	370.059 (2.884)	376.741 (2.986)	-43.730 (9.889)	-39.347 (9.976)
R^2	0.129	0.111	0.257	0.244
n	17,460	17,460	17,308	17,308

Standard errors in parentheses, , all coefficient estimates significant at the 5% level

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