How do ability peer effects operate? Evidence on one transmission channel

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Abstract

Many (quasi-)experimental studies show that students tend to learn more in classes with better peers. However, the (presumably numerous) factors mediating the positive relationship between peer and own achievement have received less attention in the literature. I present evidence on one particular transmission channel: teachers tend to mark tougher in classes with better students, inducing parents to send their children to remedial tutorial lessons, which have a positive effect on student outcomes. This study provides an example for negative peer ability externalities that are (over-)compensated by parental educational investments.

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1 Introduction

A number of empirical studies employing credible identification strategies find that students tend to benefit from increases in the achievement levels of their peers.[1] It has further been shown that parents value the quality of both the schools and neighborhoods their children are exposed to.[2]

The causes behind the positive relationship between peer and own achievement levels, however, are still subject to current research. The few theoretical considerations on this issue highlight the potential relevance of disruptive student behavior (Lazear 2001), effort spillovers (Fruehwirth 2013), or parental investments in their child's education (Pop-Eleches and Urquiola 2013), all which are supported by the empirical evidence: the detrimental impact of disruptive student behavior has been shown by Carrell and Hoekstra (2010) and Lavy et al. (2011). Foster and Frijters (2009) and Fruehwirth (2013) find that the relationship between own and peer learning efforts is complementary. Das et al. (2013) and Pop-Eleches and Urquiola (2013) show that parental educational investments are sensitive to the quality of their child's school.

As highlighted by Carrell et al. (2013), a profound understanding of transmission channels is crucial for the provision of effective policy recommendations. Based on reduced form peer effects estimates from a natural experiment, they design student grouping policies aimed at raising achievement levels of weaker students. Follow-up assessments, however, reveal that – compared to non-treated weaker students – targeted students were

[1] Empirical assessments of ability peer effects use several methods to minimize biases due to self-selection. Some researchers employ fixed-effects frameworks (e.g., Hanushek et al. 2003, Ding and Lehrer 2007, Burke and Sass 2013). Others analyze data from controlled randomized trials (Boozer and Cacciola 2001, Duflo et al. 2011) or exploit natural experiments (Ammermueller and Pischke 2009, Sund 2009 , Imberman et al. 2012, Kiss 2013). These studies suggests that, on average, a one standard deviation increase in peer achievement raises own achievement by 0.1 standard deviations within a year. Throughout, (i) the terms ability, (academic) achievement, skills, and (test) scores are used interchangeably, and (ii) "peer" is simply a synonym for "classmate".

[2] The seminal paper by Black (1999) shows that houses are more expensive if they are located in catchment areas of higher quality schools. As emphasized by Bayer et al. (2007) and Ries and Somerville (2010), though, it is less clear whether better schools increase the valuation of houses granting access to them, or simply result from spatial concentration of households with both high incomes and favorable socioeconomic backgrounds. Taken together, these findings point towards the direction that parents presumably value both, good neighborhoods and high-quality schools.

actually hurt by their intervention. The authors therefore conclude that "[the use of] reduced-form estimates to make out-of-sample policy predictions can lead to unanticipated outcomes."[3]

This paper provides evidence for an additional transmission channel that – to the best of my knowledge – has not been validated empirically so far. My findings are consistent with the model depicted in Figure 1: increases in peer math achievement levels lower a student's percentile in the within-class distribution of math skills. Because "marking on the curve" is common, average math marks will drop as a consequence. Parents respond to this with a higher propensity of sending their child to private tutorial lessons, which tend to raise math skills. One can easily infer from Figure 1 that the positive relationship between peer and own achievement is not mechanical, but the (net) result from actions chosen by various decision makers. Unlike other related papers, this study provides an example of negative peer ability externalities that are (over-)compensated by parental educational investments.

I focus on math skills for two reasons. First, tutorial services are mostly purchased to remedy deficits in math (see Mischo and Haag 2002 and Lee 2007). Second, math skills of secondary students turn out to be strong predictors of subsequent labor market success. Simple reduced form estimates provided by Altonji (1995) indicate that returns to additional math classes are higher than those from other subjects like languages or social studies. Betts and Rose (2004) complement this finding by showing that returns to math courses are positively related to their difficulty level. Findings by Joensen and Nielsen (2009) support the hypothesis that math classes actually cause improvements in labor market outcomes. Taking a more macroeconomic perspective, cross-country comparisons conducted by Hanushek and Kimko (2000) and Jamison et al. (2007) suggest that a one standard deviation increase in country-level math test scores boosts annual GDP growth by up to 1.0pp.

The paper proceeds as follows. Section 2 provides a brief institutional overview, and

[3] The quote is taken from the abstract of the working-paper version Carrell et al. (2011).

a description of the data and variables used in the analysis. Results are presented in Section 3, which is divided in three subsections – one for each step in Figure 1. Section 4 concludes.

2 Data and institutional details

German children enroll in elementary school in fall at the age of six or seven, and make the transition to secondary school by the end of the fourth grade. The most common secondary school types are upper-, middle-, and lower-secondary school. Upper-secondary school is the most academic track and prepares students for university study. Graduates from middle- and lower-secondary school usually enroll in vocational training. Few secondary schools host multiple tracks, other types of secondary schools are comparably rare. Elementary school teachers provide track recommendations, mainly based on the student's marks received during the fourth grade. In some federal states, track recommendations are binding, meaning that parents cannot enroll their child to higher-level tracks than recommended by the teacher. In most federal states, however, track choice is not constrained.

Turning to the data, this study employs three data sets: the Progress in International Reading Literacy Study (PIRLS) 2001, and data on two different "starting cohorts" from the National Educational Panel Study (NEPS). PIRLS is an international assessment of the reading proficiency of 10-year-old students. In 2001, PIRLS additionally included an in-depth assessment of math skills.

NEPS is a longitudinal study that follows various age-cohorts – called starting cohorts (SC) – of persons living in Germany. The first waves were collected in fall 2010.[4] Taken together, the starting cohorts cover a wide age-range: SC1 follows new-borns (at most 12 months old at the time of first assessment), whereas SC6 is comprised of working-age adults. This study employs SC3 (students enrolled at the fifth grade when assessed

[4] See Bela et al. (2012) for details. Blossfeld et al. (2011) provide a general introduction to the NEPS.

the first time) and SC4, which follows ninth-graders.

These data are used to construct the four cross-sectional data sets that are analyzed in this study. The fourth-grader cross section is derived from PIRLS 2001. The fifth-(seventh-)grader cross section is based on the first (third) wave of NEPS SC3. Sixth-graders are excluded because math skills are assessed only once in two years. Finally, the first wave of NEPS SC4 constitutes the cross-section of ninth-graders.

All variables used in the analysis are summarized in Table 1. The first and second variables in Table 1 correspond to the dependent variables in Figure 1 (steps one and two). Math marks are standardized, with larger values indicating higher proficiency. (Private) tutoring is coded as a dummy variable. One can see that private tutoring is relatively common in Germany: except for the fifth grade, parents of roughly 20% of students report that their child receives at least one hour of remedial tutoring per week.

Depending on the time of measurement, own math achievement may either serve as a dependent or control variable. In a simple educational production function, math achievement measured at the end (beginning) of a school year would denote the explained (most important control) variable. Regarding this study, PIRLS and NEPS assessed math skills only at the beginning of the school year. As NEPS is longitudinal, math scores from the subsequent grade may have served as proxies for final math skills at the current grade. However, math skills were assessed only every second year in NEPS which impedes estimation of step 3 in Figure 1. To bridge this gap, I draw on empirical findings from other studies in Section 3.3.

Own math skills in Table 1 therefore denote a control variable – it can be can be interpreted as an aggregate of all past educational investments (Todd and Wolpin 2003). Based on this variable, peer math achievement is computed as the class average of math scores net the student's own math test score.[5] Like math grades, both math and peer achievement are standardized. The additional control variables are age and indicators for

[5] Let i, j index students, c classes, and let N_c denote both class size and the set of student IDs that constitute class c. Then, the peer math achievement level $pmat_i$ student i is exposed to equals $(N_c - 1)^{-1} \sum_{j \in N_c \setminus \{i\}} tsmat_j$, with $tsmat_j$ denoting the math test score of classmate j.

gender, type of school attended, and the highest educational background of parents.

3 Results

The discussion of the results is structured as follows: each subsection is dedicated to one step in Figure 1. That is, I first discuss the impact of changes in peer achievement levels on teachers' marking practices. I then turn to the willingness of parents to purchase tutorial services in response to changes in their child's math marks. The third and final subsection summarizes empirical evidence on the impact of remedial tutoring on educational outcomes.

3.1 The impact of peer achievement on marks

This subsection presents empirical findings that are consistent with the notion that increases in peer achievement levels induce teachers to mark tougher (or to provide more difficult exams). To support this hypothesis, I show that relative marking ("marking on a curve") is common, meaning that a student's marks are not only determined by his/her absolute performance but also by his/her percentile in within-class skill distribution. Consequently, increases in peer achievement levels are accompanied by lower percentile ranks, leading to worse marks.

In Table 2, a student's math mark is regressed on his or her quartile in the within-class math skill distribution, math test score, and additional control variables. This model is estimated separately for students enrolled at the fourth, fifth, seventh and ninth grades. One can infer from Table 2 that, conditional on own math skills, comparatively weak students receive worse math marks. For example, math marks of students at the bottom quartile are lower by 0.33 to 0.40 standard deviations on average. One can further observe that the relationship is monotonous, i.e., the lower the quartile, the larger the "penalty" on math marks.

The fifth grade is the only exception. The relationship between math marks and within-class quartile is also negative, however, the magnitude of the estimated coefficients is much smaller. This could result from the fact that fifth-graders are grouped into newly formed classes at the beginning of their secondary education. To facilitate the adaptation to their new environment, secondary school teachers might be more reluctant in applying relative marking . Therefore, as one moves from the fourth to the fifth grade, teachers tend to emphasize less a student's relative performance when assessing his or her math knowledge. Moving further to higher secondary school grades, teachers' marking practices become similar again to the ones applied by elementary school teachers. This pattern is robust to the replacement of quartiles by terciles or quintiles, and the inclusion of squared and cubic math skills as additional controls.

Based on this result, one may hypothesize that shifts in the distribution of math skills affect math marks because – holding student skills constant – distributional shifts are equivalent to changes in the student's within-class percentile. Therefore, as indicated in Figure 1, one could expect that rightward-shifts in the achievement distribution (as represented by increases in peer achievement levels) are associated with poorer math marks. The intuition is as follows: at the beginning of a school year, initial peer achievement levels can only be raised if weaker students are replaced by better ones. Depending on the percentile rank of the replacement, the number of students experiencing a reduction in their own percentiles may vary. If, for instance, the weakest student was replaced by one who outperforms every classmate, then the class as a whole would have experienced a drop in percentile ranks. However, replacing a weak student by a median-performer only lowers the percentile ranks of those in the bottom half of the within-class skill distribution.

Estimates from Table 3 are consistent with this notion. At the fourth, seventh, and ninth grades, students tend to receive worse math marks as peer math achievement increases. A one s.d. increase in peer skills depresses math marks by 0.13 to 0.17 standard deviations. As before, math marks of fifth-graders are less responsive to changes in peer achievement levels – the corresponding coefficient turns out to be 2.0 to 2.5 times smaller – presumably because fifth-grade teachers are less willing to assess students based on relative performance. Therefore a lower percentile due to better peers turns out to have a less detrimental effect on marks. To summarize, Table 3 (in conjunction with Table 2) is interpreted as evidence for better peers causing worse marks because relative marking is common.

3.2 The relationship between math marks and private tutoring

This subsection provides an empirical assessment of the second arrow in Figure 1. Simple LPM estimates in Table 4 show that – as expected – students with worsening math marks are more likely to be sent to private tutoring: a one s.d. decrease in math marks is associated with an 7 to 8 percentage point increase in the probability of receiving private tutorial lessons.

Even though the dependent variable is now chosen by parents, the pattern described in Section 3.1 also emerges here: at the fifth grade, the estimated coefficient on math marks turns out to be much smaller. Parents of fifth-graders with math deficits may opt for delaying their decision about the necessity of remedial tutoring, and give both their child and themselves more time to adapt to the new school environment.[6] Unlike before, the reasons for this pattern are of secondary importance as long as Table 4 can be interpreted as empirical support for the second arrow in Figure 1.

3.3 The impact of tutoring on math skills

The final step in the establishment of the transmission channel outlined in Figure 1 concerns the impact of private tutoring on math skills. Ideally, one would regress current math scores on both an indicator for recently received tutoring and lagged math scores. Because NEPS assessed math skills only once in two years, the data do not permit to estimate this relationship.

Fortunately, a number of empirical studies – summarized in Table 5 – with credible identification strategies provide evidence on the impact of remedial tutoring on educa-

[6] This may also explain the comparatively low share of fifth-graders receiving tutoring in Table 1.

tional outcomes. These studies vary along many dimensions: country, target population, type of intervention, identification strategy, and outcomes. In four out of six cases, their results suggest that remedial tutoring does have a positive effect on educational outcomes.

As indicated by the last column in Table 5, the persistence of treatment effects was assessed in four studies. As one of these did not find any short-run effects, the number of relevant studies becomes three (De Paola and Scoppa 2014, Jacob and Lefgren 2004, Taylor 2014). In two out of three cases, treatment effects persist two years after the intervention (or, more precisely, do not fade out entirely). According to De Paola and Scoppa (2014), remedial courses may have a (lasting) positive impact only in cases where gaps in knowledge are filled, but fail to enhance deficits stemming from poor family backgrounds.

4 Summary and conclusion

This paper empirically validates a particular transmission channel through which increases in peer achievement levels may improve student outcomes. Unlike other related studies, it provides an example of negative peer ability externalities that are (over-)compensated by parental educational investments. However, this paper falls short in quantifying the magnitude of the effect illustrated in Figure 1 as there are numerous, potentially interacting, channels through which own achievement is shaped by peers. In the spirit of Carrell et al. (2013) and Das et al. (2013), this study highlights that one should not draw too strong conclusions based on “causal” reduced form estimates of ability peer effects. Instead, estimated treatment effects should rather be taken as a point of departure for further, more in-depth investigations.

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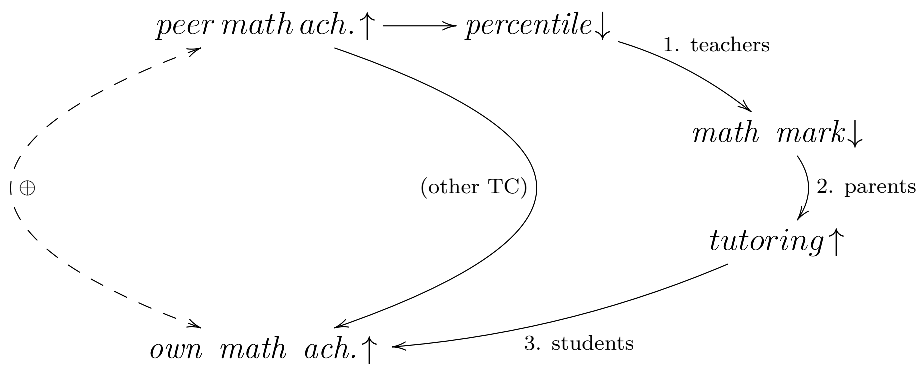
Tables and Figures

Figure 1: The relationship between peer and own achievement levels



Increases in peer math achievement lower a student's percentile in the within-class distribution of math skills. Because "marking on the curve" is common, average math marks will drop as a consequence. Parents respond to this with a higher propensity of sending their child to private tutorial lessons, which tend to raise math skills. The inner-right arrow encompasses all remaining transmission channels (TC) through which own achievement is shaped by peer achievement levels. The dashed double arrow on the left highlights that (positive) social multiplier effects are present because every student is also a classmate's peer.

Table 1: Descriptive statistics (German fourth-, fifth-, seventh- and ninth-graders)

Grade	4^{th}		5^{th}		7^{th}		9^{th}	
Schooling level	primary		secondary		secondary		secondary	
Variable	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Math mark	.00	1.0	.00	1.0	.00	1.0	.00	1.0
(private) Tutoring	.18†		.09		.17		.21	
Own math achievement	.00	1.0	.00	1.0	.00	1.0	.00	1.0
Peer math achievement	.00	1.0	.00	1.0	.00	1.0	.00	1.0
Female	.49		.48		.49		.48	
Age (years)	10.4	.45	10.4	.58	12.4	.58	14.6	.68
Attended school type								
Elementary school	1.00		.00		.00		.00	
Lower-secondary	.00		.13		.09		.20	
Middle-secondary	.00		.21		.21		.21	
Upper-secondary	.00		.54		.56		.42	
Multi-track	.00		.08		.09		.07	
Comprehensive school	.00		.04		.05		.10	
Highest parental educ.								
Lower secondary	.14		.06		.05		.06	
Vocational training	.23		.32		.28		.38	
High school	.07		.09		.08		.08	
Tertiary	.56		.53		.59		.48	
N(students)	3353		2977		3096		8041	
Data source	PIRLS 2001		NEPS SC3		NEPS SC3		NEPS SC4	

Standard deviations not reported for binary random variables. Unit of analysis: students enrolled at the fourth, fifth, seventh, and ninth grade in Germany. (Private) tutoring is a binary variable – it equals 1 if the student receives at least 1h of private lessons per week and 0 else. Math marks, own math achievement, and peer math achievement are standardized to mean 0 and standard deviation 1. Higher values in these three variables reflect better performance. Peer math achievement equals the average math achievement level of a class net the student's own achievement: let i, j index students, c classes, and let N_c denote both class size and the set of student IDs that constitute class c. Then, the peer math achievement level $pmat_i$ student i is exposed to equals $(N_c - 1)^{-1} \sum_{j \in N_c \setminus \{i\}} tsmat_j$, with $tsmat_j$ denoting the math test score of classmate j. The highest educational degree of the parents is classified according to the International Standard Classification of Education (ISCED) guidelines, see OECD (1999) for details.

†: In PIRLS, only 507 parents provided information on whether or not their child received paid private tutorial lessons.

Table 2: The prevalence of relative marking ("marking on the curve")

Dependent variable	Math mark			
Grade	4th	5th	7th	9th
Within-class quartile (4th = reference cat.)				
1st quartile	-0.404^{***} (.068)	-0.123 (.080)	-0.352^{***} (.084)	-0.328^{***} (.050)
2nd quartile	-0.195^{***} (.051)	-0.074 (.063)	-0.292^{***} (.067)	-0.304^{***} (.040)
3rd quartile	-0.043 (.041)	0.061 (.053)	-0.123^{**} (.053)	-0.188^{***} (.034)
Own math achievement	0.354^{***} (.023)	0.435^{***} (.032)	0.319^{***} (.034)	0.382^{***} (.021)
R^2	0.31	0.23	0.20	0.21
N(students)	3353	2977	3096	8041

P-values: $^{*} < 10\%$, $^{**} < 5\%$, $^{***} < 1\%$, based on robust standard errors (in parentheses). Math marks are standardized to mean 0 and standard deviation 1 (with larger values indicating higher proficiency). Within-class quartiles are derived from the student's math performance in PIRLS or NEPS. All regressions additionally control for age, gender, highest educational background of parents, and secondary school type (estimates not reported).

Table 3: The impact of peer math achievement on math marks

Dependent variable	Math mark			
Grade	4th	5th	7th	9th
Peer math achievement	-0.148^{***} (.016)	-0.062^{**} (.031)	-0.128^{***} (.031)	-0.170^{***} (.022)
Own math achievement	0.525^{***} (.016)	0.496^{***} (.020)	0.467^{***} (.020)	0.536^{***} (.013)
R^2	0.32	0.23	0.20	0.21
N(students)	3353	2977	3096	8041

P-values: $^{*} < 10\%$, $^{**} < 5\%$, $^{***} < 1\%$, based on robust standard errors (in parentheses). Math marks, peer, and own math achievement are standardized to mean 0 and s.d. 1 (with larger values indicating higher proficiency). All regressions additionally control for age, gender, highest educational background of parents, and secondary school type (estimates not reported).

Table 4: The relationship between math marks and private tutoring (LPM estimates)

Dependent variable	Tutoring			
Grade	4th	5th	7th	9th
Mean	.18	.09	.17	.21
Math mark	-0.078^{***} (.022)	-0.027^{***} (.006)	-0.079^{***} (.007)	-0.085^{***} (.005)
Own math achievement	-0.077^{***} (.020)	-0.041^{***} (.007)	-0.056^{***} (.009)	-0.042^{***} (.006)
R^2	0.13	0.05	0.09	0.07
N(students)	$507^{\dagger}$	2977	3096	8041

P-values: $^{*} < 10\%$, $^{**} < 5\%$, $^{***} < 1\%$, based on robust standard errors (in parentheses). The dependent variable equals 1 if the student receives at least 1h of private tutorial lessons per week, and 0 else. Both math marks and own math achievement are standardized to mean 0 and s.d. 1 (with larger values indicating higher proficiency). All regressions additionally control for age, gender, highest educational background of parents, and secondary school type (estimates not reported).

†: In PIRLS, only 507 parents provided information on whether or not their child received paid private tutorial lessons.

Table 5: The impact of remedial interventions on various educational outcomes

Study	Country	Treatment & target population	Identif. strat.	ATT (short run)	Persist?
De Paola and Scoppa (2014)	Italy	Remedial courses for university freshmen	IV	Earned credits ↑, Dropping out ↓ by 30%	yes (2 yrs)
Jacob and Lefgren (2004)	USA	Summer school for under-performing 3rd-graders	RDD	Reading & math achievement ↑ by 20%	yes (2 yrs)
Keslair et al. (2012)	UK	"Special Needs Programme" for primary students	IV	No effects found (on test scores)	n.a.
Lavy and Schlosser (2005)	Israel	Add. instruction to under-perf. high school students	DiD	Matriculation rates ↑ by 22%	n.a.
Martorell and McFarlin (2011)	USA	Remedial courses for university freshmen	IV	No effects on academic or labor market outcomes	no (7 yrs)
Taylor (2014)	USA	Remedial math class for underperf. mid-school students	RDD	Match achievement ↑ by 0.16 s.d.	no (2 yrs)

This table summarizes various empirical assessments of the effect of remedial interventions on various educational outcomes. Only studies that make serious attempts to minimize biases due to potential self-selection are considered here. The last column contains information on the persistence of treatment effects over time, which have been investigated in four studies – in these cases, the number of years since the intervention is reported in parentheses.